AN ABSTRACT OF THE THESIS OF

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Title: Food Habits and Diet Quality of Deer and Cattle and Herbage Production of a Sagebrush-Grassland Range.

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Research was conducted on the Keating rangelands in northeastern Oregon to determine the food habits of deer and cattle and similarity of their diets, and to estimate deer and cattle months of grazing on both a quantitative and nutritional basis. Data were collected during the winters of 1978-1979, 1979-1980 and during the spring and fall of 1979 and 1980. In the Crystal Palace, Tucker Creek and Spring Creek study areas, field fecal collections were made and the microhistological method was used in the laboratory to determine the food habits of both deer and cattle. Similarity indices were calculated comparing food habits of both deer and cattle. In delineated plant communities, available herbaceous forage was estimated within $0.5m^2$ circular plots employing a double sampling technique, and available browse was estimated employing a multiple linear regression technique. Subsamples of available forage were analyzed for *in vitro* dry matter digestibility and crude protein. An extensive literature review was conducted to determine nitrogen (N) and metabolizable energy (ME) requirements of both deer and

cattle. Cattle and deer months of grazing were calculated for each plant community on a quantitative (i.e., forage biomass) and nutritional (i.e., metabolizable energy and nitrogen) basis employing the following relationships: number supported = $\frac{\text{resources available}}{\text{resources required}}$. Management recommendations were made based on data collected in this study.

Grass was the most dominant forage consumed by cattle, while deer consumed both grass and browse. Forbs were not an important dietary constituent for either cattle or deer. During the early winter period of 1978-1979, browse and grass averaged 57.4 percent and 1.6 percent of the deer diets, respectively. However, during the late winter period of 1978-1979, browse and grass averaged 40.2 percent and 31.5 percent of the deer diets, respectively. During the 1979-1980 winter, browse and grass averaged 35.4 percent and 51.9 percent of the deer diets, respectively. The predominant grass and browse consumed by deer was Sandberg's bluegrass and big sagebrush, respectively. During the spring period, crested wheatgrass, cheatgrass and Sandberg's bluegrass averaged 21.8, 29.1 and 19.5 percent of cattle diets, respectively. During the fall period, cheatgrass and Sandberg's bluegrass averaged 30.4 and 24.9 percent of cattle diets, respectively. Diet similarity ranged from 27.1 percent to 52.8 percent while the average spring overlap for both years was 37 percent and the average fall overlap was 50 percent. Most of the dietary overlap occurred on Sandberg's bluegrass.

The literature review revealed that on a forage biomass basis a cow-calf pair in spring required 14 kg/day, while a dry pregnant cow in the fall required 10 kg/day. On an energy and nitrogen basis, a nursing cow required 26.6 Mcal/day of ME and 206 g of N, while a dry pregnant cow required 10.0 Mcal/day of ME and 94.5 g of N. On a forage biomass basis, a wintering adult deer required .9 kg of forage per day while a fawn required .6 kg per day. Considering the length of the winter period, the energy obtained by catabolism of fat, and the energy and nitrogen required in gestation, I determined that during the early and late winter periods of 1978-1979 deer required 1.81 and 1.80 Mcal/day of ME and during the 1979-1980 winter, they required 1.73 Mcal/day of ME. The literature also revealed that a wintering deer required 12.9 g of N per day.

Quantitative forage analysis showed that depending upon study area and pasture on a kg/ha basis the predominant grasses available to cattle were crested wheatgrass, Sandberg's bluegrass and cheatgrass. Determination of available browse biomass was made employing a multiple linear regression model for mountain big sagebrush ($\log y = -6.37 + .9337 \log H + 1.49 \log W_2$), and a simple linear regression model for gray rabbitbrush ($\log y = -3.70 + 1.81 \log W$) and basin big sagebrush ($\log y = -3.84 + .9870 \log A$). Depending upon study area and plant community, quantitative analysis of the forage showed that big sagebrush and Sandberg's bluegrass were the dominant species available to deer.

Early spring grazed pastures could carry more AUMS on a nutritional basis than on a quantitative basis. Pastures sampled in late spring showed that total AUMS on a forage quantity basis exceeded those on a nutritional basis. During the fall on an old-growth (i.e., previous year's growth) and fall growth basis, total AUMS based on N generally exceeded those based on ME or forage quantity, except in the crested wheatgrass-dominated pasture where more AUMS were calculated on a quantity basis than on a nutritional basis. On a fall-growth-only basis, more AUMS were calculated on a nutritional basis than on a quantity basis. Generally, the least number of AUMS could be carried on the medusahead communities while the most AUMS could be carried on the crested wheatgrass seedings.

Deer months calculated for the two winters across the three study areas showed more deer months per plant community were calculated on a forage quantity basis than on an ME or N basis. However, an exception to this trend occurred in the grassland communities where more deer months were calculated on an N basis than on an ME or forage quantity basis. Generally, the most deer months were calculated for the basin big sagebrush communities while the least number of deer months were calculated on the medusahead communities.

Food Habits and Diet Quality of Deer and Cattle and Herbage Production of a Sagebrush-Grassland Range

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Introduction

The sagebrush-grassland ecosystem of the Keating Valley in northeastern Oregon is used primarily as a spring-fall range for cattle (*Bos taurus*) and as a wintering range for Rocky Mountain mule deer (*Odocoileus hemionus hemionus*). Historically, Keating rangelands were heavily grazed by cattle and sheep; and deer use was not common. Anthony (1903) reported "in an area of not over six miles from my camp on the Powder River in May, not less than 20,000 sheep could be observed". Huff (1953) explained between 1895-1915 deer numbers were low in eastern Oregon; but after that period, they began to build, except in 1932 when herds diminished somewhat after a hard winter. Currently there are approximately 4,000 to 6,000 mule deer utilizing the area during the winter months and approximately 2,000 AUMS of forage are available to range cattle on Bureau of Land Management (BLM) allotments during the spring and fall period. The recent increase in mule deer numbers and current livestock grazing practices have created an urgent need for common use assessment of the area. Proper resource management of the Keating rangelands has been hindered because of a deficiency of data on the interactions between cattle and deer.

A number of studies have been conducted on the interactions between cattle and deer; however, these previous studies show large variation between geographic location and sampling technique. Few studies have determined grazing capacity and forage allocation using food habits and forage nutrition and availability information.

In the past, estimating grazing capacity and allocating forage for big game and livestock have usually been done by intuition and at the expense of one of the species (Hubbard and Hansen 1976). This study examined the seasonal forage yield and quality of forage in several plant communities and determined the botanical composition of cattle and deer diets by season. Food habits and forage quantity and quality estimates were used to calculate cattle and deer months of grazing on a forage biomass, metabolizable energy and nitrogen basis. The study will be useful to resource managers for allocating forage and estimating grazing capacity of cattle and deer utilizing Keating rangelands.

Specific objectives of this study were:

1. Determine the available herbaceous and browse biomass on a seasonal basis in plant communities commonly used by deer and cattle.

2. Determine seasonal nutritional quality of the forage biomass.

3. Determine seasonal diets of deer and cattle using the same range but at different seasons of the year.

4. Determine cattle and deer months of grazing on both a quantitative and nutritional basis.

LITERATURE REVIEW

The Concept of Herbivore Competition

Miller (1967) defined competition as an active demand by two or more individuals of the same species' population (intraspecies competition) for a common resource or requirement that is actually or potentially limiting. Further, competition may involve elements of "interference" as well as "exploitation" (Miller 1967). Interference refers to any activity which directly or indirectly limits a competitors access to a necessary resource, usually in a spatial context. Interspecies aggression approaching territoriality, as required by Miller's (1967) definition of interference, is not known among ungulates, at least in western North America (Machie 1976). Evaluations of interspecies relations and competition among larger herbivores, including mule deer, have largely been exploitive in nature. Exploitation refers to utilization of a resource once access have been achieved, usually in the sense that two individuals or species with unlimited access to space, cover, water and food will have different abilities or opportunity to exploit the available supply (Machie 1976).

Factors that generally are considered by most students of large herbivore competition include: (1) diet similarity, (2) forage availability, (3) animal distribution, and (4) timing (Nelson 1982). However, diet similarity is considered by many to be the most important single factor in exploitive competition (Nelson 1982). Impact of forage resource exploitation by one species or another is related to the amount of food eaten by one species that otherwise potentially could have been consumed by another (Smith and Julander 1953). Furthermore, Cole (1958) emphasized that, in order for competition to occur, forage species used in common must comprise an important part of at least one or the other species' diet; and as forage availability is reduced by common utilization, level of competition increases (Nelson 1982). Smith and Julander (1953) affirmed that competition for food occurs if two species vie for forage resources, but the level of competition is related inversely to the availability of these resources. It then follows that as resource availability is reduced by common utilization, level of competition increases (Nelson 1982).

In a later publication, Mackie (1981) reported that interspecific competition may be indirect or more or less direct in process and effect. Direct competition does not require that both species' populations or all members of the populations use the same area or resources at the same time (Cole 1958 in Mackie 1981). Furthermore, the use of a food by one animal during one season may preclude subsequent usage of that area or food for another (Mackie 1981). Indirect competition involves subtle and long-term changes or trends in the supply or some other attribute of resources or in the behavior, distribution, or dynamics of one or more of the associated species populations: i.e., gradual reductions in the vigor of plants, elimination or reduction of cover types, and general alterations in the kinds, quality and amount of preferred plants (Mackie 1981). Furthermore, Nelson and Burnell (1976) reported that unilateral competition occurs when one animal species precedes another onto seasonal range and, in one way or another, uses one or more habitat resource such that the resource or resources are not fully available to or usable by the species which occupies the range after the first species has departed. Intensity of unilateral competition depends on when and how long each animal species occupies a given area (Nelson and Burnell 1976).

In conclusion, Nelson (1982) stated that competition for food, therefore, is influenced by diet similarity and the relative importance of each forage species in diets of competing animals. Interaction between competitiors is modified by the relative availability of forage species which, in turn, is influenced by utilization. Animal distributional patterns, as well as time and duration of grazing, affect overall impact of competition for food between two species (Nelson 1982).

However, Connell (1961) pointed out various limitations and shortcomings of natural field experiments investigating competitive interactions. He makes a strong case for experimental manipulation of densities in the field and using a suitable control. Introduction and/or removal of species with concomitant monitoring of changes in population densities and/or niche shifts, before, during and/or after the experimental manipulation is potentially a worthwhile avenue to studying competition in the field (Connell 1961).

Interspecific Competition Between Deer and Cattle

Interspecific competition is important to resource managers who are involved with the management actions on millions of hectares of mule deer range throughout western North America.

Indeed, wild animals, more than any other range resource, are of intimate concern to the range manager (Stoddart et al., 1975). Furthermore, competitive interaction between livestock and mule deer is one of the most controversial aspects of mule deer management because all the potentially interacting ungulate forms are highly valued economic or aesthetic resources on western rangelands (Mackie 1981).

Historically, the effects of heavy grazing probably contributed to the decline of mule deer populations during the late 1800's and early 1900's (Mackie 1981). Later, the conversion of much western rangeland by livestock grazing from perennial grassland to a diverse array of shrubs or annual grass-forb type was believed to have favored mule deer in many areas (Mackie 1981, Julander 1962, and Urness 1976). Many shrubs and other plant species that invade or increase on disturbed rangelands are more palatable and digestible for deer than are perennial forage species (Longhurst et al. 1968a, 1976, and Urness 1976). Therefore, livestock grazing has to rate as one of the most important land use or environmental factors affecting mule deer habitat values (Mackie 1981).

The net effect of long-term influences of livestock grazing on mule deer habitat excluding the kinds, quality, and amount of available food and cover is poorly understood; but both benefits and adverse effects occur (Mackie 1981). A number of studies in the literature report that interspecific relationships with cattle have been either beneficial or detrimental to mule and white-tailed (Odocoileus virginianus) deer populations. However, according to Mackie (1981), there are no documented instances of deer directly influencing the numbers, distribution or general well being of any domestic species on rangeland, although range forage consumption and possible disease transmission occasionally have caused concern among stockmen and others.

Numerous studies have suggested livestock may interfere with deer use of available habitats (in Mackie 1981). These studies included: McCullock (1955), McMahan (1964), McMahan and Ramsey (1965), Ellisor (1969), McKean and Bartman (1971), Hood and Inglis (1974), Knowles (1975, 1976a), Komberec (1976), and Gallizioli (1977). However, Mackie (1981) warned that direct evidence of exclusion and quantification of exclusion and quantification on the effects of competition by cattle on deer populations was generally lacking from most studies.

McCullock (1955) and Gallizioli (1977) both found higher mule deer populations on an ungrazed range in Arizona, compared with similar adjacent vegetational types where cattle were grazed. McMahan (1964), working on the Kerr Wildlife Management Area in the Edwards Plateau region of Texas, observed moderate to heavy competition between white-tailed deer and livestock during the winter period. McMahan and Ramsey (1965) reported a low carrying capacity for white-tailed deer in all pastures continuously grazed by a mixture of livestock, including cattle, as compared with deer-only managed areas. Reproduction and survival of fawns in the grazed pastures varied in relation to stocking rates with no fawns ever surviving to yearling age on heavily stocked pastures (McMahan and Ramsey 1965). Knowles (1975) indicated that radio-marked mule deer in rest-rotationally grazed pastures during summer and fall either moved from the area or moved further and used all parts of their home range more frequently after cattle were turned into the pastures in which they occurred. McKean and Bartman (1971) found that daily weight gains by livestock were not affected by moderate grazing by mule deer on controlled pastures during winter. However, they observed that mortality of mule deer was two or three times greater in areas where controlled study pastures were stocked and grazed heavily with livestock than in areas where pastures were grazed moderately by livestock.

Food habits of mule deer may change in areas where heavy livestock grazing has or is occurring. Knowles (1976a) found much greater use of forbs by mule deer in an ungrazed pasture. However, on an adjacent pasture where cattle were grazed, browse was used to a greater extent by mule deer. Lucich and Hansen (1981) found when cattle were forced from a grass-dominated diet to browse forage on overstocked ranges that diet overlapped and, therefore, forage competition increased between mule deer and cattle.

The amount of forage lost through trampling should also be considered. Mackie (1981) reported that, although direct herbage consumption may account for only 36-47 percent of the total herbage removed or lost on rangelands where cattle are grazed (Pearson 1975), the remainder can be lost to trampling and other factors.

Other studies have shown that cattle grazing may have beneficial effects on deer. Longhurst et al. (1976), working on an annual grassland range in California, suspected that declines in black-tailed deer (Odocoileus hemionus columbianus) populations may be attributed to the long-term decline in domestic sheep grazing, which has resulted in plant succession toward species less palatable and digestible for deer. In the same light, many other researchers (Thilenius and Hungerford 1967, Lesperance et al. 1970, Ansotequi et al. 1972, and Neal 1978) adhere to the concept that "sound grazing practices play an important role in maintaining adequate browse stands essential for big game".

Neal (1978), working on bitterbrush (Purshia spp.) ranges in southeastern Oregon, found that many years of plant succession under careful grazing management had caused the perennial bunchgrasses to increase, while the bitterbrush shrubs had become old and decadent. He recommended that heavy early livestock grazing would allow more bitterbrush seedlings to become established, thus improving the range for mule deer.

In Nevada, a series of studies were initiated to better delineate the actual areas of competition between cattle and mule deer (Lesperance et al. 1970). In these studies, rumen-fistulated cattle were used to obtain a total of 493 samples of forage on three study areas, while rumen contents were obtained from 171 mule deer on five study areas. The data indicated cattle extensively selected grass on all study areas. However, when grasses were no longer available, cattle selected browse, mainly bitterbrush. They further observed that on winter and summer ranges mule deer selected browse approximately to the same degree that cattle selected grass. Additionally, deer selected three to five browse species; whereas, cattle appeared to concentrate on only one browse species in any area (Lesperance et al. 1970). After analyzing food habits data, Lesperance et al. (1970) and Tueller and Lesperance (1970) concluded that the two periods of prime importance for competition are early spring use of grass and late fall selection of browse, primarily bitterbrush. Lesperance et al. (1970) recommended that spring competition may be avoided by delaying cattle turnout on deer-use ranges until May and fall use of browse may be regulated similarly. Lesperance et al. (1970) also agreed with Neal (1978) in that management of bitterbrush stands with periodic livestock grazing suggests that more forage may be produced for mule deer. Because browse comprised 97 and 91 percent of the mule deer diets for two winters and grass made up less than 5 percent, Lesperance et al. (1970) concluded their report by stating "data from this study, as well as others, suggest that maximum production of mule deer can only be obtained on ranges properly managed with domestic livestock".

Raleigh and Lesperance (1972) reviewed two studies (Thilenius and Hungerford 1967, and Ansotequi et al. 1972) and concluded that competition beween the two species was almost nonexistent, except that cattle did appear to consume some browse during the fall months. However, cattle could be managed to avoid dietary competition with mule deer simply by removing them before the fall months. They reported that, although deer consumed 14 percent grass during early spring, direct competition did not occur because cattle grazed the lowlands and mule deer were associated with more mountainous terrain. Raleigh and Lesperance (1972) concluded by stating "the information available at this time leads to the conclusion the maximum production of all animals will only be obtained by multiple utilization of the range forage resource by such diverse species as cattle and deer". However, mismanagement of either species will upset the balance that now exists between them (Raleigh and

Lesperance 1972). Dusek (1975), studying the range use, food habits, and interspecific relationshps of mule deer and cattle in the prairie habitat of north-central Montana, concluded that there was no significant forage competition between the two classes of animals during the summer, fall, winter and spring period. He concluded by stating the dual use of the range by cattle and deer, even when both were utilizing the same forage species, was efficient land use because the combined use was not excessive.

Willms et al. (1979), studying the interactions between mule deer and cattle on big sagebrush (Artemisia tridentata) range in British Columbia, indicated that the potential for direct competition was greatest in spring. However, the potential for competition did not occur because the forage species consumed by deer and cattle were different [i.e., cattle preferred crested wheatgrass (Agropyron desertorum) whereas deer preferred Sandberg's bluegrass (Poa sandbergi) on the flat-field habitat type]. Furthermore, they also reported that moderate or heavy fall grazing by cattle made the spring forage more attractive to mule deer by removing mature forage. Subsequently, Willms et al. (1981), found that deer grazing in spring preferred bluebunch wheatgrass (Agropyron spicatum) plants that had been defoliated the previous fall. Mule deer displayed preference for the fall-grazed field after green growth exceeded the height of stubble (Willms et al. 1981). Willms et al. (1979) also reported that social interaction between mule deer and cattle was thought to be minor. Also, Kraemer (1973) observed no interference between mule deer and cattle when the distance between them was greater than 47 m; avoidance was observed with shorter distances (in Willms et al.

1979).

Other studies that have documented relatively low level of forage competition between mule deer and cattle include: Campbell and Johnson (1983), Hansen and Clark (1977), and Hubbard and Hansen (1976). Employing Kuleyznski's similarity index (Oosting 1956), Campbell and Johnson (1983) determined dietary overlap between mule deer and cattle to be 15 percent. Hansen and Clark (1977) determined a much lower value of 4 percent, Hubbard and Hansen (1976) 2 to 4 percent, whereas, Hansen and Reid (1975) determined forage competition to be between 12 and 38 percent.

As the above literature review indicates, forage competition and interaction studies show large variation between studies, location and technique used. The time of year, vegetative mix, the species of animals and the intensity of use of the range all affect the degree of competition (Mackie 1981). Most of the comparative studies (Thilenius and Hungerford 1967, Lesperance et al. 1970, Ansotequi et al. 1972, and Neal 1978) indicated differences in the use of physiographic sites as well as in forage preferences of mule deer as compared with cattle. From these studies, it was documented that competition was minimal when ranges were properly stocked and in a successional stage of plant development. However, other studies indicated that cattle often make sufficient use of important deer forage plants and feeding areas to compete seriously where stocking rates were high, when plant growth was reduced by drought or prior heavy usage, or when grazing began too early, extended too late, or occurred on critical winter or other seasonal range areas (Mackie 1981). Because of the studies mentioned, the actual occurrence and intensity of conflict vary widely in time and space (Mackie 1981).

In conclusion, Mackie (1981) stated few firm conclusions could be made concerning the existence for or against competition. The researcher believed lack of adequate means of measuring the biological and ecological effects of competition and distinguishing these effects from those of other population regulation mechanisms may be a major reason few firm conclusions have emerged from the literature. Mackie (1981) further reported one must recognize most existing information on mule deer food habits and habitat selection has been collected in places where livestock grazing occurred and some impact was implicit. Therefore, data used to determine whether competition is occurring or likely to occur usually reflect the effects of grazing (Mackie 1981). Indeed, heavy use and the apparent "preference" by mule deer for browse, conceivably may be caused by use of other forage by domestic livestock. And, use of certain habitat types, steeper slopes or particular forage plants may reflect the presence and activities of prior foraging by livestock rather than an inherent requirement or preference of deer (Mackie 1981).

Procedures for Determining the Botanical Composition of Cattle and Deer Diets

Direct observation, utilization, stomach analysis, fistula sampling and fecal analysis are methods that have been employed for estimating botanical composition of range herbivore diets. Information on the botanical composition of the grazing animal's diet is essential for: optimal allocation of forage to different types of herbivores, selecting types of grazing animals compatible with the forage resource, selecting species for reseeding on deteriorated ranges, predicting the outcome of overgrazing by different animals, identifying key species on which to base management, and in determining the suitability of exotic animals for a particular range type (Holechek et al. 1980).

Direct observation has been one of the oldest and most commonly used techniques for the determination of an animal's diet. This method has been reviewed by Bjugstad et al. (1970), Theurer (1970), and Theurer et al. (1976). Quantification of forages consumed has been a problem with this method (Holechek et al. 1980). The feeding-minutes and bite count techniques have been used to obtain quantitative information. The bite count technique involves recording the number of bites taken from each plant species (Reppert 1960); whereas, the feeding-minutes approach involves the length of time an animal spends grazing each species (Bjugstad et al. 1970). Bjugstad et al. (1970) reported that active grazing was difficult to differentiate between mere nibbling when tame animals were used. Holechek et al. (1980) reported that a problem encountered when wild animals are observed include locating the feeding animals and approaching close enough for accurate observation. The researchers also speculated that perhaps the greatest drawback to the observation method was the use of tame animals because diet selection is a complex behavioral act that is influenced by several factors (Arnold and Dubzinski 1978, Krueger et al. 1974). Individual plant species and amounts of each selected by a grazing animal appear to be influenced by: physiological condition and degree of hunger, topography and social behavior based on another animal's presence, and the grazing behavior based on past experiences (Holechek et al. 1980). However, Mautz (1978) suggested that if tame animals are employed care should be taken that the animal has consumed a diet representative of that consumed by animals of the same species in a wild population. Allowing experimental animals to forage in a study area for a period of time prior to the actual study can be used to reduce bias (Mautz 1978).

Utilization has been defined by Stoddart et al. (1975) as the percentage of the annual production of forage that has been removed by animals throughout a grazing period or grazing season. Smith et al. (1962) and Martin (1970) reviewed various utilization techniques for estimating diets of grazing animals. Pieper (1978) reported that determining utilization has been one of the most perplexing problems facing range scientists down through the years, and many methods have been developed, but none is completely satisfactory. Utilization methods include: oculuar estimate by plot or plant, clipping before and after grazing, cage comparison method, stem count method, percent of plants grazed or ungrazed, height-weight methods, stubble-height class, and residue method. Methods for the determination of browse species include: Hormay's method, percent of twigs browsed, length of twig removed and twig diameter (Pieper 1978).

Utilization methods are advantageous because they generally are quick and they do provide information on how plants are used in relation to availability and where a range is being grazed. However, Cook and Stoddart (1953) and Martin (1970) gave several problems which may occur when utilization is used to determine diets. Large-scale losses from weathering, trampling, and animals other than the grazing animals of interest can confound results (when a forage species was utilized and how often a forage species was utilized cannot be determined), and fall growth may heavily bias results.

Stomach and intestinal tract analysis are methods that provide information on the kinds of food taken by grazing animals; however, animals must be sacrificed so sample size becomes limiting and location of feeding sites cannot be determined (Holechek et al. 1980). Moen (1981c) reported that there are several problems associated with the stomach or rumen analysis: differences in the recognizability of different plant fragments, differences in the rates of mechanical and chemical breakdown of different plant materials, and differences in the abilities of different persons to recognize the plant species from the fragments.

Esophageal and rumen fistulae have been used with moderate success with domestic livestock. The method involves a surgical incision and the installation of a cannula or plug into the esophagus or rumen. In the early development stages of esophageal surgery, animal losses were great; however, refinement in surgical procedures and cannulae type have reduced animal mortality in recent years (Holechek et al. 1980).

The use of the esophageal fistula is generally preferred to the use of the rumen fistula because: rumen evaluation subjects animals to abnormal physical conditions, is limited to large animals, and is more laborious (Rice 1970). However, rumen fistula samples contain all the forage consumed during the collection period (Holechek et al. 1980). Lesperance et al. (1972) reported that with esophageally fistulated animals forage can be lost from the collection bags or the fistula may become plugged and material allowed to pass through to the rumen. However, the use of an esophageal fistula alleviates the problem of differential digestibility encountered with other methods.

In recent years, fecal analysis has been used widely to describe an animal's food habits. Holechek et al. (1980) reported that Crocker (1959), Ward (1970) and Anthony and Smith (1974) found that fecal analysis allowed practically unlimited sampling, did not interfere with normal habits of animals, placed no restrictions on animal movement, had particular value where animals range extensively over mixed plant communities, and was the only feasible procedure to use when studying secretive and/or endangered species.

The accuracy of fecal analysis has been questioned by a number of researchers (Storr 1961, Stewart 1967, Slater and Jones 1971, Zyznar and Urness 1969, and Gill et al. 1983). Stewart (1967) fed known quantities of eight grasses and found significant differences between the amount fed and counts of epidermal fragments. Zyznar and Urness (1969) questioned the method because only a small percentage of the fecal material could be identified when known quantities of shrub and herbaceous plant material were fed to captive mule deer. Storr (1961) fed known diets to captive kangaroo (*Macropus giganteus*) and concluded that plant epidermis well encased in cutin (i.e., perennials) could be identified but the method did not cope satisfactorily with material not encased in the cutin (i.e., annuals). Slater and Jones (1971), studying the diets of domestic sheep (*Ovis aries*), found that one forb was underestimated while another was overestimated, and the overestimated forb tended to depress the percentage of grass fragments in the feces (Slater and Jones 1971); and Gill et al. (1983) predicted that (1) fecal analysis will underestimate shrubs when woody stems comprise the bulk of the shrub diet, (2) fecal analysis will overestimate forbs when forb species, which are readily identified in fecal samples, dominate forb diets, (3) fecal analysis will underestimate forbs when legumes comprise a significant portion of forb diets, and (4) correction factors will not consistently improve the estimation of mule deer diet composition from fecal analysis when those diets contain a diversity of several species wihin each of the three forage classes--shrubs, grasses, and forbs. In contrast to the above, Hansen (1971) claimed close agreement between composition of ingesta and fecal material of wild sheep (Ovis canadensis).

Comparison studies between rumen, fecal, esophageal and utilization studies have been reported (Lesperance 1960b, Galt et al. 1968, Free et al. 1970, Casebeer and Koss 1970, Free et al. 1971, Todd and Hansen 1973, Anthony and Smith 1974, McInnis 1977, Vavra et al. 1978, Smith and Shandruk 1979, Sanders et al. 1980, Johnson and Pearson 1981, and Kessler et al. 1981). Galt et al. (1968) found considerable difference existed between ocular observations and rumen sample analysis of cattle. Free et al. (1971) reported correlation coefficients of .81, .86, .86, and .95 for spring, summer, autumn, and winter cattle diets when esophageal fistula samples were compared to the bite-count technique. Sanders et al. (1980) reported similar results when the bite-count and fecal analysis methods were used, although the research suggested that the bite-count method was not practical for use on large, brush-infested pastures with rough terrain because of difficulty in observing the animals. Smith and Shandruk (1979) compared diets of pronghorn antelope using four methods: rumen, intestinal feces, site feces and utilization. The researchers found fewer plant species in intestinal and site feces than in the rumen, and even fewer species were recorded by utilization estimates. Lesperance et al. (1960) found that there was little agreement between utilization data and esophageal fistula samples. And, McInnis (1977) found that utilization data gave lower estimates of graminoids and higher estimates of forbs in sheep diets when compared to fistula samples.

Anthony and Smith (1974) compared rumen and fecal samples collected from white-tailed and mule deer in southeastern Arizona. Rumen samples and fecal samples were quite similar although a larger number of rumen samples were needed. Free et al. (1970) estimated the dry weight composition of food plants for esophageal samples from steers, fecal samples of steers, and fecal samples from sheep fed on the esophageal samples. They concluded that there were only small differences in the estimated mean percent dry weight of the species of grasses found in the esophageal samples from steers, the fecal samples from steers and the fecal samples obtained from sheep that had consumed the same esophageal-collected samples. They also noted that the epidermal tissue of forbs were not as easily found in the cattle and sheep feces as they were in the fistula samples and that the epidermal fragments and diagnostic trichomes of some food plants were often subdivided in the feces of sheep to such an extent that only an extremely careful, well-trained technician could recognize their presence. Although Casebeer and Koss (1970) reported close similarity between the stomach contents and fecal material of wildebest (Connochaetes taurinus), zebra (Equus burchelli), and cattle, their data showed certain species were consistently either under- or overestimated. McInnis (1977) fed synthesized diets to bifistulated sheep and compared esophageal, rumen and fecal samples. Fecal samples were significantly higher in their composition of grasses and significantly lower in their composition of forbs than the esophageal or rumen samples. However, Todd and Hansen (1973) compared microrumen and microfecal samples from wild sheep and found no statistical differences between rumen and fecal samples. Vavra et al. (1978) determined steer diets by esophageal and fecal analysis. Regression analysis showed differences between the two techniques; however, comparison-by-importance value ranking resulted in similar diet estimates between esophageal and fecal analysis. Recently, Kessler et al. (1981) studied pronghorn antelope (Antilocarpa americana) diets from three different study sites employing three methods of diet analysis: macrorumen, microfecal, and microrumen. They found general agreement in dietary composition by the three methods employed at two of the three study sites. On the study site that did not show agreement, macrorumen differed from microrumen and microfecal, which did agree. This disagreement resulted, at least in part, from the failure of macrorumen analysis to detect many of the species reported by microanalysis (Kessler et al. 1981). Johnson and Pearson (1981) recently compared esophageal, fecal and exclosure estimates of cattle diets. They found that the estimates from esophageal and fecal samples were about 90 percent similar, but each of these diet estimates was less than 80 percent similar to data obtained from exclosures. However, regardless of the technique, all three diet estimates were highly correlated (r=.99) (Johnson and Pearson 1981). They concluded that in order to obtain accurate results technicians must be trained in a program designed to build their confidence and skills for accurately quantifying compositions of mixtures.

Procedures for Analyzing Rumen, Esophageal and Fecal Samples

Methods used in determining the botanical composition of rumen, esophageal and fecal samples have been reviewed by Theurer (1970), Ward (1970), Theurer et al. (1976), and Holechek et al. (1980). These methods, grouped into four categories by Theurer et al. (1976), include visual appraisal, manual separation with weight or volume analysis, microscope point methods, and microhistological methods.

Theurer et al. (1976) reported that visual analysis without the aid of a microscope gave only qualitative estimates of botanical composition, and most browse plants could be identified using this method but grasses and forbs were frequently masticated beyond visual recognition (Cook et al. 1958).

Theurer et al. (1976) reviewed studies involving manual separation into major plant groups or specific species, and concluded this procedure was time consuming and precision was low when more than one individual performed plant separations.

The microscope point technique involves identifying the forage species which occurs under the cross hairs of a binocular microscope at 16X magnification (Holechek et al. 1980). Usually 100 points are read for each sample and the percent occurrence of each species is calculated. Regression equations are then used to estimate the percent species composition by weight from point data because a 1:1 ratio does not exist between percent points and percent weight. Known diets must be fed and analyzed to develop these regression equations (Holechek et al. 1980). Theurer et al. (1976) reviewed several modifications of the technique as reported by Heady and Torrell (1959), Van Dyne and Heady (1965), Galt et al. (1969) and Durham and Kothmann (1977).

Baumgartner and Martin (1939) first described microhistological examination of foodstuffs. Dusi (1949) made further refinements on the technique and applied it to fecal analysis. Sparks and Malechek (1968) verified the technique by artificially mixing known amounts of grasses and forbs and observed a 1:1 ratio between estimated dry weight percentages and actual dry weights of mixtures. For the technique to be valid, some identifiable portion of the plant must pass through the animal's system undigested. The plant residue (cutin) found in the feces can be identified by cellular structure or some identifiable cellular characteristic. The cuticle (made of cutin) has been described by Hercus (1960) as a morphological entity, being a continuous layer on the outer surface of the shoots of green plants formed by the polymerization of unsaturated fatty substances. The cuticle forms a solid film molded to the contours of the underlying epidermal cells. Schrumpf (1968) provided a more complete description of plant cuticles and their biochemistry. Each plant species has its own peculiar epidermal and, hence, cuticular pattern that allows identification. However, epidermal patterns vary within one plant species according to the type of morphological structure (Schrumpf 1968), leaf surface (Brusven and Mulkren 1960), leaf location on the plant, and growth stage of the plant (Davies 1959). Vavra et al. (1978) found that during the growing season, microhistological analysis of fecal sampling for diet composition tended to underestimate the incidence of forbs and overestimate the occurrence of grasses. In the winter months when plants were mature, fecal samples were more comparable in composition to esophageal samples (Vavra et al. 1978). However, in two studies by Holechek et al. (1981) and Holechek and Gross (1981), the authors reported that growth stage had little effect on accuracy of microhistological analysis.

The procedure of Sparks and Malechek (1968) has become a standard practice in microhistological analysis. The procedure is as follows: samples are oven-dried and ground through a 1-mm screen to reduce all fragments to a uniform size, and five slide mounts of mixed samples are analyzed under a compound binocular microscope under 12X magnification. Only fragments that are known to be epidermal tissue are recorded as presence of a plant species. Frequency percentages are calculated for each species in the mixture and converted to density using a table developed by Fracker and Brischle (1944). Their table had been generated to calculate the number of plants (N) per 100 quadrats likely to be present under strict mathematical probability when any given percentage (i) of quadrats contain one or more plants each (Pfister 1979). Sparks and Malechek (1968) adopted it for use in diet determinations. Once calculated, relative density, expressed as a percentage, is used as a direct estimate of the percent dry weight of a species in the diet (Pfister 1979). Dry weight percentages are predicted directly from relative density (Holechek et al. 1980).

Correlations have been made between observed and expected values for known mixtures when microhistological analysis was used to estimate species composition by weight (Denham 1965, Sparks and Malechek 1968, Westoby et al. 1976, and Holechek and Gross 1981). Denham (1965) obtained a highly significant value (r=.97) when the expected and observed values of six species were correlated. Sparks and Malechek (1968) reported an overall correlation between the expected and observed of .99, and Holechek and Gross (1981) reported a coefficient of .98 between the estimated and actual percent weight composition for 26 mixtures in hand-compounded diets subject to grinding through a 1-mm screen compared to those hand mascerated so that the fragment length did not exceed 2 cm. McInnis (1977) found fewer identifiable fragments in ground than unground fecal samples, and Slater and Jones (1971) reported that less clover was found in ground compared to unground fecal samples.

Presently, limited information is available concerning variation associated with observers when microhistological analysis is used. Holechek and Gross (1981) reported that the average variation associated with four observers was 17 percent when several hand-compounded diets were analyzed. In another study, Holechek et al. (1981) showed the actual estimates of five experienced observers for two hand-compounded diets, and the data suggested that considerable difference can exist between observers. Observers trained by a detailed training procedure were much more accurate than an untrained observer with much greater experience (Holechek et al. 1981). The researchers recommended that trained observers should be replicated when microhistological analysis is used so the source of variation can be quantified. Also, hand-compounded diets should be routinely used by observers to check accuracy (Dearden et al. 1975, Vavra and Holechek 1980, Holechek and Gross 1981, and Holechek et al. 1981).

Another problem with the microhistological technique is differential destruction of epidermal tissues. This situation occurs due to lack of lignification and/or cutinization. In other words, epidermal fragments of certain plant species may not pass through the digestive tract in identifiable condition and thereby bias quantitative food habits data. Storr (1961) found that epidermal cells of annual clovers were almost totally digested, whereas perennial species survived maceration and digestion. Kessler et al. (1981) reported that Fitzgerald and Waddington (1979) used bacterial degradation and chemical maceration to treat brush tailed opossum (Trichosurus vulpecula) fecal samples, and confirmed that differential loss of epidermal tissue fragments occurs during digestion of food plant materials. Pulliam (1978) fed known diets to penned elk (Cervus elaphus nelsoni) for determination of digestibility coefficients. He found significant differences in digestibility between forage species, vegetation classes and phenological stages for seven of 11 species tested.

