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Bureau of Land Management

WILD UNGULATE FORAGE REQUIREMENTS -- A REVIEW

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This report discusses the nutritional and intake requirements of the major big game ungulates of North America. Forage intake rates for the various species are detailed, and major factors governing intake rates are discussed. The importance of forage nutritional value as much as quantity is emphasized, and both biotic and abiotic factors influencing forage quality are presented. Methods of forage protection and improvement are briefly defined.
INTRODUCTION

The wild ungulates treated in this report all qualify as ruminants—creatures which possess a four-chambered stomach unique in the animal kingdom. Unlike most monogastric animals (those without enlarged ceaces), which are best equipped to utilize diets high in proteins, fats and simplicity of carbohydrates, ruminants have evolved to make use of foods which are bulky, high in cellulose and lignin, and frequently low in easily digestible plant materials (Nagy 1970).

From man's point of view, this digestive specialization affords ruminants several advantages over other meat-producing animals. Due to the role of rumen microorganisms in amino acid synthesis, ruminants are freed from the necessity of obtaining the amino acids they require from protein in the foods they eat, and may therefore take better advantage of available forage than can most monogastric herbivores. The role of cellulolytic rumen microbes in converting fibrous feeds to meat enables man to utilize lands which would prove marginal or unsuccessful if placed under cultivation, and provides him with a reasonable method of obtaining food from areas of low herbage productivity (Nagy 1970, Van Dyne et al. 1980). Demand for meat, as well as meat and milk production, from pasture and range lands has increased at the same time that the total area of grazing lands has decreased (Van Dyne et al. 1980), and this trend will likely continue. Man must therefore make the maximum use of what grazing lands remain, while preventing the productivity of that land from deteriorating due to misuse or overuse of the resource.

For this reason, land managers have long sought valid procedures for measuring the capacity of pasture and grazing lands to support grazing and wildlife. In early years, the sole criterion used to estimate range value for livestock and wildlife was simply the quantity of forage produced by the range (Sell et al. 1959, Dietz 1970). These early methods of range evaluation were comparative, and consisted mostly of determining grazing capacities of ranges which had been utilized at a known rate for a long period of time without showing obvious signs of deterioration, and then applying the values obtained to similar ranges with unknown performance histories (Stoddart 1952). Clearly these techniques had severe limitations and overlooked many important factors; more recently forage yield, forage quality, and animal response have emerged as some of the important components of a good range evaluation program (Dietz 1970).

The nutritional value of a forage—its quality—ranks equally with the quality of available forage in terms of animal carrying capacity (Savage and Heller 1947, Cook and Harris 1950b, Leopold 1950, Dietz 1970). From the standpoint of animal production, the two most important characteristics to consider are nutritive value and rate of intake (Morris and Kovner 1970). Even with our present advanced state of knowledge in the area of animal nutrition as measured by chemical composition and digestibility of foods, many problems associated with the concepts of forage quality and voluntary intake rates remain unsolved (Dietz 1970). Forage intake rates depend upon forage acceptability, rate of digestion, and voluntary intake rates depend upon forage acceptability, rate of digestion, rate of passage, amount of forage available, and environmental effects on animals (Morris and Kovner 1970).

Nutritional studies done to date have often proven to be highly site-specific, and researchers caution against applying data from one study to another. Urness et al. (1977) studied nutritive values for mule deer on ranges on ponderosa pine ranges in Arizona and concluded that their data, while gathered locally, had considerable application in ponderosa pine communities throughout Arizona because of the relative homogeneity of vegetational composition and other habitat factors within the type. But they also point out, along with Smith (1952), Rosley (1956) and others that dietary findings generally have only local application. Cowen (1945) indicated that palatability ratings could be applied only under the precise conditions existing when they were calculated and that to transfer such data by inference to areas where different conditions prevail could lead to invalid conclusions.

And so for all the progress in animal ecology and nutrition, the precise calculation of forage nutritional values and intake rates for a given species in a given environment is often quite difficult, since it depends on a complex interrelationship of factors which in many instances are but poorly understood. Studies dealing with wild herbivores are conducted only at very few locations in the world today, and many difficulties arise when one attempts to extrapolate data from studies conducted on domestic livestock to little-studied herbivores in the absence of collecting accurate information from wild animals makes the carrying capacities of the range species difficult indeed. Hopefully, the information compiled in this report will provide a broader base of general knowledge to aid in making management decisions under field conditions.
ENERGY REQUIREMENTS

Energy shortages can occur if animals must use low-quality forage, however abundant. Insufficient food, heavy snow cover, and low dry matter content of very moist spring forage also contribute to energy shortages. Such energy deficiencies in foods most frequently occur either on overbrowed winter range or on early spring ranges where animals change from their winter diet to lush green grass and forbs (Dietz 1965).

In winter, range animals require more energy than do farm animals because they often need to travel farther to obtain food, and must at the same time maintain body temperature under harsh winter conditions without the aid of shelters (Stoddart and Smith 1952). The energy needs of range animals above the resting state has not been well defined (Platt and Copcock 1965, Halls 1970), but some work on domestic stock may serve as guidelines. Blaxter (1962) stated that a 500 kg steer with a basal metabolism of 8000 kcal/day spends 50 kcal/hour more energy standing than he gains from browse; each time the animal stands or reclines it expends 12 kcal more energy. Young animals at play may require energy at a rate 10 percent above basal metabolism requirements. Cattle need 15 percent more energy for normal range activities than for fasting conditions; similar values probably apply to all herbivores under normal range and climatic conditions (Short and Colley 1968). Grimes (1966) maintained that grazing sheep required energy at levels up to 77 percent above energy used by sheep maintained in pens.

Strenuous physical activity consumes much energy, and under severe environmental conditions animals may expend more energy in the search for food than they gain from its digestion (Halls 1970). While ungulates may, at least theoretically, meet increased energy demands by increasing their food intake, ability to ingest additional forage diminishes radically once the rumen reaches threshold capacity (Annan et al. 1973). Food intake and passage rates remain about the same whether foods are high or low in fiber (Nagy 1974). This becomes a problem in winter, when most of the forage utilized by wild ungulates is both high in fiber and low in digestibility. Short (1966) believed that white-tailed deer may at times be unable to metabolize browse rapidly enough to supply energy sufficient to maintain body temperature in cold weather.

PHOSPHORUS REQUIREMENTS

Winter phosphorus deficiencies reported from many western ranges may explain low fawn survival and production on these areas. Most grasses and even many shrubs do not maintain adequate phosphorus levels on fall and winter ranges, and game species rely even more heavily on those that do. Range managers should consider the role of plants which maintain adequate phosphorus levels when formulating management plans for winter ranges (Dietz 1965).

Other dietary components and requirements are listed and discussed in the appendix.

FACTORS AFFECTING FORAGE NUTRITIONAL VALUE AND QUALITY

Many factors influence the nutritive value of range forages, and often show complex interrelationships which may vary considerably from place to place.

Seasonal Changes in Forage Plants

The stage of maturity appears to be the most important factor affecting the chemical composition and digestibility of range forage plants. During early growth stages, nearly all forages are very succulent and have greatly enhanced palatability. Additionally, the ratio of protein to fiber content is highest in spring, offering greater nutritional value at this time (Olberg 1956).

In general, protein and phosphorus reach their highest levels during spring growth stages and decline through summer months and into the fall. These nutrients are at their lowest from late fall through winter, until growth begins again. These changes usually take place more rapidly in forbs and grasses than in browse plants due to their short life cycles as well as to the desiccating effect of the summer climate. The period of highest nutritive value of forbs and grasses is restricted to early parts of the growing season, although a few grasses retain their nutritive value after maturity (Olberg 1956, Dietz 1965, Dietz et al. 1958). Big sagebrush retains its foliage throughout the year and also shows relatively high late fall and winter protein levels; this species may provide critical sources of protein for overwintering game animals (Dietz et al. 1958). Aspen leaves also retain higher protein and fat levels than many plants, into late autumn (Tew 1970).

Fiber, lignin and calcium levels usually change in reverse of those of protein and phosphorus, increasing as the season advances, due to the greater amount of cellular material incorporating these substances. Digestibility decreases as lignin and fiber increase because of the resistance of these materials to digestion in the rumen (Olberg 1956).

Migration

Animal migration as it influences big game ungulate forage requirements is itself affected by several abiotic factors resulting from the encroachment of civilization upon wildlife habitat. These encroachments include urban development, highways, and water impoundments; their effects on animal migration are discussed in the appropriate sections of this report.

Livestock Grazing

The effect of livestock grazing is a controversial subject, inherently too complex to permit generalized conclusions. For any given situation, the influence of livestock grazing on big game habitat depends on the feeding behavior of the species involved, stocking rates, the plant community and season during which grazing occurs.

There is no doubt that excessive grazing may cause damage both to wildlife habitat and big game populations. Heavy grazing pressure in the late
Nineteenth and early Twentieth Centuries brought about loss of habitat for bighorn sheep, elk and pronghorn populations in the West. Even though successional changes caused by grazing ultimately benefited some deer and elk populations, they appear to have eliminated bighorn sheep and pronghorn from much of these species' former ranges (Wolfe 1978).

However, grazing has much potential as a tool for management of wildlife habitats. Properly regulated with respect to timing and intensity, grazing may be used to maintain a particular plant community or to produce desired successional changes. The deliberate application of forage consumption by one species of domestic herbivore may serve to modify competition of the plants of a given community, and thereby enhance production of species preferred by wild ungulates. To be successful, this must utilize stocking rates such that domestic grazers forage on their preferred food, and that timing and duration of grazing be applied at proper plant growth stages to effect the desired changes in the plant community (Wolfe 1978).

Smith and Duell (1968) and Jensen et al. (1972) showed that spring livestock grazing by sheep and cattle on deer-elk winter ranges composed mostly of bitterbrush (Purshia tridentata) did not cause significant competition with big game for forage as long as grazing was restricted to the early spring season before rapid shrub growth began. Actually, removal of herbaceous vegetation from around the bitterbrush by grazing livestock had the effect of increasing browse production for winter use by big game by making more moisture available to the bitterbrush.

Proper use of grazing animals to manipulate habitat for big game is an effective and sound management tool, often less expensive than the mechanical means which might otherwise be used to achieve the same goal.

**Grazing Intensity**

Cook et al. (1948) showed that increasing range utilization by domestic sheep resulting in increasing lignin content and decreasing metabolizable energy, protein, cellulose and phosphorus. Because grazing animals normally consume the most palatable parts of range plants first—the leaves and tender stems—they remove relatively more nutritious than non-nutritive elements of the plant (Dina and Klickoff 1973), reduce the photosynthetic area of the plant and upset the root-shoot balance (Cook et al. 1948). Gelberg (1956) stated that as a general rule, browse plants and perennial grasses withstand grazing better than forbs; excessive grazing most seriously effects the most palatable species.

Nevertheless, clipping of range plants by grazing animals, if not too extensive or severe, may actually increase the nutritional value of forage. Removal of herbage through grazing or clipping interrupts plant development, prevents maturity, and prolongs growth or initiates regrowth (Laycock and Price 1970).