Recently, microdigestion technique has been used to investigate differential destruction of plant species during passage through the digestive tract. Dearden et al. (1975) and Vavra and Holechek

(1980) subjected hand-compounded diets to microdigestion and then estimated percent weight by the microhistological technique of Sparks and Malechek (1968). Estimated diets were significantly different than actual diets in both studies. This problem was solved by developing regression equations to correct estimated percent weight to the actual percent. Vavra and Holechek (1980) recommended that when fecal analysis is used in ruminant diet quantification sufficient plant material should be collected so that hand-compounded mixtures can be made and digested in vitro. Regression equations can then be developed from estimated and actual values to correct for bias due to differential digestion (Holechek et al. 1980). However, the use of correction factors assumes that digestion rates are essentially constant among individual animals of the same species and remain constant for each species even as diet composition changes (Gill et al. 1983). Recent research by Gill (1972) and Milchunas et al. (1978) suggests that when the array of items in the diet is the same, changes in their relative proportions can alter their individual rates of digestion through associative effects. Furthermore, Gill et al. (1983) concluded that correction factors will not consistently improve the estimation of diet composition from fecal analysis of mule deer diets when those diets contain a diversity of several species within each of the three forage classes--shrubs, grasses, and forbs.

The Food Habits of Mule Deer

Selection of food by deer is determined by many factors, particularly availability, animal preference and plant quality (Willms et al. 1976). Kufeld et al. (1973) summarized the results of 99 food habit studies conducted on mule deer ranges in the western United States and Canada. They reported that during winter, shrubs and trees averaged 74 percent of the diet, forbs comprised an average of 15 percent, and grass, sedges and rushes 11 percent. The greatest number of browse species reported were used in summer and autumn and the smallest number in spring. The report also showed that the consumption of grass and grasslike plants was quite variable in winter diets ranging from 0 to 53 percent. The studies also showed that during spring consumption of grasses rose to 26 percent, and bluegrasses (Poa spp.) were highly preferred as soon as new growth became available. Other important grass species in the spring diet of mule deer were wheatgrasses (Agropyron spp.), especially crested and bluebunch, according to Kufeld et al. (1973). Wallmo and Regelin (1981) further summarized Kufeld's report and listed the most frequently cited forages in the diets of Rocky Mountain mule deer. Snowberry (Symphoricarpos spp.), big sagebrush, rose (Rosa spp.), black chokecherry (Prunus spp.), and bitterbrush were the most cited browse while bluegrass, wheatgrass, and sedge (Carex spp.) were the most frequently cited grasses. They also listed buckwheat (Eriogonum spp.), aster (Aster spp.), lupine (Lupinus spp.), and phlox (Phlox spp.) as the most frequently cited forb in the diet.

In the past, the importance of grasses in mule deer diets generally has been discounted (Wallmo and Regelin 1981). However, recent studies indicate that grasses may be a major portion of mule deer diets (Carpenter 1976 and Leach 1956). Although Aschroft (1973 in Wallmo and Regelin 1981) considered browse important to sustain mule deer populations in winters of extended snow-cover on Great Basin ranges in California, he felt that it could provide only a maintenance diet and that herbaceous forage was the "key to high productivity". Wallmo and Regelin (1981) speculated that grasses--with high cellulose, high digestibility, and low protein--are not only important for high energy value but may increase digestibility of shrubs with low digestibility but higher protein levels; however, more research needs to be done on this complex phenomenon.

The Food Habits of Range Cattle

Grasses were the most important component of cattle diets on sagebrush-grass ranges as reported by Cook and Harris (1968a), Ansotequi et al. (1972), Lesperance et al. (1970), Connor et al. (1963) and Bohman and Lesperance (1967). Bohman and Lesperance (1967) presented data that verified cattle prefer grass over browse when both were available. These workers observed that on a sagebrush-bunchgrass range during an exceedingly dry year cattle consumed 24 percent browse and 71 percent grass. However, during a wet year, when grass was available and fairly succulent throughout the grazing season, no browse was consumed, and grass accounted for 83 percent of the diet (Bohman and Lesperance 1967). Lesperance et al. (1970) compared food habits data from two grazing areas of a desert shrub type range in southern Nevada. One area had been grazed extensively so that during the summer, grasses made up less than 10 percent of plant cover; while in contrast, the other area had limited grazing for 26 years prior to the cattle grazing study. Rumen fistula samples revealed that, at the limited grazing area, grasses comprised 93 to 99 percent during April-May; while in fall, grass comprised only 47 percent of the diet (Lesperance et al. 1970). At the grazed extensively area, grass comprised only 48 percent of the diet between April and May; while during fall, grass comprised 57 percent of the diet. In a 2-year study, Ansotequi et al. (1972) found that rumen fistulated cattle selected over 95 percent grass during May-September on a sagebrush-aspen range in northeastern Nevada. Cook and Harris (1968a) reported that on a sagebrush-grass range in Utah grass comprised 76 percent of the diet from June to September. Uresk and Rickard (1976) working in the shrub-steppe rangeland in southcentral Washington found that the botanical composition of the diets of steers changed throughout the spring grazing season with changing availability and maturation of herbage. Grass accounted for 73 percent of the diet while forbs and half-shrubs contributed 26 percent. The researchers further reported that steers preferred Sandberg's bluegrass, the second most abundant species.

The Concept of Carrying Capacity

The concept of carrying capacity has been defined numerous ways and by a variety of authors (Leopold 1933, Dasmann 1945, 1948, Allen 1962, Range Term Glossary 1964, Dasmann 1971, Heady 1975, and Wallmo et al. 1977, and others). Leopold (1933) described the carrying capacity of a range for deer as the maximum density of deer that a range can support. Allen (1962) simply defined carrying capacity as what a given land unit will support. Allen (1962) further stated that for most game species in the north, the carrying capacity of a land unit usually declines during the cold season and the population is pinched down to fit a late winter "bottleneck". Allen (1962) believed that the carrying capacity of deer ranges commonly depended upon food available in the winter concentration areas during the winter "bottleneck" period.

Dasmann (1945) defined carrying capacity as the maximum number of foraging animals of a given class that can be maintained in good flesh year after year on a range unit without injury to the range forage, growing stock, or to the basic soil resource. Dasmann (1948) further stated that the number of animals that will take no more than the forage crop in all but poorest growth years is the maximum number a range unit will support on a sustained basis. Dasmann (1948) suggested that the range manager should make periodic surveys to enable him to readjust carrying capacity numbers because of fluctuations in precipitation, temperature, evaporation, and varying use patterns that occur on a dynamic, continually changing range.

"Maximum carrying capacity" and "optimum carrying capacity" are two concepts described by Dasmann (1971). Maximum carrying capacity was defined as the greatest number of animals that can be supported on a strictly maintenance basis (<u>in</u> Connolly 1981). Connolly (1981) stated that carrying capacity will fluctuate and rise during favorable years and fall in poor years; and a deer herd will increase during a succession of favorable years when forage production is above average and will decrease when changing environmental conditions causes a drop in forage production. Optimum carrying capacity involves a relatively stable number of animals that can be supported in good condition on a sustained basis--that is, without damage to or depletion of the range (Dasmann 1971 in Connolly 1981).

Carrying capacity was defined by the Range Term Glossary Committee (1964) as the maximum number of individual animals that can survive the greatest period of stress each year on a given land area. However, Heady (1975) believed the Range Term Glossary Committee's definition should be questioned because it does not encompass the capability of rangeland to produce several different products. Heady (1975) stated that carrying capacity should include more than numbers of animals that can survive and do no damage to the range. Heady (1975) further believed the concept should express the greatest return of combined products without damage to the physical resource, and that rangeland carrying capacity resulted from the productivity levels of several rangeland resources. Therefore, Heady (1975) concludes that as many carrying capacities can be defined as there are management objectives.

However, Stoddart et al. (1975) considered grazing capacity and carrying capacity to be synonymous and defined the concept as the maximum animal numbers which can graze each year on a given surface of range, for a specific number of days, without inducing a downward trend in forage production, forage quality or soil.

The nutritional quality of the forage and the knowledge of an animal's nutritional requirements interact to form a framework from which a biological or nutritional carrying capacity analysis has recently been made for big game populations by numerous authors (Ullrey et al. 1970, Moen 1973, Mautz 1978, Wallmo et al. 1977, and Hobbs et al. 1982). Ullrey et al. (1970) stated that a proper evaluation of the food potential of winter deer range must ultimately take into account such estimates of digestible and metabolizable energy of this browse. Only then can the appropriate deer-supporting capacity of the range be established (Ullrey *et al.* 1970).

Mautz (1978) defined carrying capacity as the number of healthy animals that can be maintained by habitat on a given unit of land. He reported that carrying capacity was to be governed by the season of year which is most limiting to a population in question and for most big game populations, winter food limits a population. However, recent work in wildlife energetics showed that some big game species (i.e., white-tailed deer) have a number of mechanisms that tend to reduce the importance of winter food as the sole factor influencing winter survival (Mautz 1978). The buildup of body fat from summer and fall foods, subsequent catabolism of this fat during winter, lowered metabolic rate, development of a highly insulative coat, and changes in behavior all tend to refute or complicate the simplistic notion of a single limiting season (Mautz 1978). Therefore, behavioral, physical, and morphological characteristics of an animal population should be considered in assessing a habitat's nutritional carrying capacity. Mautz (1978) defined his concept of nutritional carrying capacity as the size of a healthy and productive population that the food resources of a unit of land can maintain. He developed the following formula to estimate carrying capacity on a nutritional basis: $A = \frac{BXC}{D}$; where A is the number of animal days which an area can support, B is the food resource (grams available food per acre), C is the amount of metabolizable energy contained in this food (kilocalories per gram), and D is the amount of metabolizable food energy required by an individual animal per day (total energy requirement minus energy provided by catabolism of body tissue).

Moen (1981b) also described a concept of biological carrying capacity. In this definition, he used both the resources available on the range and resources required by an animal to calculate the biological carrying capacity. He proposed that the basic relationship for calculating carrying capacity may be expressed with the following word formula where food energy is the fundamental resource to be considered:

$$\text{Number supported} = \frac{\text{Resources available (metabolizable range energy)}}{\text{Resources required (metabolizable energy per individual)}}$$

Moen (1981b) uses metabolizable energy in his formula because "it is the ultimate level of interaction between animal and range; the biochemical plane at which the interaction occurs". He suggested that a person cannot make a single calculation for a given area and say that the answer is the carrying capacity because animal requirements as well as the range resources change through time. Therefore, biological carrying capacity will change with seasons as both the resources available and resources required by the animal change.

Recently, Hobbs et al. (1982) calculated energy and nitrogen based estimates of elk winter range carrying capacity in Rocky Mountain National Park, Colorado. Carrying capacity was based on quantification of forage energy and nitrogen supply and knowledge of elk energy and nitrogen requirements for nine habitat types according to a modification of the formula of Mautz (1978):

$$K = \frac{N(Bi \times Fi)}{(Rq \times days)-En} \text{ where}$$

K = Number of elk the range can support for the winter period
N = Number of principal forages
Bi = Consumable biomass of principal forage species
Fi = Nutrient content of principal forage species
Rq = Individual elk requirements
Days = Number of days elk occupy the winter range
En = Endogenous reserves of nutrient

The objective of the study was to demonstrate that estimates of nutritional carrying capacity were viable habitat-evaluation procedures. They concluded that nutritionally based estimates of carrying capacity offered a valuable procedure for evaluation of elk habitat. That is, they provided accountable estimates of the quality of ungulate ranges based on measurable attributes of the habitat that were directly related to individual animal condition and population performance. They also suggested that when resource supply fluctuates from year to year, managers should anticipate variation in animal numbers and individual animal condition unless populations are maintained well below maximum carrying capacity. Thus, carrying capacity should be reviewed as a liable rather than a static characteristic of the habitat (Hobbs et al. 1982).

Wallmo et al. (1977) working in northcentral Colorado evaluated mule deer habitat on both a quantitative and qualitative basis to determine its carrying capacity. For the qualitative evaluation, a model of the ability of ingested forage to supply the energy needs of deer was developed using the following parameters: body weight (W), metabolic weight ($BW^{.75}$), activity metabolic rate (AMR), forage intake (INT), gross energy (GE), and dry matter digestibility (DMD). The quantitative evaluation was accomplished by simply estimating the kilograms per hectare of forage available and applying the appropriate proper use factor. Wallmo et al. (1977) found that in terms of forage quantity and quality, the habitat would carry more deer on a quantitative basis than on a qualitative basis. On the late winter range, forage quantity was calculated to be adequate for 14,000 deer. However, the available forage did not meet either the protein nor energy requirements of the deer. In fact, the available energy in the forage was little over 50 percent of the estimated requirement. Furthermore, the researchers stated that over-wintering mortality rates of deer are not governed by the potential of the total forage resource to support deer but by snow conditions (which determined the energy cost for the energy gained from grazing) and by the duration of the winter. Because of the changing environmental conditions, Wallmo et al. (1977) concluded "the concept of a stable carrying capacity for deer in the high valleys of the central Rockies is unrealistic".

Forage Intake Values for Deer and Cattle

Experimental data on determining the quantitative intake of grazing livestock was reviewed by Cordova et al. (1978). According to Cordova et al. (1978), intake estimates for grazing livestock were highly variable but those values considered most valid showed a range of 40 to 90 g of dry matter per kg/MBW. From several studies conducted with grazing cattle and sheep in the western United States, intake estimates have generally ranged from about 1 to 2.8 percent of body weight; and most studies showed a decline in intake with advancing plant maturity (Cordova et al. 1978). A study by Connor et al. (1963), working with Hereford steers on a sagebrush-grassland range in northern Nevada, determined the intake rate to be between 69.4 and 85.9 g per kg/MBW. However, on a desert-shrub range in southern Nevada, Connor et al. (1963) determined the intake rate in July to be between 42.1 and 74.4 g per kg/MBW. Handl and Rittenhouse (1972), working with 275-kg steers on a crested wheatgrass seeding in eastern Oregon, determined an April intake value between 5.7 and 7.2 kg. Kartchner et al. (1979), working with commercial grade Herefords in eastern Oregon, determined the intake rate for six fall-calving and six spring-calving cow-calf pairs grazing in common on a crested wheatgrass pasture. The combined cow-calf intake for early spring was determined to be approximately 14 kg/day or 420 kg/month, while dry mature cows during the fall had an intake rate of approximately 10 kg/day or 300 kg/month (Kartchner et al. 1979).

A consumptive rate of approximately 1.4 kg of air-dry forage per 100 weight for mule deer has been reported by Doman and Rasmussen (1944), Rasmussen and Doman (1943), French et al. (1955), Hill (1956), and Richens (1967). Mautz et al. (1976), determining the digestibility of white-tailed deer browse, estimated a maintenance requirement of 1.7 kg per day. Twenty-month-old mule deer grazing in a small pasture in Middle Park, Colorado, in February had intakes ranging from 15 to 50 g/kg of BW per day (Carpenter and Baker 1975). Allredge et al. (1974) estimated the seasonal daily forage intake of free-ranging mule deer in northern Colorado from concentrations of fallout cesium-137 in vegetation and deer muscle tissue. Their findings indicated a cyclic pattern of forage intake by free-ranging adult deer with greatest intake in summer and restricted intake in winter. They reported the average winter intake was 21.9 g/kg of BW per day for fawns and 21 g/kg of BW per day for adults.

Protein Requirement of Wintering Deer

The protein requirements of deer have been reported by numerous researchers (French et al. 1955, Magruder et al. 1957, McEwen et al. 1957, Dietz 1965, Murphy and Coates 1966, Halls 1970, Holter et al. 1979). Murphy and Coates (1966), and Halls (1970) suggested that 7 percent crude protein was the minimum necessary for maintenance assuming energy supplies are sufficient so that body protein does not have to be catabolized for energy. Murphy and Coates (1966) also found that white-tailed deer fed diets containing 7 percent crude protein developed slower and had poorer condition and fawn survival than deer fed more protein. However, McEwen et al. (1957) indicated a protein content of 7 to 9 percent caused no apparent stress to white-tailed deer entering winter in good condition. Magruder et al. (1957) suggested that diet dry matter for white-tailed deer older than one year of age should have about 7 to 8 percent crude protein for body weight maintenance and about 14 to 18 percent crude protein for "optimum" body weight gain. Holter et al. (1979) found that maintenance requirement for crude protein was computed to be met by a diet containing 5.8 ± 2.0 percent crude protein. Dietz (1965) found the postpartum survival of mule-deer fawns was reduced by low levels of protein in the diet of pregnant females, and fawn mortality apparently resulted from delayed or inadequate lactation by undernourished does. Dietz (1965) concluded that productivity, survival and condition of breeding does were adversely affected by reduction of protein in the diet to 7 and 11 percent and rumen functions were serously impaired if crude protein levels fell below 6 percent. Dietary crude protein levels for white-tailed deer have been suggested at 13 to 16 percent for optimum growth and 6 to 7 percent for maintenance (French et al. 1955). Moen (1981c) agreed with the National Research Council (1950) which reported "less than 8 percent crude protein in the dry matter of dry range forage . . . is deficient for all classes of livestock".

Because some of the protein required is met by recycled urea, animal requirements are more complicated as the amount of urea recycled is a function of the protein content of the forage. Urea recycling represents a means of conserving nitrogen which may contribute significantly to the nitrogen economy of the ruminant consuming poor quality forage (Robbins et al. 1974). This unique phenomena has been derived from experiments involving measurements of total N intake and N losses in urine and feces (Church and Pond 1974). Moen (1981c) reported that recycling of urea was a nitrogen conservation adaptation when protein intake went down, "a characteristic of winter range conditions when many species of wild ruminants are on a browse or highly lignified diets". Robbins et al. (1974) reported that as urea recycling increased, the biological value (percent of N absorbed from the gut) increased because of the protein synthetic abilities of the GIT microflora in ruminant animals. The researcher found that at a 5 to 26 percent dietary protein intake, as much as 40.6 to 92.3 percent of urea entering the body pool was recycled in the GIT. If a single estimate was to be made for deer on natural diets of about 10 percent crude protein, Moen (1981b) estimated recycled nitrogen represented about one-third of the total nitrogen intake, which may be interpreted to mean about three-fourths and one-fourth of the daily nitrogen requirement is met by diet and urea recycling, respectively.

Protein Requirements of Range Cattle

Dietz (1970) reported range animals must have protein to form new cells essential for body maintenance, growth, reproduction, and lactation. Halls (1970) reported adequate protein was essential for growth, weight gain, appetite, milk secretion, and regular oestrus. Crampton and Harris (1969) reported lactation represented a direct loss of protein to the body which must be replaced. Appreciable deficiencies in total protein or in protein quality were usually reflected in decreased voluntary food intake and in less efficient use of food that was eaten (Crampton and Harris 1969, and Halls 1970).

Raleigh and Lesperance (1972) reported protein requirements of ruminants grazing arid land would appear to be the same as those for animals under confinement. Extreme activity may result in some increase in protein requirement simply because of excessive tissue destruction; however, Raleigh and Lesperance (1972) reported this increase is, in all likelihood, very slight.

Halls (1970) reported the NRC (1963) tables showed protein requirement for a wintering mature pregnant cow was 7.5 percent, while a cow nursing a calf during the first 3 to 4 months postpartum had a protein requirement of 8.3 percent. The NRC (1976) table showed a 350-kg pregnant mature cow had a protein requirement of 5.9 percent, while a 400-kg cow nursing a calf during the first 3 to 4 months postpartum had a protein requirement of 9.2 percent.

Digestible and Metabolizable Energy Requirements of Wintering Adult Deer and Fawns

Dietz (1970) stated energy is a highly significant measure of the nutritive value of feeds and considerably more nutrient is required to maintain normal energy metabolism than for all other purposes combined. With the possible exception of protein and phosphorus deficiencies, the most common nutritional deficiency affecting range animals is lack of either available energy, digestible energy, or both (Dietz 1970). Dietz (1970) further reported a shortage of energy-producing feed is most common on overused winter ranges and on early spring ranges at the time animals switch to watery green grass and forbs. Range animals may eat an excessive quantity of watery green forage after spring growth begins and the result may be scours or the inability of the weakened animal to adjust to the new feed, with heavy mortality (Dietz 1970).

It is generally agreed the energy requirements of wild ruminants in their natural environment are poorly understood, and food or nutrient requirements of big game have received only limited study (Baker et al. 1979 and Mautz 1978). However, big game ecologists presently have greater knowledge of energy requirements than of other nutrient requirements even though with energy there is still much to be learned (Mautz 1978). Blaxter (1967), Ullrey et al. (1969, 1970), Silver et al. (1969, 1971), and Moen (1973) have attempted to estimate the energy requirement for adult deer while Nordon et al. (1970), Ammann et al. (1973), Thompson et al. (1973), Mattfield (1974), Holter et al. (1977), Kautz (1978), and Baker et al. (1979) have attempted to estimate the energy requirement for fawn deer.

Silver et al. (1969) measured heat production (energy expenditure) of fasting white-tailed deer over all months of the year by indirect calorimetry employing a respiration chamber. The average heat production for does per 24 hours from December to March was 97.1 kcal/kg $BW^{.75}$/day; while for fawns during February, the heat production was 90.2 kcal/kg $BW^{.75}$/day. In a later study, Silver et al. (1971) measured heat production of fasting adult white-tailed deer in a respiration chamber of seven successively lower levels of environmental temperature within the range of approximately 20°C to 13°C. At the lowest chamber temperatures, average energy expenditure was 138 kcal/kg $BW^{.75}$/day. However, with the development of an improved metabolism unit which permitted the quantitative collection of both urine and feces, Ullrey et al. (1970) was able to determine ME needs. The average estimated daily maintenance requirement for the winter period was 158 kcal of digestible energy (DE) and 131 Kcal of ME/kg $BW^{.75}$/day (Ullrey et al. 1970). Even though different deer and a different diet were used in a different year, Ullrey's et al. (1970) estimate of DE needed for winter maintenance of white-tailed does (158 kcal/kg $BS^{.75}$/day) was very close to his previous 1969 estimate assuming ME was .82 of DE. Ullrey et al. (1970) converted Silver's et al. (1971) estimate of 138 kcal/kg $BW^{.75}$/day to metabolic rate/feed weight $^{.75}$ (i.e., 5% higher body weight due to the weight of contents in the digestive tract) and calculated a similar estimate of 131 kcal ME/kg $BW^{.75}$/day energy required.

Thompson et al. (1973) carried out 37 complete digestibility, nitrogen balance, and indirect respiration calorimetry trials on eight hand-reared white-tailed deer fawns. Apparent maintenance ME requirements were determined to be 109 kcal ME/kg $BW^{.75}$/day during January, and buck and doe fawns exhibited similar energy and protein utilization patterns over the period studied.

Kautz (1978), employing a respiratory face mask technique on three mule deer fawns during winter, estimated the energy expended for bedding, standing, and walking to be 121, 193, and 304 kcal/kg $BW^{.75}$/day, respectively. Mattfeld (1974), also using a respiratory face mask and working with white-tailed deer fawns during winter, estimated the energy expended during bedding, standing, walking, and running to be 197, 318, 651, and 1465 kcal/kg $BW^{.75}$/day, respectively. High values reported in the above two studies may be related to use of the face mask procedure, which may result in a somewhat wider range of activity and sensory input for these animals than for those studied in respiration chambers (Kautz 1978).

Baker et al. (1979), working under winter conditions in north-central Colorado and employing digestion trials, determined the maintenance requirements of tame mule deer fawns to be 158 kcal of ME/kg $BW^{.75}$/day. Ammann et al. (1973), also employing digestion trials with white-tailed fawns during January, February and March, determined the DE intake to be 155 kcal/kg $BW^{.75}$/day. At this intake level, fawns were able to maintain a constant energy balance (Ammann et al. 1973); while Nordon et al. (1970), using a respiration chamber, determined the energy requirement for a resting male black-tailed fawn to be 80 kcal/kg $BW^{.75}$/day and for a resting female black-tailed fawn the energy requirement was 149 kcal/kg $BW^{.75}$/day. Finally, Holter et al. (1977), employing a respiration calorimetry technique, determined that white-tailed deer in their first winter required 148 ± 19 Kcal/kg $BW^{.75}$.

Expenditure and Conservation of Energy by Wintering Deer

The extent to which the results of energy requirement experiments can be extrapolated to free-ranging deer is speculative. Baker et al. (1979) concluded energy values obtained from his study are, at best, a first approximation of the energy budget of mule-deer fawns in winter. They reported energy requirements determined from penned animals probably underestimated the requirements for free-ranging animals because unrestrained deer are presumably more active, exposed to more harsh weather, and consume forages of lower digestibility.

The high costs of locomotion through snow at different depths was investigated by Mattfeld (1974) employing a respiratory collection technique. Mattfeld (1974) concluded snow conditions had a significant effect on energy expenditure per unit distance and logarithmic increases in energy expenditure occurred as the depth white-tailed deer sank into snow increased.

There are many ways a free-ranging deer can minimize energy expenditure. Moen (1968b) reported the occupation of microclimates with stable temperatures increased solar radiation and reduced wind velocity was a way for deer to minimize energy expenditure.

Jacobsen (1973) investigated the effects of bedding posture and the stage of winter hair growth on heat transfer. He reported conductive heat transfer was reduced by 38 percent by changing from a maximum open posture to a minimum closed posture. Carpenter and Baker (1975), studied the 24-hour activity patterns for mule deer, and showed mule deer conserved energy by spending 57.3 percent of their time bedded and 42.7 percent of their time grazing during winter months.

Mautz et al. (1976) suggested deer can meet a portion of their energy and protein needs during winter by catabolizing stored fat and protein. They reported the net usable caloric yield from catabolized fat is about 6 kcal/g. Robbins et al. (1974) found the fat content of pen-fed white-tailed deer of about 60 kg to be approximately 15 percent or 9 kg. Wallmo et al. (1977) stated this amount (i.e., 9 kg) of fat catabolized at the rate of 292 g/day would be used up in 30 days.

There are also several physiological mechanisms regulating food intake in deer during winter months. Seasonal changes in apparent function of endocrine glands of white-tailed deer were noted by Hoffman and Robinson (1966). The depressed state of the thyroid during midwinter is particularly noteworthy, as this organ is believed to be involved in acclimation to cold exposure. There is an observed voluntary reduction in intake during the breeding season and winter (French et al. 1960, Long and Cowan 1964, Long et al. 1965, Behrend 1966, Fowler et al. 1967, Nordon et al. 1968, Ozoga and Verme 1970, and Seal et al. 1972). Ozoga and Verme (1970) found white-tailed deer not only progressively reduced food intake throughout the early part of the winter but, at the same time, also voluntarily restricted their activity. The relative inactivity or resting state during midwinter helps to conserve vital body heat and energy. As spring approaches, deer appetite and movements increase (Verme and Ullrey 1972). The cyclic patterns in food consumption and activity suggests the animal adjusts physiologically and behaviorally to withstand severe environmental stress (Verme and Ullrey 1972).

Energy Requirement of Range Cattle

Hall (1970) reported the NRC (1963) stated that lack of energy was the most common deficiency in the diets of sheep and cattle. Raleigh and Lesperance (1972) reported nutritional studies have generally indicated animals grazing arid land forages are subjected to nutrient deficiencies, in decreasing order of importance: energy, protein, phosphorus, and vitamin A. The development of more precise requirements for P and vitamin A, as well as more usable sources on nonprotein N as a protein substitute, places increasing emphasis on energy as being the basic limiting nutrient for most animals using the arid land resource (Raleigh and Lesperance 1972).

Hall (1970) also reported the NRC (1963) stated wintering mature pregnant cows require 18,000 kcal ME while cows nursing calves the first 3 to 4 months postpartum require 33,600 kcal ME. He further reported that using the interspecies mean of 70 kcal/$BW^{.75}$ and Blaxter's (1967) conversion factors, the estimated maintenance requirement of ruminants was 95.2 kcal ME/$BW^{.75}$. Recently, the NRC (1976) reported a 350-kg dry pregnant mature cow required 1.9 Mcal of ME per kg of intake, while a 450-kg cow with a nursing calf the first

3 to 4 months postpartum also required 1.9 Mcal of ME per kg of intake. Kartchner and Campbell (1979) reported a combined cow-calf intake for early spring was 14 kg/day while dry mature cows during the fall had an intake rate of 10 kg/day. Employing the NRC (1976) requirement figures and Kartchner and Campbell's (1979) intake figures, I calculated that a 450-kg cow with a nursing calf the first 3 to 4 months postpartum required 26.6 Mcal of ME, while a 350-kg dry pregnant mature cow required 19 Mcal of ME.

However, few, if any, energy metabolism studies have been undertaken with range livestock; their energy requirements are often extrapolated from standards developed in livestock feeding trials conducted indoors (Halls 1970). Osuji (1974) reported energy requirements of free-ranging animals have been more difficult to estimate than animals indoors because of complications of environmental factors. After reviewing the work of several researchers (Wallace 1955, Reid 1958, Corbett et al. 1961, and Hutton 1962), he concluded livestock at pasture have maintenance needs 50 to 100 percent greater than livestock indoors. He suggested this increased requirement might be due to the energy cost of eating, walking, grzing, and the "work of digestion" done by the gut in handling bulky pasture materials. Recently, Havstad and Malechek (1980), employing an isotope dilution technique in combination with the principles of indirect calorimetry, found energy expended by heifers grazing crested wheatgrass rangeland in western Utah was 160 kcal/kg $BW^{.75}$. The study also showed the daily energetic cost of restrained animals was at least 20 percent below values associated with free-ranging animals (Havstad and Malechek 1980).

Procedures for Determining the In Vitro Dry Matter Digestibility of Forages

The digestibility of forages is related to the structure of the plant cell and refers to the proportion of cell contents to cell wall. The cell contents or cell solubles are composed of sugars, soluble carbohydrates, starch, pectin, protein, nonprotein nitrogen, lipids and other soluble components and are 98 percent digestible in mule deer (Short and Reagor 1970), sheep and cattle (Van Soest 1967). The cell wall material, the substance of plant fiber, is composed largely of cellulose, hemicellulose, lignin and cutin and is of varying digestibility due to the relationship between the digestible components and structural or chemical inhibitors of digestion (Wallmo 1978). Cellulose and hemicellulose in pure form are entirely digestible by rumen bacteria; whereas, lignin and cutin are not digested and apparently inhibit cellulose and hemicellulose digestion (Wallmo 1978). Annual oscillations in forage digestibility are due to seasonal climatic factors which affect forage quality. The phenomena of decreasing digestibility, protein, and soluble carbohydrate levels in plants with increasing lignification and cell wall content, over summer maturation and winter dormancy period, is well documented in the literature (Arnold 1962, Dietz et al. 1962., Reynolds 1967, Rice et al. 1971, Smith et al. 1971, Urness et al. 1971, Wallace et al. 1972, Milchunas 1977, and others).

A conventional digestion trial, often referred to as the total fecal collection method (in vivo), has been used to determine the digestibility of forages for mule deer (Smith 1952, Bissell et al.

al. 1955, Urness et al. 1977, and Milchunas 1977) and for range cattle (Gallinger and Kescher 1964, Wallace et al. 1965, Wallace and Van Dyne 1970, and Scales et al. 1974). The method involves collecting a large number of forages representative of a range animal's diet and determining the amount of food consumed and feces excreted over a given period of time.

The task of conducting a conventional digestion trial is often impractical and both prohibitively expensive and time consuming (Palmer and Cowan 1980, Mautz 1978, and Milchunas 1977). The collection of sufficient native forage alone is a difficult task (Milchunas 1977). Also, deer must be hand raised and tamed before they satisfactorily submit to confinement in metabolism cages (Reichert 1972 and Milchunas 1977). Ammann (1973), Dietz et al. (1962), Mautz (1971), and Ullrey et al. (1964) have reported difficulty in using deer in metabolism cages. Therefore, indirect micromethods involving the use of internal indicators, fecal indexes, and microdigestion techniques have been widely used for determining the digestibility of range forages.

A microdigestion method that is commonly used is the artificial rumen or in vitro method. This technique consists of a series of test tubes that simulate the rumen itself and a constant-temperature water bath that maintains thermal conditions similar to those inside the rumen. The test tubes are partially filled with the experimental forage and appropriate buffers and innoculated with rumen fluid that has been extracted from a rumen-fistulated animal. After an incubation period, the products of digestion are analyzed, and in vitro dry matter digestibility is calculated by subtracting the weight of the digested sample from the original sample. Three *in vitro* methods have been proposed by the following investigators: Tilley and Terry (1963), Van Soest et al. (1966), and Pearson (1970).

Van Dyne and Hanz (1968) reported the following variables which affect results from *in vitro* fermentation: variation in microbial populations; variation due to storage, grinding and processing techniques; differences attributable to medium; and procedural variations such as length of fermentation. Johnson (1969) felt inoculum was the largest source of error and he reported the following factors can attribute to variability: diet of the animal; feeding system (time); time of removal of rumen contents; methods of processing rumen contents; handling rumen liquor between animal and *in vitro* vessel; and treatment in the laboratory prior to incubation. Moen (1973) reported the *in vitro* technique if it was used properly was an excellent supplementary tool for research in ruminant nutrition. However, he stressed an artificial rumen was not identical to a natural one and the dynamics of the living rumen musculature and the motion caused by gross animal activity were missing, as are the histological changes that occur continually in the rumen lining (Moen 1973).

Although there are potentially many sources of error involved with the *in vitro* method, there are advantages to this technique, including the large number of artificial rumens (test tubes) that can be set up and analyzed at one time, and the small amount of forage required per sample. It has been experimentally proven that the *in vitro* acid pepsin digestion of Tilley and Terry (1963) can produce significant correlations with apparent *in vivo* digestion trials as demonstrated with livestock by Wallace et al. (1965), Oh et al. (1966), and Scales et al. (1974), and with deer by Ruggiero and Whelan (1976), Palmer et al. (1976), Milchunas (1977), Wilson et al. (1977), and Urness et al. (1977).

Questions have been raised concerning the validity of using the inoculum from an animal fed a forage different from that forage being evaluated. Several workers have studied this subject and recommended the inoculum source animal either be fed on the same forage to be evaluated (Pearson 1970), or be fed a standard forage that is analyzed simultaneously with other forages and used as a correction factor (Van Dyne 1962, Bezeau 1965, Johnson 1966, Bruggemann et al. 1968). Pearson (1970) investigated the effect of analyzing native range species with inoculum from animals grazing introduced species, and vice versa. He found no overall difference in the forage digestibilities due to inoculum source, but examination of the individual samples revealed differences of up to 10 percent. He concluded since individual values are important, his results substantiate use of inoculum from animals grazing the forage to be analyzed (Pearson 1970). In the work of Van Dyne (1962), cellulose digestion was higher when inoculum was taken from a steer fed alfalfa hay than from a steer fed oat hay. However, Scales et al. (1974) did not find it necessary to feed the fistulated donor animal the same forage as that to be evaluated. Inoculum taken from animals grazing the same forage from which the analyzed forage samples were obtained did not produce as reliable results as did inoculum obtained from stall-fed steers (Scales et al. 1974).

Recently, Palmer (1976) experimentally compared the feasibility of using inoculum from a nonlactating rumen fistulated Jersey cow to inoculum obtained from a rumen fistulated white-tailed deer. He demonstrated using a modification of the Tilley and Terry (1966) method that inoculum from a cow yielded *in vitro* dry matter digestibility (IVDMD) values less variable and more closely correlated with deer *in vivo* values than those obtained with inoculum from a fistulated deer. The following disadvantages associated with using deer inoculum were reported by Palmer (1976):

1. Repeatability of IVDMD with cow inoculum was excellent; whereas, values obtained from deer inoculum were inconsistent.
2. Several people were required to restrain a deer during collection.
3. The donor deer went "off feed" for several days after collection and periods of recovery were required before subsequent collections were made.