Soil moisture levels on semiarid ranges may prevent the increased protein content of plants possible in areas of higher moisture regimes through decreased herbage production (Laycock and Price 1970).

Grazing intensity on a given range should be structured to remove the optimum amount of forage without damaging the area through removal of excessive amounts of nutrients.

**Fire**

Controlled burning may be utilized under certain conditions to increase nutritive value of forage plants or to change the composition of shrub stands (Schmautz 1970). Lyon and Stickney (1966) identified four conditions which should exist before prescribed burning can be used effectively:

1. Shrubs should have high crown volumes. High crown volumes indicate greater current production and more rapid potential recovery rates.

2. Species present on the shrub stand should have known palatability to big game species. They should also possess high sprouting vigor following burning.

3. Sometimes soil samples will show the presence of stored seeds of more desirable forage species than are currently present on the stand, especially when unpalatable species occur and/or crown volume is low.

4. Potential erodibility of the soil must be known to prevent soil loss following fire. In cases where erosion potential is great, more care must be exercised in planning the burn.

Prescribed burning can result in temporary increases in the nutritive values of some forage plants (Dietz 1965, DaWitt and Derby 1955, Lav 1957, Schmautz 1970). However, sites should be studied carefully beforehand with respect to the conditions presented above, and thought should be given to the response of forage plants to different fire intensities at different times of the year and with varied frequencies of application (Schmautz 1970).

**Fertilization**

Because the amounts applied can be measured and controlled, fertilizers have often been used to improve forage quality. They may effect changes in both quality and quantity of forage, but as with other factors, their influence varies with soils, climate, growth habits and stages of plants, sampling methods, and fertilizer type and rate of application (Duncan and Hylton 1970).

Nitrogen fertilization often increases the percentage and total yield of plant protein and is used more than any other technique to improve forage quality. Many studies of nitrogen-fertilizer methods document increased forage succulence and extended periods of green growth as well as increased protein contents (Clark and Tisdale 1945, Smolik 1965, Hall 1963, Lavin 1967, Fisher and Caldwell 1959, McKell et al. 1960). On semiarid ranges, nitrogen fertilization works best when coupled with adequate soil moisture levels; in Arizona Stroehlein et al. (1966) found that extensions of the
green feed period, protein levels and production increased the most when fertilization was initiated after the onset of summer rains. But even while nitrogen fertilization in semiarid areas improved forage quality, forage yield may not increase. Under humid conditions, the addition of potassium to nitrogen may increase forage yield and total protein yield, although the percentage of protein may decrease due to increases in plant growth (Teit 1962, Duell 1965, Vincent-Chandler et al. 1967).

Fertilizers other than nitrogen seem to have little effect on the quality of grass herbage on the plains and mountains of the United States (Cook 1965, Hull 1963, Lavin 1967, Duncan and Hylton 1970).

Fertilization of rangeland with nitrogen, phosphorus, potassium and sulfur alone or in combination has served to achieve vegetational composition of shrub components of plant communities through fertilization. Soil Influences

Heady (1964) cited a number of studies which demonstrated that plants of the same species grown on different soils often differed in chemical composition. This rather straightforward observation is complicated by the introduction of climatic factors to the environment, which may alter plant physiological processes to the point that plants grown on identical soils also show differing chemical composition (Beeson 1941).

Many edaphic factors influence plant growth, among them soil moisture, acidity, texture, porosity and nutrient content. It is often difficult or impossible to isolate the effects of a single characteristic on plant growth over a wide geographical range owing to the impossibility of controlling other factors.

Soil moisture affects growth and composition of plants but its effects are confused by the interaction of temperature, stage of plant maturity and other factors. Droughts which cause early drying and subsequent maturity of plants hasten the normal progression of chemical changes in plants discussed earlier (Laycock and Price 1970).

Certain shrubs, however, seem to be less affected by droughts possibly due to their deeper and more extensive root systems which minimize the adverse effects of low soil moisture (Oelberg 1956). Dina and Klickoff (1973) reported changes in carbohydrates in moisture-stressed big sagebrush. Under moisture stress, starch content remained basically unchanged, but sugar levels in leaves, stems and roots increased. Leaf moisture content decreased significantly; the nitrogen lost from leaves accumulated in stems. Stems and twigs thus form important reserve storage sites for carbohydrates and nitrogen, at least in big sagebrush (Coyne and Cook 1970), and overgrazing during summer drought conditions could adversely affect forage quality by removing reserve nitrogen and carbohydrate from the range (Dina and Klickoff 1973).

Soil acidity may develop indirectly as a function of the parent material, and with soil texture, can influence chemical composition of forage plants. Both factors interact with soil moisture content. Finer soils have high nutrient-exchange capacities and hold more water, but little agreement exists among studies comparing chemical composition of plants and soils of different textures (Laycock and Price 1970). Oelberg (1956) stated that poorly aerated soils limit the absorption of growth elements, especially phosphorus. Soil acidity further affects the nutrient content of plants to assimilate soil nutrients. Below pH 6, phosphorus reacts with hydrous oxides of magnesium and water to form insoluble compounds unavailable to plants; phosphorus is most readily absorbed between pH 6 and pH 7. Above pH 7 phosphorus again becomes insoluble as calcium phosphate (Oelberg 1956).

Although Megedy (1973) concluded that abundant plant nutrients in soil appear in the chemical composition of plants grown in that soil, this relationship cannot be applied to all species of plants or all soil types (Laycock and Price 1970). The effects of the nutritive values of the soil may be modified by such factors as interspecies competition, light and soil moisture levels (Cook and Harris 1950), and the genetic makeup of plants, which may prevent them from reflecting increased soil nutrient levels in their own chemical makeup (Daniel and Harper 1954).

Weather and Climate Effects

Climatic factors affect plant respiration, assimilation, photosynthesis and metabolism; they may strongly modify the mineral and organic matter content of plants in different areas even when these plants grow in similar soils (Oelberg 1956).

Rainfall, as it influences soil moisture available for growth, tends to bring about increases in plant nitrogen, phosphorus and soluble fat levels, and may decrease calcium levels as well (Oelberg 1956). But at the same time, exposure to rain causes leaching of nutrients in mature herbaceous plants, and frequently results in large decreases in levels of protein, phosphorus and carotene (Gulibert et al. 1931). Since cellulose and lignin are insoluble in water, they are not leached but in percentage as leaching progresses, resulting in lowered plant palatability and digestibility (Gulibert et al. 1931). Not all species show identical responses to leaching; some plants lose few nutrients while others display significant losses (Watkins 1943, Savage and Helder 1947, Laycock and Price 1970). Leaching of nutrients from actively growing herbaceous plants through the action of rain and dew can also be significant. As many as 15 elements and inorganic compounds, 8 carbohydrates, 23 amino acids, and 15 organic acids have been identified from plant leachates. Many of these are important to plant growth and animal nutrition. Because these compounds are leached from plants under field conditions, the chemical composition of plants grown indoors cannot be considered representative of the chemical composition of identical species grown in the field (Laycock and Price 1970).

Temperature conditions influence rate of development and yield of plants, but effects of temperature may be confused with moisture and other conditions (Laycock and Price 1970). Several investigators have reported increases in protein content of foliage as air or soil temperatures approach 80°F (27°C) (Bowman and Law 1966, Nielsen et al. 1960). Some of these increases are attributable to phenological changes in plants.
Soil temperature increases also may cause increased phosphorus levels in some plants (Nielson et al. 1960, Laycock and Price 1970). Other nutrients vary considerably in response to temperature changes (Laycock and Price 1970). As temperatures decrease, they initiate the transformation of starches into sugars used in plant metabolism (Olberg 1956).

Lack of adequate light affects plants in several ways, mostly indirect. In general, plants grown in shaded areas display less herbage production (Cooper 1960, Van Dyne and Ready 1965a), lower percentages of total carbohydrates (Watkins 1940), and greater amounts of lignin (Van Dyne and Ready 1965b) and protein (McIwen and Dietz 1965). Since soil moisture is often higher in shaded areas (Cook and Harris 1950b) and stage of development is retarded (McIwen and Dietz 1965), shaded plants often remain succulent longer into the summer. Reduced leaching through interception of rain by overstory plants may bring about higher nutritive values in shaded plants (Laycock and Price 1970). While low light levels may reduce production in some species (Leopold 1964), they probably do not greatly affect shade-tolerant species (Laycock and Price 1970).

The interrelationship of light intensity, carbon dioxide levels and precipitation occurring as a result of altitudinal changes influences plant compositions (Olberg 1956); nutritive value (Roberts 1926) as well as nitrogen and phosphorus content (McCreary 1927) of plants grown at higher elevations seem to be greater than that of plants grown at lower elevations, while crude fiber is decreased at higher altitudes.

Urban Expansion

The trend toward urban sprawl resulting from the continuing movement of human populations into urban centers has in recent years resulted in major and minor losses of big game habitat. In mountainous subdivisions and even entire cities are located in foothill and valley areas that formerly provided crucial wintering ranges more free of excessive snow deposits than higher elevations. The inevitable result of urban growth, may inflict further losses on local ungulate populations, especially deer (Wolfe 1978).

Fences

An increase in fencing on both public and private lands in the West has resulted from the gradual transition from sheep to cattle ranching. Where herders previously tended sheep on both winter and summer ranges, the increased cost of using herders, the greater ratio of cattle to sheep on open range, and the implementation of rest-rotation system for grazing lands have all led to greater use of fences to control livestock (Wolfe 1978). The use of fences to control trespass is also an important factor (May 1968).

Most big game animals can readily clear livestock fences; some mortalities occur when animals become tangled in fence wire. Pronghorn in particular are affected by fences. Poor jumpers, they can pass under properly constructed barbed wire fences used to control cattle, but are totally unable to negotiate woven wire fences used for sheep. Where such fences enclose pronghorn herds during severe winters, many animals may starve to death (Wolfe 1978). See Yoakum (1980: 55-63) for current recommendations for fencing which allow antelope mobility.

Highways and Transportation Systems

The proliferation of vehicular transportation systems during the Twentieth Century has had major impacts, both direct and indirect, on big game populations. While highways and highway construction destroy some big game habitat, this loss is minor when compared to the effects of transportation corridors in isolating otherwise contiguous habitats, in providing more ready access to remote natural areas by recreationists, and in disrupting migration routes. These are the major effects of the highways themselves in influencing animal movements and food-gathering (Wolfe 1978). Of further concern is the effect of burgeoning numbers of off-road vehicles (ORV's) on wildlife populations. Increased disturbance and potential displacement of animals from areas subjected to heavy ORV use is most critical at two times of the year—during calving and in winter—both times when depletion of critical energy reserves can cause some animals to be under most stress. These disturbances can also displace animals from areas of critical shelter and food resources. The long-term use of ORV's can further degrade habitat through soil and snow compaction, erosion, destruction of vegetation, and change of species composition (Dorrance et al. 1975, Wolfe 1978).