Other investigators encountering problems using deer in digestion trials are Dietz et al. (1962), Ullrey et al. (1964), Mautz (1971), Ammann (1973), and Palmer (1976). Since the results from Palmer's (1976) experiment showed no difference between results obtained with inoculum from the deer and cow and considering the above-mentioned problems with fistulated and/or sacrificed deer, "it seems logical to use inoculum from a cow or steer fed a standard diet when deer foods are evaluated with the *in vitro* technique" (Palmer 1976). The results from Palmer's experiment also showed the *in vitro* digestion technique, with the cow as the inoculum source, can be used successfully in predicting *in vivo* digestibilities of deer foods. Furthermore, Moen (1981c) reported the source of inocula need not be a major consideration when employing *in vitro* digestion studies. Results with inocula from a captive deer on an alfalfa (*Medicago* sp.) diet were within 2 percent of *in vivo* determinations from a wild deer and from a cow, within 3 percent (Robbins et al. 1975). Moen (1981c) believed the above differences may not satisfy a nutrition specialist, but they are all well within the range of accuracy when estimating diets, populations, and other ecological parameters of free-ranging animals. He further stated "the accuracy of *in vitro* determinations of digestibilities by wild ruminants are fully as great as the accuracies in determining food habits and other characteristics of free-ranging animals" (Moen 1981c).

Procedures for Determining Digestible and Metabolizable Energy of Forages

Recently, energy is the nutritional entity to which most attention has been directed; although this does not necessarily imply energy is more important than other nutrients. It is generally agreed that if a wild animal is able to meet its energy needs, its requirements for protein and other nutrients probably will be covered incidentally (Swift, 1957). However, exceptions include possible mineral and/or protein deficiencies in some big game populations during one or more seasons of the year (Dietz and Nagy 1976, Mautz 1978).

The energy value of forages is usually described by a sequence of values from gross to digestible to metabolizable to net energy, with the last three values dependent on the animal's efficiencies in extracting and using the potential energy in the forage (Mautz 1978).

Gross energy (GE) in a forage is generally thought of as the amount of energy released when a sample of forage is completely oxidized in a bomb calorimeter. Expressed as Kcal/g, it is the initial nutritive measurement of the energy in the product of primary production. However, as a result of the biochemical functions in the gastrointestinal tract, GE is not necessarily related to the nutritive energy of a forage (Moen 1981c).

Mautz (1978) defined DE as the energy (in Kcal) or percent of gross energy of an ingested food which is absorbed from the gastrointestinal tract. Digestible energy is usually thought of as the GE in ingested food minus the energy in the feces. And the calculation of DE requires the energy content (Kcal/g) of food and feces as well as the actual amounts of dry matter ingested and excreted over a period of time (Mautz 1978).

Because there is only a small difference in energy concentrations (Kcal/g) between food ingested and feces excreted, DE is generally very similar to in vitro dry matter digestibility. Milchunas et al. (1978) and Mautz et al. (1974) reported a 1:1 relationship between in vivo digestible dry matter (IVDMD) and in vivo digestible energy (IVDE). Moir (1961), working with sheep in Australia, reported a high correlation (r=.98) between DE and dry matter digestibility. Rittenhouse et al. (1971), working with range cattle on the Great Plains grassland, developed the following regression equation to predict DE from IVDMD:

$$\text{DE, Mcal/kg DM} = .038\ (\%\ \text{IVDMD}) + .18$$

The above equation was developed with several different forages and should be applicable on other range types (Holechek 1980).

Robbins et al. (1975) developed the relationship between the in *vivo* apparent digestible dry matter and DE of forages and pelleted diets fed to white-tailed and mule deer using the results of his study and published values of Short and Remenga (1965), Ullrey and Kemp 1968, Ullrey et al. (1967, 1969, 1971a, b, and 1972), Motherhead et al. (1972), and Mautz et al. (1974). Robbins et al. (1975) concluded the apparent digestible energy was approximately in a 1:1 relationship to apparent digestible dry matter for feeds consumed by deer. The developed regression equation was (Robbins et al. 1975):

$$\text{DE, Mcal/kg} = -.713 + .991x$$

Digestible energy absorbed by the blood is not completely useful to the ruminant animal. Some portions of the nutrients are lost through urine and methane gas. Metabolizable energy is the energy left after true digestible energy, heat energy of fermentation, energy in methane (product of fermentation eliminated by eructation), and urinary energy have been partitioned out of gross energy (Moen 1981c). Thus by taking urine and methane gas into consideration, it is possible to obtain a more accurate measure of a food's nutritive value. According to Moen (1981c), ME is converted to body tissue and is used for basal metabolic processes, activity, production, and other processes basic to life. Mautz et al. (1974) reported that it is likely that ME is the best measure of energy value for a food when it is consumed during a time when the environmental temperature is low.

Metabolizable energy can be predicted from DE because of the general predictability of methane and urine production (Robbins 1973). Methane and nitrogen-corrected urinary energy increases as the digestible energy of the diet increases. Robbins (1973) found that ME coefficients for white-tailed deer, based on the observed urinary and methane energy losses, averaged 93.5 percent for hardwood browse and 83.9 percent for coniferous browses. Ullrey et al. (1970) studied ME requirements for adult white-tailed does using a feeding trial method. The researcher calculated ME to be 82.8 percent of DE by combining the measured urinary energy loss and estimated urinary loss in methane production and subtracting the total from apparent digestible energy requirements.

Thompson et al. (1973) studied energy requirements of fawns using a feedlot technique and found efficiency of conversion of DE to ME was 87 percent and the conversion was not influenced by sex or season.

Milchunas (1977), working with mule deer, found ME as a percent of DE ranged from 65.5 percent to 77.0 percent and forages of lower DE had increasingly lower ME coefficients. Milchunas' (1977) results did not agree with Blaxter et al. (1966) where the ratio of ME to DE in sheep varied little from mean values of .82. Milchunas (1977) further stated that range forage may have high GE and DE but relatively lower ME values because essential oils are absorbed but not metabolized and are largely excreted in the urine.

Mautz et al. (1976) observed ME to DE ratios in deer consuming forages ranging from .74 to .86, and Holter et al. (1976) observed a ratio of .88 for deer consuming a pellet concentrate. Wallmo et al. (1977) reported that Brody (1945) and Smith (1971) found ME to be about 85 percent of DE.

The NRC (1976) gave the following conversion using DE values to calculate ME values:

$$\frac{\text{DE in Mcal/kg}}{1.22}$$

Net energy (NE) for maintenance, activity and heat production is often thought of as the ME less the energy required for the digestive process. The energy required for the digestive process has been given various names including work of digestion, heat increment, heat of nutrient metabolism and specific dynamic action. Understanding NE is confusing because the energy expended in the digestion process eventually is "degraded" to the form of heat (Mautz 1978). However, if an animal is in a situation where this heat is used to help maintain body temperature, then the "work of digestion" does not represent a loss (Mautz 1978). Because NE is not as clear-cut as the previously discussed energy losses, it is usually not considered, especially when attempting to determine a forage's energy supply during winter months. Mautz (1978) further reported it is likely the true value of a food in terms of usable energy during the winter months lies somewhere between ME and NE. Moen (1981c) stressed that because of the complexity of NE determination, ME is the finest division that can be applied to ecological situations.

Procedures for Determining the Crude Protein Content of Forages

Proteins are nitrogeneous compounds made up of amino acids. Many amino acids linked together form a polypeptide, and very long polypeptides are proteins (Moen 1981c). Crude protein does not give an indication of the kinds and amounts of amino acids present, but there is no evidence that ruminant animals require certain amino acids in their forage since digestion in the rumen is a microbiological process and amino acids are synthesized as needed by rumen microorganisms.

Subsequent digestion of these microbes by the ruminant releases amino acids by the host animal (Mautz 1978). Rumen microflora have the ability to synthesize all required amino acids provided an adequate source of energy, nitrogen and other components are available in food in order to provide necessary nourishment for rumen microflora. Milchunas (1977) reported fiber-digesting bacteria in the rumen were most commonly limited by shortage of nitrogen (Schwartz and Gilchrist 1975). Nitrogen intakes have marked effects, not only on nitrogen digestion, but also on feed intake and digestion of dry matter (Leibholz and Hartmann 1972, and Weston and Hogan 1967). Milchunas (1977) further speculated diets low in nitrogen may both reduce digestion and intake of energy and nitrogen.

The basis for the requirement of protein involves losses the ruminant suffers in nitrogeneous end products. In order to maintain the ruminant in nitrogen (or protein), equilibrium intake must be sufficient to balance output loss. Moen (1981c) reported protein requirements may be estimated directly by measuring the amount of and evaluating the protein fraction of selected metabolic products. These measurements involve the use of captive animals, and feces and urine collections. The amount of feces and urine, and the metabolic nitrogen fraction of each of these waste products, provides an indication of how much protein has been catabolized (Moen 1981c).

A micro-Kjeldahl digestion procedure with portable distillation equipment has been successfully used to determine the crude protein content of forages (Geist 1973). Crude protein represents protein and nonprotein nitrogen. It is calculated by multiplying the nitrogen percentage of a forage by a factor--usually 6.25 (Dietz 1965).

THE STUDY AREAS

Location

The Keating Valley is located approximately 25 km northeast of Baker, Oregon (Figure 1). Three known areas where deer concentrate during the winter and cattle are grazed during the spring and fall were delineated on topographic maps by personnel at the Bureau of Land Management district office in Baker, Oregon. The three areas consisted of the Crystal Palace allotment, Spring Creek pasture, Middle pasture in the Goose Creek allotment and the Tucker Creek allotment (Figure 2).

The exact location of the Crystal Palace study area lies within the SW1/4 and the SE1/4 of section 30, the NE1/4 and the SE1/4 of section 31, all of section 32 and the NW1/4 and the SW1/4 of section 35 Township 8S and Range 43E; and the NE1/4 of section 6, the NE1/4 and NW1/4 of section 5, and the NW1/4 of section 4 Township 45E and Range 43E. Topography varies from gently rolling hills to steep southeast and southwest facing canyons, elevation ranges from 750 to 1031 meters. This study area includes the Bacher Creek pasture and the Crystal Palace allotment. The Crystal Palace allotment consists of a three-pasture deferred rotation grazing system. The three pastures in the allotment are: (1) Crystal Palace pasture, (2) Pittsburg Gulch pasture, and (3) Powder River pasture. The Bacher Creek pasture is a separate pasture and is grazed annually.

The Spring Creek study area is located in the SE1/4 and the SW1/4 of section 15, all of section 21 and 9, the SW1/4 of section 10 and the N1/2 of section 16 Township 8S Range 43E. This study area con-

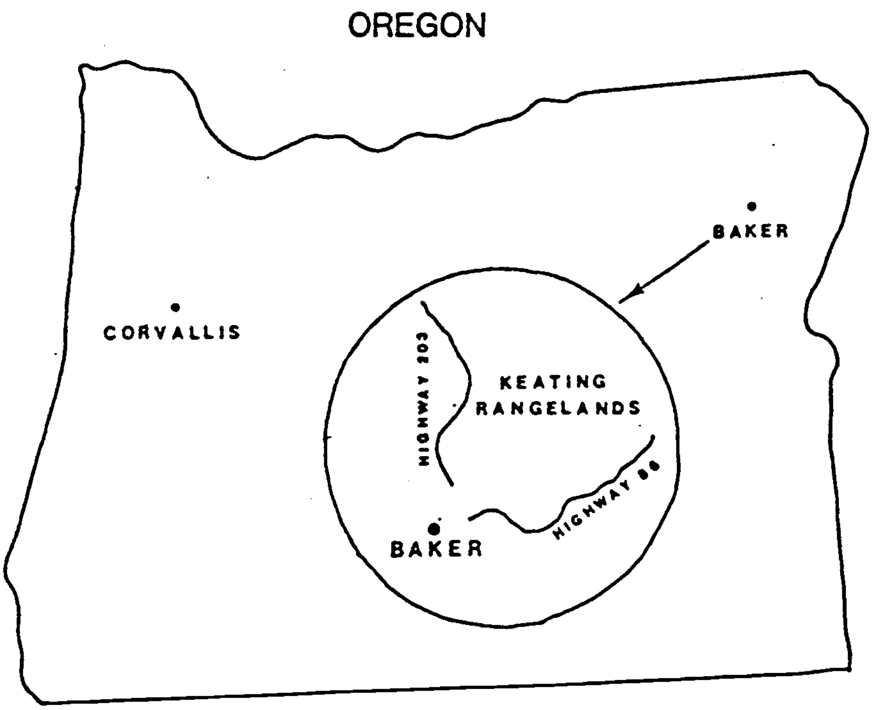
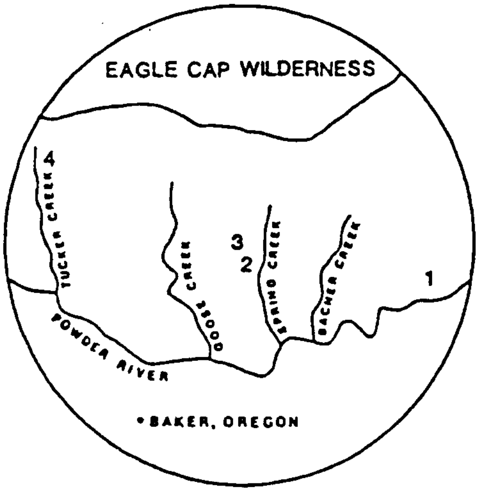


Figure 1. Location of Keating Rangelands.



STUDY AREAS

1. CRYSTAL PALACE ALLOTMENT
2. SPRING CREEK ALLOTMENT
3. MIDDLE PASTURE
4. TUCKER CREEK ALLOTMENT

Figure 2. Locations of Study Areas.

sists of two pastures: (1) Spring Creek pasture, and (2) Middle pasture in the Goose Creek allotment. The Spring Creek pasture is grazed annually while the Middle Pasture is one pasture in a three-pasture, rest-rotation system. Topography varies from gently rolling hills to moderately steep canyons. Elevation ranges from 906 to 1125 meters.

The Tucker Creek study area is located in the NE1/4 and the SE1/4 of section 4, and the NW1/4 of section 3 Township 8S Range 42E; and the NE1/4 and SE1/4 of section 33, the NW1/4 and SE1/4 of section 32, the NW1/4 and SE1/4 of section 34, the NW1/4 and the SW1/4 of section 27 and all of section 28 Township 7S Range 42E. This study area includes the Tucker Creek allotment that consists of a two-pasture rotational grazing system. The two pastures are the North and South Tucker Creek pastures, and the south pasture is grazed in early spring while the north pasture is grazed in late spring. Topography varies from gently rolling hills in the South Tucker pasture to a steep south-facing slope in the North Tucker pasture. Elevation ranges from 938 to 1219 meters.

Soils

Soils in the three study areas are different according to the Soil Conservation Service handbook (1973). Soil in the Crystal Palace study area are characteristic of the Brownscombe association. The Brownscombe association, as described in the Soil Conservation Service Handbook (1973), consists of gently sloping to steep, moderately well-drained soils with a silt loam surface layer and clay subsoil over allite granite. Soil surface is very dark grayish brown silt loam and subsoil is a dark brown clay while the substratum consists of allite granite bedrock. The soil depth is 20 to 40 inches.

Soils in the Spring Creek study area are characteristic of the Ruckles-Lookout association and consist of gently sloping to steep, shallow, well-drained soils with a very stony clay subsoil over basalt. The soil surface is a very dark grayish brown, very stony loam and subsoil is a dark brown, very cobbly clay while the substratum consists of basalt. The soil depth is 10 to 20 inches.

Soils in the Tucker Creek study area are characteristic of the Keating association and are gently sloping to steep, moderately deep well-drained soils with a silt loam surface layer and clay subsoil over greenstone bedrock. The surface is a very dark brown silt loam while the subsoil was a dark yellowish brown clay and substratum was a greenstone bedrock.

Climate

The overall climate in the Keating Valley is maritime with cold winters and warm to hot summers. Spring and fall rains occur regularly and winter snowfall will vary from year to year. Primary growing season for major forage species begins about the first of March and ends about the middle of June. The mean daily temperature and mean monthly precipitation were recorded from 1977 to 1980. Temperature-precipitation data were recorded from a rain gauge and hygrothermograph located in the Pittsburg Gulch pasture in the Crystal Palace study area. Data made available from personnel at The Range and Wildlife Habitat Lab in La Grande, Oregon are presented in table 1. Although average precipitation during the winters of 1978-1979 and 1979-1980 were comparable, much of the precipitation that occurred during the winter of 1978-1979 was snowfall. Mean daily temperatures were considerably colder during the winter of 1978-1979 compared to the 1979-1980 winter.

Description of Plant Communities

Oosting (1956) defined a community as "an aggregation of living organisms having mutual relationships among themselves and to their environment". Daubenmire (1968) explained the concept of community necessarily presumed a degree of biologic homogeneity in structure and species composition associated with area having boundaries. In describing vegetation in the three study areas, I used the term Plant Community as vegetation characterized by the presence of certain dominant species on a dry weight basis. Furthermore, habitat types were described for all the identified plant communities. The habitat type classification is a land classification system based on climax vegetation (Daubenmire 1968). It is the aggregate area of land that supports, or until recent time supported a particular climax plant community. The habitat type is the total area that has the potential of supporting the same climax community, regardless of the nature or kind of plant communities that may be presently occupying the area (Hironaka and Fosberg 1979).

The following is a list of the plant communities that were described in the three study areas. Habitat types as previously described elsewhere by other plant ecologists were identified for each plant community. The habitat type is generally named after the

TABLE 1. ANNUAL SUMMARY OF PRECIPITATION (CM) AND TEMPERATURE ($\bar{x}$ DAILY TEMPERATURE °C). DATA TAKEN IN THE CRYSTAL PALACE STUDY AREA FROM 1977 to 1980.

	1977		1978		1979		1980	
Month	$\bar{x}$ ppt cm	$\bar{x}$ temp °C	$\bar{x}$ ppt cm	$\bar{x}$ temp °C	$\bar{x}$ ppt cm	$\bar{x}$ temp °C	$\bar{x}$ ppt cm	$\bar{x}$ temp °C
January	.8	-4.6	4.6	2.1	2.3	-10.6	4.3	*
February	1.5	2.8	3.3	2.9	3.6	- 4.1	1.5	*
March	1.0	4.0	2.3	8.3	2.5	1.5	2.8	*
April	1.0	12.9	12.7	8.3	2.3	4.8	1.4	8.9
May	4.8	12.1	2.1	12.1	4.2	9.8	6.0	11.1
June	.5	22.2	1.0	18.4	2.2	19.1	4.5	13.5
July	.5	*	4.6	23.3	0	24.7	1.4	20.3
August	1.0	23.9	1.3	21.9	2.8	28.7	.2	17.9
September	3.8	16.7	3.2	16.1	.5	22.4	5.2	13.8
October	*	12.0	1.1	12.1	2.2	14.1	.9	8.2
November	8.1	3.5	1.1	.09	3.6	1.0	2.0	1.9
December	7.1	*	*	*	* .8	11.5	5.6	*
Totals	30.1		37.3		27.0		35.8	

* Data are missing.

unique combination of dominants in the overstory and understory, distinguishing it from other habitat types. In most cases, a binomial system is adequate; but at times, a trinomial system is necessary (Hironaka and Fosberg 1979). (Appendix A is a list of the dominant species measured in the three study areas.)

1. Basin Big Sagebrush/Cheatgrass/Sandberg's Bluegrass--Artemisia tridentata tridentata/Bromus tetorum/Poa Sandbergii.

   This plant community occurred in the Bacher Creek, Powder River, Pittsburg Gulch, Spring Creek, Middle and North Tucker pastures. On a dry weight basis (i.e., kg/ha), Basin big sagebrush was the dominant plant species while cheatgrass and Sandberg's bluegrass were two grasses that were consistently measured in this community. Other grasses that were inconsistently measured were squirreltail (Sitanion hystrix), Thruber's needlegrass (Stipa thurberiana), and needleandthread grass (Stipa comata). Thurber's needlegrass occurred in this community in the Tucker Creek and Spring Creek study areas, while needleandthread grass only occurred in the Crystal Palace study area. Tisdale and Hironaka (1981) reported that needleandthread grass usually occurred on soils that were coarse textured (sandy loam to loamy sandy) and fairly deep. In contrast, Thurber's needlegrass usually occurred on coarse-silty soils with deep, poorly defined horizons, low content of organic matter in the "A" horizon, and a lime-silica hardpan at 37 to 50 cm (Hironaka and Fosberg 1979). Forbs were inconsistently measured in this community and included: filaree

(*Erodium cicutarium*), annual willow-weed (*Epilobium paniculatum*), fiddleneck (*Amsinckia lycopsoides*), rattlepod (*Astragalus argophyllus*), long-leaf phlox (*Phlox longifolia*), tailcup lupine (*Lupinus caudatus*), desert parsley (*Lomatum gragi*), camas (*Zigadenus venenosus*), and prickly lettuce (*Lactuca serriola*).

The large amount of cheatgrass and Sandberg's bluegrass in this community is probable evidence of past disturbance or misuse. The most desirable grasses, bluebunch wheatgrass (*Agropyron spicatum*) and Idaho fescue (*Festuca idahoensis*) were sparse in all stands investigated. This plant community probably represents a low seral stage of a former Basin big sagebrush-bluebunch wheatgrass habitat type as described by Hironaka (1979), Schlatterer (1972) and Daubenmire (1970).

2. Mountain big sagebrush/Idaho fescue--*Artemisia tridentata vaseyana*/*Festuca idahoensis*.

This plant community occurred in the Pittburg Gulch, Bacher Creek and Powder River pastures on the steep north-facing slopes. On a dry weight basis, basin big sagebrush or mountain big sagebrush was the dominant plant species. Idaho fescue was the dominant grass species although some bluebunch wheatgrass, cheatgrass, and Sandberg's bluegrass did occur in varying amounts. Infrequent forbs found in this community included: yarrow (*Achillea millefolium*), tailcup lupine, long-leaf phlox, slimpod shooting star (*Dodecathleon conjugens*), Saxifraga (*Saxifraga integrifolia*), nine leaf lomatium (*Lomatium triternatum*) and annual willow-weed. This plant community has been described as a habitat type by Daubenmire (1970) and Hironaka and Fosberg (1979). Winward (personal communication) reported that this habitat type is potentially very productive; however, mountain big sagebrush tends to become extremely dense. Spray release or proper controlled burnings have resulted in open stands of sagebrush with a good understory of native herbaceous species (Winward, personal communication).

3. Mountain big sagebrush/Crested wheatgrass--Artemisia tridentata vaseyana/Agropyron desertorum.

This plant community occurred in the South Tucker pasture. Standard crested wheatgrass was the dominant herbaceous species while mountain big sagebrush was the dominant browse species. Cheatgrass and Sandberg's bluegrass were common grasses found in this community. Forbs that occurred infrequently included: scabland fleabane (Erigeron bloomeri), desert parsley, annual willow weed, rattlepod, long-leaf phlox, douglas phlox (Phlox douglasii), onion (Allium parvum) and tailcup lupine.

The probable habitat type for this plant community was the mountain big sagebrush-bluebunch wheatgrass as described by Daubenmire (1970), Schlatter (1972) and Hironaka and Fosberg (1979). This is considered a highly productive habitat type; however, mountain big sagebrush, as previously mentioned, has a tendency to increase its cover several fold on this site in absence of fire and with heavy grazing (Winward, personal communication).

4. Mountain big sagebrush/Crested wheatgrass/Intermediate wheatgrass--Artemisia tridenta vaseyana/Agropyron desertorum/ Agropyron intermedium.

This plant community occurred in the North Tucker pasture. Intermediate wheatgrass and crested wheatgrass were the dominant herbaceous plants while mountain big sagebrush was the dominant browse species. Infrequently occurring forbs included: vetch (Vicia americana), desert parsley, tailcup lupine, fleabane, and annual willow-weed.

The probable habitat type for this plant community was the mountain big sagebrush-bluebunch wheatgrass as previously mentioned in the preceding plant community.

5. Mountain big sagebrush/Sandberg's bluegrass--Artemisia tridentata vaseyana/Poa sandbergii.

This plant community was floristically similar to the previous two plant communities except that crested or intermediate wheatgrass were not seeded into this plant community. This plant community occurred in both the North and South Tucker pastures. Mountain big sagebrush was again the dominant browse species while Sandberg's bluegrass was the dominant herbaceous species. Cheatgrass and squirreltail were two grasses that frequently occurred in this community. The following forbs were infrequently measured in this community: scabland fleabane, desert parsley, annual willow-weed, tailcup lupine, onion, douglas phlox, rattlepod, mullein (Verbascum thapsus), salsify (Trogopogon dubius), fiddleneck and vetch.

Again, the probable habitat type for this community was the mountain big sagebrush-bluebunch wheatgrass habitat type. Winward (*personal communication*) further reported that annual bromes or forbs invade or increase on this type when the native species are destroyed.

6. Stiff sagebrush/Sandberg's bluegrass--*Artemisia rigida*/*Poa sandbergii*.

This plant community actually occurred as a complex with the basin big sagebrush-cheatgrass-Sandberg's bluegrass plant community. This complex has been described in the Soil Conservation Service Handbook (1973) as a biscuit scabland complex or sometimes referred to as a mound-intermound area. The intermounds consisted of the stiff sagebrush-Sandberg's bluegrass community, while the mounds consisted of the basin big sagebrush-cheatgrass-Sandberg's bluegrass community. This complex of two plant communities occurred in the Spring Creek, Middle and North Tucker pastures.

The stiff sagebrush-Sandberg's bluegrass community supported a very sparse cover of Sandberg's bluegrass with an occasional occurrence of squirreltail and Thurber's needlegrass. Infrequently encountered forbs included: long-leaf phlox, onion, fern-leaved lomatium (*Lomatium dissectum*), nine-leaf lomatium (*Lomatium triternatum*), Cous biscuitroot (*Lomatium cous*), biscuit root (*Lomatium nudicaule*), scabland fleabane, and douglas phlox. This plant community has been described as a habitat type by Hironaka and Fosberg (1979) and Daubenmire (1970). Soils of this habitat type were extremely shallow and became saturated and, if the type was grazed in early spring, trampling damage could be severe (Hironka and Fosberg 1979). The sparse cover afforded little protection from surface runoff and frost heaving was severe in this habitat type (Hironaka and Fosberg 1979). Pedestaled and upheaveled Sandberg's bluegrass plants were common in this plant community.

Generally, the basin big sagebrush-cheatgrass-Sandberg's bluegrass community that occurred on the biscuits was more deteriorated than the interspersed scablands where the stiff sagebrush-Sandberg's bluegrass plant community occurred. This was probably due to heavy grazing pressure on the biscuits as compared to the relatively unproductiveness of the scablands.

7. Bluebunch wheatgrass--Agropyron spicatum.

This community was located on steep south slopes in the Bacher Creek, Pittsburg Gulch, Spring Creek, Middle, Powder River and North Tucker pastures. Bluebunch wheatgrass was the dominant herbaceous plant in all three study areas where the plant community was located. Gray rabbitbrush (Chrysothamnus nauseous) was the dominant browse species, particularly in the Powder River pasture. Subordinate plants occurring in this community were different depending upon study area.

In the Crystal Palace study area where soils were granitic in origin, Sandberg's bluegrass, needleandthread and cheatgrass were commonly occurring grasses. Infrequently occurring forbs in this community in the Crystal Palace study area included: long-leaf phlox, blue-eyed Mary (Collinsia parviflora), Torrey's cryptantha (Cryptantha torreyana), scabland penstemon (Penstemon deustus), evening primrose (Oenothera deltoides), gilia (*Gilia sinuata*), phacelia (*Phacelia wyethia*), skullcap (*Scutellaria antirrhinoides*) and mat buckwheat (*Erigonum compositum*).

In the Spring Creek and Tucker Creek study areas, bluebunch wheatgrass was the dominant grass species while Sandberg's bluegrass and cheatgrass were common occurring grasses. Because the soils in these two study areas are basalt in origin, Thurber's needlegrass occurred rather than needleandthread. Infrequently occurring forbs included: peavine (*Lathyrus rigidus*), mules ear wyethia (*Wyethia amplexicaulis*), scabland fleabane, buckwheat, onion, annual willow-weed, and douglas phlox.

In the Tucker Creek and Spring Creek study areas, the probable habitat type this plant community occurred in was the bluebunch wheatgrass-Sandberg's bluegrass habitat type as described by Daubenmire (1970), Tisdale and Hironaka (1981), Mueggler and Handle (1974). However, in the Crystal Palace study area, the probable habitat type the plant community occurred in was the Bitterbrush (*Purshia tridentata*)-Bluebunch wheatgrass habitat type as described by Daubenmire (1970), Mueggler and Handle (1974), and Erhard (1979).

Bluebunch wheatgrass is the most abundant and widespread perennial grass of the sagebrush region and the most important economically (Hironaka 1981). It occurs under an exceptionally wide range of climate and soil conditions. Once established, bluebunch wheatgrass is a highly drought tolerant, long-lived species, well adapted to the various habitats occupied

(Hironaka 1979). However, annuals such as cheatgrass are able to compete better for soil moisture because the growth of cheatgrass roots are much greater over the winter than bluebunch wheatgrass roots (Harris 1967, 1970, 1977).

8. Crested wheatgrass--Agropyron desertorum.

This plant community occurred in the Bacher Creek, Crystal Palace, Pittsburgh Gulch, and Middle pastures. Crested wheatgrass was the dominant herbaceous plant in this community. Bulbous bluegrass (Poa bulbosa), Sandberg's bluegrass and cheatgrass were common occurring grasses in this community. Infrequently occurring forbs included: annual willow-weed, prickly lettuce, filaree, fiddleneck, Jim Hill mustard (Sisymbrium altissimum), buckwheat, and desert parsley. This plant community probably occurred within the basin big sagebrush-bluebunch wheatgrass habitat type as previously discussed.

Crested wheatgrass is an introduced perennial bunchgrass that has become a favorite for seeding semiarid rangelands because: (1) successful seedings are more common with it than with many adapted species, (2) it is well adapted to semiarid environments and is strongly competitive when established, (3) it produces palatable and nutritious spring feed, and (4) it withstands heavy grazing (Hyder and Sneva 1963). However, an important difficulty with crested wheatgrass results from the growth of stiff culms that become unpalatable and are of poor nutritive quality. The stems do not break down over winter, but remain standing and interfere with subsequent grazing. Therefore, it is essential that crested wheatgrass be grazed to keep "wolf plants" from developing and to maintain a good, vigorous stand. Crested wheatgrass is quite tolerant of grazing to a 2-inch stubble height or approximately 65 percent use of weight year after year (Currie 1969).

9. Intermediate wheatgrass--*Agropyron intermedium*.

This plant community occurred in the North Tucker pasture. Intermediate wheatgrass was the dominant herbaceous plant in the community while Sandberg's bluegrass was the only other common occurring grass. Vetch (*Vicia americana*) was a common occurring forb and annual willow-weed, tailcup lupine, onion, desert parsley, and rattlepod were all infrequently occurring forbs. This plant community probably occurred in the mountain big sagebrush-bluebunch wheatgrass habitat type as previously described.

Intermediate wheatgrass is another introduced perennial bunchgrass that has been used for seeding semiarid rangelands. It is an important cool-season, sod-forming grass from the U.S.S.R. and has been used for pasture and hay in the western United States and the Great Plains. Although the grass is slightly inferior to crested wheatgrass in persistence, drought tolerance, and winter hardiness, it is easily established and grows quite vigorously. The plant is closely related to tall wheatgrass (*A. elongatum*) and pubescent wheatgrass (*A. trichophorum*). Growth begins 4 to 6 weeks earlier than native grasses and it is late maturing but will stay green longer than crested wheatgrass (U.S.D.A., Agr. Handbook No. 58, 1953).

10. Cheatgrass--*Bromus tectorum*.

This plant community occurred in the Bacher Creek, Powder River, Crystal Palace, Pittsburg Gulch and Middle pastures. Cheatgrass was the dominant plant in all communities sampled. Other species frequently encountered in this community included: Sandberg's bluegrass, annual willow-weed, fiddleneck, prickly lettuce, and filaree.

Cheatgrass communities probably occurred in the following habitat types: Basin big sagebrush-bluebunch wheatgrass, mountain big sagebrush-bluebunch wheatgrass, and bitterbrush-bluebunch wheatgrass. Cheatgrass is a prolific seed producer, and it has been reported that the plant produces ample seed to maintain stands even in unfavorable years. The root system develops rapidly and has remarkable ability to continue growth under low temperatures while aerial growth is dormant (Harris 1967, 1970). The roots of this grass will reach depths of one millimeter or more with laterals extending as much as 30 centimeters (Hironaka and Fosberg 1979). Because of its extensive root system, cheatgrass can usually outcompete other forages for water and nutrients. Cheatgrass is considered a palatable forage in its early growth stages but becomes unpalatable as its phenology advances.

11. Medusahead--*Taeniatherum asperum*.

This plant community occurred in the Bacher Creek, Powder River, Pittsburg Gulch and Spring Creek pastures. This plant community was very homogeneous; however, other species sparsely occurring in this community included cheatgrass and prickly lettuce. The plant community occurred in all habitat types discussed except in the mountain big sagebrush-Idaho fescue.

Medusahead is considered one of the primary range weeds in the western United States (Hilken and Miller 1980). It is a serious threat to rangelands with sparse native plant communities and more complex communities degraded to a low seral state (Young and Evans 1970). An aggressive competitor with other plants, medusahead is a low-value forage species for livestock and wildlife. It has been estimated that carrying capacity of rangeland for domestic livestock has been reduced by about 75 percent after medusahead invasion (Major et al. 1960).

12. White-top--*Cardaria draba*.

This plant community occurred in the Bacher Creek, Powder River, Spring Creek and Pittsburg Gulch pastures. White-top was the dominant plant in all communities sampled. Other species frequently measured were: Cheatgrass, Sandberg's bluegrass, annual willow-weed and fiddleneck.

This community probably occurred in the basin big sagebrush-bluebunch wheatgrass and mountain big sagebrush-bluebunch wheatgrass habitat types. White-top is considered an aggressive noxious weed (Hitchock and Cronquist 1964).

13. Forbs.

This plant community occurred in the Tucker Creek study area. The community consisted of cheatgrass and a variety of "weedy" forbs that included; fiddleneck, filaree, Jim Hill mustard, and salsify. This community occurred in low, poorly drained areas in the mountain big sagebrush-bluebunch wheatgrass habitat types.

Table 2 summarizes plant community location with reference to pasture, total hectares, and percentages occupied by each plant community. Figures 3, 4, and 5 illustrate plant community boundaries within each of the three study areas.

TABLE 2. TOTAL HECTARES OF EACH PLANT COMMUNITY BY PASTURE.

Plant Community Index Number[1]	Pasture	Hectares
1	Bacher Creek	82
	Powder River	171
	Pittsburg Gulch	82
	Spring Creek	223
	North Tucker	126
	Middle Pasture	136
2	Bacher Creek	18
	Pittsburgh Gulch	50
	Powder River	17
3	South Tucker	260
4	North Tucker	74
5	South Tucker	136
	North Tucker	32
6	Spring Creek	236
	North Tucker	31
	Middle Pasture	34
10	Bacher Creek	35
	Powder River	17
	Crystal Palace	93
	Pittsburgh Gulch	32
	Middle Pasture	36
11	Bacher Creek	6
	Powder River	8
	Pittsburgh Gulch	21
	Spring Creek	3
12	Bacher Creek	17
	Powder River	6
	Spring Creek	20
13	South Tucker	12

[1] Plant community names corresponding to index numbers.

1. Basin big sagebrush/cheatgrass/Sandberg's bluegrass

2. Mountain big sagebrush/Idaho fescue

TABLE 2. Continued.