Water Impoundments

Large-scale water impoundments have inundated large areas of big game habitat. Martin and Hanson (1966) documented more than 1500 large reservoirs in the United States with a total impoundment area of nearly 6 million hectares (15 million acres). The detrimental effects of these reservoirs extend beyond the areas actually flooded. As with highways, large reservoirs may disrupt big game migration patterns and isolate otherwise suitable habitat. Where critical winter range of migratory populations is impounded, the total effective loss of habitat may far exceed that of the area submerged (Wolfe 1978).

FORAGE INTAKE

Because of the increasing need to apportion shrinking rangeland between livestock and big game, range managers have shown greater interest in the forage intake rates of both domestic and wild ungulates. While many intake studies have been completed for domestic sheep and cattle, there remains virtually no data base for determining wild ungulate forage intake requirements, on a seasonal basis, for the widely varying range conditions of the western United States. The few studies attempting to describe big game intake values have arrived at their conclusions through inference or by undertaking conventional feeding trials of penned animals; virtually no true grazing studies have been employed to describe forage intake rates for the species being treated in this report. When one considers the great expense and difficulty of compiling a valid data base under field conditions for even one wild game species grazing a single vegetation type for an entire year, and then expands the difficulties encountered there to include all wild ungulates under all possible conditions in the great variety of

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While information on forage requirements (quantitative) may be of widespread interest, I personally have considerable doubt as to the value or use of such information in management. After more than 20 years of research on deer and deer-habitat relations, I fail to see how any system of management based on forage allocations could possibly work. Indeed, the results of our efforts would indicate that forage quantity and quality are but two of many habitat/environmental factors that determine the abundance, distribution and dynamics of deer, elk and other wild ungulates. Moreover, I doubt very much that the total quantity of forage available has often or widely been, by itself, the factor limiting deer or elk numbers.

There is obviously some disagreement with this position within the wildlife management community, although it is true that the use, as a management tool, of only the qualitative or quantitative forage needs of wild ungulates without consideration to other regulating factors would be both inadequate and improper, especially given today's poor understanding of wildlife nutrition.

Forage Intake studies completed to date show some serious drawbacks. Virtually none has attempted to measure intake on a seasonal basis. In feeding trial studies conducted with penned animals, consideration has usually not been given to the influences of temperature, photoperiod, climate or the added energy needs of maintenance and growth under natural conditions. These studies have been compiled over a number of years, and investigators have used widely differing methods to arrive at their conclusions. Thus studies completed to date have little comparative value. In most cases consideration was not given to environmental conditions, physiological development of the forage plant species, physiological condition, sex or age of the subject animals, and in a few cases, even the weights of the animals being studied. All the above factors need to be incorporated into standardized investigative methods which can then be applied in ways which will help researchers achieve the data base they need in order to make valid range management decisions.

FACTORS INFLUENCING FORAGE INTAKE

Palatability

Palatability may be defined as the plant characteristics which affect or stimulate a given response by a feeding animal when a choice between plants exists (Young 1948, Cowlishaw and Alder 1960, Heady 1975, Dietz 1970, Longhurst et al. 1968). Palatability may rank equally in importance with intake rates and nutritive value of forages since it directly affects the rate and total intake of forage (Hurd and Blaser 1962).
Forage preference ratings have traditionally been used as a management tool to increase or sustain big game herds through the use of large-scale plantings of "preferred" forage species (Yoakum and Dasmann 1969). Nudds (1980) disputes this use of preference values, and suggests that preference data may depend on the method and season of data collection as well as on the statistical used to quantify preference. He states that deer, and probably other temperate-latitude ungulates as well, function as habitat specialists that remain diet generalists in winter, when energy is more cheaply available but food resources are less costly to remain under shelter in fasting conditions than to forage in exposed areas to harsh weather (Kearnley and Gilbert 1976). When resource levels are high, deer can afford to be selective, but at low food levels energy becomes the primary factor upon which diet is optimized. Nudds concludes that manipulating winter habitat by increasing densities of forage plants with high preference values is unwarranted when the "preferred" designation is an artifact of experimental design or data analysis. In such cases, management efforts should be directed toward providing an acceptable interspersal of food and shelter in winter habitats (Nudds 1980).

**Digestibility**

It is important to keep in mind that the ruminant animal obtains most of its nutrients from the digestive activities of its billions of symbiont rumen microorganisms; therefore factors which can influence these microbe populations ultimately determine the fate of the animal itself.

Rumen microorganism populations do not remain static, but change throughout the lifetime of the animal in response to various factors, some of which act directly on the animal and indirectly influence rumen microbes, and others which act directly on the rumen environment and thereby influence rumen microorganism populations. Certainly man's influence has been an important factor in directly affecting North American wild ungulates through changes in ecological distributions of elk, pronghorns and bighorns, which exposed them to different climatic regimes and changed the availability of primary plant species utilized as food (Nagy 1970).

The diet itself largely determines environmental conditions in the rumen, including available nutrients, rumen pH, and the concentration of end-products in the rumen. As rumen microbes digest food items, they produce short-chain fatty acids and other end-products which are utilized either by other microorganisms or by the host animal. The ratios of the short-chain fatty acids produced varies with diet, and as they vary they alter the rumen fermentation, changing pH and other factors, which in turn influence the types and numbers of rumen microorganisms present. Diets high in roughage produce rumen ingesta of nearly neutral pH; then the number of cellulose-producing bacteria will be high. Diets high in concentrate and low in roughage cause low rumen pH and decrease the numbers of cellulytic microbes. A rapid change in diet from high roughage to high concentrate—one containing large amounts of starches and sugars—can cause such a great increase in lactose-fermenting bacteria that they will become dominant and upset the normal balance of rumen microbes. The pH of the rumen will drop due to the large amount of lactic acid produced, and the animal may literally die of acid indigestion (Nagy 1970). This may happen when wintering animals are provided with food concentrates as emergency dietary supplements.

**Antimicrobial substances** may also upset the balance of rumen microorganism populations. In nature, these substances exist as volatile oils which occur in varying concentrations in such forage plants as pines, junipers and sagebrush. They can kill or inhibit the functions of a variety of rumen microbes (Nagy et al. 1964, Oh et al. 1968, Nagy 1970). Longhurst et al. (1968) and Oh et al. (1968) have demonstrated that plant species having substances with the most effective antimicrobial actions are the least palatable to deer. Nevertheless deer, and presumably other ruminants, may consume plants containing toxic volatile oils with no ill effects so long as their diet contains other foods as well. But if only sagebrush flow in the animal will be seriously impaired (Nagy and Tengderly 1968).

During winter months under starvation conditions, the rate of removal of microbes from the rumen becomes an important digestive factor. Some species of microbes may temporarily disappear from the rumen after only two days of starvation, causing decreased rates of digestion of sugars and cellulose. Nesbitt et al. (1958) state that as little as three or four days of starvation can completely remove some species from the rumen, and a new source of infection is needed for reestablishment of the species. Protozoa show greater susceptibility to such decreases than do bacteria. If the functional population of rumen microbes is lost through starvation or through acid indigestion or inhibition by antimicrobial compounds, the animal often stops taking in food. Even if food is ingested, no digestion can take place and the animal dies (Nagy 1970).

As fiber content of the diet increases, either in winter or on poor quality range, food stays in the rumen longer because of the prolonged digestion times required for cellulose and lignin. Lowered rates of digestion due to this phenomenon cause lower rates of passage through the digestive tract and consequent lowered intake rates. The persistence of this condition, with the accompanying loss of the rumen microbe population, often leads to a point of no return, where the animal dies even if food is available (Nagy 1970).

**Seasonal Factors**

Many investigators have observed a marked drop in forage consumption by deer which begins in autumn and continues through winter; the trend reverses at the onset of spring. Males display greater reductions in intake than do females (Boen 1973, 1978).

Nordan et al. (1968), working with black-tailed deer, observed a very obvious decline in food intake which began with the onset of rutting behavior. Males on a high nutritional plane lost up to 35 percent of their body weight during the rutting season, and refused food completely for as long as sixty days. Females also displayed this pattern, but to a lesser degree than males. Even male deer on low planes of nutrition did not increase their food intake when put on an ad libitum diet during rutting season, but continued to show feeding behavior characteristic of the rut.

Sexually immature animals do not always display a marked decrease in food intake or weight during rutting season. This indicates that food intake and weight loss, at least in deer, vary seasonally and with the age and...
sexual maturity of the animal. Therefore, winter weight loss is more than a function of stress and likely involves the endocrine system of the animal. More experimental work in this area is needed to understand the physiological mechanisms employed in the regulation of intake and weight loss in wild ruminants (Moen 1973, 1978).

**FORAGE INTAKE RATES**

Presented below, in tabular form, are the results of forage intake studies conducted on wild western North American ungulates, by species. The reader will note the wide variability of results due to several factors. Some studies have reported intake rates as percentages of animal body weight, but failed to present the forage weights themselves or the body weights, ages and sexes of the animals used in the study. Others have not provided adequate reference to season or range type in which the work was carried out. Some papers report deaths of experimental animals, missed sampling periods or other failures during the course of the study. Some workers used inconsistent forage samples for different aspects of their research programs. Forage ingestion rates themselves have been reported as organic matter intake, dry matter intake, digestible organic matter intake, percentage of body weight, unit of weight per animal per day, or percentage of metabolic body weight. These variables make valid comparisons of the statistics between studies impossible. The tables below present as much information as possible from the studies available, but it will be apparent that wide gaps exist in our knowledge of forage intake rates by wild ungulates. No intake data appears in the literature for barbary sheep, Rocky Mountain goat, desert bighorn, Tule elk or Roosevelt elk. Use great caution in applying the figures from any intake studies listed to other species or localities.

It is unfortunate, but most forage intake studies have been quite vague with respect to details of diet on open range. This is reflected under the heading "Diet" in Tables 1-7. Where diet is given as "native forage," a reference to the original paper may lead one to major dietary components by inference from the geographical location of the study area, but for other studies information on diet is simply inadequate.

For those wishing to calculate forage intake rates where studies have not been completed, the following equation may be used as a rule of thumb for determining daily dry matter intake for ruminants:

\[ I = 0.11 \times (W^{0.75}) \]

where

- \( I \) = dry matter intake in kg/day
- \( W \) = live body weight in kg of the subject animal

This equation is based on Kleiber's standard value for basal metabolic rates for ruminants of 70 kcal/day (kg^{0.75}) (Hansen et al. 1975). **NOTE** that this equation describes intake rates under fasting conditions; forage intake would have to be increased over the results obtained from the above equation.

W. G. Hepworth (1981, personal communication) recommends using a dry food intake rate of 3 to 3.5 percent of live body weight for maintenance where forage contains adequate nutrient levels. During certain periods of growth, lactation and gestation, and during times of lush, green forage growth, dry matter intake could rise to four to six percent of live body weight.