3.	Mountain big sagebrush/crested wheatgrass
4.	Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
5.	Mountain big sagebrush/Sandberg's bluegrass
6.	Stiff sagebrush/Sandberg's bluegrass
7.	Bluebunch wheatgrass
8.	Crested wheatgrass
9.	Intermediate wheatgrass
10.	Cheatgrass
11.	Medusahead
12.	White-top
13.	Forbs

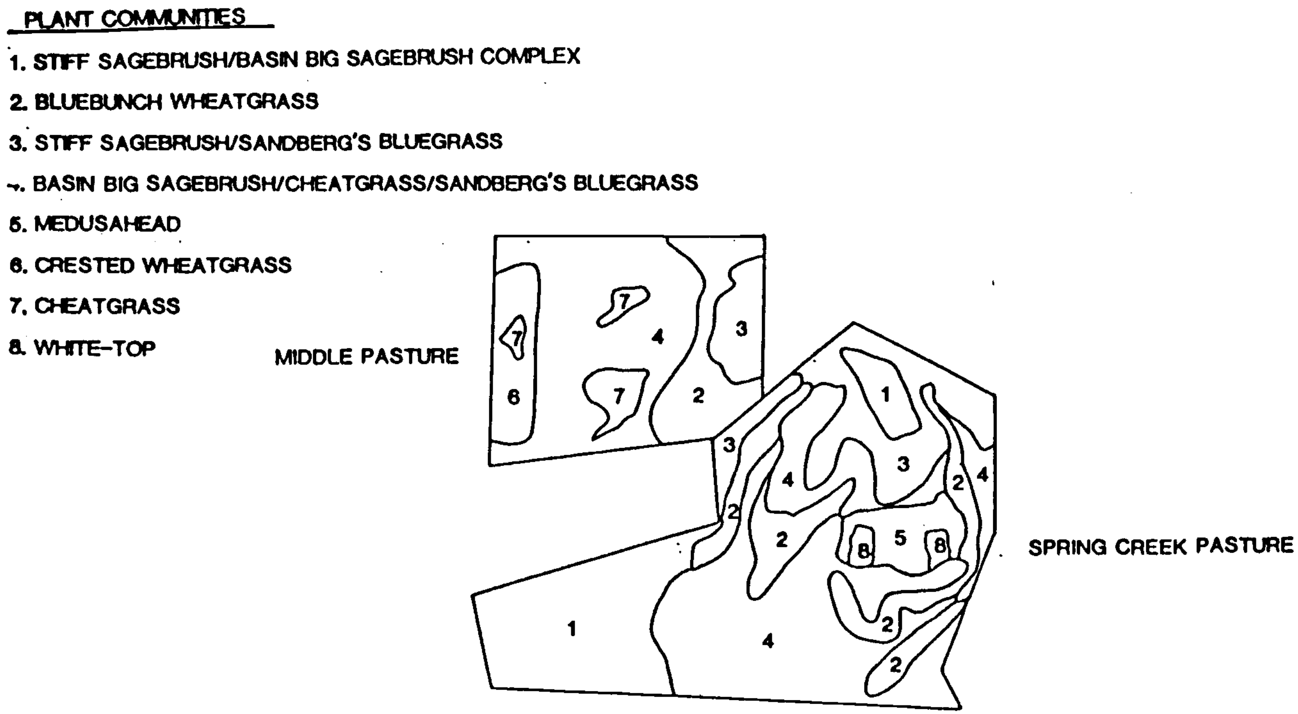


Figure 3. Plant communities located in the Spring Creek study area.

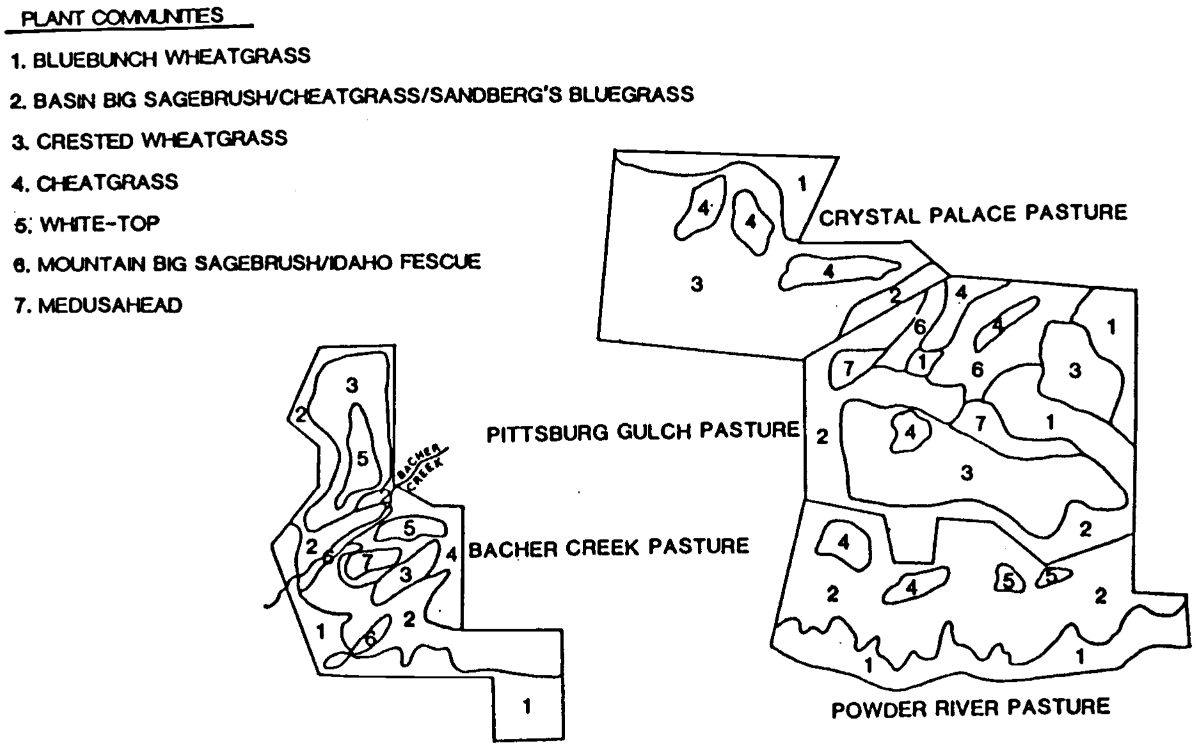


Figure 4. Plant communities located in the Crystal Palace study area.

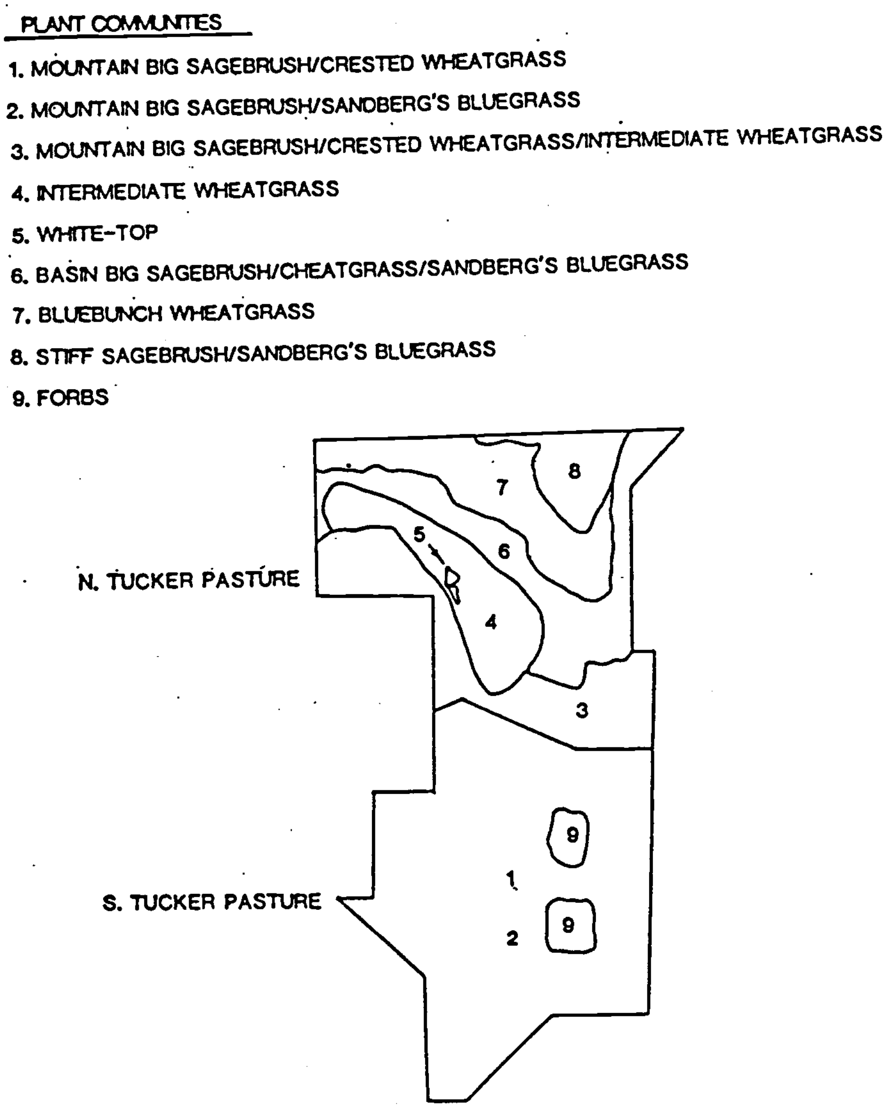


Figure 5. Plant communities located in the Tucker Creek study area.

METHODS

Determination of Available Herbacous Production

Available herbaceous biomass of plant communities within the pasture in the three study areas was determined within 0.5-m^2 circular plots. Available herbaceous biomass was recorded in units of kilograms per hectare of dry weight of the current aerial growth of forage.

The procedure involved allocating a number of randomly located, clustered circular plots within delineated plant communities. Random-cluster centers were located following procedures of Harris (1951). The method involved placing a transparent dot grid over a large scale topography map and a random dot was chosen from a group of dots that fell within the delineated plant community. A pin hole was punched at that point on the map and a cluster center was established in the field at that point on the map. A cluster consisted of 10 circular plots and two 48.5-m by 1.3-m belt transects. The 10 circular plots were separated into two transects, each consisting of five circular plots. The five circular plots were spaced at 6-m intervals and were located 360° azimuth and 90° azimuth from the cluster center. The two 48.5-m by 1.3-m belt transects were located 180° and 270° azimuth from the cluster center. Cluster centers were identified with a steel fence post. All transects were rotated clockwise 20° for subsequent resampling.

Double sampling and simple linear regression analysis procedures were used to predict oven-dry weight of available herbaceous biomass from estimated green weights (Pechanec and Pickford 1937, and Wilm et al. 1944). For each cluster, two of the 10 circular plots were clipped to ground level and the other eight were estimated. In the event that all or part of the .5-m^2 circular plot included shrubs or snow, the herbaceous vegetation obstructed by the snow or shrub (i.e., growing within the base) was judged unavailable and was not clipped or estimated. Estimates of green biomass were obtained by previous training that involved estimating biomass on a number of plots and checking estimates by clipping and weighing the biomass. Only dominant species were estimated after the training period, and two of the circular plots were estimated, clipped, weighed, and oven dried at 60°C for 24 hours. Estimated green weights were recorded on the eight circular plots. From these data, predicted green weights were calculated from actual green weight by a simple linear regression equation. The relationship was represented by the following prediction equation: $y = mx + b$ where y was predicted green weight and x was the estimated green weight. Predicted green weights were converted to predicted dry weights by the dry weight conversion factor. The conversion factor for individual plant species was calculated by dividing actual green weight by actual oven dry weight.

Available herbaceous biomass was expressed in kilograms per hectare by species on an oven dried and previous year's growth (i.e., old growth) and current year's growth (i.e., regrowth) basis for each plant community. This was accomplished by simply multiplying the mean oven dry weight of each species averaged over all clusters by 20 in each plant community.

Browse and herbaceous biomass available to deer was sampled during an early (November, December, January) and a late sampling (February, March, April) period during the 1978-1979 winter. During the late sampling period, both old growth and regrowth of herbaceous biomass were estimated separately. Available herbaceous biomass was sampled on an old growth and regrowth basis once during the 1979-1980 winter. Sampling was done during the month of December.

Herbaceous biomass available to cattle was sampled the second week cattle were turned onto the pastures. For those pastures grazed in the fall, available herbaceous biomass was estimated on an old growth and fall growth basis. Exclosure cages were used to protect plots from being grazed.

Determination of Browse Production

Current year's browse production and density were studied within 48.5-m by 1.3-m belt transects. Belt transects were paired with the circular plots as previously described. Canopy volume measurements and shrub height were used as a to estimate current year's production for the following three species of shrubs: basin big sagebrush, mountain big sagebrush, and rubber rabbitbrush. The twig count method as modified from Shafer (1962) was used for the following species: stiff sagebrush, bitterbrush and mockorange (*Peraphyllum ramosissimum*). Shrub biomass was estimated only during winter sampling periods because a previous study showed that shrubs contribute less than 5 percent of cattle diets (Vavra 1979).

The twig count method involved estimating browse biomass by determining the number of twigs per plant and average oven dry weight per twig. Prior to sampling, ≈100 twigs were clipped on a shrub outside the belt transect and oven dried for 24 hours at 60°C. From these data, the mean dry weight per twig was calculated simply by dividing total weight of all twigs by the total number of twigs. Shrub biomass was determined by multiplying the mean dry weight per twig times the number of twigs per shrub. Shrub biomass on a per-hectare basis was determined by multiplying the mean weight per shrub times the mean number of shrubs per hectare. The number of shrubs per hectare was determined by dividing the total number of shrubs counted in the two belt transects by .0126.

As previously mentioned, crown volume, height and weight relationships were used on the dominant species of shrubs. Gray rabbitbrush was sampled in the Powder River pasture of the Crystal Palace allotment, and basin big sagebrush and mountain big sagebrush were sampled in the Bacher Creek and South Tucker Creek pastures, respectively. The sampling procedure involved selecting plants at 10-m intervals along a 100-foot tape from the three different pastures during the winter of 1979. Fifty plants per species were sampled and the current year's growth on each shrub was clipped following measurements of height (H), and two measurements of crown width (W_1 and W_2). The W_1 was the longest intercept, and the W_2 was taken on a perpendicular line bisecting the W_1. Intercept was defined as a vertical projection to a line for photosynthetic plant tissue (Rittenhouse and Sneva 1977). Plant height was measured to the tallest growing plant part. W_1 and W_2 measurements were converted to elliptical crown area (A) using the following formula derived by Rittenhouse and Sneva (1977):

$$A = \frac{\Pi W_1 W_2}{4}$$

Cut current year's growth of individual shrubs was placed in large plastic bags and oven dried in the laboratory at 60°C for 72 hours. Current year's growth was weighed and expressed as kilograms on an air-dry basis per shrub. This weight served as the dependent variable while A, W_1, W_2, and H served as the independent variables in the development of simple and multiple regression models.

Twenty-seven regression models per shrub were constructed and evaluated on a cyber 170 model 720 computer using the Nos. 1.4 operating system and statistical interactive programming system (SIPS). The data were transformed to fit the following two functions: $y = a+b^x$ and $y = ax^b$, where y was current year's growth, x was the independent variable, and b was the rate of change. For linear approximation, the functions were fitted to the following form: $\log y = b_o + b_{1x}$ and $\log y = b_o + b_1 \log x$. Transformations were done to linearize the regression function and to stabilize the error term variance (Neter and Wasserman, 1974).

After the data were transformed and fitted to linear models, equations, scatter diagrams, residual plots (normal plots and histograms), standard errors of the estimates ($sy{\cdot}x$ or mse), coefficients of determination (R^2 or r^2) and T values were all used as criteria to analyze the relationship between the independent variables, to determine the best "set" of independent variables, and to aid in construction of an appropriate regression model.

After the appropriate regression equation was developed, all basin and mountain big sagebrush and gray rabbitbrush were measured by the method previously described. The measurements were then integrated into the developed regression equation and production per shrub was determined. The mean weight per shrub per transect was calculated by summing the total production per transect and dividing by the number of shrubs per transect. Shrub biomass on a kg/ha basis was determined by calculating the number of shrubs per hectare multiplied by the mean weight per shrub.

Shrubs were sampled concurrently with herbaceous forage estimates. Therefore, shrubs were sampled twice during the 1978-1979 winter and once during the 1980 winter.

Determination of the Food Habits of Deer and Cattle

The winter diets of deer and spring-fall diets of cattle in the three study areas were estimated by collecting fecal samples and identifying plant fragments within them. It was assumed that identifiable plant fragments found in the feces of mule deer and cattle would adequately describe their diets. Problems with this assumption were discussed in the literature review.

In each study area, 60 fresh fecal groups were collected per sampling period and subsequently analyzed in the laboratory. Deer were sampled tri-weekly from December to April during the winters of 1978-1979 and 1979-1980. Fresh fecal samples from cattle were collected monthly during the spring and fall of 1979 and 1980.

Collection periods during the 1978-1979 winter were the weeks of December 20, 1978, January 7, 1979, January 28, 1979, February 18, 1979, March 12, 1979, April 2, 1979, and April 23, 1979.

Collection periods during the 1978-1979 winter were the weeks of December 20, 1978, January 7, 1979, January 28, 1979, February 18, 1979, March 12, 1979, April 2, 1979, and April 23, 1979. However, deer were not sampled the week of April 23, 1979 in the Spring Creek and Tucker Creek study areas because deer had migrated from these two areas. Collection periods during the 1979-1980 winter were the weeks of December 17, 1979, January 7, 1980, January 28, 1980, February 18, 1980, March 10, 1980, March 31, 1980 and April 21, 1980. Fresh fecal samples from cattle were collected 2 weeks after cattle were turned onto the pastures.

Microscope slides of identified reference plants and fecal samples were prepared as described by Sparks and Malechek (1968) and Flinders and Hansen (1972). The procedure involved collecting six combined samples per collection period. A combined sample consisted of 10 fresh fecal samples and, therefore, 60 fresh fecal samples were colleted per sampling period. The samples were then taken to the laboratory and oven dried for 36 hours at 50°C. The 60 fecal samples were then composited by weight to comprise six 50-g samples. The six samples of the composited oven-dried fecal material were then individually soaked in ethanol for 24 hours. After 24 hours of soaking, the ethanol was poured off and the samples were then mascerated in a waring blender for 2 minutes. The fecal material was then washed over a 200-mesh screen and again oven dried for 3 days at 50°C for 36 hours. Dried samples were then reduced to a uniform particle size by grinding them through a micro-Wiley Mill using a 20-mesh screen. After soaking the fecal material in H_2O

for 20 minutes, the material was then washed over a fine mesh cloth sieve. A small portion of fecal material was taken off of the mesh cloth sieve and spread on each of four slides. Five to six drops of Hertwig's solution were heat fixed on each slide by passing the slide over a Bunson burner. Hertwig solution acted as a clearing agent and aided in plant fragment identification. Hoyer's mounting medium was also applied to the slide and a cover slip was then placed over the medium. The medium was then brought to a boil by passing the slide over the Bunson burner. Formulae for both the Hoyer's mounting medium and Hertwig's solution are listed in appendix A. Four microscope slides were made per sample and were oven dried at 50°C for 36 hours.

Three slides of the four slides made were used in identifying plant fragments following the technique of Sparks and Malechek (1968) for each sample. The frequency of occurrence of individual species of plant fragments in 20 microscope fields per slide was recorded for a total of 60 fields per sample. Each epidermal fragment encountered in a field of the microscope was identified if its observed epidermal characteristics matched the observed epidermal characteristics of the same material on the reference slide. Epidermal characteristics observed were cell size and shape, stomata size or shape and the presence or absence of hairs. Frequency percentages (i.e., number of fields that the species occurred in out of 60 locations) were tabulated. The frequency percentages were converted to particle density per field by using a table developed by Fracher and Brischle (1944). Their table had been generated to calculate the number of plants (N) per 100 quadrats likely to be present under strict mathematical probability when any given percentage (i) of quadrats contain one or more plants each (Pfister 1979). The relative density of each species was determined on a percentage basis for each sample using the following formula (Sparks and Malechek 1978):

$$\text{Relative Density} = \frac{\text{Density of fragments of a species}}{\text{Total density of fragments of all species}}$$

Percent dry weight composition was assumed to be the same as its calculated relative density (Sparks and Malechek 1968). Todd and Hansen (1973) reported that the percentage relative density of identified plant fragments was a good approximation for the relative amount of the plant eaten. The mean dry weight composition for each species consumed per sampling period was expressed as the mean of six samples.

Deer food habits were further summarized by determining the mean amount of forages consumed during the early and late winter collection periods. Early winter period diets were estimated by calculating the mean for the first three collection periods and late period diets were estimated by calculating the mean for the last three or four collection periods, depending upon the number of collection periods. Means between the early and late period for both years in all three study areas were tested using t-tests to determine if total grasses and total browse consumption changed between the two periods within a study area.

Statistical tests followed McClave and Dietrich (1979) student's statistic assuming both sample populations were approximately normally distributed with equal population variances, and the random samples were selected independently of each other (McClave and

Dietrich 1979).

Determination of Similarity Indices

Similarity indices were calculated to determine the amount of dietary overlap between deer and cattle using Kulcynski's mathematical expression of similarity (Oosting 1956) as applied to food habits by Olsen and Hansen (1977). The indices were calculated by the following formula:

$$\frac{2W}{a + b}$$

where W was the lowest of the two values being compared and a and b were the two values being compared. The similarity indices represent the percentages of two diets that were identical (Olsen and Hansen 1977). The overlap coefficient varies from 0, for completely distinct samples (i.e., no food categories in common), to 1, for identical samples.

The mean of food habits data during the last three sampling periods deer in the Spring Creek and Tucker Creek study areas was compared to cattle food habits data in the Spring Creek, South and North Tucker pastures to determine spring, 1979 similarity indices. However, in the Crystal Palace study area, an extra sampling period for food habit analysis was collected because the animals stayed in the area longer than in the other two study areas. Therefore, the mean of four sampling periods was compared to cattle food habits in the Crystal Palace, Powder River and Bacher Creek pastures. During spring of 1980, the mean of deer food habits data for the last four sampling periods in two of the study areas (i.e., Tucker Creek and Crystal Palace) was compared to the cattle food habits data in the

North and South Tucker Creek pastures and the Pittsburgh Gulch and Powder River pastures, respectively.

The mean of the food habits for deer during the first three sampling periods in the Spring Creek and Crystal Palace study areas was compared to the food habits data of cattle in the Middle Pasture in the Spring Creek study area and in the Pittsburgh Gulch pasture in the Crystal Palace study area to determine fall 1979 similarity indices. Fall, 1980 cattle food habits data in the Spring Creek, Crystal Palace and Bacher Creek pastures were compared to the mean of food habits data for the first three sampling periods in the Spring Creek and Crystal Palace study areas during 1979 because food habit data for deer was not collected during the 1980-1981 winter.

Determination of Crude Protein and In Vitro Dry Matter Digestibility of Forages.

Hand-plucked forage samples were analyzed for crude protein and *in vitro* dry matter digestibility (IVDMD). Samples were collected from clipped plots when herbaceous and browse production estimates were made. Records were kept on where samples were collected and date collections were made. Duplicate subsamples were analyzed in the laboratory and means were reported.

The crude protein content of hand-plucked forage samples was determined using a micro-Kjeldahl method following procedures outlined by Geist (1973). Samples were analyzed at the OSU/ARS laboratory in Burns, Oregon. Percent crude protein figures were expressed on a g/kg basis by dividing the crude protein content by 6.25 and multiplying by 10.

In vitro dry matter digestibility was determined on hand-plucked forage samples using inoculum from a steer fed alfalfa hay. Digestible energy values were determined by converting IVDMD values to DE values using the equation developed by Rittenhouse et al. (1971): DE Mcal/kg = .037(χ) + .18. For cattle, metabolizable (ME) energy was determined by dividing the DE value by 1.22 (NRC 1976). For deer, ME values of the samples were determined by multiplying DE by 85 percent (Wallmo et al. 1977).

Determination of Animal Unit Months on a Forage Quantity, Energy and Nitrogen Basis

Animal unit months (AUMS) of grazing on a quantity basis per plant community, season and pasture were calculated using the oven dry weights of herbaceous forage per hectare. Utilizable forage (UF) per hectare was determined by multiplying the estimated oven dry weights per hectare of individual forage species by the estimated use factor (EUF). Estimated oven dry weights of the primary forage species available to cattle are listed in appendix C. Estimated use factors employed in determining UF for deer months and animal unit months are shown in table 3. Stoddart et al. (1975) defined proper use "as the percentage use that is made of a forage species under proper management, and it is expressed as the percentage that is consumed of the current year's forage production of a particular species". Furthermore, a proper use factor is the cumulative utilization of a species (the product of preference and quantity available) when correct use has been made of the range (Stoddart et al. 1975). The estimated use factor was a combined

TABLE 3. ESTIMATED USE FACTORS USED IN DETERMINING UTILIZABLE FORAGE AVAILABLE TO DEER AND CATTLE.

	Deer		Cattle		
	Winter		Spring	Fall	
Species	Old growth EUF (%)	Regrowth EUF (%)	EUF (%)	Old growth EUF (%)	Fall growth EUF (%)
Grasses					
Crested wheatgrass	5	20	50	50	50
Intermediate wheatgrass	5	20	50		
Bluebunch wheatgrass	5	20	50	50	50
Cheatgrass	5	40	40	10	40
Idaho fescue	5	25	50	40	40
Sandberg's bluegrass	0	40	40	20	40
Squirreltail	5	20	40	30	40
Needleandthread	5	30	40	30	40
Medusahead	0	10	10	10	10
Forbs					
Yarrow			20	0	
Fiddleneck			20	0	
White-top	15	5	10	10	10
Filaree		20	50	0	
Mat buckwheat	5				
Willow weed	5		10	10	
Prickly lettuce	5		20		
Desert parsley			25		
Tailcup lupine	5	20	10	0	
Jim Hill mustard	5		10		
Browse					
Big sagebrush	40		0		
Stiff sagebrush	20				
Gray rabbitbrush	10				
Mockorange	20				
Bitterbrush	40				

estimate derived from food habits data and a BLM proper use table. Because of topography, in some areas, cattle were unable to utilize entire plant communities. Therefore, the correction factors listed in table 4 were applied to some plant communities.

Hectares per cattle month were calculated by dividing the monthly animal requirements by the utilizable forage per hectare. Cattle requirement figures were obtained from a review of the literature. Intake values reported by Kartchner and Campbell (1979) were used in determining spring and fall animal unit months. The combined cow-calf intake used for early spring was 14 kg per day or 420 kg per month, while dry mature cows during the fall had an intake rate of approximately 10 kg per day or 300 kg per month (Kartchner and Campbell 1979). Animal unit months per plant community, season and pasture were obtained by dividing hectares per plant community by hectares per cattle month.

The metabolizable energy (ME) content (Mcal/kg) and nitrogen (N) content (g/kg) of the primary forages in cattle diets and ME and N requirements of cattle were used to determine the number of cattle months per plant community, season and pasture following modified procedures similar to Hobbs' et al. (1982) equation:

$$K = \frac{\sum_{i}^{N} (BiXFi)XH}{Rq \text{ X Days}} \text{ where}$$

K = Number of AUMS per plant community.
N = Number of principal forages in cattle diets.
Bi = Utilizable forage on a kg/ha basis.
Fi = Nutrient content of forage.
H = Total hectares of plant community.
Rg = Cattle requirement per day.
days = 30.

Employing the above equation, AUMS on a nutritional basis were

TABLE 4. CORRECTION FACTORS USED TO CORRECT FOR PORTIONS OF A PLANT COMMUNITY AVAILABLE TO CATTLE.

Plant Community Index Number[1]	Pasture	Correction factor, % available
7	Powder River	40
7	Spring Creek	60
6	Spring Creek	80
7	Middle	70
2	Pittsburgh Gulch	40
7	Pittsburgh Gulch	50
2	Bacher Creek	70
7	Bacher Creek	60
7	North Tucker	50
6	North Tucker	25

1 Plant community names corresponding to index numbers.

2. Mountain big sagebrush/Idaho fescue

6. Stiff sagebrush/Sandberg's bluegrass

7. Bluebunch wheatgrass

calculated the following way:

1. The utilizable forage per hectare of the dominant species occurring in cattle diets was multiplied by the species ME or N content, depending if AUMS were to be expressed on an ME or N basis.
2. The products were then summed and multiplied by total hectares of plant community.
3. The product from step 2 was then divided by the ME or N required by cattle on a monthly basis.

The NRC (1976) reported that a 350-kg dry pregnant mature cow required 1.9 Mcal of ME per kg of intake. Multiplying the ME required by 10 kg (Kartchner and Campbell 1979), I determined that dry cows needed 19.0 Mcal of ME in the fall. The NRC (1976) also reported that a 400-kg nursing cow required 19.0 Mcal of ME per kg of intake. Again, multiplying the ME required by 14 kg, (Kartchner and Campbell 1979), I determined that nursing cows needed 26.6 Mcal of ME.

The NRC (1976) also reported that a 350-kg cow in the fall required 5.9 percent protein per kg of intake. By dividing the protein requirement by 6.25 and then multiplying by 10 kg per day (Kartchner and Campbell 1979), I determined that a cow during fall required 94.5 g of protein per day. Furthermore, the NRC (1976) reported that a 400-kg cow during spring required 9.2 percent protein per kg of intake. Again, dividing the protein requirement by 6.25 and then multiplying by 14 (Karthner and Campbell 1979), I determined that a cow-calf pair required 206 g of protein per day during spring. Metabolizable energy and N content of the primary forages available to deer and cattle are listed in table 5.

Determination of Deer Months on a Forage Quantity, Energy and Nitrogen Basis

Deer months of grazing on a quantity basis per plant community, season and pasture were calculated similarly to animal unit months. The winter of 1978-1979 was divided into early (November, December, January) and late (February, March, April) periods, and available herbaceous and browse biomass was sampled during those two periods. The early sampling period was from January 1, 1979 to February 1, 1979, while the second period was from March 1, 1979 to April 1, 1979. The calculation of deer months on a forage quantity and quality basis was divided up into an early and late season for the 1978-1979 winter. However, during the winter of 1979-1980, available herbaceous biomass and browse production was sampled only in December, 1979, and the winter season was not divided into an early and late period.

Forage requirements for deer were obtained from a review of the literature. Intake values reported by Allredge et al. (1974) were used as deer requirements in calculating winter deer months. On the Keating winter range, an adult mule deer weighed approximately 52.5 kg, while a fawn weighed 22.6 kg (Kneisel _personal communication_). Using Allredge's et al. (1974) figures, it was determined that on a monthly basis an adult deer consumed approximately 26.8 kg of forage, while a fawn consumed 21.7 kg of forage. However, because there are only 50 fawns per 100 adults (Kneisel, _personal communication_), the total forage required by deer per month was calculated to be 25.1 kg.

Deer estimated use factors and available forage biomass are

TABLE 5. METABOLIZABLE ENERGY (ME) AND NITROGEN (N) CONTENT OF FORAGES AVAILABLE TO CATTLE AND DEER. PASTURE REFERS TO PASTURE WHERE SAMPLE WAS COLLECTED AND DATE REFERS TO DATE WHEN SAMPLE WAS COLLECTED.

Species	Pasture Index Number[1]	Date	Cattle ME Mcal/kg	Cattle N g/kg	Deer ME Mcal/kg	Deer N g/kg
Crested wheatgrass	3	3/19/79	.		2.57	35.9
	3	5/1/79	2.14	24.0		
	8	5/15/79	2.34	16.5		
	8	6/15/79	2.19	10.1		
	2	12/9/79[2]	1.47	4.0	1.52	4.0
	2	12/26/79	2.35	20.0	2.44	20.0
Intermediate wheatgrass	8	1/30/79[2]			1.65	3.4
	8	3/20/79			2.51	26.1
	8	6/20/79	1.84	7.9		
	8	12/25/79			2.52	24.0
Bluebunch wheatgrass	5	1/12/79[2]	1.42	5.0	1.47	5.0
	1	3/15/79			2.54	23.2
	4	5/15/79	2.13	18.6		
	1	6/1/79	1.93	10.8		
	8	6/25/79	1.79	8.6		
	2	12/25/79	2.27	18.6	2.35	18.6
Cheatgrass	5	3/10/79			2.31	27.5
	3	5/1/79	2.41	18.8		
	1	5/15/79	2.36	14.1		
	8	6/1/79	1.92	8.5		
	5	6/25/79	1.34	4.5		
	4	12/19/80[2]	1.60	4.4	1.67	4.4
	2	12/20/79	2.58	26.9	2.68	26.9
Idaho fescue	4	1/30/79[2]	1.29	2.3	1.59	2.3
	1	3/15/79			2.45	15.2
	4	5/15/79	2.16	13.3		
	8	6/9/79	1.73	8.3		
Sandberg's bluegrass	3	3/19/79			2.54	36.3
	7	5/1/79	2.19	20.0		
	4	5/15/79	2.29	14.5		
	8	6/5/79	1.98	7.3		
	5	6/25/79	1.87	6.3		
	5	9/20/80	2.52	29.1		
	2	12/26/79	2.51	31.1	2.64	31.1
	2	12/26/79[2]	1.52	2.7	1.58	2.7
	5	1/30/79[2]	1.54	3.6	1.89	3.6
	8	5/15/79	2.33	24.0	2.42	24.0
	5	6/15/79	2.05	11.0		
	6	12/18/79	2.67	21.4	2.76	21.4

TABLE 5. Continued.

Species	Pasture Index Number[1]	Date	Cattle ME Mcal/kg	Cattle N g/kg	Deer ME Mcal/kg	Deer N g/kg
Needleandthread	1	1/30/79[2]	1.26	2.7	1.54	2.7
	4	4/15/79	2.11	20.2	2.18	20.2
	4	5/9/79	2.07	17.8		
	1	6/1/79	1.82	13.3		
	1	6/15/79	2.01	10.8		
Medusahead	4	4/25/79	2.08	14.2		
	4	5/15/79	1.90	10.8		
	2	12/28/79	2.65	25.8	2.75	25.8
Yarrow	1	12/28/79[1]	1.63	2.5	1.69	2.5
	5	6/21/79	2.04	15.4		
Fiddleneck	7	5/15/79	2.08	17.8		
	8	6/15/79	1.57	18.6		
White-top	4	2/15/79[2]	1.37	11.3	1.42	11.3
	7	5/15/79	2.53	23.4	2.64	23.4
	5	6/15/79	2.26	14.3		
Filaree	4	5/1/79	2.13	18.7	2.21	18.7
	1	6/1/79	1.79	14.5		
Mat buckwheat	1	2/16/79[2]			.98	1.0
Willow weed	1	1/15/79[2]	.95	2.8	.99	2.8
	5	6/15/79			1.46	17.8
Prickly lettuce	2	2/16/79[2]	1.37	2.7	1.42	2.7
	5	6/21/79	2.43	18.7		
Desert parsley	5	3/15/79			2.31	24.0
	7	5/1/79	2.61	29.8		
	5	6/15/79	2.22	14.0		
Tailcup lupine	1	2/16/79[2]			1.13	1.4
	4	5/1/79	2.32	18.7	2.47	18.7
	5	6/15/79	2.11	15.3		
Jim Hill mustard	5	1/15/79[2]	1.1	4.4	1.12	4.4
	5	6/9/79	1.85	18.6		
Basin big sagebrush	5	11/23/79			1.67	15.4
	4	1/24/79			1.52	11.3
	1	2/9/79			1.60	12.5
	1	2/21/79			1.55	12.4
Mountain big sagebrush	8	11/23/79			1.65	16.0
	7	2/26/79			1.28	9.1
	7	3/12/79			1.33	11.0
Stiff sagebrush	5	11/23/79			1.24	5.1
Gray rabbitbrush	1	1/10/79			1.38	10.0
	1	2/21/79			1.34	8.7
	1	3/10/79			1.45	10.1
Mock orange	1	2/16/79			1.05	4.8
Bitterbrush	1	2/16/79			1.16	7.2

1 Pasture names corresponding to index numbers.

1. Powder River
2. Pittsburg Gulch
3. Crystal Palace
4. Bacher Creek
5. Spring Creek
6. Middle
7. South Tucker
8. North Tucker

2 Refers to old growth.

listed in table 3 and appendices D, E, and F, respectively. Available herbaceous biomass and browse production and forage required by deer were used to estimate deer months on a quantity basis similar to the way AUMS were calculated.

A review of the literature, revealed an adult wintering white-tailed deer required 131 kcal of ME per kg $BW^{.75}$ per day (Ullrey et al. 1970) while a fawn required 158 kcal of ME per kg $BW^{.75}$ per day (Robbins et al. 1974). Therefore, if there were 50 fawns per 100 does, 140 kcal of ME/kg $BW^{.75}$/day was required. However, the amount of energy obtained by catabolism of fat and amount of energy required in gestation was considered when determining deer energy costs. Mautz (1978) reported the net usable caloric yield from catabolized fat was about 6 kcal/g and the average body weight loss was 20 percent for a wintering wild ruminant. Energy required for white-tailed deer does during gestation was investigated by Robbins and Moen (1975). The researchers developed the following equations to determine the amount of energy required: $\log ey = .2803 + .0283 (x)$ where x was days of gestation and log ey was energy required (kcal/kg). Gill (1972b) determined that the breeding season for mule deer was approximately November 15 to December 15. I assumed a 120-day gestation period for wintering mule deer on the Keating Range (December to April).

Mule deer ME requirements were calculated separately for the two periods of the 1978-1979 winter. The following calculations illustrate how required energy figures were derived for the early and late period. The procedure followed the general formula of Mautz (1978).