Hepworth further maintains that forage allocations based solely on intake figures bear little resemblance to reality without considering food habits and feeding behavior. Stocking rates cannot be based simply on weight of forage intake; dietary overlap between species precludes using straight weight conversion factors to determine range use by animals. Differing habitat preferences among species further confounds the use of conversion factors based on body weight and intake rates, which may be validly applied only to monocultures on flat land lacking escape cover of any kind. Realistic forage allocation processes should include data on food habits, feeding behavior, and diet overlap between species, relating them to the vegetative components and their availability in the area in question (Hepworth 1981).
Table la. FORAGE INTAKE REQUIREMENTS FOR MULE DEER (*Odocoileus hemionus*)

<table>
<thead>
<tr>
<th>Location</th>
<th>Season</th>
<th>Diet</th>
<th>Age Class</th>
<th>Body Weight</th>
<th>Forage Intake Per Animal Per Day</th>
<th>Remarks</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nichole 1938</td>
</tr>
<tr>
<td>Utah</td>
<td>Winter</td>
<td>Whole barley &amp; alfalfa hay</td>
<td>Adult</td>
<td>135 61.2</td>
<td>4.8 2.2 3.6</td>
<td>Year-round average for all age and sex classes</td>
<td>Doman and Rasmussen 1944</td>
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<tr>
<td>Utah</td>
<td>Winter</td>
<td>Alfalfa hay</td>
<td>Adult</td>
<td>135 61.2</td>
<td>3.4 1.5 2.5</td>
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<td></td>
</tr>
<tr>
<td>Utah</td>
<td>Winter</td>
<td>Whole barley &amp; alfalfa hay</td>
<td>Adult</td>
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<td>4.8 2.2 3.6</td>
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<tr>
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<td>Yearling</td>
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<td>Smith 1953</td>
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<td>5/31-6/20</td>
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<td>&quot;</td>
<td></td>
<td>3.32</td>
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<tr>
<td></td>
<td>6/20-7/11</td>
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<td>&quot;</td>
<td></td>
<td>3.43</td>
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<td>7/12-8/1</td>
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<td>&quot;</td>
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<td>2.71</td>
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<td>8/1-8/22</td>
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<td>&quot;</td>
<td></td>
<td>3.05</td>
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<tr>
<td></td>
<td>8/22-9/11</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9/13-9/30</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>3.85</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>5/31-6/20</td>
<td>&quot;</td>
<td>2 yrs.</td>
<td></td>
<td>3.65</td>
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<td>6/21-7/11</td>
<td>&quot;</td>
<td>&quot;</td>
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<td>4.47</td>
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<td>7/12-8/1</td>
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<td></td>
<td>3.5</td>
<td></td>
<td></td>
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<tr>
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<td>3.97</td>
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<tr>
<td></td>
<td>9/13-9/30</td>
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<td>&quot;</td>
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<td>3.42</td>
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Table 1b. FORAGE INTAKE REQUIREMENTS FOR MULE DEER (*Odocoileus hemionus*)

<table>
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<th>Location</th>
<th>Season</th>
<th>Diet</th>
<th>Age Class</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Remarks</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Alfalfa hay &amp; oats</td>
<td>Male fawn</td>
<td>50</td>
<td>22.5</td>
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<td>2.2</td>
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<td></td>
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<td>.76</td>
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<tr>
<td></td>
<td></td>
<td>Male fawn</td>
<td>76</td>
<td>34.2</td>
<td>1.9</td>
<td>.86</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Adult</td>
<td>102</td>
<td>45.9</td>
<td>1.8</td>
<td>.81</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
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<td>Male fawn</td>
<td>56</td>
<td>25.2</td>
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<td>.72</td>
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<td></td>
<td>Female</td>
<td>Adult</td>
<td>103.5</td>
<td>46.6</td>
<td>1.9</td>
<td>.89</td>
<td>1.9</td>
</tr>
<tr>
<td>Utah</td>
<td>Winter</td>
<td>Sagebrush</td>
<td>Adult</td>
<td>0.42</td>
<td>.34</td>
<td>lb. TDN/CWT</td>
<td>penned deer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Juniper</td>
<td>&quot;</td>
<td>0.78</td>
<td>.51</td>
<td>lb. TDN/CWT</td>
<td>penned deer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oak</td>
<td>&quot;</td>
<td>2.25</td>
<td>.86</td>
<td>lb. TDN/CWT</td>
<td>penned deer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sage &amp; juniper</td>
<td>&quot;</td>
<td>1.23</td>
<td>.81</td>
<td>lb. TDN/CWT</td>
<td>penned deer</td>
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<td></td>
<td></td>
<td>Sage &amp; oak</td>
<td>&quot;</td>
<td>2.20</td>
<td>.79</td>
<td>lb. TDN/CWT</td>
<td>penned deer</td>
</tr>
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<td>Location</td>
<td>Season</td>
<td>Diet</td>
<td>Age Class</td>
<td>Body Weight Lb. Kg.</td>
<td>Forage Intake Per Animal Per Day Lb. Kg. % Body Weight</td>
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<td>Source</td>
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<td>-----------</td>
<td>---------------------</td>
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</tr>
<tr>
<td>Utah</td>
<td>Winter</td>
<td>Juniper &amp; oak</td>
<td>Adult</td>
<td>1.43 .55</td>
<td>.55 lb.TDN/CWT - penned deer</td>
<td></td>
<td>Smith 1959</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Juniper, Oak, &amp; sage</td>
<td>&quot;</td>
<td>2.73 .99</td>
<td>.99 lb. TDN/CWT - penned deer</td>
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<td></td>
</tr>
<tr>
<td>Cache La</td>
<td></td>
<td>Sagebrush &amp; alfalfa mix</td>
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<td>1.66</td>
<td></td>
<td></td>
<td>Dietz et al.</td>
</tr>
<tr>
<td>Poudre Drainage, Colorado</td>
<td></td>
<td>Alfalfa</td>
<td></td>
<td>2.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mountain mahogany</td>
<td></td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bitterbrush</td>
<td></td>
<td>1.85</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Colorado</td>
<td></td>
<td>Alfalfa hay</td>
<td>Adult</td>
<td>135 61.2</td>
<td>2.7 1.2 2.0</td>
<td>Good quality feed - Nagy et al. caged deer</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Alfalfa hay</td>
<td></td>
<td>135 61.2</td>
<td>.7 0.3 0.5</td>
<td>Poor quality feed - caged deer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Native hay</td>
<td></td>
<td>135 61.2</td>
<td>.6 0.3 0.4</td>
<td>Poor quality feed - caged deer</td>
<td></td>
</tr>
<tr>
<td>Arizona</td>
<td>Winter</td>
<td>Utah juniper type</td>
<td></td>
<td>2.3 1.05</td>
<td></td>
<td>Intake weights estimated from bite-</td>
<td>Neff 1974</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>count studies on tame deer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring</td>
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<td></td>
<td>2.3 1.05</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td></td>
<td></td>
<td>1.1 .52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td></td>
<td></td>
<td>1.0 .46</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Spring</td>
<td></td>
<td></td>
<td>1.9 .85</td>
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### Table 1d. FORAGE INTAKE REQUIREMENTS FOR MULE DEER (*Odocoileus hemionus*)

<table>
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<tr>
<th>Location</th>
<th>Season</th>
<th>Diet</th>
<th>Age Class</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Forage Intake Per Animal Per Day</th>
<th>Remarks</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>Summer</td>
<td>Utah juniper type</td>
<td></td>
<td>1.8 0.83</td>
<td></td>
<td>0.6 0.26</td>
<td></td>
<td>Neff 1974</td>
</tr>
<tr>
<td></td>
<td>Fall</td>
<td></td>
<td></td>
<td>0.6 0.26</td>
<td></td>
<td>0.6 0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td></td>
<td></td>
<td>0.6 0.27</td>
<td></td>
<td>0.6 0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td></td>
<td></td>
<td>1.8 1.83</td>
<td></td>
<td>1.8 1.83</td>
<td></td>
<td></td>
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<td></td>
<td>Summer</td>
<td></td>
<td></td>
<td>12.4 5.66</td>
<td></td>
<td>12.4 5.66</td>
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<td></td>
</tr>
<tr>
<td>Cache La Poudre</td>
<td>Native forage</td>
<td>1-5 mos. 76.6 34.8</td>
<td>male</td>
<td>3.28 1.49</td>
<td>4.3</td>
<td>3.28 1.49</td>
<td>Forage intake rates estimated with fallout Cesium-137</td>
<td>Allredge et al. 1974</td>
</tr>
<tr>
<td>Drainage, Colorado</td>
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<td>1-5 mos. 75.7 34.4</td>
<td>female</td>
<td>2.27 1.03</td>
<td>3.0</td>
<td>2.27 1.03</td>
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<tr>
<td></td>
<td></td>
<td>6-11 mos. 73.3 33.3</td>
<td>male</td>
<td>2.42 1.10</td>
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<td>2.42 1.10</td>
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<tr>
<td></td>
<td></td>
<td>6-11 mos. 70.6 32.1</td>
<td>female</td>
<td>2.27 1.03</td>
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<td>2.27 1.03</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>12-17 mos. 119.0 54.1</td>
<td>male</td>
<td>3.97 1.76</td>
<td>3.3</td>
<td>3.97 1.76</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>12-17 mos. 103.6 47.1</td>
<td>female</td>
<td>3.52 1.32</td>
<td>2.8</td>
<td>3.52 1.32</td>
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<td></td>
<td></td>
<td>18+ mos. 160.4 72.9</td>
<td>male</td>
<td>2.73 1.24</td>
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<td>2.73 1.24</td>
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<td></td>
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<td>18+ mos. 130.7 59.4</td>
<td>female</td>
<td>3.33 1.13</td>
<td>1.9</td>
<td>3.33 1.13</td>
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Table 1e. FORAGE INTAKE REQUIREMENTS FOR MULE DEER (*Odocoileus hemionus*)

<table>
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<th>Location</th>
<th>Season</th>
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<th>Age Class</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Remarks</th>
<th>Source</th>
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<tbody>
<tr>
<td>Cache La.</td>
<td>Summer</td>
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<td></td>
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<td>Poudre</td>
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<td>Female</td>
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<td>2.5</td>
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<td>Drainage,</td>
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<td>3.1</td>
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<td>Colorado</td>
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<td>2.1</td>
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</tr>
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<td>Female</td>
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<td>2.0</td>
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</tr>
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<td>Adult</td>
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<td>Colorado</td>
<td>Native Forage</td>
<td>Adult</td>
<td></td>
<td>135</td>
<td>61.2</td>
<td>2.4 1.1 1.8</td>
<td>Carpenter and Baker 1975</td>
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<td>Middle Park,</td>
<td>Summer</td>
<td>Native Forage</td>
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<td>Intake rates estimated using</td>
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<td>Female</td>
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<td>154</td>
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<td>techniques developed by</td>
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<td></td>
<td></td>
<td>Male</td>
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<td>154</td>
<td>70</td>
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<td>Allredge et al. 1974</td>
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<td></td>
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<td>Early</td>
<td>55</td>
<td>25 1.8 0.8 3.2</td>
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<td>Winter</td>
<td>Fawn</td>
<td></td>
<td>Yearling</td>
<td>143</td>
<td>65 3.5 1.6 2.5</td>
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<td>Yearling</td>
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*Best Document Available*
Table 1f. FORAGE INTAKE REQUIREMENTS FOR MULE DEER (*Odocoileus hemionus*)