Early period (December 1-February 1)

1. 140 kcal of ME/kg $BW^{.75}$/day was required
2. 10% weight loss for first 60 days
3. From catabolizing stored fat, the average metabolic weight during 60-day winter weight loss period was:
$$\frac{42.4 + (42.4 - (42.4 \times .10)}{.2} = 40.28 = 15.99^{.75}$$
4. Energy supplied by catabolism of fat for first 60 days (weight loss/day):
$$\frac{.10 \times 42.4}{60} = .07066 \text{ kg or } 70.67 \text{ g}$$

5. Mcal required for wintering deer during early period of 1978-1979:

   $15.99^{.75}$ x 140 kcal of ME/kg $BW^{.75}$/day - 70.67 g x 6 kcal/day = 1.8 Mcal

   1.8 Mcal
   +.007 Mcal required for 60-day gestation
   1.81 Mcal required

Late Period

1. Average metabolic weight during the last 60 days of winter was the average metabolic weight during the first 60 days minus another 10% weight loss for the last 60 days:
$$\frac{40.28 + (40.28 - (40.28 \times .10)}{2} = 38.27 = 15.39^{.75}$$

2. Energy supplied by catabolism of fat (weight loss/day):
$$\frac{.10 \times 38.27}{60} = .0638 \text{ or } 63.8 \text{ g}$$

3. Energy required for wintering deer during the late period of 1978-1979:
   15.39 x 140 kcal of ME/kg $BW^{.75}$/day - 63.78 g x 6 kcal/day = 1.77 Mcal
   +.032 required in gestation (.007 - .039)
   1.80 Mcal required

The following calculations were used to determine the energy required by deer during the winter of 1979-1980:

1. Average metabolic weight during 120-day winter weight loss period:
$$\frac{42.4 + (42.4 - .20)}{2} = 38.16 \text{ or } 15.35^{.75}$$

2. Energy supplied by catabolism of fat, weight loss/day:
$$\frac{.20 \times 42.4}{120} = .07066 \text{ kg or } 70.66 \text{ g}$$

3. Mcal required for wintering deer:
15.32 kg $BW^{.75}$ x 140 kcal of ME/kg $BW^{.75}$/day - 70.66 g x 6 kcal/day
= 1.73 Mcal
+ .0039 Mcal (energy required for gestation)
1.73 Mcal of energy required

A review of the literature determined an adult deer required approximately 8 percent crude protein for maintenance (French et al. 1955, Magruder et al. 1957, Deitz 1965, and Halls 1970), while a fawn required 12 percent. Dividing the crude protein requirement by 6.25 and then multiplying by the intake per day (.89 kg), I determined an adult doe mule deer required 11.3 g of N per day. However, the amount of nitrogen required for a 120-day gestation period was determined using the following equation developed by Robbins and Moen (1975):

$$\text{Log } e^y = -3.3856 + 0.0275\,(x) = .92 \text{ g required in gestation}$$
$$x = \text{days of gestation}$$

Therefore, an adult wintering doe required 12.3 g N/day. A 13.8 g of N/day requirement for fawns was determined by dividing 12 percent by 6.25 and then multiplying by the intake per day (i.e., .72 kg). Wintering deer on the Keating range required 12.9 g N/day because there are approximately 50 fawns per 100 does.

Deer months expressed on an ME and N basis by season, plant community and pasture were calculated using modified procedures similar to Hobb's et al. (1982) equation as previously described.

Employing the equation, deer months on a nutritional basis were calculated following procedures very similar to the way AUMS were calculated. However, deer requirement figures were adjusted for the amount of energy supplied by catabolism of stored fat and the amount of N required in gestation.

Development of Regression Equations to Correct for Differential Digestibility

Because some plant species are sensitive to epidermal destruction during passage through the digestion tract, it has been recommended some form of correction be used when fecal analysis is used to quantify animal diets (Vavra and Holechek 1980, Dearden et al. 1975). Dearden et al. (1975) further reported correction terms applied to relative densities of food fragments appearing on microscope slides improve estimates of dry weight of ingested foods from microhistological analysis. Therefore, in developing a reference collection, sufficient plant material was collected so hand-compounded mixtures could be made. Regression coefficients were then developed from estimated and actual dry weight of hand-compounded mixtures to correct for bias due to differential epidermal destruction.

Six primary forage plants (i.e., basin big sagebrush, rubber rabbitbrush, Sandberg's bluegrass, cheatgrass, Thurber's needlegrass, and white-top) consumed by wintering deer were mixed into 15 hand-compounded mixtures in the following way: six mixes of basin big sagebrush, Sandberg's bluegrass, and white-top; three mixes of basin big sagebrush, cheatgrass, Thurber's needlegrass, and white-top; three mixes of gray rabbitbrush, cheatgrass and Thurber's needlegrass; and three mixes of rubber rabbitbrush, cheatgrass, and Sandberg's bluegrass. Thurber's needlegrass was not mixed with Sandberg's bluegrass because of similarity in cuticular characteristics. Although originially deer mixtures contained mullein, it was later disregarded since estimates of the mixtures were highly overestimated because the presence of numerous hairs caused the underestimation of the other forages in the mixtures. Estimated dry weights of the other three forages in the mixtures were recalculated after mullein was èliminated from the mixture (table 6). In vitro microdigestion trials with mullein indicated it was not very digestible and, therefore, I assumed it to be of insignificant nutritional importance. Dearden et al. (1975) reported a similar occurrence with mosses in reindeer (Rangifer tarandus) diets.

Six primary forage plants (crested wheatgrass, cheatgrass, Sandberg's bluegrass, squirreltail, bluebunch wheatgrass, Thurber's needlegrass) consumed by cattle during the early grazing season (April-May) and late grazing season (June-July) were hand compounded into six of 12 mixtures, respectively. The early season period consisted of six mixtures of crested wheatgrass, cheatgrass, and Sandberg's bluegrass, while the late season period consisted of six mixtures of crested wheatgrass, cheatgrass, and Sandberg's bluegrass, and six mixtures of squirreltail, bluebunch wheatgrass, and Thurber's needlegrass. The early season was separated from the late season because it was suspected that cuticular characteristics change with plant phenology (tables 7 and 8).

All hand-compounded mixtures were digested in vitro following the procedures of the Tilley and Terry (1963) two-stage technique. Microscope slides of reference plant material were also digested in

TABLE 6. MIXTURES, ACTUAL % WEIGHT AND ESTIMATED % WEIGHT FOLLOWING *IN VITRO* MICRODIGESTION OF HAND-COMPOUNDED FORAGES CONSUMED BY WINTERING DEER DURING LATE SPRING.

	Mixtures													
	1		2		3		4		5		6		7	
Species Code[1]	A[2]	E[3]	A	E	A	E	A	E	A	E	A	E	A	E
19	50.0	47.4	33.7	58.1	55.4	37.4	21.9	27.7	14.0	18.8	19.4	38.7	38.9	32.6
22														
6	12.5	18.5	21.5	10.8	33.0	51.2	43.5	42.9	70.5	58.2	22.0	18.0		
4													11.2	14.1
7													29.4	37.5
11	37.4	34.0	44.8	31.2	11.6	11.4	34.5	29.4	15.4	23.0	58.5	43.2	20.3	15.7

TABLE 6. Continued.

Species Code[1]	Mixtures 8 A[2]	8 E[3]	9 A	9 E	10 A	10 E	11 A	11 E	12 A	12 E	13 A	13 E	14 A	14 E	15 A	15 E
19	29.8	30.6	44.5	36.7												
22					10.1	17.7	30.2	36.9	11.6	14.9	7.9	38.8	40.8	58.0	50.9	53.5
6											8.6	17.9	48.8	29.8	25.8	23.2
4	20.9	26.0	27.7	30.5	39.9	25.8	49.6	26.1	58.5	37.5	3.4	43.2	10.4	8.2	23.2	23.2
7	39.6	37.2	9.8	16.4	49.9	56.3	20.3	36.9	29.9	47.6						
11	9.7	6.1	17.9	16.4												

1 Species names corresponding to index code.

19 Basin big sagebrush

22 Gray rabbitbrush

6 Sandberg's bluegrass

4 Cheatgrass

7 Thurber's needlegrass

11 White-top

2 Actual percent weight.

3 Estimated percent weight.

TABLE 7. MIXTURES, ACTUAL % WEIGHT AND ESTIMATED % WEIGHT FOLLOWING *IN VITRO* MICRODIGESTION OF HAND-COMPOUNDED FORAGES CONSUMED BY CATTLE DURING EARLY SPRING.

	Mixtures											
	1		2		3		4		5		6	
Species Code[1]	A[2]	A[3]	A	E	A	E	A	E	A	E	A	E
1	32.8	36.8	39.6	42.2	10.9	28.1	59.7	58.2	20.7	17.9	39.9	33.3
4	45.2	36.1	49.4	38.9	59.8	57.7	29.6	26.0	39.5	38.3	10.1	11.8
6	22.1	26.9	11.0	18.8	29.3	14.1	10.6	15.7	39.8	43.8	49.9	54.9

[1] Species name corresponding to index code.

1 Crested wheatgrass

4 Cheatgrass

6 Sandberg's bluegrass

[2] Actual % weight.

[3] Estimated % weight.

TABLE 8. MIXTURES, ACTUAL % WEIGHT AND ESTIMATED % WEIGHT FOLLOWING *IN VITRO* MICRODIGESTION OF HAND-COMPOUNDED FORAGES CONSUMED BY CATTLE DURING LATE SPRING.

Species Code[1]	Mixtures																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	A[2]	E[3]	A	E	A	E	A	E	A	E	A	E	A	E	A	E	A	E	A	E	A	E	A	E
1	33.1	30.5	40.1	48.0	10.1	13.6	59.9	58.0	20.2	20.5	40.7	29.6												
4	46.1	42.7	49.9	37.5	59.7	53.1	29.8	29.8	39.9	42.4	9.8	15.1												
6	20.7	26.7	9.9	14.5	30.2	33.3	10.2	12.2	39.9	36.9	49.5	56.2												
25													46.2	43.4	49.8	47.8	59.6	47.2	29.9	31.5	37.6	44.4	11.9	13.4
3													32.4	29.0	40.3	35.7	11.0	14.0	59.6	47.2	25.3	16.9	49.2	33.7
7													21.5	27.5	9.8	16.6	29.4	38.8	10.6	21.3	37.5	38.6	38.9	52.9

1 Species names corresponding to index code.

1 Crested wheatgrass

4 Cheatgrass

6 Sandberg's bluegrass

25 Squirreltail

3 Bluebunch wheatgrass

7 Thurber's needlegrass

2 Actual % Weight.

3 Estimated % weight.

vitro. Microscope slides of hand-compounded mixtures and reference material were prepared as described by Sparks and Malechek (1968). Sixty fields (three slides of 20 fields) were examined for each mixture. The mean relative percent density (estimated weight) of recognized plant fragments in each mixture was estimated using the procedures of Sparks and Malechek (1968) as previously described.

Linear regression equations with one independent variable were calculated to equate estimated percent weight of forage items observed on microscope slides with the corresponding actual dry weight of forages represented in the mixtures of the hand-compounded diets. The relationship between the actual dry weight (y) and the estimated dry weight (x) was expressed by $y=b_o+b_1x_1$ where y was the dependent variable, x was the independent variable, b_o was the y intercept of the regression line, and b_1 was the slope of the line. Regression lines for individual species occurring in two or three of the sampling seasons (i.e., deer-winter, cattle-early and late) were compared and the following hypothesis was tested:

H_o: $b_{o1}=b_{o2}$ and $b_{11}=b_{12}$ (i.e., intercepts and slopes were the same).

H_a: either $b_{o1}\neq b_{o2}$ or $b_{11}\neq b_{12}$ or both (i.e., intercepts and slope were different).

The pooling of regression lines increased the precision of predictions (Neter and Wasserman 1974). All regressions were forced through the origin and the following hypothesis was tested:

H_o: $b_o=o$ (i.e., intercepts were the same).

H_a: $b_o\neq o$ (i.e., intercepts were different).

Regression lines were compared across three seasons (winter, early and late spring) for cheatgrass and Sandberg's bluegrass, and across two seasons (early and late spring) for crested wheatgrass and Thurber's needlegrass. The procedure used for comparing regression lines as outlined by Neter and Wasserman (1974) involved first fitting the full or unrestricted model and obtaining the error sum of squares SSF(F), and secondly, obtaining the reduced or restricted model SSE(R) and determine the error sum of squares. The test statistic was calculated by employing the following formula:

$$F \text{ calc.} = \frac{\dfrac{SSE(R)-SSE(F)}{(N_1+N_2)-(N_1+N_2-4)}}{\dfrac{(SSE(F)}{N_1+N_2-4}}$$

The extension of the test statistic for testing the equality of two or more regressions was straight forward. SSE(F) was the sum of three error sums of squares for each separate regression line, and degrees of freedom were modified accordingly (Neter and Wasserman 1974).

RESULTS AND DISCUSSION

Regression Models Used to Estimate Browse Production

Based on the selection criteria for all three shrubs, the relationship between current year's growth and crown volume and height was best expressed by the following function: $y=ax^b$. The entire search procedure for the best set of variables and best model was a very pragmatic and subjective process; and for each shrub, the best set of independent variables was different. All 27 regression models with their associated sy·x, R^2 or r^2, and T values are given in tables 9, 10 and 11.

For mountain big sagebrush, a multiple linear regression model was a good predictor of current year's growth where log W_2 and log H were the best performing independent variables in the model (log y = -6.37 + .9337 log H + 1.49 log W_2). The addition of log W_1 to the model did not improve the R^2, sy·x, or appearance of the residual plots and did not significantly contribute to the model.

For basin big sagebrush, a simple linear relationship was a good estimator of current year's growth where log A was the best performing independent variable (log y = -3.84 + .9870 log A). Log A accounted for 93 percent of the variability in current year's growth and the sy·x was considerably smaller than with the addition of any of the other variables to the model. Although a model with the variables log W_1 and log W_2 was significant and the residual plots were acceptable, the variables accounted for only 89 percent of the variability in the current year's growth and the sy·x was not as small as with a model that only contained log A.

TABLE 9. REGRESSION COEFFICIENTS, STANDARD ERROR OF THE ESTIMATES, COEFFICIENT OF DETERMINATION, AND T VALUES FOR MOUNTAIN BIG SAGEBRUSH.

Variables (Dep.)	Variables (Ind.)	b_0	b_1	b_2	b_3	$s_{y.x}$	R^2	r^2	T values	Residual plot
y	H	-129.48	2.50			53.34		.53	6.60**	-[2]
y	W_1	- 50.52	1.53			46.01		.65	8.47**	-
y	W_2	- 41.09	1.77			35.36		.79	12.15**	-
y	A	19.35	.0125			35.30		.79	12.18**	-
y	A+H	- 48.71	.9339			31.67	.84		A = 8.41** H = 3.19**	-
y	$H+W_1$	- 95.92	.9298	1.14		44.52	.68		H = 1.89* W_1= 4.19**	-
y	$H+W_2$	- 99.16	.9589	1.42		31.43	.84		H = 3.33** W_2= 8.51**	- -
y	$H+W_1W_2$	- 96.45	.8393	.1539		31.70	.84		W_1= .6120 W_2= 6.08** H = 2.40*	-
y	W_1+W_2	- 55.56	.4912	1.35		33.67	.82		W_1= 2.22* W_2= 5.83**	+[3]
log y	log H	- 7.40	2.61			.4707		.69	9.33**	-
log y	log W_1	- 2.64	1.54			.4243		.75	10.76**	-
log y	log W_2	- 1.83	1.44			.4277		.74	10.65**	-
log y	log A	- 1.98	.7460			.4991		.65	8.56**	-
log y	log A+log H	- 6.67	1.65			.3711	.82		A = 4.92** H = 5.63**	+
log y	log H+log W_1	- 5.93	.9822	1.29		.3603	.83		H = 3.96** W_1= 5.27**	+
[1]log y	log H+log W_2	- 6.37	.9337	1.49		.2914	.89		H = 6.69** W_2= 7.88**	+
log y	log H+log W_1+log W_2									
log y	log W_1+log W_2	- 3.44	1.45	.3264		.2459	.92		W_1= 7.4** W_2= 2.1*	+
log y	H	1.17	.0473			.5593	.61		7.7**	-
log y	W_1	2.44	.0202			.3415		.85	15.04**	-
log y	W_2	2.89	.0192			.4493		.75	10.71**	-
log y	A	3.66	.0001			.5984		.55	6.9**	-
log y	A+H	1.94	.0316	.0001		.5428		.65	H = 3.03** A = 1.8*	-
log y	$H+W_1$	2.68	-.0066	.0223		.3428		.85	H = -.8530 W_1= 8.0110**	-
log y	$H+W_2$	2.4590	.0101	.0160		.4483		.75	H = 1.08 W_2= 4.7**	-
log y	$H+W_1+W_2$	2.77	-.0082	.0200	.0030	.3344		.86	H= -1.03 W_1= 5.18** W_2= .8410	-
log y	W_1+W_2	2.46	.0182	.0021		.3344		.85	W_1= 5.2** W_2= .6080	-

** Significant at the .01.
* Significant at the .05.
[1] Equation used to estimate browse production.
[2] Poor residual plot.
[3] Good residual plot.

TABLE 10. REGRESSION COEFFICIENTS, STANDARD ERROR OF THE ESTIMATES, COEFFICIENT OF DETERMINATION, AND T VALUES FOR BASIN BIG SAGEBRUSH.

Variables (Dep.)	Variables (Ind.)	b_o	b_1	b_2	b_3	sy.x	R^2	r^2	T values	Residual plot
y	H	- 90.11	1.89			100.51		.23	3.8**	-[2]
y	W_1	-113.09	2.48			47.78		.83	15.75**	-
y	W_2	- 68.81	2.85			55.88		.76	12.44**	-
y	A	6.25	.0186			41.39		.87	17.9*	-
y	A+H	19.66	-.1530	.0187		41.66	.87		A =15.24** H = -.6270	-
y	$H+W_1$	- 94.72	-.2763	2.59		47.83	.83		H = -.959 W_1=12.85**	-
y	$H+W_2$	- 87.79	.2469	2.74		56.11	.76		H = .779 W_2=10.34**	-
y	$H+W_1W_2$	- 92.22	-.2848	1.74	1.19	42.73	.87		H =-1.11 W_1= 5.92 W_2= 3.58**	-
y	W_1+W_2	-111.17	1.63	1.18		42.84	.86		W_1= 5.8** W_2 =3.5**	-
log y	log H	- 6.03	1.61			.3213		.54	7.44**	-
log y	log W_1	- 4.52	1.99			.3576		.85	17.10**	+[3]
log y	log W_2	- 1.05	1.33			.5843		.62	8.92	-
[1]log y	log A	- 3.84	.9870			.2586		.93	24.55**	+
log y	log A+log H	- 3.39	1.01	-.1434		.2588	.93		A =21.00** H = -.967	+
log y	log H+log W_1	- 4.29	2.02	-.0788		.3608	.85		H = -.379 W_1=14.29**	-
log y	log H+log W_2	- 3.59	1.18	.6793		.5592	.66		H = 2.32* W_2= 7.59**	-
log y	log H+log W_1+log W_2	- 6.09	.3062	.7664	1.29	.2868	.89		H = 4.9** W_1= 1.49 W_2= 4.70**	+
log y	log W_1+log W_2	- 2.83	.8524	.7742		.3662	.82		W_1= 3.85** W_2= 3.74	+
log y	H	1.46	.0309			.4814		.68	9.03**	-
log y	W_1	2.55	.0175			.4427		.73	10.02**	-
log y	W_2	2.82	.0182			.4611		.71	9.60**	-
log y	A	3.51	.0001			.5530		.58	7.25**	-
log y	A+H	1.95	.0214	.0001		.4102	.78		H = 5.66** A = 3.91**	-
log y	$H+W_1$	1.78	.0157	.0109		.3881	.75		H = 3.67** W_1= 4.63**	+
log y	$H+W_2$	1.71	.0183	.0115		.3317	.85		H = 6.04** W_2= 6.56**	+
log y	$H+W_1+W_2$	1.78	.0151	.0042	.0092	.3247	.86		H = 4.2* W_1= 1.6 W_2= 4.1*	+
log y	W_1+W_2	2.52	.0102	.0096		.3913	.79		W_1= 3.97** W_2= 3.55**	-

** Significant at the .01.
* Sirnificant at the .05.
[1] Equation used to estimate browse production.
[2] Poor residual plot.
[3] Good residual plot.

TABLE 11. REGRESSION COEFFICIENTS, STANDARD ERROR OF THE ESTIMATES, COEFFICIENT OF DETERMINATION, AND T VALUES FOR GRAY RABBITBRUSH.

Variables (Dep.)	(Ind.)	b_0	b_1	b_2	b_3	sy.x	R^2	r^2	T values	Residual plot
y	H	-237.07	5.19			51.68		.69	9.23**	-[2]
y	W_1	- 85.98	2.08			35.75		.85	14.82**	-
y	W_2	- 47.84	2.10			36.58		.85	14.40**	-
y	A	28.68	.0125			44.03		.77	11.47**	-
y	A+H	- 82.82	2.05	.0087		41.00	.81		H = 2.61** A = 4.83**	-
y	$H+W_1$	-109.51	.6406	1.88		35.93	.85		H = .7950 W_1= 6.45**	-
y	$H+W_2$									-
y	$H+W_1+W_2$	- 78.06	.0876	1.12	1.03	32.54	.88		H = .7526 W_1= .3655 W_2= .3424	- -
y	W_1+W_2	- 74.73	1.13	1.04		32.10	.88		W_1= .3232 W_2= .3276	-
[1]log y	log H	- 8.97	3.18			.5674		.60	7.5**	+[3]
log y	log W_1	- 3.70	1.81			.2561		.92	20.78**	+
log y	log W_2	- 1.46	1.39			.3823		.82	13.1**	-
log y	log A	- 1.3	.6826			.5305		.65	8.45**	-
log y	log A+log H	- 6.28	.4373	1.68		.4686	.74		A= 4.33** H = 3.42**	-
log y	log H+log W_1	- 4.03	1.76	.1310		.2589	.92		H = 2.20* W_1= 12.06**	+
log y	log H+log W_2	- 4.12	1.14	.8898		.3650	.84		H = 2.20* W_2= 7.40**	+
log y	log H+logW_1+log W_2	- 4.26	1.61	.4612	.0948	.3708	.89		H = -.5290 W_1= 10.29** W_2= 4.15**	
log y	log W_1+log W_2	- 4.53	1.57	.4599		.3081	.89		W_1= 11.18** W_2= 4.17**	+
log y	H	2.41	.0173			.8038		.29	4.40**	-
log y	W_1	2.41	.0203			.4196		.81	14.11**	-
log y	W_2	2.80	.0228			.5061		.72	11.04**	-
log y	A	3.46	.0001			.5095		.71	10.94**	-
log y	A+H	3.16	.0033	.0001		.5079	.72		A = 8.56** H = 1.13	-
log y	$H+W_1$	2.37	.0200	.0001		.4238	.81		H = .2330 W_1= 11.21**	-
log y	$H+W_2$	2.43	.0048	.0208		.4958	.73		H = 1.74** W_2= 8.89**	-
log y	$H+W_1+W_2$	2.39	.0005	.0142	.0082	.3990	.83		H = .2230 W_1= 5.16** W_2= 2.65**	-
log y	W_1+W_2	2.43	.0144	.0082		.3950	.83		W_1= 5.64** W_2= 2.68**	+

** Significant at the .01.
* Significant at the .05.
[1] Equation used to estimate browse production.
[2] Poor residual plot.
[3] Good residual plot.

A simple linear relationship was also a good estimator of current year's growth for gray rabbitbrush where log W_1 was the best performing independent variable in the model (log y = -3.70, + 1.81 log W_1). Given log W_1 in the model, the addition of log H was a significant contributor to the model. However, the R^2, sy·x, and residual plots were similar to the model that contained only W_1 and; therefore, log H was dropped from the model.

The F statistic calculated to test the regression through the origin (bo=0 and bo≠0)for the selected three models proved the intercepts to be significant and; therefore, they were not deleted from any of the three best models. All regression equations were significant (P<.05).

Rittenhouse and Sneva (1977) found the best expression of photosynthetic biomass of Wyoming big sagebrush to be a log-log transformation; however, log A and log H were the best fitted variables using the sy·x and R^2 as criteria in their model construction. Based on the sy·x and R^2, Dean et al. (1981) found the best expression of annual production of basin big sagebrush and mountain big sagebrush to also be a log-log transformation where the best set of independent variables were maximum and minimum diameter of the crown, crown denseness and crown depth.

Volumetric or crown area relationships based on crown height and diameters have been described for serviceberry (Amelanchier alnifolia) by Lyon (1968) and for eight Chihuahuan desert shrubs by Ludwig et al. (1975). Bryant and Kothman (1979) used a conical volume derived from height and diameter measurements to predict browse biomass for 12 species of shrubs in the Sonoran desert.

Herbaceous and Browse Production

The winter of 1978-1979 was divided into an early (November, December, January) and late (February, March, April) sampling period. Only those species that protruded through the snow were estimated during the early sampling period. During the late sampling period, both previous year's growth (i.e., old growth) and current year's growth (i.e., regrowth) of available herbaceous biomass was estimated as well as browse. The mean biomass (kg/ha) and standard error ($P<.20$) of dominate species available to deer on both an old and regrowth basis during the 1978-1979 winter are given by plant community and pasture in appendices D and E. During the winter of 1979-1980, herbaceous and browse production was sampled in December. The mean biomass (kg/ha) and standard error ($P<.20$) of dominate herbaceous and browse species available to deer on an old and regrowth basis are given by plant community and pasture in appendix F.

The dominant herbaceous species available to cattle by plant community and pasture are given in appendix C. For the pastures grazed in the fall, available herbaceous biomass was estimated on an old and fall growth basis. Herbaceous biomass was usually sampled the second week after cattle were turned into the pastures.

The number of clustered plots allocated to each plant community during each sampling period are given in table 12. An attempt was made to proportionally allocate plots based on the size of the plant community. Fewer plots were read during the winter of 1979-1980

TABLE 12. SUMMARY OF THE NUMBER OF CLUSTERS READ PER PLANT COMMUNITY BY PASTURE AND SAMPLING DATE. E AND L REFER TO EARLY AND LATE PERIOD, RESPECTIVELY.

Pasture		Index Code[2]												
Code[1]	Date	8	9	7	6	1	3	4	2	5	10	12	11	13
8	6/79		8	4	6	4		6		6				
	6/80		8	4	6	4		6		6				
	79E		8	4				6						
	79L		8	4				6						
	80		4	2		2		3		2				
7	5/79						8			6				4
	5/80						8			6				4
	79E						6							
	79L						6							
	80						3			3				
6	12/79	6		4	4	6					4			
5	6/79			6	6	8						6	4	
	9/80			6	6	8						6	4	
	79E			6		8								
	79L			6		8								
	80			3	3	4						2	2	
4	5/79	6		4		4			4		4	4	4	
	12/80	6		4		4			4		4	4	4	
	79E	6		4		4					2	2	2	
	79L	6		4		4					2	2	2	
	80	3		2		2					2	2	2	
3	5/79	8									8			
	12/80	8									8			
	79E	6									4			
	79L	6									4			
	80	3									2			
2	12/79	8		6		8			8		8		8	
	6/80	8		6		8			8		8		8	
	79E	6		4		4			4		4		4	
	79L	6		4		4			4		4		4	
	80	3		2		2			2		2		2	
1	6/79			6		8			4		4	4	3	
	5/80			6		8			4		4	4	3	
	79E			6		6						4		
	79L			6		6						4		
	80			3		3						2		

TABLE 12. Continued

[1] Pasture names corresponding to index code.

8 North Tucker
7 South Tucker
6 Middle
5 Spring Creek
4 Bacher Creek
3 Crystal Palace
2 Pittsburg Gulch
1 Powder River

[2] Plant community names corresponding to index code.

1 Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2 Mountain big sagebrush/Idaho fescue
3 Mountain big sagebrush/crested wheatgrass
4 Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
5 Mountain big sagebrush/Sandberg's bluegrass
6 Stiff sagebrush/Sandberg's bluegrass
7 Bluebunch wheatgrass
8 Crested wheatgrass
9 Intermediate wheatgrass
10 Cheatgrass
11 Medusahead
12 White-top
13 Forbs

because of a lack of time and manpower.

The most productive communities during the two winters were the basin big sagebrush/cheatgrass/Sandberg's bluegrass and bluebunch wheatgrass, while the least productive communities were the stiff sagebrush/Sandberg's bluegrass, and cheatgrass (table 13). During the early summer months, the most productive communities available to cattle were the intermediate and crested wheatgrass, while the least productive communities were the sagebrush communities. A similar trend was observed for cattle during the fall months.

Biomass figures reported here should not be taken as absolute figures. Stoddart et al. (1975) reported that weather on range areas is subject to great annual variability, and annual forage production tends to vary even more, being correlated especially with seasonal distribution of precipitation. The forage production may be two to three times as much in one year as another on perennial rangeland. And on annual rangeland, it may be 10 times as much 1 year as another (Stoddart et al. 1975).

Regression Equations Used to Correct for Differential Digestibility

Regression equations and coefficients of determination used to correct estimated dry weight to actual dry weight of primary forages consumed by deer and cattle are given in table 14. Regression lines for cheatgrass, Sandberg's bluegrass, Thurber's needlegrass and crested wheatgrass were not statistically different across seasons and were subsequently pooled.

B_0 could be dropped from all regression equations because

TABLE 13. SUMMARY OF TOTAL AVAILABLE HERBACEOUS BIOMASS AND BROWSE ON A KILOGRAM-PER-HECTARE BASIS BY PLANT COMMUNITY, PASTURE, AND SAMPLING DATE. E AND L REFER TO EARLY AND LATE PERIOD, RESPECTIVELY.

Pasture Code[1]	Date	Index Code[2]												
		8	9	7	6	1	3	4	2	5	10	12	11	13
8	6/79		824	370	85	249		634		65				
	6/80		1110	386	98	211		634		98				
	79E		174	176				165						
	79L		415	298				317						
	80		287	532		337		442		228				
7	5/79						175			88				462
	5/80						232			226				460
	79E						152							
	79L						249							
	80						337			400				
6	12/79	179		294	117	71					208			
5	6/79			352	180	1079						544	622	
	9/80			465	104	168						386	489	
	79E			46		414								
	79L			110		586								
	80			313	139	388						288	316	
4	5/79	594		203		212			330		377	623	215	
	12/80	447		406		108			213		390	502	508	
	79E	19		69		298					30	69	59	
	79L	287		107		548					258	497	481	
	80	181		410		599					210	247	287	
3	5/79	302									395			
	12/80	634									316			
	79E	35									38			
	79L	306									246			
	80	276									140			
2	12/79	416		280		91			160		188		306	
	6/80	435		422		244			223		633		703	
	79E	41		39		383			138		14		51	
	79L	274		203		653			538		216		359	
	80	405		337		320			407		205		280	
1	6/79			276		290			274		538	552	572	
	5/80			260		182			235		1164	1080	594	
	79E			129		370					19			
	79L			208		747					153			
	80			417		425					181			

[1] Pasture names corresponding to index code.

8 North Tucker
7 South Tucker
6 Middle
5 Spring Creek
4 Bacher Creek
3 Crystal Palace
2 Pittsburg Gulch
1 Powder River

[2] Plant community names corresponding to index code.

1 Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2 Mountain big sagebrush/Idaho fescue
3 Mountain big sagebruh/crested wheatgrass
4 Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
5 Mountain big sagebrush/Sandberg's bluegrass
6 Stiff sagebrush/Sandberg's bluegrass
7 Bluebunch wheatgrass
8 Crested wheatgrass
9 Intermediate wheatgrass
10 Cheatgrass
11 Medusahead
12 White-top
13 Forbs

TABLE 14. REGRESSION EQUATIONS AND COEFFICIENTS OF DETERMINATION USED TO CORRECT ESTIMATED DRY WEIGHT TO ACTUAL DRY WEIGHT OF PRIMARY FORAGES CONSUMED BY CATTLE AND DEER.

Species	r^2	Regression Equation
Basin big sagebrush	.90**	y=1.0151x
Gray rabbitbrush	.82*	y= .7529x
White-top	.89**	y= .5142x
Mullein	.75*	y= .2889x
Sandberg's bluegrass	.90**	y= .9796x
Cheatgrass	.78**	y=1.1697x
Squirreltail	.87**	y=1.0437x
Crested wheatgrass	.81**	y= .9823x
Bluebunch wheatgrass	.91**	y=1.2469x
Thurber's needlegrass	.81**	y= .7797x

* $P<.05$.
** $P<.01$.

the null hypothesis could not be rejected. The test statistic used by the computer was:

$$F\ calc = \frac{MSRU}{MSE}$$

where the MSRU was the uncorrected mean squared regression (i.e., the regression line no longer goes through X, Y, but through 0). Gray rabbitbrush, white-top, mullein, and Thurber's needlegrass were overestimated while cheatgrass and bluebunch wheatgrass were underestimated in the hand-compounded diets (table 14). Big sagebrush, Sandberg's bluegrass, squirrel-tail, and crested wheatgrass had close to a 1:1 ratio between RD and actual percent dry weight. Mullein was severely overestimated because of the presence of abundant stellate hairs. Sanders et al. (1980) reported that silverleaf nightshade (Solanum elaeagnifoluim) was severely overestimated in cattle diets because of an abundance of stellate hairs. White-top was probably overestimated because of the numerous identifiable seeds that the animals (i.e., deer) consumed.

Other investigators have also used correction factors in food habit analysis, including Tueller (1979), Vavra and Holechek (1980), Dearden et al. (1975), and Gill et al. (1983). Tueller (1979) analyzed deer rumen samples using a microscope point method and used correction factors to account for large items such as leaves, stems and inflourescence of some species which cause overestimates of these plants. They reported that .89 was a correction factor used for big sagebrush while the average correction factor for all grasses was 1.18. Vavra and Holechek (1980) using a microhistological technique, developed a regression equation from hand-compounded mixtures to correct for a shrub that was consistently underestimated in the diet of steers. Dearden et al. (1975) also employed a microhistological technique and developed regression equations from hand-compounded mixtures. They reported that a grass (Festuca altacca) and a browse (Salix pulchra) were both underestimated in the hand-compounded diets. However, Gill et al. (1983) warned that applying correction factors to diets where real composition is already known leads to a final prediction.

Cattle Food Habits

The uncorrected mean percent, standard error and corrected mean percent of the primary species occurring in the diet of cattle by date and pasture are given in appendix G. Because there was not a statistical difference ($P<.05$) between years, data were pooled across years and are presented in tables 15 and 16 for the spring and fall seasons, respectively. During the spring grazing season, crested wheatgrass was the dominant forage consumed where it was available, except in the Pittsburgh Gulch and Bacher Creek pastures where cheatgrass and Sandberg's bluegrass were dominant grasses consumed. During the fall grazing period, cheatgrass and Sandberg's bluegrass were dominant forages consumed. Primary forbs consumed included filaree, prickly lettuce, mustard and white-top, while primary browse consumed was sagebrush.

During the spring grazing period, crested wheatgrass was not utilized in the Pittsburgh Gulch and Bacher Creek pastures to the

TABLE 15. CORRECTED MEANS (%) OF THE PRIMARY SPECIES CONSUMED BY CATTLE DURING THE SPRING SEASON BY PASTURE ACROSS YEARS.

Species	Pasture index code[1]						
	8[2]	7[2]	5	3	1[2]	2	4
Cheatgrass	14.8	19.4	33.8	23.9	53.5	25.9	32.4
Sandberg's bluegrass	9.4	22.2	17.9	25.7	21.4	21.7	18.8
Thurber's needlegrass	3.3	4.4	14.9	1.2	3.9	3.8	2.7
Idaho fescue	3.5	1.3	.3	T	1.8	3.0	7.0
Squirreltail	4.9	9.4	5.5	4.1	.9	3.1	6.9
Crested wheatgrass	17.2	26.7	—	36.1	--	13.5	15.6
Intermediate wheatgrass	29.7	--	--	--	--	--	--
Bluebunch wheatgrass	3.9	3.3	8.6	T	13.1	9.4	3.6
Medusahead	.6	.6	3.1	T	1.3	4.6	1.6
TOTAL GRASSES[3]	91.7	92.3	85.2	92.6	98.1	98.9	92.0
TOTAL FORB	3.5	2.2	6.0	2.4	3.2	1.1	4.8
TOTAL BROWSE	2.1	2.0	7.0	.9	5.1	1.1	4.8

[1] Pasture names corresponding to index code.

1 Powder River
2 Pittsburg Gulch
3 Crystal Palace
4 Bacher Creek
5 Spring Creek
7 South Tucker
8 North Tucker

[2] Pasture means were pooled across two seasons.

[3] Totals represent all grass species found in the diet.

TABLE 16. CORRECTED MEANS (%) OF THE PRIMARY SPECIES CONSUMED BY CATTLE DURING THE FALL SEASON BY PASTURE.