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<th>Season</th>
<th>Diet</th>
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<td>Age Class</td>
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<td>% Body Weight</td>
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<td>3.4 1.5</td>
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Table 2. FORAGE INTAKE REQUIREMENTS FOR BLACK-TAILED DEER (*Odocoileus hemionus columbianus*)

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<th>Age Class</th>
<th>Body Weight</th>
<th>% Body</th>
<th>Remarks</th>
<th>Source</th>
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<tbody>
<tr>
<td>Washington</td>
<td>Winter</td>
<td>Huckleberry, western red cedar, salal, Douglas fir, western hemlock, willow, cascara</td>
<td>Adult Male</td>
<td>2.83</td>
<td>2.88</td>
<td>Average values for penned deer</td>
<td>Brown 1961</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female</td>
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<td>Vancouver, B.C.</td>
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<td>Pelleted feed</td>
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<td>Nordan et al. 1970</td>
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<td>Fawn</td>
<td>22</td>
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Table 3a. FORAGE INTAKE REQUIREMENTS FOR ROCKY MOUNTAIN ELK (*Cervus elaphus nelsoni*)

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<th>Age Class</th>
<th>Body Weight Lb.</th>
<th>% Body Weight</th>
<th>Remarks</th>
<th>Source</th>
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<tbody>
<tr>
<td>Idaho</td>
<td>Winter</td>
<td>Grass Hay, Native Forage</td>
<td>Adult</td>
<td>400 181.4</td>
<td>10.7</td>
<td>Hungerford, 1948</td>
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<tr>
<td>Montana</td>
<td>Winter</td>
<td>Native Grass, Meadow Hay, Browse, (willow) Hay-browse mix</td>
<td>Adult</td>
<td>400 181.4</td>
<td>9.2</td>
<td>Geis, 1950</td>
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<tr>
<td>Wyoming</td>
<td>Winter</td>
<td>Grass Hay</td>
<td>Adult</td>
<td>400 181.4</td>
<td>12.5</td>
<td>Murie, 1951</td>
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<td>New Mexico</td>
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<td>Native Forage</td>
<td>Adult</td>
<td>500 225</td>
<td>9-10</td>
<td>Lang, 1958</td>
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<td>Sybille, Wyoming</td>
<td>Winter</td>
<td>Native hay</td>
<td>Adult</td>
<td>300 135</td>
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<td>Good quality, Blunt, 1962</td>
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<td>Adult</td>
<td>450 202</td>
<td>8.5</td>
<td>Feed, bare maintenance,</td>
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<td>Adult</td>
<td>600 270</td>
<td>10.5</td>
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<td>Alfalfa hay</td>
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<td>300 135</td>
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<td>450 202</td>
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<td>Adult</td>
<td>600 270</td>
<td>9.5</td>
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<td>Grass Hay, Alfalfa pellets</td>
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<td>10.0 4.5</td>
<td>2.0</td>
<td>National Elk, Frances, Wyoming</td>
<td>Robbins, 1973</td>
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<td>Forage Intake</td>
<td>Remarks</td>
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<td>Per Animal Per Day</td>
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Table 4a. FORAGE INTAKE REQUIREMENTS FOR PRONGHORN (*Antilocapra americana*)

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<th>Age Class</th>
<th>Body Weight</th>
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<td>90</td>
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<td>1.8 0.8 1.9</td>
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<td>90</td>
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<td>1.7 0.8 1.9</td>
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<td>1.32 0.61 2.8</td>
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<td>Adult</td>
<td>90</td>
<td>40.8</td>
<td>1.98 0.9 1.0</td>
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<td>90</td>
<td>40.8</td>
<td>1.8 0.8 1.9</td>
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<td>Spring and summer, moderate activity</td>
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Table 4b. FORAGE INTAKE REQUIREMENTS FOR PRONGHORN (*Antilocapra americana*)

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<th>Age Class</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Remarks</th>
<th>Source</th>
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<td>Winter</td>
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<td>2 months</td>
<td>19.6 8.9</td>
<td>0.5 0.23</td>
<td>2.6 Winter maintenance and growth</td>
<td>Barrett 1974</td>
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<td>Spring, summer</td>
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<td></td>
<td>19.6 8.9</td>
<td>0.5 0.21</td>
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<td>Winter</td>
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<td>0.6 0.31</td>
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<td>Spring, summer</td>
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<td>19.6 8.9</td>
<td>0.53 0.24</td>
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<td>Winter</td>
<td>Artemisia cana</td>
<td></td>
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<td></td>
<td></td>
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<td>Concentrate 8%</td>
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<td></td>
<td>4.0</td>
<td>Breeding-penned animals</td>
<td>Smith 1974</td>
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<td>3.4</td>
<td>Lactation - &quot;</td>
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<td>Gestation - &quot;</td>
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<td>Lactation - &quot;</td>
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### Table 4c. FORAGE INTAKE REQUIREMENTS FOR PRONGHORN (*Antilocapra americana*)

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<th>Diet</th>
<th>Age Class</th>
<th>Body Weight Lb. Kg.</th>
<th>Forage Intake Per Animal Per Day Kg. Lb. % Body Weight</th>
<th>Remarks</th>
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<td></td>
<td>Fawn</td>
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<td></td>
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</tr>
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<td></td>
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<td>Doe</td>
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<td></td>
<td>Buck</td>
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<td>4.2 1.9</td>
<td>BLM 1981</td>
<td>BLM Bakersfield District, Bodie-Coleville</td>
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<td></td>
<td></td>
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<td>BLM 1981</td>
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<td></td>
<td>4.3 1.9</td>
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<td>BLM Craig District, Kremmling</td>
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<td>2.5 1.1</td>
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<td></td>
<td>2.8 1.3</td>
<td>BLM Socorro District, West Socorro</td>
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<td>Wyoming</td>
<td></td>
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<td>2.5 1.1</td>
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Table 5a. FORAGE INTAKE REQUIREMENTS FOR BIGHORN SHEEP (Ovis canadensis)

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<th>Location</th>
<th>Season</th>
<th>Diet Class</th>
<th>Age Class</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Remarks</th>
<th>Source</th>
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<tbody>
<tr>
<td>Idaho</td>
<td></td>
<td></td>
<td></td>
<td>124 Lb.</td>
<td>55.8 Kg.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.9 Lb.</td>
<td>1.8 Kg.</td>
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<td></td>
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<td>East Fork Salmon River</td>
<td>Anderson and Denton 1978</td>
</tr>
<tr>
<td>Alberta, Canada</td>
<td>Oct.</td>
<td>Pelleted conc.</td>
<td>Male</td>
<td>156.2 Lb.</td>
<td>71 Kg.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>92 g Dry matter</td>
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<td></td>
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<td></td>
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<td>0.75/day</td>
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<tr>
<td></td>
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<td>&quot;</td>
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<td>76 Kg.</td>
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<tr>
<td></td>
<td>Feb.</td>
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<td>Male</td>
<td>176.0 Lb.</td>
<td>80 Kg.</td>
<td>50 &quot;</td>
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<tr>
<td></td>
<td>May</td>
<td>&quot;</td>
<td>Male</td>
<td>191.4 Lb.</td>
<td>87 Kg.</td>
<td>62 &quot;</td>
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<td></td>
<td>Oct.</td>
<td>&quot;</td>
<td>Male</td>
<td>134.2 Lb.</td>
<td>61 Kg.</td>
<td>103 &quot;</td>
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</tr>
<tr>
<td></td>
<td>Dec.</td>
<td>&quot;</td>
<td>Male</td>
<td>145.2 Lb.</td>
<td>66 Kg.</td>
<td>74 &quot;</td>
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<td>&quot;</td>
<td>Male</td>
<td>156.2 Lb.</td>
<td>71 Kg.</td>
<td>51 &quot;</td>
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<td>May</td>
<td>&quot;</td>
<td>Male</td>
<td>147.4 Lb.</td>
<td>67 Kg.</td>
<td>61 &quot;</td>
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<tr>
<td></td>
<td>Oct.</td>
<td>Female</td>
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<td>132.0 Lb.</td>
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</tr>
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<td>Dec.</td>
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<td>Female</td>
<td>143.0 Lb.</td>
<td>65 Kg.</td>
<td>66 &quot;</td>
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<td></td>
<td>Feb.</td>
<td>&quot;</td>
<td>Female</td>
<td>138.6 Lb.</td>
<td>63 Kg.</td>
<td>41 &quot;</td>
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<td>May</td>
<td>&quot;</td>
<td>Female</td>
<td>145.2 Lb.</td>
<td>66 Kg.</td>
<td>43 &quot;</td>
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<tr>
<td></td>
<td>Oct.</td>
<td>&quot;</td>
<td>Female</td>
<td>138.6 Lb.</td>
<td>63 Kg.</td>
<td>57 &quot;</td>
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</tr>
<tr>
<td></td>
<td>Dec.</td>
<td>&quot;</td>
<td>Female</td>
<td>140.8 Lb.</td>
<td>64 Kg.</td>
<td>47 &quot;</td>
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</tr>
<tr>
<td></td>
<td>Feb.</td>
<td>&quot;</td>
<td>Female</td>
<td>140.8 Lb.</td>
<td>64 Kg.</td>
<td>40 &quot;</td>
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</tr>
<tr>
<td></td>
<td>May</td>
<td>&quot;</td>
<td>Female</td>
<td>127.6 Lb.</td>
<td>58 Kg.</td>
<td>57 &quot;</td>
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### Table 5b. FORAGE INTAKE REQUIREMENTS FOR BIGHORN SHEEP (*Ovis canadensis*)

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<th>Location</th>
<th>Season</th>
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<th>Age Class</th>
<th>Body Weight Lb. Kg.</th>
<th>% Body Weight Lb. Kg.</th>
<th>Forage Intake Per Animal Per Day</th>
<th>Remarks</th>
<th>Source</th>
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<tr>
<td>Alberta, Canada</td>
<td></td>
<td>Pelleted conc.</td>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
<td>Average Daily Intake</td>
<td>Chappel and Hudson 1978</td>
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<tr>
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<td></td>
<td>Lambs</td>
<td>6.2</td>
<td>27.1</td>
<td>1.9 0.8 3.17</td>
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<td>Hepworth 1981</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Ewes</td>
<td>120.8</td>
<td>54.4</td>
<td>3.8 1.7 3.17</td>
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<td>Rams</td>
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<td>67.2</td>
<td>4.7 2.1 3.17</td>
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<td>Colorado</td>
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<td>BLM 1981</td>
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<td></td>
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<td>Bighorn</td>
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<td>4.8 2.2</td>
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<td>4.8 2.2</td>
<td>BLM Vernal District, Duchesne</td>
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<tr>
<td>Wyoming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.9 1.8</td>
<td>BLM Rawlins District, Green Mtn.</td>
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<td></td>
<td>3.9 1.8</td>
<td>BLM Worland District, Grass Cr.</td>
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### Table 6. FORAGE INTAKE REQUIREMENTS FOR MOOSE (*Alces alces*)