Species	Pasture index code[1]				
	5	6	3	2	4
Cheatgrass	28.9	22.3	32.3	29.8	38.9
Sandberg's bluegrass	19.5	28.9	31.9	18.4	25.8
Needle grass	4.8	8.4	1.5	2.4	1.3
Idaho fescue	3.8	4.1	1.7	3.9	2.4
Squirreltail	10.0	5.7	.5	1.4	<1
Crested wheatgrass	--	8.4	13.9	10.2	9.9
Bluebunch wheatgrass	7.2	9.6	1.1	8.5	.4
Medusahead	3.3	2.0	1.5	4.5	.3
TOTAL GRASSES[2]	85.2	92.2	89.7	85.7	84.6
TOTAL FORB	6.0	2.8	.9	6.1	8.7
TOTAL BROWSE	6.5	1.7	3.4	<1	3.8

1 Pasture name corresponding to index code.
- 2 Pittsburg Gulch
- 3 Crystal Palace
- 4 Bacher Creek
- 5 Spring Creek
- 6 Middle

2 Total grasses represent all grass species found in the diet.

extent it was utilized in other pastures that contained seedings of crested wheatgrass. Under-utilization of crested in the Pittsburgh Gulch and Bacher Creek pastures was due to the presence of the previous year's standing crop, which inhibited selection for current year's growth. If the seedings were fenced and animals forced to consume crested wheatgrass, utilization would improve.

In the Middle, Crystal Palace, Pittsburg Gulch and Bacher Creek pastures, crested wheatgrass was one of the primary forages available to cattle during the fall months. However, cheatgrass and Sandberg's bluegrass were consumed in greater amounts. Because these fall pastures were deferred in the spring, crested wheatgrass plants had considerable previous year's growth present and, subsequently, were under-utilized. Improved fall utilization on crested can be attained by using a two-crop, one-crop system of grazing as outlined by Hyder and Sneva (1963).

Deer Food Habits

The uncorrected mean percent, standard error, and corrected mean percent of the primary species consumed by deer by sampling period and year are given in appendix H. Sagebrush was the dominant browse consumed by deer, while Sandberg's bluegrass was the dominant grass consumed (table 17). Averaged across all three study areas, total grass consumption during the early and late winter periods was 1.6 and 31.5 percent, respectively, while total browse consumption during the early and late winter periods of 1978-1979 was 57.4 and 40.2 percent, respectively. During the late winter period of 1978-1979,

TABLE 17. CORRECTED MEANS (%) OF THE PRIMARY SPECIES OCCURRING IN THE DIETS OF DEER DURING THE EARLY (E) AND LATE (L) SAMPLING PERIODS BY YEAR AND STUDY AREA.

	Study area											
	Crystal Palace				Spring Creek				Tucker Creek			
	78-79		79-80		78-79		79-80		78-79		79-80	
Species	E	L	E	L	E	L	E	L	E	L	E	L
Sandberg's bluegrass	<1	13.7	25.9	36.7	<1	10.4	26.5	18.4	<1	16.1	16.2	20.0
Cheatgrass	<1	11.1	14.2	14.5	<1	1.8	11.8	12.3	<1	5.9	10.9	8.0
Needlegrass	<1	2.4	1.9	3.3	<1	3.1	5.7	7.6	<1	5.2	2.6	4.9
Squirreltail	<1	1.2	4.0	1.3	<1	1.7	3.7	3.1	<1	1.6	3.1	3.3
Crested wheatgrass	<1	3.1	4.4	3.7	<1	<1	<1	<1	<1	2.8	3.9	3.4
TOTAL GRASS[2]	1.9[a]	36.1[b]	56.4[c]	65.4[c]	1.4[a]	21.5[b]	53.9[c]	50.4[c]	1.4[a]	36.8[b]	40.1[c]	45.4[c]
TOTAL FORB[2]	16.8	16.6	1.9	1.7	23.7	17.5	2.5	3.1	12.8	6.8	10.0	2.1
Sagebrush	51.5	27.9	28.3	29.4	33.6	31.5	27.2	32.6	36.9	35.5	28.7	33.9
Gray rabbitbrush	4.9	1.5	1.1	.8	2.6	.9	1.0	1.3	1.4	1.7	1.8	1.7
Willow	3.8	1.7	.5	.4	9.2	7.1	.3	.3	11.2	5.9	.8	<1.0
TOTAL BROWSE[2]	61.0[a]	32.8[b]	33.7[c]	31.2[c]	51.7[c]	41.4[c]	32.6[c]	39.7[c]	59.5[c]	46.4[c]	35.1[c]	39.9[c]

1 Total means with different letters are significantly different (P<.05).

2 Totals represent totals for all grass, forb and browse species consumed.

total grass consumption significantly (P<.05) increased in the diets of deer across all three study areas. Also, during the late winter period, total browse consumption decreased but was significant (P<.05) only in the Crystal Palace study area. In contrast during the winter of 1979-1980, no significant (P<.05) change occurred between in the amount of total grass and browse consumed in the amount of total grass and browse consumed. Averaged across all three study areas, total grass consumption during the early and late periods was 50.1 and 53.7 percent, respectively, while total browse consumption was 33.8 and 36.9 percent during the early and late periods, respectively. Although total forb consumption appeared to be higher in the winter of 1978-1979 as compared to the winter of 1979-1980, forbs were difficult to evaluate because of variability, both in the diet as well as their occurrence on the range.

Browse consumption was high during the early winter of 1978-1979 because snow accumulation limited the amount of herbaceous plant material available to deer. However, as snow-melt occurred, grass regrowth became available and grass consumption increased during the late period. However, during the "open winter" of 1979-1980, grass and browse consumption were comparable across the early and late sampling periods. Forb consumption (predominantly mullein and white-top) was relatively high during the early and late periods of 1978-1979 as compared to the early and late periods of 1979-1980. Deer probably consumed more mullein and white-top during the winter of 1978-1979 because these forbs protruded above the snow and were available. Why deer continued to consume mullein and white-top after snow melt is difficult to explain. However, in studies of Rocky Mountain and Desert mule deer, buckwheat (Eriogonum sp.) (Urness 1973) and sulfur buckwheat (Eriogonum umbellatum) (Gill and Wallmo 1973), respectively, were very low in apparent nutritional quality but highly preferred (in Wallmo and Regelin 1981). Milchunas (1977) pointed out that lignin sometimes makes forage "brittle" so that it breaks down to smaller particle size and passes through the rumen more rapidly. Thus, net digestible and metabolizable energy may increase (in Wallmo and Regelin 1981). However, this does not imply that plants with lignin are ideal forage, but suggests lignin may enhance the opportunity for deer to obtain maximum benefit from forage of otherwise limited digestibility (in Wallmo and Regelin 1981). This may explain why mullein and white-top were consumed during the early and late winter period of 1978-1979. During the open winter of 1979-1980, mullein and white-top were consumed less, probably because alternative species were available.

These results can be compared to a number of studies; however, only a few will be discussed here (Leach 1956, Willms et al. 1976, Carpenter 1976, and Willms and McLean 1978). Leach (1956) studied the food habits of mule deer in northeastern California over three winters: a cold and dry winter, a mild and wet winter, and a winter when heavy snowfall occurred. He reported during the cold and dry winter a small amount of green grass was available, but the diet contained a large percentage of dry grass and forbs and a decreasing percentage of browse. In the mild and wet winter, Leach (1956) reported green grass was available throughout the winter and constituted 45 to 55 percent of November to March diet samples and 100 percent of the April sample; while during the heavy snow fall winter, juniper and sagebrush composed nearly the entire diet. Wilms et al. (1976) studied the diets of mule deer in the Kamloops area of British Columbia from September to April. They reported grass consumption was less than 10 percent during early winter but it later increased to 100 percent during late spring. Also, more forbs were consumed in fall than in winter, while shrubs were consumed more in early fall and late winter than in late fall. They further reported snow depth altered the proportion of both small and large plants in the diet; and as snow depth increased, fewer small plants but more large plants were consumed. Recently, Willms and McLean (1978), working with tame mule deer on a big sagebrush range in British Columbia, reported deer showed marked selection for non-grasslike plants during most of winter but considerable deviation occurred in early spring from mid-March to mid-April when grass consumption was high. Sandberg's bluegrass constituted the most bites in the diet but bluebunch wheatgrass was preferred (Willms and McLean 1978). Carpenter (1976), working on a big sagebrush range in Middle Park, Colorado reported that, contrary to general belief, grasses consistently made up over 60 percent of deer diets during winter grazing trials using tame, trained deer.

Similarity Indices

Diet similarity between deer and cattle ranged from 27.1 to 52.8 percent (table 18). Mean spring overlap for both years was 36.9 per-

TABLE 18. SIMILARITY INDICES SHOWING THE PERCENTAGE OF CATTLE AND DEER DIETS THAT WERE IDENTICAL BY PASTURE, SEASON AND YEAR.

Pastures	Fall 1979, %	Spring 1979, %	Fall 1980, %	Spring 1980, %
North Tucker		29.4		35.2
South Tucker		36.6		42.5
Spring Creek		27.1	50.7[1]	
Middle pasture	53.8			
Bacher Creek		39.0	52.8[1]	
Crystal Palace		33.6	50.6[1]	
Pittsburgh Gulch	42.4			47.9
Powder River		40.6		

[1] Compared with fall deer diets during 1979.

cent, while average fall diets overlapped 50.5 percent. Most of the dietary overlap occurred due to common use on Sandberg's bluegrass and cheatgrass, while the least amount occurred on total forbs and browse.

Although there appeared to be a relatively high overlap in the diet between deer and cattle during fall, it is impossible to determine if there is forage competition because animals may or may not occupy the same portions of the range. This study did not investigate or determine the distribution of the two animals when they occurred on range together. If we assume both deer and cattle occupied the same areas, it is very possible interspecific forage competition existed during the fall period provided available forage was in short supply. The spring overlap period is difficult to interpret because deer have left the range prior to the time livestock were turned onto the pastures. However, it is very possible that spring use by deer could impact cattle, especially if deer utilized the same areas as livestock, although this idea has not been reported in the literature (Mackie 1981).

These results can be compared to two studies (Hansen and Reid 1975, and Vavra and Sneva 1978). Hansen and Reid (1975) determined that diet similarity between mule deer and cattle ranged from 12.1 to 37.8 percent for a 4-month period of cattle grazing and an annual use by deer. Although high overlap occurred in the diets for sedge (*Carex* sp.), bluegrass (*Poa* sp.), fescue (*Festuca sp.*) and mountain mohogany (*Cerocarpus sp.*), they concluded there was probably little interaction because mule deer and cattle were most concentrated in different areas. Vavra and Sneva (1978) reported the seasonal food habits of mule deer and four other classes of ruminants near Burns, Oregon, and found, in winter, cattle and deer diets were 13 percent similar, while in summer, diets were 16 percent similar. A later report by Vavra et al. (1981) suggested, however, that potential for competition for forage between deer and cattle may occur on ranges in poor condition where quality and quantity of forage is limited or where extensive fall cattle grazing on native range removes fall growth and little herbaceous material remains for wintering deer. Stoddart et al. (1975) also reported that competition can increase if range deterioration results in a limited number of plant species.

Animal Unit Months on a Forage Quantity, Energy and Nitrogen Basis

Variation occurred in total AUMS per pasture on a forage quantity and nutritional basis for the spring grazing period during the 3 months (May, June, and July) that sampling occurred (tables 19 and 20). Although cattle were turned onto the early pastures (Crystal Palace and Powder River) April 15, these pastures were not sampled for forage quantity and quality until the mid-grazing period (May 1).

Total AUMS on a nutritional basis exceeded total AUMS on a quantitative basis for the Crystal Palace and Powder River pastures. On a nutritional basis, total AUMS calculated on an N basis exceeded those AUMS calculated on an ME basis. These results indicated that early growth on some intermountain range plants may be very high in N content and relatively low in ME and biomass. Therefore, deferment of early turnout dates may enhance livestock performance.

TABLE 19. SUMMARY OF AUMS ON A FORAGE QUANTITY (Q), ENERGY (E) AND NITROGEN (N) BASIS BY PASTURE, PLANT COMMUNITY AND DATE FOR THE SPRING GRAZING PERIODS.

Plant community code[2]	Date: 6/1/79			5/1/80			5/1/79			5/15/79			6/15/79			6/15/80			5/15/79			5/15/80			6/15/79			6/15/80		
	Pasture index code[1]: 1			1			3			4			8			8			7			7			5			2		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8							57	64	81	20	24	21																72	73	40
9													70	72	35	95	98	47												
7	8	8	6	8	9	9				6	7	7	16	16	10	16	15	9							22	20	12	13	13	7
1	36	38	23	31	36	33				12	13	11	29	23	14	25	22	10							185	182	141	20	17	9
2	3	5	3	5	6	7				4	5	4																2	4	2
6													1	2	1	1	1	1												
3																			52	64	54	72	82	70						
4													57	63	33	49	53	28												
5													2	2	1	3	3	1	11	13	10	24	29	33						
10	9	9	6	23	23	30	37	43	50	14	15	13																17	14	8
12	1	1	1	2	3	3				6	7	6													6	5	3			
13																			5	6	6	4	5	5						
11	1	3	1	1	2	2				1	2	1													7	7	5	4	4	3
TOTAL	58	64	40	70	79	84	94	107	331	63	73	63	175	178	94	189	192	96	68	83	70	100	116	108	220	214	161	128	125	69

[1] Pasture names corresponding to index code.
1 Powder River
2 Pittsburg Gulch
3 Crystal Palace
4 Bacher Creek
5 Spring Creek
7 South Tucker
8 North Tucker

TABLE 19. Continued

[2] Plant community names corresponding to index code.

1 Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2 Mountain big sagebrush/Idaho fescue
3 Mountain big sagebrush/crested wheatgrass
4 Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
5 Mountain big sagebrush/Sandberg's bluegrass
6 Stiff sagebrush/Sandberg's bluegrass
7 Bluebunch wheatgrass
8 Crested wheatgrass
9 Intermediate wheatgrass
10 Cheatgrass
11 Medusahead
12 White-top
13 Forbs

TABLE 20. SUMMARY OF AUMS ON A FORAGE QUANTITY (Q), ENERGY (E) AND NITROGEN BASIS (N) ON AN OLD GROWTH AND FALL GROWTH BASIS BY PASTURE PLANT COMMUNITY, AND DATE FOR THE FALL GRAZING PERIOD. O AND F REFER TO OLD GROWTH AND FALL GROWTH, RESPECTIVELY.

Plant community code[2]	Date: 12/15/79						12/15/80						12/15/79						10/1/80						12/15/80					
	Pasture index code[1]: 2-O			2-F			4-O			4-F			6-O			6-F			5-O			5-F			3-O			3-F		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8	83	71	76	17	22	43	23	19	14	2	3	4	11	8	11	3	4	9							165	138	122	21	26	45
7	10	8	8	2	2	3	19	16	14	3	4	6	15	13	18	3	5	8	31	25	23	8	5	8						
1	6	7	15	4	6	14	6	8	14	4	6	13	7	8	15	4	6	14	26	26	46	14	18	42						
2	4	3	4	3	2	3	4	3	4	1	1	1																		
6													5	2	4	1	4	4	20	19	34	13	13	32						
10	3	4	6	2	2	5	12	15	30	10	14	29	4	3	4	1	2	3							20	27	43	14	19	40
12							4	5	8	<1	<1	6							4	4	7	2	3	6						
11	2	2	2	1	<1	1	1	1	1	<1	<1	<1							7	6	3	1	<1	<1						
TOTAL	108	95	111	29	35	69	69	67	85	22	30	60	42	34	52	12	21	38	88	80	113	38	40	89	185	165	165	35	45	85

[1] Pasture names corresponding to index code.
2 Pittsburg Gulch
3 Crystal Palace
4 Bacher Creek
5 Spring Creek
6 Middle

[2] Plant community names corresponding to index code.
1 Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2 Mountain big sagebrush/Idaho fescue
6 Stiff sagebrush/Sandberg's bluegrass
7 Bluebunch wheatgrass
8 Crested wheatgrass
10 Cheatgrass
11 Medusahead
12 White-top

The Bacher Creek and South Tucker pastures were grazed from May 1 to June 1 and were sampled on May 15. In both pastures, AUMS based on ME exceeded the AUMS based on forage quantity or N.

The Spring Creek, Pittsburg Gulch and North Tucker pastures were grazed from June 1 to July 1 and were sampled June 15. Total AUMS, based on quantity, exceeded those based on nutrition in the Pittsburgh Gulch and Spring Creek pastures. In the Spring Creek and Pittsburg Gulch pastures, total AUMS based on N were approximately one-half as much as AUMS based on ME; and total AUMS, based on ME, were quite similar to AUMS based on forage quantity. In the North Tucker pasture, total AUMS, based on ME, were similar to total AUMS based on forage quantity. However, similar AUMS based on N were approximately one-half as much as total AUMS based on energy or quantity.

Because the South Tucker and North Tucker pastures were grazed the same time each year, differences between years could be observed (table 19). This temperal difference could have resulted from one of two things: the effects of climate and/or level of sampling intensity.

Fall cattle months were calculated two ways: (1) AUMS were calculated on a forage quantity, ME and N basis using both old and fall growth together; and (2) AUMS were calculated using only the fall growth that was available. Calculations of AUMS on a fall growth basis would probably be more accurate than AUMS based on the poor quality forage of the old growth because range animals tend to select the most nutritious forage. All pastures were sampled for available herbaceous biomass between December 15 and December 20, except for the Spring Creek pasture which was sampled October 1, 1980.

Changes in total AUMS on a forage quantity, ME and N basis on an old and fall growth basis were comparable across all pastures grazed in the fall (table 20). Total AUMS based on N were consistently higher than total AUMS based on ME or quantity, except for the Crystal Palace pasture where total AUMS based on N were the same as those based on ME. On all pastures, total AUMS based on quantity were consistently higher than those based on ME. Total AUMS based on ME were always lower than total AUMS based on N or biomass.

For the three methods, total AUMS on a fall growth basis showed comparable trends across all pastures grazed in the fall (table 20). Total AUMS on an N basis were generally twice those based on quantity or ME. Total AUMS on an ME basis were slightly more than AUMS on a quantity basis.

The data showed that during early and late spring the crested wheatgrass and cheatgrass communities would carry the most animals, while the stiff sagebrush, mountain big sagebrush/Sandberg's bluegrass and medusahead communities would carry the least number of animals. Considering only fall growth during the fall period, more animals could be carried on the crested wheatgrass, cheatgrass and white-top communities, while the least number of animals could be carried on medusahead, bluebunch wheatgrass, mountain big sagebrush/Idaho fescue, and stiff sagebrush/Sandberg's bluegrass communities.

Because an analysis similar to this one has, to my knowledge, never been made with livestock, these results cannot be compared to other investigations. One problem with this analysis was forages collected for nutritive analysis during 1979 were used for determination of AUMS on a nutritional basis in 1979 as well as in 1980. Also, forage samples collected for nutritive evaluation were not necessarily collected from the same pasture where the forage biomass samples were collected. Another problem was some forbs (i.e., yarrow, annual willow-weed, prickly lettuce and Jim Hill mustard) were sampled for energy and nitrogen on June 15 and their nutritive value was used for the late spring sampling period as well as the early spring. Because of the costs and time involved, it was not possible for us to nutritionally evaluate each sample that was collected for herbaceous biomass estimates. Therefore, I had to assume that forage samples collected in one pasture for nutritive evaluation were comparable to the available herbaceous biomass animals were actually consuming. This assumption was probably not correct as investigators have long recognized that total forage available to the animal is not necessarily representative of what is actually consumed (Kartchner and Campbell 1979). Because forbs did not significantly contribute to cattle diets or to available herbaceous biomass, sampling forbs for ME and N content once during the growing season would probably not influence the results.

Despite these problems, estimates of AUMS are useful for comparative purposes. In some cases, there were both small and large differences in total AUMS calculated by the three methods. From these results, the following general conclusions can be drawn. First, during early spring, it appears that forage quantity was the limiting factor in providing total AUMS; whereas during late spring, nitrogen was the limiting factor. Secondly, during the fall grazing period, energy was the limiting factor in providing total AUMS. Considering only fall growth during the fall period, available herbaceous biomass was the limiting factor. These differences could have important management implications. To avoid overstocking, pastures could be stocked at the least amount of AUMS calculated from the three methods used. However, because energy and nitrogen requirements of range cattle have not been intensively studied and are not well defined, I believe AUMS calculated on a forage biomass basis are probably the most accurate and conservative estimate of total AUMS. Moreover, managers should anticipate adjustments in stocking rates because resource supply fluctuates from year to year.

Deer Months on a Quantity, Energy and Nitrogen Basis

Deer months for the early period of 1978-1979, based on forage quantity, ME and N showed that less total deer months per pasture were calculated on an ME or N basis than on a forage quantity basis (table 21). In all pastures except for the Crystal Palace, deer months based on ME were less than deer months based on N. The Crystal Palace pasture consisted of a large crested wheatgrass seeded area, and lacked a stand of shrubs that were relatively high in nitrogen content compared to the old growth of grasses. The large discrepancy between available forage biomass and forage quality

TABLE 21. SUMMARY OF DEER MONTHS ON A FORAGE QUANTITY (Q), ENERGY (E), AND NITROGEN BASIS (N) BY PASTURE AND PLANT COMMUNITY DURING THE EARLY WINTER PERIOD OF 1978-1979.

Plant community code[2]	Pasture index code[1]																					
	2			1			3			4			4			7			8		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8	11	2	5				19	14	11	2	2	1									
9																			48	35	29
7	5	4	2	23	15	10				12	8	4	12	9	6				102	70	78
1	165	126	133	602	457	494				307	235	255	845	641	684						
2	66	48	52																		
6																					
4																			108	77	85
3																468	325	379			
10	5	3	4	2	1	1	19	13	14	4	3	3									
12										6	4	4									
11	3	2	1							4	4	4									
TOTAL	255	190	197	627	473	505	38	27	25	332	253	268	857	650	690	468	325	379	258	182	192

[1] Pasture name corresponding to index code.

1. Powder River
2. Pittsburg Gulch
3. Crystal Palace
4. Bacher Creek
7. South Tucker
8. North Tucker

[2] Plant community names corresponding to index code.

1. Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2. Mountain big sagebrush/Idaho fescue
3. Mountain big sagebrush/crested wheatgrass
4. Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
6. Stiff sagebrush/Sandberg's bluegrass
7. Bluebunch wheatgrass
8. Crested wheatgrass
9. Intermediate wheatgrass
10. Cheatgrass
11. Medusahead
12. White-top

during the early winter period of 1978-1979 was because grass regrowth was not available to deer due to prevailing deep snow-pac. However, it is difficult to evaluate deer months by pasture because deer were free to move between pastures.

During the late winter period of 1978-1979, deer months were calculated on an old growth and regrowth combined basis and regrowth only basis (table 22). As in the early period of 1978-1979, deer months based on ME were much lower than deer months based on quantity or N, considering both old and regrowth together. However, considering only regrowth, there is one exception to this general trend. In the Crystal Palace pasture, more deer months were calculated based on ME and N than on quantity. Again, this occurred because the shrub component was absent and regrowth of crested wheatgrass was highly nutritious but its production was limited at this time of year.

Deer months, based on the three methods for the 1979-1980 winter, are shown in table 23. The 1979-1980 winter was not divided into early and late periods because vegetation was sampled only once. Overall trends in the 1979-1980 winter were comparable to trends in the 1978-1979 winter. Again, the Crystal Palace showed less deer months calculated on forage quantity than on a nutritional basis.

In summary, the data showed that across all three study areas, more deer could be carried on the shrub-dominated communities while the grassland communities carried the least amount of deer. However, since deer are free to move freely through both types of communities, the available nutrients on the grassland communities probably complement the forage production of the shrub communities, thus making the

TABLE 22. SUMMARY OF DEER MONTHS ON A FORAGE QUANTITY (Q), ENERGY (E), AND NITROGEN (N) BASIS ON BOTH AN OLD AND REGROWTH BASIS BY PASTURE AND PLANT COMMUNITY DURING THE LATE WINTER PERIOD OF 1978-1979 ON AN OLD GROWTH AND REGROWTH BASIS, RESPECTIVELY.

Plant community code[2]	Pasture index code[1]																				
	1-0			1-R			2-0			2-R			3-0			3-R			4-0		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8							133	131	189	97	106	180	229	228	369	167	185	341	40	39	50
9																					
7	39	32	23	18	16	17	76	80	109	67	75	106							19	15	14
1	1147	896	1025	1049	817	997	547	422	492	516	405	483							552	421	480
2							299	240	254	287	231	252									
3																					
4																					
10	13	13	19	11	11	18	57	56	81	45	47	77	102	95	131	74	76	123	38	35	47
12																			43	30	31
11							8	6	5	3	3	4							2	2	1
TOTAL	1199	941	1067	1078	844	1032	1120	935	1130	1015	867	1102	331	323	500	241	261	464	694	542	623

TABLE 22. Continued

Plant community code[2]	Pasture index code[1] 4-R			5-O			5-R			7-O			7-R			8-O			8-R		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8	30	32	47																		
9																148	137	172	107	107	164
7	13	11	13	40	62	44	17	25	40							145	104	126	126	90	120
1																					
2																					
3										674	487	652	656	414	523	212	166	227	196	155	223
4																					
10	27	28	44																		
12	2	2	3																		
11	<1	<1	<1																		
TOTAL	591	468	578	1036	810	848	860	668	801	674	487	652	656	414	523	505	407	525	429	352	507

[1] Pasture names corresponding to index code.
1. Powder River
2. Pittsburg Gulch
3. Crystal Palace
4. Bacher Creek
5. Spring Creek
7. Souh Tucker
8. North Tucker

[2] Plant community names corresponding to index code.
1. Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2. Mountain big sagebrush/Idaho fescue
3. Mountain big sagebrush/crested wheatgrass
4. Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
7. Bluebunch wheatgrass
8. Crested wheatgrass
9. Intermediate wheatgrass
10. Cheatgrass
11. Medusahead
12. White-top

TABLE 23. SUMMARY OF DEER MONTHS ON A FORAGE QUANTITY (Q), ENERGY (E) AND NITROGEN (N) BASIS ON BOTH AN OLD GROWTH AND REGROWTH BASIS BY PASTURE AND PLANT COMMUNITY DURING THE WINTER OF 1979-1980. O AND R REFER TO OLD GROWTH AND REGROWTH, RESPECTIVELY.

Plant community code[2]	Pasture index code[1]																				
	1-O			1-R			2-O			2-R			3-O			3-R			4-O		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8							141	138	89	75	138	122	216	229	259	159	185	243	32	31	35
9																					
7	126	58	44	82	20	15	83	70	75	54	48	65							58	46	38
1	900	711	773	846	697	767	353	299	348	349	295	346							500	409	463
6																					
2							273	207	227	269	203	226									
3																					
4																					
5																					
10	19	22	28	17	20	27	52	59	67	32	42	61	76	87	109	58	72	104	21	24	29
12																			61	70	104
11							7	9	11	6	9	11							3	4	4
TOTAL	1045	791	845	985	737	809	909	782	817	785	735	831	292	316	368	217	257	347	475	584	673

TABLE 23. Continued

Plant community code[2]	Pasture index code[1]																				
	4-R			5-O			5-R			7-O			7-R			8-O			8-R		
	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N	Q	E	N
8	26	27	33																		
9																111	113	134	80	88	127
7	37	30	32	100	103	120	57	72	106							270	222	245	227	189	231
1	488	400	440	1205	1000	1163	1186	988	1158							458	378	450	436	362	445
6							227	223	243	205	200	238									
2																					
3										828	681	801	765	633	784						
4																285	231	268	257	209	261
5										493	471	612	446	433	597	98	90	123	96	90	123
10	16	19	25																		
12	48	60	94	28	25	30	11	14	19												
11	3	4	4	47	58	89	47	58	89												
TOTAL	618	540	648	1607	1409	1645	1506	1332	1610	1321	1152	1413	1211	1066	1382	1222	1034	1220	1098	938	1187

1. Powder River
2. Pittsburg Gulch
3. Crystal Palace
4. Bacher Creek
5. Spring Creek
7 South Tucker
8. North Tucker

2 Plant community names corresponding to index code.
1. Basin big sagebrush/cheatgrass/Sandberg's bluegrass
2. Mountain big sagebrush/Idaho fescue
3. Mountain big sagebrush/crested wheatgrass
4. Mountain big sagebrush/crested wheatgrass/intermediate wheatgrass
5. Mountain big sagebrush/Sandberg's bluegrass
7. Bluebunch wheatgrass
8. Crested wheatgrass
9. Intermediate wheatgrass
10. Cheatgrass
11. Medusahead
12. White-top

entire shrub-grassland mosiac optimum habitat.

The same problems encountered in calculating AUMS were also encountered in calculating deer months, i.e., forage samples collected in the winter of 1978-1979 and subsequently analyzed for nutrient content were used for the calculation of deer months for the winter of 1979-1980. There were some plant species that were not collected during the time available forage biomass measurements were made. For example, Idaho fescue and needleandthread grass were not collected until March 15, 1979; but their nutritive value figures were used in the calculations for the regrowth period of 1979-1980. Because medusahead was only collected during December 28, 1979, its nutritive value during that time was used to calculate deer months during the late period of 1978-1979. Also, some of the forbs were, unfortunately, not collected during the late period of 1978-1979 but were collected during the early spring when AUMS were calculated. Therefore, forbs such as whitetop, filaree, and lupine that were collected May 1 and nutritionally analyzed were used in the calculations during the late winter period of 1978-1979. Also, the primary shrubs (basin big sagebrush, mountain big sagebrush, and rabbitbrush) were sampled over a 3-month period for nutritive content; and their means were used for calculations of DM on a nutritional basis.

These results can be compared to two other studies (Wallmo et al. 1977, and Hobbs et al. 1982). In Rocky Mountain National Park, the carrying capacity of a winter range for elk (Cervus elaphus nelsoni) was estimated based on the range supply of energy and nitrogen during two consecutive winters. Based on the energy and nitrogen requirements of a 200-kg elk, Hobbs et al. (1982) reported that more elk could be carried on N-based than on ME based estimates, although individual habitat types differed in carrying capacity. Wallmo et al. (1977) reported a deer herd's nitrogen needs could be satisfied during the early winter period before snowfall, although only two-thirds of the herd's energy needs could be met in terms of forage quality. During the late winter period with snowfall, forage quantity was calculated for 14,000 deer. However, during this time of year, the forage could meet neither the protein nor energy requirements of the deer (Wallmo et al. 1977).

In this study, an estimate of deer months during the early period of 1978-1979 was misleading. Many of the available forages used in the estimation of deer months on a nutritional basis would not meet the maintenance requirements of deer. Across all three study areas, an estimate of total metabolizable energy and nitrogen in the deer diets was obtained in the following way: (1) multiplying the average percent of grass, forb and shrub in the diet by their metabolizable energy and nitrogen content, (2) adding the products together, and (3) dividing the total by the total percent grass, forb and shrub in the diet. During the early winter period of 1978-1979, metabolizable energy and nitrogen in the diet was 1.47 Mcal/kg and 11.3 g, respectively. However, maintenance metabolizable energy and nitrogen content during this time period was 1.80 Mcal/kg and 12.9 g, respectively.

Similar calculations were employed on the food habits and forage quality data during the late winter period of 1978-1979. In contrast to the early winter period, metabolizable energy and nitrogen content was 1.94 Mcal/kg and 18.8 g, respectively. Thus, it can be generally concluded that during winters of snow accumulation deer on the Keating rangelands will be hard pressed to meet their maintenance requirements. Wallmo et al. (1977) found similar results in Colorado and reported that overwinter mortality rates will be governed, not by the potential of the total forage resource to support deer, but by snow conditions (which determine the energy gained from grazing) and by the duration of the winter. Because of the annual variable snow fall and deer dependence on grass regrowth, the potential for periodic winter deer die-off does exist on the Keating rangelands.

Management of Dominant Plant Communities

1. Intermediate wheatgrass.

The intermediate wheatgrass community occured in the North Tucker pasture and was the most productive plant community in the three study areas. A management option for this community is to fence the seedings and manage it as a separate pasture. This grass species cannot tolerate the amount of utilization that crested wheatgrass can and, therefore, should be managed under a deferred rotation system. Although intermediate wheatgrass comprised approximately 30 percent of cattle diets, very little was found in deer diets.

2. Bluebunch Wheatgrass.

Bluebunch wheatgrass communities could be managed primarily for livestock production. These native perennial grasses averaged less than 10 percent of wintering deer diets. These plants tend to initiate growth too late in the season for deer on winter range to consume (Leckenby et al. 1980). Because Thurber's needlegrass and squirreltail are slower developing compared to annual grasses, these plants provide forage for livestock but are of lesser importance to deer during early spring. Livestock grazing would remove the current year's forage crop thus any fall growth that does occur would be available to deer. Willms et al. (1981) showed that free-ranging deer would not select forage from standing litter of bluebunch wheatgrass when alternate sources were available. Furthermore, fall burning increased the number of plants that were selected by deer (Willms et al. 1980).

3. Cheatgrass.

Cheatgrass communities comprised a total of 213 ha in the three study areas. Depending upon location of the plant community, cheatgrass areas could be managed in two different ways. Cheatgrass communities that occur in or near the crested seedings could be erradicated and a desirable perennial grass, forb or browse species seeded. Cheatgrass communities not occurring within or adjacent to crested seedings that could not be seeded due to topography or poor soils (i.e., Spring Creek study area) could be managed as a cheatgrass community. Young cheatgrass is a nutritionally rich forage, it develops earlier (fall and spring) than many native perennials and it is very resistant to intense grazing (Leckenby et al. 1980). In this study, fall growth of cheatgrass averaged 18.2 percent CP and 75.1 percent IVDMD. Although cheatgrass averaged only 10.0 percent of the deer diets, it is a very important plant to wintering deer. Leckenby et al. (1980) reported that fall greenup permits deer to top off nutrient reserves before the stress of winter begins. The rich and digestible new green growth probably increases ovulation rates through a flushing effect (Leckenby et al. 1980). And, during early spring greenup, the grass supplies deer with quality forage at critical times when body reserves are nearly depleted, fetuses are rapidly growing and deer are migrating (Leckenby et al. 1980). However, a disadvantage of cheatgrass is that forage values (i.e., CP and IVDMD) decline more rapidly as its phenology advances and its production fluctuates more from year to year depending upon environmental conditions.

I suspect that deer were consuming more than 10 percent cheatgrass; because it was very difficult to distinguish cheatgrass from other grasses (i.e., Thurber's needlegrass and Sandberg's bluegrass) in feces; also, it is highly digestible. These inherent problems with the microhistological technique were addressed at length in the literature review.

A management option for this plant community that would probably benefit both deer and cattle would be to graze this community by cattle during late spring or early fall (i.e., before greenup). Livestock grazing would remove the standing crop and subsequently make the shorter nutritious young leaves more available to wintering deer, although livestock performance may be hindered. Cheatgrass stands could also be manipulated by fall burning to produce results similar to grazing perennial grass stands with livestock (Leckenby et al. 1980). It is also important that cheatgrass communities are adjacent to cover and only then can the grasslands be valuable forage areas to deer (Tueller and Monroe 1975, Leckenby 1978c, Willms et al. 1976 in: Leckenby et al. 1980).

This community is important to livestock during early spring. The forage qualtiy (i.e., CP content of 9.1 percent and IVDMD of 70.1 percent) exceeds the minimum requirement of a lactating cow. However, after the grass matures, it loses its forage quality and cattle weight gains will probably decrease.

4. Medusahead.

Medusahead was not a major constituent in either cattle or deer diets. The plant is reported to be unpalatable to both livestock and deer (Hilken and Miller 1980). Therefore, the management recommendation for this community is to eradicate the plant following procedures previously outlined by Hilken and Miller (1980) and reseed the community where topography and soil permits (i.e., Pittsburg Gulch and Bacher Creek pastures) with a desirable grass, forb or browse species. Another management option would be to simply burn the areas in the fall after the forage cured to increase the availability of fall growth to wintering deer. Although our data showed fall growth of medusahead to have an average CP and IVDMD of 18.2 percent and 93.1 percent, respectively, very little was found in the diet because: (1) problems with identification inherent in the microhistological method, and (2) the high silica content in the litter of medusahead tends to slow the decomposition of the old growth thereby making the fall growth unavailable.