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<th>Age Class</th>
<th>Body Weight</th>
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<td>Kg.</td>
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<td>Summer</td>
<td>Hay</td>
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<td>Hay</td>
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<td>1.35</td>
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<td>Wyoming,</td>
<td>Summer</td>
<td>Hand-cut</td>
<td>Calf</td>
<td>413</td>
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<td>Michigan</td>
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<td>BLM Moab Dist., Price R.</td>
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<td>Winter</td>
<td>Hand-cut</td>
<td>39.6</td>
<td>18-</td>
<td>22.3</td>
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<td>10.0</td>
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<tr>
<td>Wyoming</td>
<td>Summer</td>
<td>Hand-cut</td>
<td>21.7</td>
<td>9.8</td>
<td>21.7</td>
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<td>browse</td>
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<td></td>
<td>10.0</td>
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<td>10.0</td>
<td>21.7</td>
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<td>10.0</td>
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Remarks:
- Estimate for penned animal (Palmer 1944)
- BLM Vernal Dist., Duchesne
- BLM Rawlins Dist., Green Mtn.
- BLM Rock Springs Dist., Salt Wells
- BLM Worland Dist., Grass Creek
### Table 7. FORAGE INTAKE REQUIREMENTS FOR CARIBOU/REINDEER (*Rangifer tarandus*)

<table>
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<tr>
<th>Location</th>
<th>Season</th>
<th>Diet</th>
<th>Age</th>
<th>Body Weight</th>
<th>% Body Weight</th>
<th>Forage Intake Per Animal Per Day</th>
<th>Remarks</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td>Alaska</td>
<td></td>
<td>Lichens</td>
<td></td>
<td>165 Lb.</td>
<td>75 Kg.</td>
<td>9.9 - 4.5 - 6-9.3</td>
<td>Estimate based on maintenance energy of 500 kg. cow grazing outdoors in</td>
<td>Herre</td>
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<td>15.4 - 7.0</td>
<td>winter</td>
<td>1955</td>
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<tr>
<td>Northern Canada</td>
<td></td>
<td>Lichens</td>
<td></td>
<td>165 Lb.</td>
<td>75 Kg.</td>
<td>7.7 - 3.5 - 4.6 - 9.9</td>
<td>Estimate based on maintenance energy of 500 kg. cow grazing outdoors in</td>
<td>Kelsall</td>
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<td>4.5 - 6.0</td>
<td>winter</td>
<td>1968</td>
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<tr>
<td>Canada</td>
<td>Winter</td>
<td>Native forage</td>
<td>Adult</td>
<td>154 Lb.</td>
<td>70 Kg.</td>
<td>7.9 - 3.6 - 5.1</td>
<td>Estimate based on maintenance energy of 500 kg. cow grazing outdoors in</td>
<td>McEwan</td>
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<td>3.6 - 5.1</td>
<td>winter</td>
<td>and White-head 1970</td>
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<td></td>
<td>176 Lb.</td>
<td>80 Kg.</td>
<td>2.8 - 1.3 - 1.5</td>
<td>Penned animals - maintenance requirements</td>
<td>McEwan</td>
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<td>3.1 - 1.4 - 1.6</td>
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<td>1970</td>
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<td></td>
<td></td>
<td>Adult</td>
<td>198 Lb.</td>
<td>90 Kg.</td>
<td>3.1 - 1.4 - 1.6</td>
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<td>Anaktuvuk</td>
<td>Winter</td>
<td>Lichens</td>
<td>Adult</td>
<td>165 Lb.</td>
<td>75 Kg.</td>
<td>9.9 - 4.5 - 6 - 11</td>
<td>Based on estimates using fallout Cesium-137</td>
<td>Hanson et al.</td>
</tr>
<tr>
<td>Pass, Alaska</td>
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<td></td>
<td></td>
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<td>15.4 - 7.0 - 5.0 - 6.6</td>
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<td>1975</td>
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FORAGE IMPROVEMENT

Vigorous game habitat management strategies will be necessary in the coming years to adequately address the problems of big game and live-stock production. Many techniques have been developed to modify range habitat; to discuss the specific effects of all the various habitat manipulation techniques in the many climatic, physiographic and vegetative areas of the western United States is beyond the scope of this report. It must be remembered, though, that the response of a plant community to a particular management treatment is largely site specific and that the beneficial effects obtained by a given practice in one area might not result on a site where plant species composition or growth conditions differ significantly (Wolfe 1978).

Vegetative Treatments

Treatment of vegetation to enhance range forage quality may be effected by chemical or mechanical means. Mechanical treatment usually involves costly machinery, and by itself is effective only for clearing nonsprouting species. If sprouting species are involved in the treatment area, they require companion treatment with fire, chemicals or browsing with animals (Stoddart et al. 1975).

No mechanical treatment is 100 percent effective, even though all vegetation can be removed by a buldozer blade operated below ground level. The stirring of soil and removal of competition by mechanical devices favors establishment of a new vegetative stand from seed. Valuable forage species may thus produce more forage than before, a factor of importance in areas used as big game winter range in areas of the Great Basin. In chaining operations, for example, playon and juniper are readily uprooted, but bitterbrush suffers little harm and sagebrush is only reduced, not eliminated. Both latter plants serve as important big game winter forage (Stoddart et al. 1975). Valentine (1971) presents a detailed review of mechanical control methods.

Proper timing of mechanical control methods gives best results. Sprouting shrubs show more susceptibility to mechanical control methods when at low stages in their food storage cycles and under unfavorable conditions for regrowth. Small shrubs can be controlled easiest by methods that crush the stems at times of low moisture, while trees are most easily uprooted when soil is moist. In all cases, reinvasion may increase if control is undertaken after seed formation (Stoddart et al. 1975).

Chemical control of range plants increased dramatically with the discovery of organic compounds which could be applied in spray form to large areas in order to disrupt the normal physiological processes of plants. Organic herbicides have the advantages of economy of application, lower toxicity to animals than other chemicals, selectivity, and no adverse effects on soil stability. While their effects are remarkable against many species, they prove of little value against others (Stoddart et al. 1975).

The effectiveness of herbicides depends upon their mobility within the plant. Some foliar herbicides, such as pentachlorophenol, affect only the foliage they contact; others (2,4-D, dalapon and amitrol) move through the phloem, while still others (paraquat, monuron and simazine) are transported through the xylem. Picloram moves through either xylem or phloem, depending on where it gains entry to the plant. Picloram may thus be applied to shoot tips or roots; herbicides which move through phloem cells must be applied to leaves, while those which move through xylem must be applied to roots (National Research Council 1968). Some species show greater susceptibility at some phenological stages than others, due to less rapid absorption of the herbicide at certain times. Also, the location of the herbicide may not take place at certain times due to the periodic absence of functional transporting tissues (Stoddart et al. 1975).

Selectivity is the most important single characteristic of organic herbicides, and may be achieved in different ways. Some herbicides affect only seedling plants; they may prove useful in controlling annuals in established stands of perennial grasses. Placement also influences selectivity: a root-absorbed herbicide placed on the soil surface will kill shallower rooted plants but not those rooted more deeply. Proper timing of herbicide application can also increase selectivity. But the greater tolerance of grasses than broad-leaved plants to herbicides forms the most useful selective phenomenon to the range manager. This phenomenon applies especially to foliar-applied systemic herbicides (Stoddart et al. 1975).

Prediction of results of the use of herbicides in specific cases is often impossible due to the variations in chemical and plant characteristics. Generally speaking, the more effective an herbicide is at killing an unwanted species, the greater its chances for harming a valuable species as well (Stoddart et al. 1975).

Biological agents may also be used for plant control in some instances, but so far most such projects have been too successful. Nonetheless, attempts which do succeed promise long-time effects compared to direct control methods, and may thereby prove less costly. Biological control techniques proceed by either bringing together two unfamiliar organisms, usually by the introduction of exotic species, or by artificially stimulating a native organism, by production and release. The latter method is safer but more costly, while the former is cheaper but more dangerous (Stoddart et al. 1975).

The use of a biological agent depends on two criteria. First, the agent must be specific to one host, or have a narrow range of alternate hosts. Second, alternate hosts must be neither economically important nor necessary to the stability of an ecosystem. These factors obviously permit only control or elimination of the undesired plant. Biological agents may act directly by destroying their host, or indirectly by weakening it to make it noncompetitive or allow other pathogens to attack it (Huffaker 1964).

Water Development

Lack of adequate soil moisture is the most widespread factor limiting forage production. Under conditions of high seasonal runoff or low permeability of soils to water, any mechanical modification to the range that will improve soil infiltration will improve production by reducing soil-moisture stress. Several methods have been used to effect this goal.
The technique of pitting creates small basins to hold water and reduce runoff. A pit may be constructed in established stands of vegetation or in conjunction with seeding operations. Pitting has increased rainfall penetration and forage production in some areas (Stoddart and Bennet 1972), on shortgrass prairie (Barnes 1950), and on Montana rangeland (Houston 1965).

Chiseling employs road rippers or special machines with strong teeth to break through compacted soil areas, and is used on heavy clay soils and where hardpans form beneath the soil surface. In addition to aiding moisture absorption, chiseling also may be necessary to aid in seedbed reestablishment. However, chiseling has proven ineffective unless the soil surface receives considerable disturbance (Barnes and Nelson 1945, Stoddart et al. 1975).

In the Southeast and on the Great Plains, waterspreading structures are the most beneficial of all mechanical treatments to forage production. They consist of dams and dikes which intercept surface runoff and carry the maximum land surface under the influence of dikes by locating them so that floods will intercept the greatest possible area. Miller et al. (1969) surveyed waterspreading projects in the western United States and made the following conclusions regarding the use of this technique: 1) spreaders were successful only if at least one flood per year occurred, 2) forage production suffered when water was ponded and could not drain, and 3) the moisture retention capacity of the A and B soil horizons was more important than soil texture on the amount of forage produced. Water spreading, even though it dates to prehistoric times, remains one of the most promising methods of increasing forage production in arid regions (Stoddart et al. 1975).

Contour furrows are inexpensive but effective in producing greater quantities of forage on low-value ranges. Furrows are plowed along contour lines, generally close together and not smoothed after plowing. Greater infiltration and storage rates of water may result on land contour-furrowed. Where water is ponded and does not drain, furrowing effects from those of seeding (Branson et al. 1962, Stoddart et al. 1975). Contour furrows, especially broad-based ones, are better than pitting or similar soil treatments, and results are superior to fine textured soils (Branson et al. 1962). Generally, furrows and ridges are not desirable on loose, sandy soils, on rough, broken lands, on steep slopes, or anywhere where quantities of sand or silt might accumulate in them (Stoddart et al. 1975).

Range Seeding

Several techniques have been established for use in seeding range land, but most require some form of soil preparation to reduce competition and provide a suitable substrate. Such preparation in itself might cause some deterioration in soil structure and permeability, as well as a loss of existing plants; the merits of seeding should be carefully considered. Of further concern should be the relative value of artificially seeded vegetation compared with that already present, as well as whether the abuse which made seeding the area a possibility in the first place can be corrected by more natural means. Suitability of climate and soil with respect to prior experience on similar sites also should be scrutinized. These precautions are necessary because seeding is an expensive undertaking not always profitable in terms of forage produced (Plath 1954, Stoddart et al. 1975).

Several objectives, though, may justify seeding: 1) to revegetate barren areas like abandoned croplands, 2) to replace vegetation destroyed by fire, 3) to improve amount and quality of forage, 4) to reestablish native forage species otherwise unable to establish themselves, and 5) to protect an area from erosion (Stoddart et al. 1975).

Seeding of abandoned cropland often meets success; the land’s ability to support vegetation has been proven by its former use. When seeding is done prior to invasion by annual grasses and weeds, planting may often be accomplished without seedbed preparation, although cultivation often improves success (Stoddart et al. 1975).

Where perennial grasses are present on burned areas, they may recover adequately to make seeding unnecessary. Often, however, only annual grasses and shrubs were present prior to fire, and natural revegetation is slow, leaving the area subject to erosion. On burned sagebrush areas, for example, seeding of the denuded area can often proceed with little prior treatment. Even aerial seeding can be successful in such cases, although aerial seeding works best on moister sites with loose, uncompacted soils (Stoddart et al. 1975).

Where sparse or poor quality native forage occurs, interseeding the existing community with better forage plants may be an acceptable alternative to cultivation, with its attendant destruction of existing plants. In this process, seeding takes place in furrows cut in strips in the existing stands. Using this technique, there is less disturbance to the site, species may be introduced to complement existing forage production remains high during the treatment period, and it is less costly than complete cultivation. Specialized mechanical equipment makes this technique most applicable on ranges of moderate topography, free of large rocks and brush (Stoddart et al. 1975).

When valuable native plants have been eliminated, often the only way to reestablish them in a given area is artificially through reseeding. This holds true especially for shrubs, with their generally low seed motility. While seeding of shrubs requires the same care in seedbed preparation, freedom from competition, and a period of protection while they become established, additional problems exist with browse plantings. Seeds are larger and often more difficult to handle by mechanical methods due to accessory structures such as achenes, hulls or pulpy fruit. Seeds must often be hand-collected which adds greatly to the expense of shrub planting. Rodents may also consume quantities of larger browse seeds, necessitating repellents or rodenticides as additional protection. Bitterbrush has been most successfully used in such plantings since it presents fewer problems with collection, processing and establishment than others (Stoddart 1975). Plummer et al. (1968) have summarized characteristics and methods of handling a number of introduced and native shrubs in reseeding projects.
Mixtures of plants in reseeding operations appear to have several advantages over pure stands. Since all areas vary in soil moisture and slope conditions, each species in a mixture can produce abundantly on sites more closely meeting its needs. Seasonal forage production may be more uniform since periods of growth and dormancy vary in different species. Animals are more likely to prefer mixed diets and make greater gains, especially when legumes and browse are included in the mix. Mixed stands have greater longevity, with species being best suited to a particular site gradually replacing less-suited species as they disappear from the stand. Finally, some plants, notably legumes, may favorably influence other plants in the stand (Stoddart et al. 1975).

Any seeding operation requires special management, especially protection from grazing until the planting becomes well-established. This may require two to three growing seasons. Unfortunately, especially on big-game ranges, this is not always possible. Following establishment of the new growth, grazing should be managed properly to prevent deterioration of the range and repeated invasion by low-value plants. Since seeded ranges are disclinm communities, nature will proceed to reestablish the climax. Proper grazing management might slow, but will not reverse this trend toward invasion of climax plants (Stoddart et al. 1975).

Where erosion is causing critical loss of soil, range managers should consider forage quality of potential planting programs less than ease of establishment, hardiness, and soil-protecting qualities. Sod-forming grasses and layering shrubs are best suited for this purpose. Where erosion control through planting is to take place along a highway right-of-way, unpalatability is desirable, since otherwise game animals and livestock might be attracted to the seeding at risk to them and to motorists (Stoddart et al. 1975).

Big Game Trapping and Transplanting

The trapping and transplanting of big game to improve forage quality is probably the least economical and effective of all the methods reviewed here. Overgrazing a range is depleting forage quality, the scope and severity of a project attempting to remove even moderate numbers of game animals from the area would almost certainly prove less cost-effective than other improvement practices or allowing increased hunting pressure.

The wildlife literature contains results of a great many studies that supposedly document beneficial effects for big game populations of various big-game management practices. While many such studies report substantial increases in animal utilization of treated areas, few show the conclusive population responses of increased birth rates, survival or population growth. In the absence of such data, it might be concluded that increased use of a treated area reflects only redistribution of static populations with no increases in numbers. The value of future attempts at habitat improvement must be evaluated in terms of definite population responses, rather than circumstantial evidence (Wolfe 1978).

Many of the habitat "improvement" techniques today are aimed at increasing forage supplies, and are often based on the incorrect assumption that food resources in a given area comprise the sole factor limiting big-game populations, either in terms of nutritional quality or of available quantity. These assumptions can lead to manipulative techniques which produce vegetation not on neither needed nor used. In fact, residual, untreated areas of vegetation are often needed to provide game animals with cover important to thermoregulation and protection from man and predatory animals. Artificially created openings in areas of cover which exceed the distance animals will venture into them will be utilized only at their periphery, and valuable habitat may be lost instead of gained, through poorly planned manipulations of vegetative communities (Wolfe 1978).

Future research should not be aimed solely at determining forage "improvement" techniques, but should attempt to consider all the parts of the complex ecological "jigsaw puzzle" which exists on the open range. Animal energetics, the identification of important habitat components other than those providing food, and a more accurate picture of the energy and nutritive needs of wild animals on open range, all need to be more firmly established in scientific literature.

FORAGE PROTECTION

Several methods may be used, with varying degrees of success, to protect range areas from big game ungulates. Protective fencing may be used in attempts to exclude animals from ranges needing protection, but as it has been mentioned previously (Wolfe 1978), most big game animals can readily cross fences. Therefore fencing as a protective measure for grazing lands probably would meet with little success.

Road and trail closures might be used with some effectiveness in winter, when many ungulates decrease their ranges and have greatly lowered energy budgets. This technique may thus be used to protect the animals as well as the range. It is well established that off-road vehicles can do serious damage to vegetation through erosion, snow and soil compaction and other factors; therefore, observation of their effects and control of ORV use can certainly improve forage quality in some areas.

Reduction in custodial livestock grazing, where a grazing permit in issued but no follow-up range supervision is carried out, may also improve forage quality. Anywhere that domestic livestock or big game animals utilize open range, some observation of their effects on the vegetative environment is necessary to prevent overutilization of the range resource.

Hand in hand with the above techniques for range protection is law enforcement. To be fully effective, proper law enforcement requires proper laws. Laws governing use of public land by domestic livestock and other human uses should be structured, above all, to preserve the resource values of our public lands.

SUMMARY

The wild big game ungulates of North America possess digestive adaptations which allow them to utilize rangelands of low productivity for their dietary
needs. As pressures on our range resources increase, it has become more important to develop procedures which can accurately quantity the ability of a range to support its stock of grazing and browsing animals. The present direction in range resource management is to measure both qualitative aspects of range forage, and the quantitative needs range animals have for that forage on a daily, as well as a seasonal basis. But nutritional standards and intake values for wild game species remain poorly established, and those which have been worked out almost invariably apply only to the area on which the data were gathered. Nutritional and intake requirements show significant variations among individual members of a species, and are further influenced by such factors as animal size, condition, activity, age, food quality, season, weather and digestibility.

Quite often, forage requirements are established on the basis of energy needs. Energy shortages can occur when animals must utilize low-quality forage, and as a result of insufficient forage, snow cover, and low dry matter content, of early spring forages. Phosphorus and calcium levels, as well as the ratio between them, also may be limiting nutritional factors on open range.

Forage quality is influenced by several factors. Seasonal changes in forage plants affect both palatability and nutritional value. Early growth stages generally show high protein and phosphorus levels. As growth stages advance through the year, both nutritive value and digestibility decrease, and fiber, lignin and calcium levels increase as protein and phosphorus levels decrease. Livestock grazing may degrade forage quality, but in many instances can be used as a valuable management tool if properly applied. It may be used to maintain a particular plant community or to produce desired successional changes. But intense grazing may cause increased lignin content and decreased energy, protein, cellulose and phosphorus in range plants. As a general rule, browse plants withstand grazing better than do forbs. Fire may be employed under proper conditions to increase the nutritive value of forage plants or to change the composition of certain plant stands. Burning may cause temporary increases in the nutritive values of some forage plants, but thought should be given to the response of forage plants to different fire intensities at different times of the year and with varied frequencies of application. Fertilizers, since application can be measured and controlled, have often been used to improve forage quality. Most often, nitrogen fertilization is employed to increase forage abundance and to extend growth stages. But even though quality may improve, forage yield does not always increase. Fertilization has served to achieve and maintain balances of forbs and grasses favorable to livestock, but little has been done to change vegetational composition of range communities through fertilization. The influence of soil moisture, acidity, texture, porosity and nutrient content all modify the effectiveness of fertilization techniques. It is often difficult or impossible to isolate the effects of a single factor characteristic on plant growth over a wide geographical range owing to the impossibility of controlling other factors. Climatic factors affecting forage quality include rainfall, temperature, light and altitude changes; they influence plant respiration, assimilation, photosynthesis and metabolism and may strongly modify the mineral and organic matter content of plants in different areas even when these plants grow in similar soils. Other factors, mostly resulting from Twentieth Century human expansion, also affect forage quality; they include urban expansion, fences, highways and transportation systems, and water impoundments.

Virtually no true grazing studies have been employed to describe forage intake requirements, on a seasonal basis, for the wild ungulate species treated in this report. The difficulty and expense involved in determining forage requirements for wild game species are considerable, and intake studies done to date have shown serious drawbacks.

Forage intake by wild ungulates is affected by forage palatability, preference, and digestibility. Seasonal variations in intake are poorly understood, but seem to be more a function of animal physiology than winter stress.

Intake rates established to date show wide variability of results, and intake studies have not used standardized methods. Some investigators have recommended using estimated intake rates of 3 to 3.5 percent of an animal's live body weight for maintenance requirements where forage contains adequate nutrient levels. Intake requirements could increase by up to 200 percent during certain periods of growth, lactation and gestation.

Food habits and feeding behavior of animals must also be considered with intake rates to present a more realistic figure of nutrient needs. Diet overlap between species is another factor precluding the use of straight weight conversion factors to determine range use by animals. Differing habitat preferences among species further confounds the use of conversion factors based on body weight and intake rates alone.

Forage improvement practices are required in certain cases to modify range habit, but it must be remembered that the response of a plant community to manipulative techniques is largely site-specific and that beneficial effects obtained by a given practice in one area might not result on a site where plant species composition or growth conditions differ significantly.

Common forage improvement methods include mechanical vegetation treatment, use of organic herbicides and biological agents, water development through pitting, chiseling, waterspreading, or the use of contour furrows, range seeding and planting, and animal transplanting. When forage protection is needed, it may be achieved through fencing, road and trail closure, reductions in custodial grazing permits, and proper laws and law enforcement.
Cellulose degradation in the rumen produces as end products sugars which are then fermented to short chain (volatile) fatty acids, the primary source of the host animal's energy (Hungate 1965). Rumen microflora also ferment other carbohydrates and hydrolize proteins into peptides, amino acids and ammonia. These end products may then be utilized by the animal into other amino acids and proteins by rumen microbes and further digested and utilized in the lower alimentary tract (Church 1972).