5. Basin big sagebrush.

This plant community was very important to wintering deer. Basin big sagebrush was an important cover and forage plant for wintering deer. The dominant understory of this plant community was cheatgrass and Sandberg's bluegrass. Both of these plants were very nutritious during winter and were extremely important to the nutritional status of wintering deer. The importance of cheatgrass to deer has already been discussed and the importance of Sandberg's bluegrass will be discussed in the recommendations for the stiff sagebrush community. Although it appears from the food habits data that sagebrush was used as an emergency food during the early winter period of 1978-1979, it was still found in the deer diets after snowmelt and in the open winter of 1979-1980. Although it is not completely clear whether preference or necessity is the main reason for sagebrush use, Dietz (1965) concluded that a review of the literature indicated regular or normal, as well as emergency feeding on big sagebrush.

6. Mountain big sagebrush/Idaho fescue.

This community occurred on steep north slopes within the Crystal Palace study area. In Oregon, Leckenby et al. (1980) reported that Idaho fescue was a moderately important plant in the diet of deer. In this study, Idaho fescue averaged less than 5.0 percent of the deer's diet. The plant was not a significant forage consumed because it was not as widespread as other available forages and the plant needs livestock grazing to maximize availability of fall growth for deer. Because of topography, close utilization of this plant could not be attained by livestock and comprised less than 5 percent of the cattle diets. With proper grazing management, perhaps Idaho fescue could seed itself into surrounding areas.

Mountain big sagebrush has been reported as a good forage plant for deer (Sheehy 1981). Although the growth form of mountain big sagebrush is not the same as basin big sagebrush, the plant does provide both hiding and thermal cover (Leckenby et al. 1980). It has also been reported and is suspected on the Keating rangelands that deer do not browse big sagebrush forms equally.

In Oregon, Leckenby et al. (1980) ranked mountain big sagebrush as a good forage plant while basin big sagebrush was rated as a poor forage. Unfortunately, the food habits data presented in this study do not distinguish between subspecies because differentiation could not be attained employing the microhistological method. Therefore, I am unable to report whether mountain big sagebrush or basin big sagebrush was preferred. However, Edgerton (unpublished data) on the basis of limited samples and utilization estimates observed that wintering deer in the Crystal Palace study area showed a preference for mountain big sagebrush over basin big sagebrush. If Edgerton (unpublished data) and Leckenby et al. (1980) are correct, then the mountain big sagebrush sites are important foraging and cover areas for wintering deer.

7. Mountain big sagebrush/crested wheatgrass.

This plant community occurred in the Tucker Creek study area. This area could be managed for both deer and cattle following the proper recommendations. If deer are to be managed in this area, alternate homogeneous blocks of mountain big sagebrush could be erradicated. The blocks should not be wider than 380 meters (following recommendations of Leckenby et al. 1980). The forage within the treated blocks could be allocated to both deer and cattle, while the untreated areas could be allocated to deer; and the sagebrush would provide forage as well as thermal and hiding cover. The mountain big sagebrush/crested wheatgrass/intermediate wheatgrass community in the North Tucker pasture could have a similar management prescription.

8. Stiff sagebrush/Sandberg's bluegrass.

Because of stiff sagebrush's small stature, it offers little thermal or hiding cover for deer; however, the community was used by deer when mild weather occurred. Leckenby et al. (1980) also reported this community to be of significant value to deer during late winter. In early spring, the associated forbs and grasses of this community were very important to deer (Leckenby et al. 1980). Because of the decidious nature of stiff sage, it is not a desirable forage plant for wintering deer. In this study, stiff sagebrush did not occur in the diets of either deer or livestock. Although other studies have shown stiff sagebrush consumption by cattle (Maser, *personal communication*), it was not in the diets of cattle during this study probably because of other forages available to cattle.

Deer food habits data indicated that Sandberg's bluegrass was the most important grass consumed. During early spring, the IVDMD and CP content of Sandberg's bluegrass averaged 77.0 percent and 23.2 percent, respectively. Sandberg's bluegrass is the major understory plant species in this community. Observation data taken in the study showed deer were consistently seen in this community in the early spring (i.e., Spring Creek pasture and North Tucker pasture). Because the shallow, rocky soils warm quickly, especially on southerly aspects of this community, the earliest abundant new growth occurs on these scablands (Leckenby et al. 1980). Sandberg's bluegrass is a very important plant to deer because of its early phenological development (Leckenby et al. 1980). Willms and McLean (1978) found that deer utilized mostly grasses in early spring, the greatest proportion being Sandberg's bluegrass which produces forage earliest and mature stalks do not persist through the winter. Willms and McLean (1978) also reported that Sandberg's bluegrass was not considered a desirable cattle forage because its growth is highly variable and it loses its palatability early in the spring. However, in this study, Sandberg's bluegrass was a major constitutent in the cattle diets (>20.0 percent) probably because of its abundant availability compared to other perennial grasses.

Although stiff sagebrush provides little cover, the Spring Creek study area was important to deer because of the basin big sagebrush stands in the draws and the expanses of scablands on the uplands. This plant community could be grazed by cattle in early spring; however, fall grazing by cattle after "greenup" would be detrimental to wintering deer. The similarity index calculated for the late fall-early winter period was 50 percent and most of the dietary overlap was on Sandberg's bluegrass.

9. White-top and forbs.

These two plant communities comprised only 37 ha in all three study areas. However, in this study during the early winter period of 1978-1979, white-top comprised approximately 25 percent of the deer's diet. White-top was appreciably consumed only during the early win-ter period of 1978-1979 because the plant protruded above the snow and was available. It was not consumed by deer during any other time and, therefore, it could have been a starvation food. During the winter period, the plant had a CP and IVDMD of 7.2 percent and 39.2 percent, respectively. This community and the forb community could be erradicated and reseeded with a desirable grass/forb or browse species.

SUMMARY AND CONCLUSIONS

The objectives of this investigation were twofold: (1) determine cattle and deer diets and subsequently determine degree of overlap of the two diets, and (2) determine the quantity and quality of forage available to deer and cattle and estimate carrying capacity on a quantitative and nutritional basis. These objectives were studied during the fall-winter-spring of 1978-1979 and 1979-1980 in three separate study areas on the Keating rangelands in northeastern Oregon.

Fecal samples were collected to determine cattle and deer diets. These samples were analyzed for species composition in the laboratory using the microhistological technique. Correction equations were developed to correct for differential digestibility of the dominant species consumed. From these food habits data, similarity indices were calculated to determine degree of dietary overlap between deer and cattle. Quantity of available herbaceous forage within delineated plant commmunities was estimated using a double sampling-by-plot method, and available browse was estimated using a multiple linear regression technique. Subsamples of available forage were analyzed for in vitro dry matter digestiblity and crude protein. Based upon the quantity and quality of forage available and the quantity and quality of forage required, carrying capacity was estimated on a quantitative and nutritional basis.

Climatic conditions were much different during the 2 years of study. Heavy snowfall and snow-pac occurred during the winter of 1978-1979; however, the 1979-1980 winter was relatively snow free. These conditions affected forage availability and forage consumption of wintering deer.

Depending upon seasonal availability and study area, the deer food habits data showed that sagebrush and Sandberg's bluegrass were the dominant forages consumed by wintering deer. Cheatgrass, Thurber's needlegrass, squirreltail and crested wheatgrass were other grasses commonly consumed by deer, while gray rabbitbrush and willow were commonly consumed browse species. The average total grass and browse consumption across all three study areas during the early winter period of 1978-1979 was 1.6 and 57.4 percent, respectively, while forb consumption averaged 17.7 percent. The dominant forb in the diet was white-top and mullein. However, during the late period of 1978-1979, total grass, browse and forb consumption averaged 31.5, 40.2, and 13.6 percent, respectively. During the winter of 1979-1980, no significant shift in dietary consumption occurred between the early and late period, except in the Tucker Creek study area where forb consumption significantly decreased from the early to late period. Total grass, browse and forb consumption averaged 51.9, 35.4, and 3.5 percent, respectively, during the open winter of 1979-1980.

The shift in dietary consumption between seasons can probably be explained by forage availability caused by climatic conditions. However, the difference in forb consumption between seasons is difficult to explain. Wintering deer probably consumed white-top and mullein during the early winter period of 1978-1979 because the plants protruded above the snow and were available. Why wintering deer continued to consume these two forbs into the spring period can only be speculated. Perhaps the high lignin content of these forages caused them to be quite brittle, thus subsequently breaking down to smaller particle size and passing rapidly. Also, as food habits data indicate, forbs were not a significant dietary constituent in this study, perhaps because: (1) forbs are easily underestimated using the microhistological technique, and (2) a diverse array of forbs were not a dominant available forage except in isolated areas.

Grasses were the dominant forage consumed by cattle during spring and fall comprising 92.9 and 87.5 percent of the diets, respectively, across all pastures in the three study areas. During the spring grazing season, crested wheatgrass was the dominant grass consumed if the crested wheatgrass seedings were a major portion of the available herbaceous forage within the pasture sampled. In pastures where crested wheatgrass was not a major portion of the available herbaceous forage, cheatgrass and Sandberg's bluegrass were the dominant forage consumed. Other grasses consumed by cattle included: Thurber's needlegrass, Idaho fescue, intermediate wheatgrass, bluebunch wheatgrass and some medusahead. Depending upon pasture and study area, crested wheatgrass averaged between 13 percent and 36 percent of the diets; while in the fall, crested wheatgrass averaged less than 13 percent and cheatgrass and Sandberg's bluegrass averaged 30.4 and 25 percent of the cattle diets, respectively. Total browse and forb consumption by cattle during the two periods was less than 8 percent. To improve the productivity and utilization of crested wheatgrass by both deer and cattle, it was suggested that a one-crop, two-crop system of grazing be implemented on renovated, fenced crested wheatgrass seedings. A one-crop, two-crop grazing system was recommended so that the undesirable characteristics of stemminess would be minimized and the desirable characteristics (i.e., available regrowth) could be used as a forage for cattle as well as for wintering deer.

Depending upon season, year, and pasture, diet similarity between deer and cattle ranged from 27 to 53 percent. Mean spring overlap for both years was 37 percent while mean fall diet overlap was 50 percent. Most of the dietary overlap occurred on cheatgrass and Sandberg's bluegrass. The potential for "exploitative" competition defined by Miller (1967), "forage" competition defined by Smith and Julander (1953), and "unilateral" competition defined by Nelson and Burnell (1976) could be occurring in the fall period because ≈ 50 percent of the cattle and deer diets were identical.

However, the comparative food habits data presented here do not indicate that cattle were restricting deer nor deer restricting cattle. To determine the competitive ecology between deer and cattle, the collection of forage use and animal distribution data is necessary; and those data were not collected during this study.

A number of studies reported that interspecific relationships with cattle has been either beneficial or deterimental to mule deer populations, and that the actual occurrence and intensity of conflict vary widely in time and space (Mackie 1981). Although few firm conclusions can be made concerning the existence for or against interspecific competition in this study, the food habit data and subsequent similarity indices do indicate that fall competition for forage may be occurring. Sandberg's bluegrass and cheatgrass appear to be the two dominant forage species shared by both deer and cattle, while Idaho fescue, Thurber's needlegrass and squirreltail are less commonly shared species. A prerequisite for competition is that the preferred forage be in limited supply (Stoddart et al. 1975; Nelson 1982), although this concept has been challenged by Mayer (1963). In the most productive plant community (i.e., basin big sagebrush) during the 1979-1980 fall period, the available fall growth on Sandberg's bluegrass and cheatgrass available to cattle and deer averaged only ≈25 kg/ha and ≈92 kg/ha, and ≈26 kg/ha and ≈27 kg/ha, respectively. Because there is not a diverse array of shrubs, forbs or grasses that occur on most of the areas studied, the potential for competition is magnified because competition can increase if range deterioration results in a limited number of plant species (Stoddart et al. 1975; Nelson 1982).

The degree of use by deer and cattle on the same portion of the range was another prerequisite listed by Stoddart et al. (1975) and Nelson (1982) to ascertain if interspecific competition occurs, although the authors do state that forage preference is the most important factor in competition. Unfortunately, the degree to which cattle and deer use the same portion of the range was not investigated in this study; therefore, any firm conclusions on interspecific competition in this study have to be speculative at best. To ameliorate the potential detrimental effects for fall competition in this study, livestock grazing should occur only in fenced crested wheatgrass pastures and should be terminated on native range pastures. This management recommendation should be adhered to if common use by deer and cattle is a desired management objective. However, during winters of deep snow-pac, the Keating deer winter range is proably volitale to periodic die-offs because of the deer's dependence on grass and high degree of overlap between cattle and deer diets.

The spring overlap period was somewhat more difficult to interpret. Although cattle and deer diets were 36 percent similar, the animals were not utilizing the range at the same time of year. Wintering deer migrated from the study areas prior to the time livestock were turned onto their spring range. However, "direct" competition defined by Mackie (1981) and "unilateral" competition defined by Nelson and Burnell (1976) may be occurring during the spring period _if_ the animals are using the same portion of the range and available forage is in limited supply. Again, no distribution data were taken during this study; therefore, forage consumption by deer which could impact spring cattle grazing is a potential problem, although in the literature there have been no documented instances of mule deer directly influencing domestic species (Mackie 1981). To ameliorate the detrimental effects of the potential for spring competition, livestock should be turned onto crested wheatgrass pastures in early spring thus permitting native forages to recover from winter deer use. Cattle grazing in late spring on native range would be recommended for two reasons: (1) harvest the maximum of available herbaceous biomass, and (2) production of fall growth which would be available to wintering deer.

Correction equations used to correct for differential digestibility showed that gray rabbitbrush, white-top, mullein and Thurber's needlegrass were overestimated while cheatgrass and bluebunch wheatgrass were underestimated in hand-compounded mixtures. Basin big sagebrush, Sandberg's bluegrass, squirreltail, and crested wheatgrass had close to a 1:1 ratio between relative density and actual percent weight. Mullein was severely overestimated because of the presence of numerous hairs, and white-top was overestimated because of the presence of numerous identifiable seeds. The correction equations developed from this aspect of the study were used to correct the food habits data of deer and cattle.

During the early winter priod of 1978-1979, the forage production data showed that the most productive plant community available to wintering deer was the basin big sagebrush community. The least productive plant communities during the early winter period of 1978-1979 were the grass-dominated communities (i.e., crested wheatgrass, cheatgrass, and bluebunch wheatgrass). Because of the deep snow-pac during this time of year, only those plants that protruded through the snow were measured. During the late winter period of 1978-1979 and during the open winter of 1979-1980, production data showed a similar trend where browse-dominated communities were the most productive and grasslands were the least productive on a forage quantity basis.

The available herbaceous forage for cattle varied with pasture sampled. Browse production was not measured because in a previous study cattle on the three study areas did not consume an appreciable amount of browse. Generally, if a crested seeding was available within a pasture, crested wheatgrass was the most productive species available to cattle, except in the North Tucker pasture where intermediate wheatgrass was available to the cattle and more productive than crested wheatgrass on a kg/ha basis. However, where native range was only available to cattle, the cheatgrass community and the basin big sagebrush/cheatgrass/Sandberg's bluegrass community were the most productive communities available to livestock. Generally, it appeared that the least productive communities for livestock was the mountain big sagebrush and stiff sagebrush. During the fall, the same trends existed, except that more previous season's growth (i.e., old growth of forages) was available to cattle than fall growth on some grass species. For example, in the Crystal Palace pasture within the crested wheatgrass community, 520 kg/ha of old growth and only 62 kg/ha of fall growth of crested wheatgrass was available to livestock. Generally, the same situation occurred for cheatgrass, bluebunch wheatgrass and Thurber's needlegrass but did not necessarily occur for Sandberg's bluegrass. For example in the Pittsburg Gulch pasture within the basin big sagebrush community, the old growth of cheatgrass averaged 32 kg/ha, while regrowth was 8 kg/ha and the old growth for Sandberg's bluegrass was 15 kg/ha while regrowth was 36 kg/ha.

Available forages commonly consumed by deer and cattle were analyzed for their nitrogen content and digestibility. The micro-kjeldahl method was used to determine the nitrogen content and an _in vitro_ technique following the procedures of Tilley and Terry (1963) was used to determine digestibility. Digestibility figures were converted to metabolizable energy (ME). During the winter months, basin big sagebrush had an average 1.59 Mcal/kg of ME and an average N content of 12.9 g/kg, while Sandberg's bluegrass had an average ME content of 2.54 Mcal/kg and an N content of 12.9 g/kg. Qualitative analysis of the dominant forages available to cattle during the spring period showed that crested wheatgrass, Sandberg's bluegrass and cheatgrass had an average ME content of ≈ 2.24, 2.21, and 2.38 Mcal/kg, respectively, and an average nitrogen content of ≈ 20.2, 17.2, and 16.4 g/kg, respectively. In the fall, the old growth of crested wheatgrass, Sandberg's bluegrass and cheatgrass available to cattle had an average ME content of ≈ 1.47, 1.52, and 1.60 Mcal/kg, and an average N content of ≈ 4.0, 2.7, and 4.4 g/kg, respectively.

Determination of cattle and deer months of grazing were calculated by plant community, pasture and season on both a forage quantity and nutritional basis. A review of the literature indicated a cow-calf intake for early spring of 14 kg per day or 420 kg per month and an intake rate of approximately 10 kg per day or 300 kg per month for a dry mature cow during fall. Also, on a monthly basis, an adult deer consumed approximately 26.8 kg of forage while a fawn consumed 21.7 kg of forage. However, because there are only 50 fawns per 100 adults, the total forage required by deer per month was adjusted and estimated to be 25.1 kg. Finally, cattle and deer months per plant community, season and pasture were obtained by dividing hectares per plant community by hectares per cattle or deer month.

Cattle and deer months per plant community, season and pasture were also determined using the ME and N content of the available forages. A review of the literature indicated that a 350-kg dry, pregnant, mature cow requires 1.9 Mcal of energy per kg of intake and 5.9 percent protein per kg of intake; while in the spring, a 400-kg nursing cow requires 1.9 Mcal of energy per kg of intake and 9.2 percent protein per kg of intake. The amount of energy supplied by catabolism of fat and the amount of energy and nitrogen used in gestation were considered when determining wintering deer requirements. Also, deer months were calculated for the early and late season during the 1978-1979 winter; and during the 1979-1980 winter, deer months were calculated only once. During early winter of 1978-1979, a wintering deer required 1.81 Mcal of ME, while during the late period a deer required 1.80 Mcal of ME. However, during the 1979-1980 winter, a deer required 1.73 Mcal of energy. During both winters, a wintering deer required 12.9 g N/day.

For cattle, comparing the three methods (quantity, energy and nitrogen) the following trends were noted. The pastures sampled 5/1 showed that more AUMS were calculated on an N basis than on a quantity or ME basis; and during 5/15, more AUMS were calculated on an ME basis than a Q or N basis. On 6/15, more cattle months were calculated on a quantity basis than ME or N basis. During fall, data showed more AUMS were calculated on an N basis than on a quantity or ME basis. In summary, it appeared during early spring forage quantity was limiting; and during late spring, N was limiting. During fall with calculations of both old and fall growth, energy was limiting; and considering only fall growth, forage quantity was limiting to cattle. Across all three study areas and averaging the three methods (quantity, ME and N), the data showed more AUMS were calculated in the crested and intermediate wheatgrass communities, while the least were calculated in the white-top, medusahead and stiff sagebrush communities.

Deer months for the early period of 1978-1979 per plant community and pasture on a quantity, ME and N basis showed more total deer months were calculated on a quantity basis than on an ME or N basis. In most all plant communities, deer months on an ME basis were less than deer months based on an N or quantity basis. During the late winter period of 1978-1979, deer months were calculated on an old growth and regrowth basis combined, and regrowth-only basis. Considering both old and regrowth, deer months on an ME basis were generally lower than deer months on a quantity or N basis. However, considering only regrowth, there is one general exception to this trend and that was in the Crystal Palace pasture where more deer months were calculated on a quantity than on a nutritional basis. Trends in the 1979-1980 winter were generally comparable to trends in the 1978-1979 winter except in the Crystal Palace pasture. In the Crystal Palace pasture, on an old growth and regrowth basis and regrowth only basis, more deer months were calculated on a nutritional basis than on a quantity basis. Averaging the three methods (i.e., quantity, N and ME) across all three study areas, plant communities, and years, the data showed that more deer could be carried in the shrub-dominated communities while the grassland communities carried the least.

The study on the Keating Winter Range yielded information of value in the management of both deer and cattle. The following recommendations are suggested by the results of the study:

1. It is recommended that management be directed to renovating deteriorated crested seedings in Bacher Creek, Pittsburg Gulch and Crystal Palace pastures. To increase the vigor, competitive ability and productivity of crested wheatgrass range, improvement work should be directed to the control of weedy species within the seedings. The atrazine-fallow and subsequent seedings treatments recommended by Eckert (1974) could be used.
2. Another viable management option for deer is to interseed the crested seedings with palatable accessions of sagebrush and forbs. Sagebrush would provide forage as well as thermal and hiding cover and add diversity into a monoculture.

3. After seeding is accomplished, the crested seedings should be fenced and managed under a one-crop, two-crop system of grazing. A one-crop, two-crop system of grazing would accentuate the good qualities of crested wheatgrass and the undesirable qualities (i.e., stemminess) would be minimized. Common-use management could be attained in the management of crested seedings by removing the second crop in the two-crop pasture prior to fall rains so the fall growth will be available to wintering deer.
4. Native grass-dominated communities should be grazed by cattle in late spring to allow for "adequate recovery" from wintering deer and provide for adequate growth of native grasses. Livestock grazing during late spring would also remove the standing crop and subsequently make the shorter nutritious young leaves more available to wintering deer. Fall grazing by livestock on native range after "greenup" should be excluded if deer are considered.
5. The least amount of deer and cattle months were calculated for the medusahead and white-top communities and, therefore, these two communities should be completely erradicated, if possible, and seeded to perennial grasses, shrubs or forbs.
6. The browse-dominated communities were very important to wintering deer. Basin and mountain sagebrush provided forage as well as hiding and thermal cover to wintering deer. However, extensive areas of these browse communities are not beneficial to deer and blocks should not be wider than 380 meters (Leckenby et al. 1980). Sandberg's bluegrass and cheatgrass were the

dominant understory plants in this community and were consumed by wintering deer and were highly nutritious. The importance of these two species to wintering deer cannot be overemphasized.

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APPENDICES

APPENDIX A. ALPHA CODE, SCIENTIFIC NAME, AND COMMON NAME OF PLANTS OCCURRING IN THE THREE STUDY AREAS

Alpha code	Scientific name	Common name
Grasses		
AGDE	Agropyron desertorum	Standard crested wheatgrass
AGIN	Agropyron intermedium	Intermediate wheatgrass
AGSP	Agropyron spicatum	Bluebunch wheatgrass
BRTE	Bromus tectorum	Cheatgrass brome
FEID	Festuca idahoensis	Idaho fescue
FEMI	Festuca microstachys	Small fescue
HOJU	Hordeum jubatum	Foxtail barley
POBU	Poa bulbosa	Bulbous bluegrass
POSA	Poa sandbergii	Sandberg's bluegrass
SIHY	Sitanion hystrix	Bottlebrush squirreltail
STCO	Stipa comata	Needleandthread
STTH	Stipa thurberiana	Therber's needlegrass
TAAS	Taeniatherum asperum	Medusahead
Grasslikes		
CAsp.	Carex sp.	Sedges
JUBA	Juncus balticus	Baltic rush
Forbs		
ACMI	Achillea millefolium	Yarrow
AMLY	Amsinckia lycopsoides	Fiddleneck
ANDI	Antennaria dimorpha	Low pussytoes
AGGL	Agroseris glauca	Milkweed
ASAR	Astragalus argophyllus	Rattlepod
ASST	Astragalus stenophyllus	Locoweed
BASA	Balsamorhiza sagittata	Arrowleaf balsamroot
CADR	Cardaria draba	Whitetop
CHDD	Chaenactis douglassii	Hoary chaenacits
COPA	Collinsia parviflora	Blue-eyed Mary
CRAC	Crepis acuminata	Long-leaved hawksbeard
CRTO	Cryptantha torreyana	Torrey's cryptantha
POCO	Dodecathleon conjugens	Slimpod shooting star
EPPA	Epilobium paniculatum	Annual willow-weed
ERCH	Erigeron chrysopsidis	Yellow fleabane
ERCO	Eriogonum compositum	Mat buckwheat
EROV	Eriogonum ovalifolium	Oval-leafed eriogonum
ERCI	Erodium cicutarium	Filaree
GISI	Gilia sinuata	Gilia
HARE	Haplopappus resinosus	Gnarled goldenweed
HEAN	Helianthus annus	Common sunflower
LASE	Lactuca serriola	Prickly lettuce
LARI	Lathyrus rigidus	Peavine

APPENDIX A. Continued.

Alpha code	Scientific name	Common name
LEPE	Lepidium perfoliatum	Clasping peppergrass
LIRU	Lithospermum ruderale	Stoneseed
LOAM	Lomatium ambigum	Wyeth biscuitroot
LODI	Lomatium dissectum	Fern leaf lomatium
LOGR	Lomatium grayi	Desert parsley
LOTR	Lomatium triternatum	Nine-leaf lomatium
LUCA	Lupinus caudatus	Tailcup lupine
LULA	Lupinus laxiflorus	Lupine
MEAL	Mentzelia albicaulis	Blazing star
OECA	Oenothera deltoides	Rock-rose
PEDE	Penstemon deustus	Scabland penstemon
PHDO	Phlox douglasi	Douglas phlox
PHAA	Phacelia hastata	Whiteleaf phacelia
PHLO	Phlox longifolia	Long-tailed phlox
PLMA	Plectritis macrocera	Long-horn phectritis
PLTE	Plagiobothrys tenellus	Plagiobothrys
RATE	Ranunculus testiculatus	Horn-head buttercup
SAKA	Salsola kali	Russian thistle
SAIN	Saxifraga integrifolia	Saxifrage
SCAN	Scutellaria anterrhinoides	Skullcap
SIAL	Sisymbrium altissium	Jim Hill mustard
TAOF	Taraxacum otficinale	Common dandelion
TRDU	Tragopogon dubius	Salsify
VETH	Verbascum thapsus	Mullein
VIAM	Vicia americana	Veth
WYAM	Wyethia amplexicaulis	Mules ear wyethia
ZIVE	Zigadennus venenosus	Camus
Shrubs		
ARRI	Artemisia rigida	Stiff sagebrush
ARTRTR	Artemisia tridentata tridentata	Basin big sagebrush
ARTRV	Artemisia tridentata vaseyana	Mountain big sagebrush
CHNA	Chrysothamnus nauseasus	Gray rabbitbrush
CHVI	Chrysothamnus uicidiflorus	Green rabbitbrush
CRDO	Crataegus douglasii	Thorn apple
PERA	Peraphyllum ramosissimum	Mockorange
PRVI	Prunus virginiana	Common chokecherry
PUTR	Purhia tridentata	Bitterbrush
SALIX	SALIX sp.	Willow

APPENDIX B. FORMULAE FOR HOYER'S MOUNTING MEDIUM AND HERTWIG'S CLEARING SOLUTION.

Hoyer's Mounting Medium

20% gum arabic
25% distilled H_2O
12% glycerin
30% chloral hydrate
3% glucose

Hertwig's Clearing Solution

19 cc Hcl added to 150 cc H_2O
60 cc glycerine
270 chloral hydrate crystals

APPENDIX C. MEANS AND STANDARD ERRORS OF THE PRIMARY FORAGES AVAILABLE TO CATTLE BY PASTURE, PLANT COMMUNITY, SPECIES AND SEASON.

Species	Date	Pasture	Plant community: AGDE	AGIN	AGSP	ARTRT-BRTE-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	ARTRV-POSA	ARAR-POSA	BRTE	CADE	TAAS	FORB
AGDE	5/79	BC	434±95									52±17	56±21		
	12/80		400±110												
	5/79	CP	206±50												
	12/80		520±110									58±9			
	12/79	M	126±67												
	6/79	MT						346±68							
	6/80							348±110							
	12/79	PC	278±94												
	6/80		360±84												
	5/79	ST					138±23								
	5/80						164±57								
AGDE-R	12/80	BC	61±13												
	12/80	CP	62±24												
	12/79	M	38±13												
	12/79	PC	48±14												
AGIN	6/79	MT		706±68				253±62							
	6/80			958±150				153±63							
AGSP	5/79	BC			116±30										
	12/80				255±118										
	12/79	M			228±110										
	6/79	MT			212±39										
	6/80				238±83										
	12/79	PC			216±95										
	6/80				278±95										
	6/79	PR			142±67				38±68						
	5/80				150±64										
	6/79	SC			290±61										
	9/80				288±91										
AGSP-R	12/80	BC			39±17										
	12/79	M			30±12										
	12/79	PC			28±11										
	9/80	SC			28±12										
BRTE	5/79	BC	98±26		58±11	66±14						230±45	152±39	57±17	
	12/80					48±18						114±37	174±63	62±17	
	5/79	CP	60±24									270±51			
	12/80		26±21									180±64			
	12/79	M				32±18						134±53			
	6/79	MT			30±7	189±15					11±13				
	6/80				12±8	64±28					8±9				
	12/79	PC	52±31		10±8	32±11						146±33			
	6/80		66±32		50±22	136±81						662±82		13±8	
	6/79	PR			104±30	142±57			18±3			450±38	82±32		
	5/80				110±28	98±45			3±6			118±42	54±23		
	6/79	SC			36±13	270±98					32±12		202±56	50±13	
	9/80				14±6	62±24							186±39		
	5/79	ST								64±16					80±23
	5/80									12±8					104±32
BRTE-R	12/80	BC				34±27						210±110	90±42	20±9	
	12/80	CP	6±6									112±54			
	12/79	M										124±18			
	12/79	PC				8±6						30±8			
	9/80	SC			7±4	20±9							70±19		
FEID	5/79	BC							214±21						
	12/80								128±42						
	6/80	PC			64±10				126±33						
	12/79								110±34						
	6/79	PR							166±24						
	5/80								180±34						

APPENDIX C. CONTINUED.

Species	Date	Pasture	ACDE	ACIN	ACSP	ARTRT-BBTE-POSA	ARTRV-ACDE	ARTRV-ACDE-ACIN	ARTRV-FEID	ARTRV-POSA	ARRI-POSA	BBTE	CADE	TAAS	FORB
								Plant community							
FEID-R	12/80	SC							50±21						
	12/79	PC							26±9		34±14				
BIHT	12/79	H								11±16					
	6/79	HT			80±26	4±8				9±12					
	6/80				60±42	36±16					96±36				
	6/79	SC									22±8				
	9/80									6±7					
	5/79	ST								24±31					
	5/80										6±5				
BIHT-R	12/79	H									17±6				
	9/80	SC													
STCO	5/79	SC			19±11	16±6									
	12/80				82±35										
	6/79	PR			30±17	28±11									
STCO-R	12/80	SC			30±13						64±18				
STTH	12/79	H									26±9				
	6/79	SC									21±16				
	9/80										11±5				
STTH-R	12/79	H									14±9				
	9/80	SC												126±21	
TAAS	5/79	SC												378±95	
	12/80											30±19		668±93	
	6/80	PC												244±57	
	12/79													492±122	
	6/79	PR												530±141	
	5/80													514±69	
	6/79	SC												664±74	
	9/80													60±14	
TAAS-R	12/80	SC												62±18	
	12/79	PC												25±4	
	9/80	SC							72±18			30±11	25±12		
POSA	5/79	SC	43±19		10±5	40±8									
	12/80					12±5						19±14			
	5/79	CP	36±11												
	12/80		10±12												
	12/79	H			14±6	15±12		35±3		38±5	74±38				
	6/79	HT		56±5	48±8	56±11		38±19		78±18	64±22				
	6/80			114±35	68±35	86±34			36±12			38±11		22±14	
	6/80	PC	26±12		24±13	74±36									
	12/79					15±8			52±24			18±9	34±17		
	6/79	PR				54±28			52±21			32±18			
	5/80					46±21					26±5		36±13		
	6/79	SC			26±6	23±9					21±4				
	9/80				38±21	34±12				38±8					68±34
	5/79	ST					37±10			100±34					78±21
	5/80						68±37		9±4						
POSA-R	12/80	SC	6±4			14±6									
	12/80	CP	10±6								22±4				
	12/79	H	12±7		22±7	24±13			24±11			24±13			
	12/79	PC	38±13		26±8	36±15					19±5				
	9/80	SC			8±4	24±12							392±57		
CADE	5/79	SC											172±92		
	12/80												436±92		
	6/79	PR											970±144		
	5/80												304±38		
	6/79	SC				92±32							88±31		
	9/80														

APPENDIX C CONTINUED.

Species	Date	Posture	AGDE	ACIN	ACSP	ARTRT-BETT-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	ARTRV-POSA	ARRI-POSA	BETT	CADR	TAAS	FORB
			Plant community												
CADR-R	12/80	BC										66±21	66±26		
	9/80	SC											42±25		
ACLA	6/80	PC	\		10±9				9±12						
ANLY	12/79	H										14±10			
	6/80	PC										24±10			
	6/79	SC				196±42									
	5/79	ST													74±18
	5/80														34±15
ERCI	5/79	BC										75±25			
	5/79	CP										48±18			
	6/80	PC	3±7		16±19	34±21						70±15			
	5/80	PR				38±18						1014±600	56±11		
	6/79											70±25			
	5/79	ST													140±21
	5/80														120±27
EPPA	5/79	BC	3±5						22±16						
	12/80	CP										24±12			
	12/79	H										26±10			
	6/79	PR				20±18									
	6/79	SC				138±80									
	9/80					38±16									
LASE	5/79	BC												32±8	
	6/79	PR												80±60	
	5/80													64±32	
	6/79	SC				194±110								58±9	
LARI	9/80	SC			82±37										
LOGR	6/80	WT		38±20						11±18	26±21				
	6/79									16±18					
	5/80	ST								90±62					
LUCA	5/79	BC				90±33			22±8						
	12/80								26±12						
	6/79	WT		62±34											
	6/80							76±35							
	6/80	PC							32±14						
	6/79	PR				46±17									
SIAL	12/79	H										10±10			
	6/80	WT				25±20									
	6/80	PC										9±15			
	6/79	SC				166±83									
	5/79	ST													150±42
	5/80														124±31

APPENDIX D. MEANS AND STANDARD ERRORS OF THE PRIMARY FORAGES AVAILABLE TO DEER BY PASTURE, PLANT COMMUNITY AND SPECIES DURING THE EARLY PERIOD (NOVEMBER, DECEMBER, JANUARY) OF THE 1978-1979 WINTER. MEANS AND STANDARD ERRORS ARE EXPRESSED ON A KILOGRAM PER HECTARE BASIS.

		Plant community									
Species	Pasture	AGDE	AGIN	AGSP	ARTRT-BRTE-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	BRTE	CADR	TAAS
AGDE	ST					14±7					
	NT						13±15				
	CP	14±5									
	PG	18±7									
	BC	10±7									
AGIN	NT		116±21				34±30				
AGSP	NT			34±22							
	SC			13±.3							
	PG			13±6							
	PR			36±9							
	BC			40±12							
BRTE	NT			24±17							
	SC			18±16	158±128						
	CP	2±1							8±2		
	PG	6±2		7±3	98±33			6±2	2±1		
	PR			50±11	116±21				7±6		
	BC	6±3		40±12	100±27				3±2	8±6	
FEID	PG			7±4				62±21			
SINT	NT			5±4							
	SC			10±12							
STCO	BC			20±11							
TAAS	PG										18±4
	BC										26±9
POSA	ST					26±12					
	NT			32±10	3±3	32±11	30±21				
	CP								4±2		
	PG			8±6	12±6			12±7	2±1		
	PR				5±6				6±2		
	BC				3±3				7±6		
CADR	BC									50±11	
EPPA	SC				5±8						
ERCO	PR			7±9							
LASE	CP	2±6									
	PG	5±10									29±6
	BC										31±11
SIAL	SC				26±29						
	CP	10±6							16±9		
	PG	8±3							6±1		
	PR			8±3					3±2		
	BC	2±2							14±9	9±8	
ARTRT	ST					26±8					
	SC			3±6	212±68						
	CP	2±1							10±6		
	PG	6±3		1±1	225±102			40±18	6±1		6±5
	PR				201±31				3±3		
	BC	3±6			185±22				6±4		2±2
ARTRV	ST					90±34					
	NT		26±13	81±20			88±26				
	SC				10±16						
	CP	1±1									
	PG		1±1					40±20			
	PR				6±3						
CHMA	CP	4±5									
	PG	2±1			48±21						
	PR			26±11	66±11						
	BC			15±9	10±6					2±2	
PERE	PR			1±5							
PUTR	PR			1±8							

APPENDIX E. MEANS AND STANDARD ERRORS OF THE PRIMARY FORAGES AVAILABLE TO DEER BY PASTURE, PLANT COMMUNITY, AND SPECIES DURING THE LATE PERIOD (FEBRUARY, MARCH, APRIL) OF THE 1978-1979 WINTER. MEANS AND STANDARD ERRORS ARE EXPRESSED ON A KILOGRAM PER HECTARE BASIS. R REFERS TO ON A REGROWTH BASIS.

		Plant community												
Species	Pasture	AGDE	AGIN	AGSP	ARTRT-BRTE-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	ARTRV-POSA	ARRI-POSA	BRTE	CADA	TAAS
AGDE	ST					32±17							
	WT						28±19						
	CP	116±42											
	PC	120±31											
	BC	112±31											
AGDE-R	ST					14±4							
	CP	33±21											
	PC	43±11											
	SC	45±13											
AGIN	WT		258±113				76±45						
AGIN-R	WT		76±16				28±17						
AGSP	WT			92±86									
	SC			17±18									
	PC			47±21				3±4					
	PR			42±11									
	BC			42±11									
AGSP-R	WT			7±5									
	SC			2±4									
	PC			54±21				6±5					
	PR			8±3									
	BC			6±4									
BRTE	WT			26±10									
	SC			38±26	223±88								
	CP	52±18									115±51		
	PC	40±18		14±6	180±61			9±7			88±21		50±18
	PR			108±21	290±62						70±20		
	BC	34±13			175±51						100±41	104±32	94±26
BRTE-R	CP	15±6									25±11		
	PC	16±7		8±3	8±3						29±8		3±1
	PR				3±2						25±4		
	BC	18±7			4±3						32±11	6±4	2±2
FEID	PC			16±8				98±41					
FEID-R	PC			26±12				100±42					
SIMT	WT			7±8									
	SC			26±18	7±9								
SIMT-R	WT			3±6									
	RC			1±3	10±5								
STCO	PR			6±3	9±4								
	BC			24±13									
STCO-R	PR			4±3	5±3								
	BC			5±4									
TAAS	PC												250±113
	BC												325±28
TAAS-R	PC												5±3
POSA	ST					50±23							
	WT		32±7	64±29			32±11						
	SC			6±8	27±17								
	CP	25±9									54±21		
	PC	20±8		15±6	24±11			28±12			64±11		
	PR			5±3	25±11						60±11		
	BC	30±13			15±6						72±22		

APPENDIX E. CONTINUED.

		Plant community											
Species	Pasture	AGDE	ACIN	AGSP	ARTRT-BRTE-POSA	ARTRV-AGDE	ARTRV-AGDE-ACIN	ARTRV-FEID	ARTRV-POSA	ARRI-POSA	BRTE	CADE	TAAS
POSA-R	ST					13±4							
	MT		20±1	9±3			30±7						
	SC			1±3	8±4								
	CP	15±8									10±4		
	PC	14±6		[illegible]±7	20±13			28±16			8±6		
	PR				16±7						5±3		
	BC	13±[illegible]			14±6						3±2		
CADE	SC				6±7								
	BC											362±89	
EPPA	SC				14±16								
ERCI	CP										2±5		
	PC										4±6		
	PR										5±4		
	BC										3±4		
LASE	PC												45±22
	BC												57±14
LUCA	PC				12±10								
	PR				18±20								
SIAL	SC				68±81								
	CP	20±8									26±9		
	PC	12±8									15±4		
	BC										28±1[illegible]	17±11	25±9
ARTRT	ST					34±9							
	SC			5±6	225±65								
	CP	5±1									14±6		
	PC	6±4		2±2	344±104			98±32			8±6		6±5
	PR				314±89						8±3		
	BC	8±4		5±3	298±41						11±9		3±4
ARTRV	ST					116±35							
	MT		29±9	90±33			123±24						
	SC				6±4								
	CP	1±1											
	PC			2±2				170±68					
	PR				16±6								
	BC										1±4		
CHNA	SC				1±3								
	CP	4±1											
	PC	3±2			65±21								
	PR			33±2[illegible]	51±19								
	BC	2±2		25±1[illegible]	42±16							8±6	
PERE	PR			1±6									
PUTR	PR			1±4									

APPENDIX F. MEANS AND STANDARD ERRORS OF THE PRIMARY FORAGES AVAILABLE TO DEER BY PASTURE, PLANT COMMUNITY, AND SPECIES DURING THE 1979-1980 WINTER. MEANS AND STANDARD ERRORS ARE EXPRESSED ON A KILOGRAM PER HECTARE BASIS. R REFERS TO ON-A-REGROWTH BASIS.

		Plant community											
Species	Pasture	AGDE	AGIN	AGSP	ARTRT-BRTE-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	ARTRV-POSA	ARBI-POSA	BRTE	CADI	TAAS
AGDE	ST					126±51							
	WT						136±62						
	CP	182±31											
	PC	310±81											
	BC	102±42											
AGDE-R	ST					40±9							
	WT						26±9						
	CP	62±17											
	PC	38±12											
	BC	62±11											
AGIN	WT		212±69				62±37						
AGIN-R	WT		19±6				13±6						
AGSP	WT			258±95									
	SC			252±81									
	PC			236±31									
	PR			288±31									
	BC			166±36									
AGSP-R	WT			28±11									
	SC			19±9									
	PC			9±3									
	PR			1±1									
	BC			14±6									
BRTE	ST								176±81				
	WT			16±7	50±20								
	SC				28±13					18±6		34±13	
	CP										100±31		
	PC	19±7		34±9	26±11						170±37		
	PR			32±9	56±18						80±22		
	BC			16±7	52±21						78±23		
BRTE-R	ST								26±13				
	WT				13±7								
	SC				12±6								
	CP										22±9		
	PC				12±7						26±8		
	PR			8±6	5±3						44±18		
	BC				9±5						44±17		
FEID	PC							50±18					
FEID-R	PC							5±3					
SINY	WT			26±13									
	SC									30±11			
SINY-R	WT			15±8									
	SC									16±7			
STCO	BC			88±21									
STCO-R	BC			15±7									
TAAS	SC												186±47
	PC												178±32
	BC												194±31
TAAS-R	SC												72±18
	PC												82±21
	SC												78±21
POSA	ST								19±18				
	WT			34±9	19±5	18±10			28±9				
	SC				8±7								
	PC							18±7					
	PR										20±9		

APPENDIX F. CONTINUED.

		Plant community											
Species	Pasture	AGDE	AGIN	AGSP	ARTRT-BRTR-POSA	ARTRV-AGDE	ARTRV-AGDE-AGIN	ARTRV-FEID	ARTRV-POSA	ARRI-POSA	BRTE	CADR	TAAS
POSA-R	ST					24±11			68±26				
	HT			22±6	17±9			28±10		70±18			
	SC			30±11	20±9					22±6		20±16	52±13
	CP	22±9									13±4		
	PG	22±7		18±6	20±10						11±7		
	PR				14±6						10±4		
	BC	11±6			13±7							16±7	
CADR	SC											128±37	
	BC										34±21	138±28	
CADR-R	SC											60±15	
	BC										64±9	82±11	
EPPA	HT				64±15								
	SC				20±15							38±22	
	PG												10±12
SIAL	PG												10±20
ARTRT	HT				195±32								
	SC			12±14	300±52							8±9	8±12
	CP				10±8						5±6		
	PG	3±2			240±22			144±81					
	PR				292±48								
	BC	24±15			288±64						10±6	6±3	15±8
ARRI	BC									55±26			
ARTRV	ST					167±18			120±42				
	HT		22±8	150±43			179±61		130±27				
	PG			40±30				190±31					
	BC											5±3	
CEMA	PG	13±9			22±10								
	PR			88±15	39±18						27±18		
	BC	2±2		133±40	37±11								

APPENDIX C. UNCORRECTED MEANS (UM), STANDARD ERROR OF THE MEAN ($S_{\bar{x}}$), AND CORRECTED MEANS (CM) OF THE PRIMARY SPECIES OCCURRING IN CATTLE DIETS BY SEASON AND PASTURE.

		Pasture											
		NT			ST			SC			M		
Species	Date	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM
AGDE	5/79				31.2	.9	30.6						
	6/79	13.6	1.5	13.4									
	11/79												
	12/79										8.4	1.3	8.3
	5/80				23.1	1.7	22.7						
	6/80	21.4	1.9	21.0									
	12/80												
AG2H[1]	6/79	39.9	1.4										
	6/80	20.2	2.9										
AGSP	5/79				5.1	1.3	6.4						
	6/79	3.3	.8	4.1				6.9	1.7	8.6			
	11/79												
	12/79										7.7	1.4	9.6
	5/80				.2	.2	.2						
	6/80	2.9	.9	3.6									
	9/80							5.8	1.0	7.2			
	12/80												
BRTE	5/79				14.8	3.7	17.3						
	6/79	9.9	.9	11.6				28.9	2.1	33.8			
	11/79												
	12/79										19.1	1.7	22.5
	5/80				18.4	1.6	21.5						
	6/80	15.3	1.8	17.9									
	9/80							24.7	1.4	28.9			
	12/80												
FEID[1]	5/79				.8	.6							
	6/79	3.6	.6					.3	.3				
	11/79												
	12/79										4.1	1.2	
	5/80				1.7	.6							
	6/80	3.3	1.1										
	9/80							3.8	.4				
	12/80												
POSA	5/79				17.0	1.3	16.6						
	6/79	4.1	.7	4.0				18.3	1.9	17.9			
	11/79												
	12/79										29.5	2.4	28.9
	5/80				28.3	2.4	27.7						
	6/80	15.0	1.2	14.7									
	9/80							19.9	2.0	19.5			
	12/80												
STsp.	5/79				8.6	1.0	6.7						
	6/79	5.2	.8	4.1				19.1	3.1	14.9			
	11/79												
	12/79										10.8	2.0	8.6
	5/80				2.6	.6	2.0						
	6/80	3.2	1.3	2.5									
	9/80							6.1	1.9	4.8			
	12/80												

		Pasture											
		CP			PR			PC			BC		
Species	Date	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM
AGDE	5/79	36.7	1.3	36.1							15.9	1.0	15.6
	6/79												
	11/79							10.5	.7	10.2			
	12/79												
	5/80												
	6/80							13.7	3.3	13.5			
	12/80	14.1	3.2	13.9				10.1	2.0	9.9			
AG2H[1]	6/79												
	6/80												
AGSP	5/79	T	T	T							2.9	.5	3.6
	6/79				13.8	2.1	17.2						
	11/79							6.8	1.9	8.5			
	12/79												
	5/80				7.2	1.7	8.9						
	6/80							7.5	2.2	9.4			
	9/80												
	12/80	.9	.6	1.1							.3	.3	.4
BRTE	5/79	30.5	3.8	23.9							27.7	4.6	32.4
	6/79				48.2	2.7	56.7						
	11/79							27.0	4.2	29.8			
	12/79												
	5/80				42.9	3.7	50.2						
	6/80							22.1	1.7	25.9			
	9/80												
	12/80	27.6	2.2	32.3							33.3	4.2	38.9
FEID[1]	5/79	T	T								7.0	1.5	
	6/79				2.2	.5							
	11/79							3.9	1.1				
	12/79												
	5/80				1.4	.5							
	6/80							3.0	.8				
	9/80												
	12/80	1.7	1.1								2.4	.3	
POSA	5/79	26.2	2.2	25.7							19.2	2.5	18.8
	6/79				16.6	3.2	16.3						
	11/79							18.8	2.2	18.4			
	12/79												
	5/80				27.0	4.2	26.4						
	6/80							22.2	.9	21.7			
	9/80												
	12/80	32.6	2.4	31.9							26.3	2.9	25.8
STsp.	5/79	1.5	.7	1.2							3.4	.8	2.7
	6/79				6.6	.4	3.4						
	11/79							3.1	1.2	2.6			
	12/79												
	5/80				5.7	.7	4.6						
	6/80							4.9	.5	3.8			
	9/80												
	12/80	1.9	.6	1.5							1.7	.9	1.3

APPENDIX C. CONTINUED.

		Pasture																							
		BT			ST			SC			M			CP			PR			PC			BC		
Species	Date	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN	UN	S_x	CN
SINY	5/79				12.3	1.4	12.8							4.1	.9	4.3							6.7	1.4	6.9
	6/79	7.7	1.1	8.0				5.3	2.4	5.7							.7	.6	.7						
	11/79																			1.6	1.4	1.5			
	12/79										5.6	1.4	5.7												
	5/80				5.7	1.1	5.9										1.1	.7	1.1						
	6/80	1.6	.5	1.7																3.0	.6	1.1			
	9/80							9.6	1.2	10.0															
	12/80													.5	.4	.5							T	T	T
TAAS[1]	5/79				.8	.4								T	T								1.4	.8	
	6/79	.5	.3					3.1	.9								1.3	.7							
	11/79																			4.5	1.7				
	12/79										2.0	.9													
	5/80				.4	.3											1.3	.4							
	6/80	.7	.3																	4.6	.7				
	9/80							3.3	1.9																
	12/80													1.5	.7								.3	.3	
OTHER GRASSES	5/79				T	T								T	T								T	T	
	6/79	.3	.2					T	T								T	T							
	11/79																			T	T				
	12/79										2.0	.8													
	5/80				3.8	.6											T	T							
	6/80	1.8	.4																	T	T				
	9/80							2.8	.6																
	12/80													T	T								T	T	
UNKNOWN GRASSES	5/79				1.1	.5								3.4	.6								3.4	.6	
	6/79	.4	.3					.9	.6								2.2	.8							
	11/79																			6.5	.7				
	12/79										3.0	.9													
	5/80				5.5	.9											4.7	1.3							
	6/80	6.0	1.2																	13.9	2.3				
	9/80							4.9	.7																
	12/80													5.3	.9								5.6	1.6	
TOTAL[2] GRASSES	5/79				91.7		93.1							90.4		92.6							87.8		92.0
	6/79	88.5		89.9				83.0		85.2							89.4		97.7						
	11/79																			82.5		85.7			
	12/79										92.2		92.2												
	5/80				89.7		91.4																		
	6/80	91.4		93.4																94.9		98.9			
	9/80							80.9		85.2															
	12/80													86.1		89.7							80.0		84.6

APPENDIX C. CONTINUED.

Species	Date	WT UN	WT $S_{\bar{x}}$	WT CN	ST UN	ST $S_{\bar{x}}$	ST CN	SC UN	SC $S_{\bar{x}}$	SC CN	R UN	R $S_{\bar{x}}$	R CN	CP UN	CP $S_{\bar{x}}$	CP CN	PR UN	PR $S_{\bar{x}}$	PR CN	PC UN	PC $S_{\bar{x}}$	PC CN	BC UN	BC $S_{\bar{x}}$	BC CN
TOTAL	5/79				1.9	.9								4.9	.9								3.6	.8	
GRASSLIKE	6/79	.9	.3					3.3	.8								2.5	1.1							
	11/79																			1.5	.7				
	12/79										2.5	.7													
	5/80				3.2	.9											1.8	.4							
	6/80	.9	.3																	2.2	.8				
	9/80							2.7	.7																
	12/80													2.7	1.1								2.3	.8	
TOTAL	5/79				2.2	1.1								2.4	.7								4.8	1.6	
FORBS	6/79	5.6	.2					7.0	2.3								4.1	1.1							
	11/79																			6.1	1.8				
	12/79										2.8	.8													
	5/80				2.1	.7											2.3	.9							
	6/80	1.3	.5																	1.1	.4				
	9/80							6.0	1.6																
	12/80													.9	.7								8.[illegible]	1.6	
TOTAL	5/79				1.5	.8								.9	.8								1.6	1.3	
BROWSE	6/79	1.9	.8					3.2	.8								7.5	.8							
	11/79																			T	T				
	12/79										1.7	.5													
	5/80				2.5	.9											2.6	.7							
	6/80	2.3	.7																	T	T				
	9/80							6.5	1.8																
	12/80													3.4	.9								3.8	1.5	
TOTAL	5/79				3.2	1.3								1.9	.9								2.3	1.6	
UNKNOWN	6/79	3.1	.7					3.5	1.1								1.4	.6							
BROWSE	11/79																			9.4	.9				
OR	12/79										2.8	.6													
FORB	5/80				2.5	.9											2.2	.4							
	6/80	4.1	.9																	1.8	.5				
	9/80							3.9	1.1																
	12/80													6.8	1.0								5.[illegible]	.6	

[1] Correction equations were not developed for those species.

[2] Total corrected means include uncorrected means of those species not corrected for differential digestibility.

APPENDIX N. UNCORRECTED MEANS (UM), STANDARD ERROR OF THE MEAN ($S_{\bar{x}}$), AND CORRECTED MEANS (CM) OF THE PRIMARY SPECIES OCCURRING IN DEER FECAL SAMPLES COLLECTED FROM THE THREE STUDY AREAS.

		Spring Creek																				
		Sampling period																				
		1			2			3			4			5			6			7		
Species	Year	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM	UM	$S_{\bar{x}}$	CM
POSA	78-79	.6	.3	.6	.2	.2	.2	—	—	—	.3	.2	.3	7.9	1.2	7.7	23.8	3.6	23.3			
	79-80	18.9	3.1	18.5	36.9	2.2	36.1	25.4	1.3	24.9	16.5	2.5	16.2	19.3	2.1	29.1	46.1	3.0	35.8	22.9	2.8	22.4
BRTE	78-79	.6	.3	.7	.2	.2	.2	—	—	—	1.2	.4	1.4	1.1	.6	1.3	2.2	.9	2.6			
	79-80	7.6	.4	8.9	8.1	1.2	9.4	14.7	1.3	17.2	11.2	1.8	13.1	14.9	.5	13.4	8.4	1.9	9.8	7.9	2.1	9.2
STTH	78-79	.6	.5	.5	—	—	—	—	—	—	.5	.3	.4	7.4	1.4	5.8	3.9	.6	3.8			
	79-80	5.5	1.2	4.3	10.0	1.4	7.8	6.5	1.2	5.1	9.8	2.0	7.6	8.5	.9	6.6	12.9	2.1	10.1	7.7	1.8	6.0
FEID[2]	78-79	—	—		.2	.2		—	—		—	—		—	—		.8	.5				
	78-80	2.1	1.1		2.3	.9		1.9	.6		4.8	1.4		4.1	1.4		3.6	.7		6.3	1.4	
SINY	78-79	—	—	—	—	—	—	—	—		.9	.5	.9	1.1	.5	1.1	2.9	.8	3.0			
	79-80	5.7	.8	5.9	.8	.4	.8	4.3	.8	4.3	4.2	1.2	4.4	5.4	.7	3.3	2.9	.9	3.0	1.3	.5	1.4
ACDE	78-79	.5	.2	.5	—	—	—	T	T	T	.3	.2	.3	—	—	—	.5	.2	.3			
	79-80	—	—	—	.3	.3	.3	—	—	—	—	—	—	.2	.2	.2	—	—	—	.3	.3	.3
OTHER GRASSES	78-79	.8			.4			T			.8			3.2				3.9				
	79-80	3.1			2.1			1.6			.6			.9				1.1		2.5		
UNKNOWN GRASSES	78-79	T	T		T	T		T	T		1.1	.6		2.1	.6		1.1	.8				
	79-80	1.1	.5		2.9	.6		1.5	1.1		3.7	.7		T	T		2.0	1.2		4.2	1.6	
TOTAL[3] GRASSES	78-79	3.1		3.1	1.0		1.0	T		T	5.1		5.2	22.8		21.2	39.1		38.2			
	79-80	44.0		43.9	63.6		63.9	55.7		56.5	50.8		50.4	51.5		31.8	47.0		45.4	55.1		54.3
TOTAL GRASSLIKE	78-79	.2	.2		—	—		—	—		—	—		—	—		2.6	.7				
	79-80	4.6	1.1		3.3	.5		4.1	1.1		5.6	.9		3.7	.6		.9	.4		2.6	.8	
VETH	78-79	1.1	.6	.3	1.9	.9	.5	2.5	1.4	.7	2.7	1.0	.8	7.2	2.9	2.1	1.3	1.3	.4			
	79-80	1.5	1.2	.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CADE	78-79	62.5	3.2	32.1	39.9	5.8	20.5	25.9	12.0	13.3	33.9	4.2	17.4	39.1	6.8	30.1	10.6	4.4	5.5			
	79-80	1.1	.5	.7	—	—	—	.8	.8	.4	.9	.4	.5	—	—	—	—	—	—	—	—	—
OTHER FORBS	78-79	.9			.6			2.3			1.3			1.1			3.9					
	79-80	2.8			1.3			1.4			1.2			1.1			5.1			4.3		
TOTAL FORBS	78-79	64.5		33.3	42.4		21.6	30.7		16.3	37.9		19.5	47.4		33.3	15.8		9.8			
	79-80	5.4		4.3	1.3		1.3	2.2		1.8	2.1		1.7	1.1		1.1	5.1		5.1	4.3		
ARsp.	78-79	24.5	2.6	24.9	28.9	4.1	29.3	45.9	11.3	46.6	31.2	3.5	31.6	25.2	3.7	25.6	36.3	2.2	37.2			
	79-80	28.6	2.4	29.0	24.2	2.4	24.6	27.5	2.2	27.9	32.2	2.6	37.6	33.9	3.6	34.4	33.8	2.2	34.3	23.8	3.5	24.2
CHNA	78-79	2.3	.5	1.7	2.9	.9	2.2	5.3	1.4	3.9	1.5	.2	1.1	.9	.5	.7	1.1	.5	.8			
	79-80	3.4	1.4	2.6	.5	.3	.4	.2	.2	.1	.7	.5	.5	.7	.4	.5	2.7	1.1	2.0	2.4	.9	2.2
SAsp.[2]	78-79	.4	.2		16.3	2.5		12.8	3.7		10.9	1.3		1.3	.9		—	—				
	79-80	.6	.6		—	—		.1	.1		—	—		—	—		.8	.6		—	—	
PUTR[2]	78-79	1.4	.4		6.8	2.1		.8	.5		.4	.2		1.0	.3		.8	.5				
	79-80	1.5	.5		—	—		.4	.2		—	—		.5	.3		.9	.8		1.4	.8	
CRDO[2]	78-79	.7	.2		1.7	.4		1.8	.6		.7	.4		.7	.3		—	—				
	79-80	.9	.4		1.1	.8		1.0	.5		1.1	.6		5.5	.7		—	—		.8	.5	
OTHER BROWSE	78-79	2.2			2.1			1.4			1.4			.9			—	—				
	79-80	2.7			3.3	1.0		4.4	.4		5.4	1.3		2.1	.8		2.6	1.5		1.7	.6	
TOTAL[3] BROWSE	78-79	32.5		31.3	36.7		56.6	66.0		67.3	55.1		55.1	30.0		30.2	38.2		38.8			
	79-80	37.7		37.2	29.1		29.4	33.4		33.9	39.4		44.6	42.7		43.0	41.0		40.8	30.1		30.5
UNKNOWN BROWSE OR FORB	78-79	.9	.4		T	T		2.0	.4		1.9	.8		1.3	.5		4.3	1.7				
	79-80	7.4	.4		2.7	.8		4.9	.7		2.8	.4		1.5	1.6		6.9	1.6		7.2	.9	

APPENDIX H. CONTINUED

		Crystal Palace Allotment — Sampling period[1]																				
		1			2			3			4			5			6			7		
Species	Year	UN	S_x	CH	UN	S_x	CH	UN	S_x	CH	UN	S_x	CH	UN	S_x	CH	UN	S_x	CH	UN	S_x	CH
POSA	78-79	.4	.3	.4	T	T	T	T	T	T	1.1	.9	1.1	5.4	1.9	5.3	26.1	2.5	25.5	23.5	2.6	23.0
	79-80	19.8	2.6	19.4	29.2	2.1	28.6	30.3	2.5	29.7	27.6	3.1	27.0	36.4	1.9	35.7	46.8	2.8	45.8	39.2	3.3	38.4
BETE	78-79	.2	.2	.2	.2	.2	.2	.2	.2	.2	T	T	T	6.6	2.1	7.7	16.9	4.7	19.7	14.3	3.2	16.7
	79-80	7.8	1.4	9.1	10.0	.8	11.7	18.6	1.3	21.7	17.8	2.8	20.8	14.1	3.1	16.5	10.5	2.3	12.3	7.3	.6	8.5
STTH	78-79	—	—	—	—	—	—	—	—	—	.8	.7	.6	2.1	1.0	1.6	6.8	1.0	3.3	2.4	.8	1.9
	79-80	1.2	1.8	.9	5.2	1.1	4.1	1.2	.4	.9	2.8	.8	2.2	1.0	.3	.8	3.5	1.7	2.7	9.3	2.3	7.3
FEID[2]	78-79	.6	.3		T	T		.3	.2		.4	.2		2.3	1.4		1.9	.3		T	T	
	79-80	1.2	.5		1.3	.6		1.0	.5		2.8	.8		.6	.4		1.5	.5		2.3	.4	
SIHY	78-79	—	—		T	T		—	—		T	T		.4	.4	.4	1.1	.6	1.1	2.9	1.5	3.03
	79-80	1.9	.6	1.9	5.6	1.2	5.8	4.1	.9	4.3	2.1	.7	2.2	.7	.3	.7	1.3	.3	1.4	.7	.3	.7
ACDE	78-79	.6	.4	.6	.2	.2	.2	.2	.1	.2	.4	.2	.4	.8	.5	.8	7.2	2.3	7.1	4.2	.9	4.1
	79-80	3.9	1.3	3.8	6.9	1.8	6.8	2.6	1.4	2.6	3.7	.8	3.6	3.6	.3	3.5	3.8	.5	3.7	3.9	.7	3.8
OTHER GRASSES	78-79	.6			.4			.5			.8			1.7			2.1			.8		
	79-80	.6			.7			.5			.3			T			.1			1.2		
UNKNOWN GRASSES	78-79	T	T		T	T		.2	.2		.8	.4		1.7	.8		2.1	1.2		6.2	2.2	
	79-80	3.6	.3		2.9	1.1		6.2	2.5		4.9	1.1		2.4	.4		3.7	.7		4.1	.7	
TOTAL[3] GRASSES	78-79	2.6		2.4	1.0		1.9	1.5		1.4	4.4		4.2	21.0		21.5	64.2		64.9	52.3		53.7
	79-80	40.0		40.5	61.8		61.9	64.5		64.9	62.0		63.8	58.8		60.3	71.2		[illegible]	68.0		66.4
TOTAL GRASSLIKE	78-79	T	T		T	T		.1	.1		T	T		T	T		.4	.4		1.4	.6	
	79-80	1.5	.4		1.0	.4		.9	.4		.8	.3		1.3	.3		.5	.3		1.0	.3	
VETH	78-79	9.1	3.2	2.6	7.5	2.4	2.2	26.5	5.6	7.6	1.4	.3	.4	T	T	T	.3	.2	T	.2	.1	T
	79-80	.6	.6	.2	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
CADE	78-79	12.4	4.7	6.4	25.8	9.0	13.2	T	T	T	65.5	6.3	33.6	45.3	11.7	23.3	T	T	T	T	T	T
	79-80	1.2	.6	.6	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
OTHER FORBS	78-79	5.4			1.2			11.7			1.9			1.3			.9			2.2		
	79-80	4.7			.6			.4			.8			.7			.4			4.3		
TOTAL FORBS	78-79	26.9		14.4	34.5		16.6	38.2		19.3	68.8		35.9	66.6		25.6	1.2		.9	2.4		4.1
	79-80	6.5		4.5	.7		.7	.5		.5	.9		.9	.8		.8	.5		.5	4.4		6.4
ARsp.	78-79	54.7	5.2	55.5	51.1	6.4	51.8	46.6	3.3	47.3	17.4	3.7	17.6	24.4	5.6	24.7	31.2	3.3	32.[illegible]	37.1	3.0	37.7
	79-80	27.8	4.1	28.2	27.1	1.7	27.5	28.8	2.1	29.2	30.0	2.8	30.4	37.3	2.8	37.8	25.5	2.9	25.8	22.5	1.6	23.8
CHNA	78-79	5.9	1.2	4.6	4.7	2.2	3.5	9.1	2.0	6.8	2.5	.9	1.9	1.1	.6	.8	2.5	.6	1.9	2.4	1.1	1.4
	79-80	2.8	1.8	1.9	1.1	.4	.8	.9	.6	.6	.6	.4	.5	.7	.5	.5	1.3	.1	.9	.5	.3	.4
SALIX[2]	78-79	6.5	1.2		5.6	1.9		1.3	.6		3.6	.2		3.1	1.5		T	T		T	T	
	79-80	1.4	.8		T	T		T	T		1.1	.8		T	T		T	T		T	T	
PUTR[2]	78-79	2.5	.5		2.2	1.1		.3	.1		1.2	.7		1.1	.6		T	T		1.0	.6	
	79-80	2.3	.8		1.6	.7		1.7	.5		.5	.3		.4	.3		.2	.2		.2	.1	
CRDO[2]	78-79	.7	.5		.6	.3		.5	.3		.1	T		1.0	.5		T	T		T	T	
	79-80	6.5	1.4		.6	.4		T	T		1.3	.7		T	T		T	T		.2	.2	
OTHER BROWSE	78-79	.3			.3			.9			.4			.8			.2			.4		
	79-80	.6			T			T			.4			T			T			T		
TOTAL[3] BROWSE	78-79	68.4		67.9	64.5		64.[illegible]	58.7		57.1	25.2		24.8	31.5		31.5	34.0		33.9	40.7		40.8
	79-80	39.2		38.9	36.5		30.4	31.5		31.4	33.9		34.2	38.5		38.8	27.3		27.0	24.5		24.7
UNKNOWN BROWSE OR FORB	78-79	2.4	.9		.2	.2		1.1	.6		1.4	.7		.9	.4		.6	.3		3.2	1.4	
	79-80	12.9	1.4		6.7	1.0		2.7	.3		2.4	.5		1.2	.7		.9	1.0		2.9	.8	

1 Fecal samples were not taken during this time period.
2 Correction equations were not developed for these species.
3 Total corrected means include uncorrected means of those species that were not corrected for differential digestibility.

APPENDIX N. CONTINUED

Species	Year	Tucker Creek — Sampling period 1 UM			2 UM			3 UM			4 UM			5 UM			6 UM			7 UM		
		UM	S_x	CM	UM	S_x	CM	UM	S_x	CM	UM	S_x	CM	UM	S_x	CM	UM	S_x	CM	UM	S_x	CM
POSA	78-79	—	—	—	.2	.2	.2	.6	.5	.6	8.6	2.3	8.4	15.1	3.4	14.8	25.7	1.7	25.2	1		
	79-80	10.1	2.5	9.9	23.8	2.2	23.2	15.9	1.2	15.5	18.5	3.1	18.1	14.2	2.1	13.9	23.9	3.4	25.4	25.2	2.4	24.6
BRIE	78-79	—	—	—	.4	.2	.5	.2	.2	.2	.7	.3	.8	5.0	1.9	5.8	9.6	1.8	12.2			
	79-80	6.4	1.0	7.5	11.0	.6	12.8	11.2	.9	12.3	6.7	.6	7.8	6.1	1.4	7.1	8.7	1.5	10.1	5.7	2.4	6.7
STTH	78-79	--	--	--	--	--	--	--	--	--	.3	.1	.7	5.1	1.5	3.9	8.3	3.6	6.5			
	79-80	.5	.5	.4	4.0	.6	3.1	5.4	1.9	4.2	4.5	.9	3.5	5.7	1.3	4.4	8.3	1.7	6.5	7.0	1.8	5.5
FEID[2]	78-79	.7	.4		1.3	.7		—	—		2.7	.8		.9	.7		2.3	.8				
	79-80	.5	.3		.7	.5		2.9	1.3		1.4	.5		1.9	.5		1.2	.6		.9	.3	
SIHY	78-79	—	—	—	—	—	—	—	—		—	—	—	1.8	1.2	1.9	2.6	.7	2.7			
	79-80	1.9	.5	1.9	3.9	.7	4.1	3.1	.9	3.2	2.9	.6	3.0	5.4	.7	5.6	1.6	.8	1.6	2.7	.5	2.8
AGDE	78-79	.6	.4	.6	—	—		—	—		4.2	1.3	4.1	1.6	.4	1.5	4.0	1.5	3.9			
	79-80	2.4	.5	2.4	3.3	1.0	3.2	6.2	1.3	6.1	3.6	.6	3.5	3.9	.9	3.8	3.2	1.5	3.1	3.3	.5	3.2
OTHER GRASSES	78-79	.2	.2		.5	.3		—	—		.5	.3		1.9	.8		3.2	1.2				
	79-80	.9	.4		2.0	.8		.2	.2		T	T		.7	.3		.7	.5		.9	.5	
UNKNOWN GRASSES	78-79	—	—		T	T		.2	.2		2.2	.9		5.8	2.0		T	T				
	79-80	2.4	.5		1.9	.8		.4	.4		2.9	.5		3.7	.8		4.5	.3		3.9	.9	
TOTAL[3] GRASSES	78-79	1.5		.8	2.4		2.5	1.0		1.0	19.8		19.3	37.2		36.5	55.7		55.0			
	79-80	25.1		25.9	50.6		51.0	45.3		44.9	40.5		40.2	41.4		41.1	52.1		51.2	49.6		48.5
TOTAL GRASSLIKE	78-79	.2	.2		T	T		T	T		T	T		T	T		T	T				
	79-80	1.8	.6		1.0	.6		3.9	.7		3.3	.9		2.7	.6		2.7	.6		1.5	.3	
VETH	78-79	31.8	4.2	9.2	14.8	7.3	4.3	30.9	13.9	8.9	13.7	5.7	3.9	11.4	1.7	3.3	1.8	1.5	.5			
	79-80	20.5	5.0	5.9	.8	.5	.2	2.8	.6	.8	4.8	1.2	1.4	T	T	T	—	—	—	.6	.4	.2
CADR	78-79	T	T		.6	.3	.3	22.1	9.8	11.4	1.9	.9	.9	8.2	5.2	4.2	T	T				
	79-80	11.6	2.9	5.9	8.9	5.4	4.6	4.1	3.5	2.1	T	T	T	3.9	1.3	2.0	—	—	—	—	—	—
OTHER FORBS	78-79	1.1			1.6			1.8			2.2			2.4			3.0					
	79-80	6.4			1.9			2.2			1.2			.9			2.2			3.5	.9	
TOTAL FORBS	78-79	32.9		10.3	16.8		6.0	54.8		22.1	17.8		7.0	22.0		9.9	4.8		3.5			
	79-80	38.5		18.2	11.6		6.7	9.1		5.1	6.0		2.6	4.8		2.9	2.2		2.2	4.1		.7
ARsp.	78-79	34.7	2.5	35.2	51.6	2.9	52.4	22.9	1.5	23.2	41.0	2.9	41.6	33.4	2.9	33.9	30.5	1.7	30.9			
	79-80	23.5	4.4	23.8	29.3	12.5	29.7	32.1	2.6	32.6	30.7	10.8	31.2	33.9	5.6	34.4	34.7	3.4	35.2	34.3	3.4	34.8
CHNA	78-79	2.1	.7	1.6	3.1	2.3	2.3	.5	.3	.4	1.4	.4	1.1	.9	.7	.7	4.6	1.9	3.4			
	79-80	1.9	1.3	1.4	2.7	2.9	2.0	2.7	1.3	2.0	2.2	1.5	1.7	1.4	.2	1.1	4.4	.5	3.3	.9	.4	.7
SAsp.[2]	78-79	2.4	1.5		16.4	2.9		15.0	6.0		11.9	1.3		4.5	1.9		1.3	.8				
	79-80	1.8	1.4		.3	.3		.3	.3		T	T		—	—		—	—				
PUTR[2]	78-79	3.5	1.1		.3	.2		.5	.3		3.5	.6		T	T		.3	.3				
	79-80	1.4	.6		.4	.4		1.3	.9		.5	.4		--	--		--	--		.5	.4	
CEDO[3]	78-79	.1	.1		1.0	.2		4.5	1.2		1.6	.6		.8	.4		.6	.5				
	79-80	1.8	1.3		.9	.6		1.7	.7		.3	.3		—	—		.5	.3		1.3	.5	
OTHER BROWSE	78-79	16.3			2.4			T	T		1.2			1.0			1.1					
	79-80	.8			1.1			1.3			7.2			4.5			T			2.4		
TOTAL[3] BROWSE	78-79	59.2		59.2	75.0		75.0	43.4		43.6	60.6		60.0	40.6		40.9	38.4		37.6			
	79-80	31.2		31.0	34.7		34.4	39.4		39.2	40.9		40.9	39.8		40.0	39.6		39.0	39.4		39.7
UNKNOWN BROWSE OR FORB	78-79	6.6	3.6		5.9	3.2		1.5	.5		2.0	1.0		.9	.8		1.1	.9				
	79-80	4.2	2.4		2.6	.9		2.8	.9		9.6	.7		11.5	3.3		4.0	.5		5.8	.9	