Appendix II ASPECTS OF UNGULATE NUTRITION

Since the inception of a scientific approach to dietary study, investigators have focused their attention almost entirely through stomach contents or fecal analysis studies--upon the food habits of their subjects. While such studies have great value in management, as well as serving to illuminate the overall relationship of an animal with its habitat, they don't tell the organism's entire nutritional story, which is much more complex. As with other dietary studies, food habits research usually reveals high site specificity in animal diets, and the range manager should use caution when applying the results of food habits investigations to areas which have not actually been researched, even though conditions may seem similar. Nevertheless, one can use food habits data to determine the seasonal importance of forage species in the diet, and to infer the relative value to the subject animal of each forage plant species. Such information is already widely available in the literature, and the relative ease of conducting food habits studies, when compared to more advanced dietary investigations, can serve as a basis for further research into the nutritional qualities of a given range.

Wild ungulates thrive on a varied diet, and investigators have long assumed (Swift 1968, Dean 1973, Belovsky 1978, Majorana 1978) that ungulates select diets which offer the best combinations of nutrient level and digestibility available to them. As pressures on our range resources increase, simple food habits studies no longer offer sufficient data to properly evaluate the ability of a range to support its component of grazing animals; nutritional information assumes greater importance. Proper forage management research must determine not only the values of necessary nutrients on the range, but also how well the animal is able to utilize the nutrients available to it.

Appendix III DIETARY COMPONENTS AND REQUIREMENTS

Energy

Energy provides a common expression of the nutritive value of foods, since all organic nutrients contain it (Maynard and Loosli 1969). Swift et al. (1957) believed that the energy content of a forage could serve as an index of quality. The lack of available energy, digestive energy, or both, ranks with protein and phosphorus deficiencies as the most common nutritional deficiency in deer (Dietz 1965, 1970, 1972).

Considerably more nutrient than for all other purposes combined is needed to maintain the basal metabolic energy mechanism (Dietz 1972). Low energy intake brings about a reduction in or cessation of growth, loss of weight failure to conceive, increased mortality, and lowered resistance to diseases and parasites (Halls 1970).

We measure gross energy in calories per gram of feed. Digestible energy (DE), the calories contained in the feed minus those lost in the feces, are the calories apparently retained by the animal. Metabolizable energy (ME), is digestible energy less the energy lost in urine and methane production. Net energy (NE) is that available to the animal after feces, urine, methane and heat production (Harris et al. 1959, Dietz 1965). Harris et al. (1959) criticized the use of DE values on shrub ranges because the high essential oil content (see p. 13, 39) of some shrub plants such as sagebrush yields falsely high DE values.

On the average, forage plants provide about 4.5 kcal/grain to the animal (Cook 1971, Mautz et al. 1974, Swift 1957), and a nearly 1:1 relationship exists between percent digestibility, in vivo (see p. 18), of total dry matter and digestible energy (Mautz et al. 1974, Rittenhouse et al. 1971, Robbins 1973). These figures may be used to roughly estimate the energy value of range plants to grazing animals.

One may calculate energy requirements from established metabolic constants. The basal metabolism of animals of all sizes is proportional to body weight (W) raised to the 3/4 power (Baryl 1967). The resulting figure is known as the metabolic weight of the animal. Kleiber (1961) first estimated the mean standard metabolic rate for fasting mammals, in kcal, is 70 (Wkg^0.75), where Wkg is the metabolic size of the animal. From this figure, Crampton and Harris (1961) developed a formula for calculating adult maintenance energy requirements:

\[ \text{Kcal} = a \times b \times W_{kg}^{0.75} \]

where

- \( a \) = a factor used to convert the resting caloric requirement to the maintenance requirement (typically 2 for herbivores)
- \( b = 70 \) kcal required for unit of metabolic size for resting metabolism

\( W_{kg}^{0.75} \) = the metabolic size of the animal (the animal's body weight in kg raised to the 0.75 power).

It is important to remember that the value resulting from the use of this formula applies to a fasting mammal in a thermoneutral environment. The active metabolic rate can be far higher due to the added energy demands of thermoregulation, locomotion, growth, gestation and lactation. Møen (1973) calculated that the active metabolic rate for deer could range from 1.23 to 1.98 times the basal metabolic rate, depending on the amount
of time spent in various activities; it might reach 2.3 times the basal metabolic rate during lactation. Holter et al. (1975) subjected caged white-tailed deer to varying combinations of temperature and wind velocities; the deer showed summer daily metabolic rates up to three times their basal rates and winter daily metabolic up to twice their basal rates. Carpenter and Baker (1975) calculated that maintenance energy requirements of penned mule deer in Colorado approximated 1.9 times the basal metabolic rate in mid-winter. Mule deer fawns weighing 32 kg require about 6000 kcal of digestible energy per day to maintain a daily rate of 1.3 percent (Dean 1973). French et al. (1956) showed that a 45 kg white-tailed deer requires 6300 kcal of gross energy per day. Short (1971) showed that the gross energy needs of yearling white-tailed fawns was 5000-6000 kcal/day in spring, summer, and 3500-4000 kcal/day in winter. Ulrey et al. (1969) reported that daily digestible energy requirements of white-tailed does in winter approximated 160 kcal/kg of body weight. Female black-tailed deer fawns consumed 193.3 kcal/kg of body weight (Swank and Baker 1975), while buck fawns used 118.7 kcal/kg of body weight. 1.9 times the basal metabolic rate in mid-winter.

### Protein

An essential part of any organism’s diet, protein plays an important role in maintenance, growth, appetite, reproduction and lactation. Since rumin microorganisms need protein, or more correctly, nitrogen, available in order to properly digest and metabolize fats and carbohydrates, the ruminant must have a continuous supply throughout its life. The daily protein requirements of an animal increase with age and size, at least during early growth, but decrease per unit of weight and in relation to the energy requirement (Maynard and Loosli 1969, Dietz 1965, Halls 1970).

In nutritional studies involving chemical analysis of forage species, protein values are often listed as “crude protein,” which consists of both protein and non-protein nitrogen, such as that from urea. The nitrogen percentage of feed is usually multiplied by a factor of 6.25 to arrive at the crude protein value. This does not indicate the kinds or amounts of amino acids present, but since rumen microbes synthesize amino acids for the ruminant, this lack of information matters little (Sullivan 1962, Dietz 1965).

Animals require protein in minimum amounts at all times; for maintenance and growth, more than the minimum amount is needed. NAS-NRC (1963) standards use a digestion coefficient of 55 percent to calculate digestible protein from crude protein. Halls (1970) suggests that this conversion factor should be lower for range animals due to the lower protein digestibility of poor quality range forages.

Dietz et al. (1962), Swank (1956) and Segelquist (1972) all feel that 7 percent crude protein should be a minimum level for wild ungulates. French et al. (1956) indicated that white-tailed deer need 13-16 percent protein in the diet for proper growth and antler development. Hill (1969) gave a figure of 10-12 percent for mule deer. At levels below 6-7 percent, rumen function becomes critically impaired (Dietz 1965). Five percent protein levels strongly affect survival (Clarsen 1946, Dietz et al. 1962). McEwen et al. (1972) reported that fawns fed a ration of 4-5 percent protein showed stunted growth and were barely able to survive. Ulrey et al. (1967) found that female white-tailed fawns needed 12 percent and males 20.2 percent crude protein for optimum growth. Weight gain of females fed 15.7 percent protein, however, did not differ significantly from females fed 20.2 percent crude protein. Smith et al. (1975) estimated that white-tailed deer fawns required 19 g of digestible crude protein per kg of body weight during antler growth, while does required 27.4 g. The digestible energy requirements of penned mule deer fawns in Colorado approximated 193.3 kcal/kg of body weight (Swank and Baker 1975), while buck fawns used 118.7 kcal/kg of body weight. 1.9 times the basal metabolic rate in mid-winter.

### Carbohydrates

Carbohydrates comprise up to 75 percent of the dry weight of plants and include simple and complex sugars, starch, cellulose, hemicellulose, gums, lignin, and other related compounds (Dietz 1972). Rumen microorganisms break down carbohydrates to form volatile fatty acids, a principal source of energy for the ruminant (Amnisson and Lewis 1959). Carbohydrates also furnish needed bulk in the diet (Dietz 1972).

The simple hexose sugars consist mostly of glucose and fructose. Glucose occurs in plants in large quantities, both free and in condensed forms in cellulose and starch. Fructose is present in lower concentrations. Both of these simple sugars may be found in the xylem sap of various angiosperm plants. Pentose sugars, while not often found free in plants, occur importantly as pentoses in cell wall material. Sucrose and other disaccharides are abundant in trees (Dietz 1972).

The polysaccharides starch and cellulose may be found in all woody tissue; they include arabinans, xyloses, galactans and manannas. Sometimes the plants digest their hemicelluloses and use them as reserve foods, but there is no general agreement on the extent to which this occurs (Dietz 1972). Woody plants transform sugar to starch in summer and fall, then change starch back to sugar in winter. For ruminants this probably causes little actual change from a nutritional standpoint, but it may affect palatability and thus nutrient intake (Dietz 1972).

Lignin forms the indigestible portion of plant carbohydrates and occurs in cobs, hulls and the fibrous portions of roots, stems, leaves, and stems (Dietz 1970). Its exact makeup remains unknown despite years of research, but knowledge of its concentrations in plant materials is nevertheless important in determining nutritive value and digestibility of plants. Lignin concentrations increase as plants mature, and show a negative correlation with both dry matter and protein digestibility. Lignin seems to act as a barrier to rumin microorganisms attempting to digest cellulose and other plant nutrients in cell walls (Dietz 1972).

Lipids, Oils and Fats

True lipids include simple lipids, true fats and oils, compound lipids, and saturated and unsaturated fatty acids. Ruminants are able to digest most of these in varying degrees (Dietz 1972).
Fats contain almost twice as much energy per unit of weight as do carbohydrates or proteins, and as such, make up highly important reserve foods. But while fats may be present in concentrations as high as 70 percent in seeds and fruits, they seldom comprise over 5 percent of stem or leaf constituents. Fats seem to reach their highest concentrations in plants in late fall and winter, and decrease in spring through July (Dietz 1970, 1972).

Presently, researchers do not consider fats to be as important in ruminant nutrition as they were once thought to be. This is because laboratory methods of determining the fat content of forage plants include fractions of nondigestible essential oils (Sullivan 1962) which have no nutritional value to the animal and can actually inhibit digestion in the rumen (Nagy et al. 1964, Schwartz et al. 1980a, 1980b). Sagebrush and junipers, especially, have large quantities of essential oils and can give misleading laboratory results (Dietz et al. 1982).

Rumen microorganisms synthesize fats in the rumen from proteins and carbohydrates, and so ruminants do not depend on fats from forage plants in their diets. But they do utilize plants such as aspen and winterfat which contain relatively high fat levels (Kaplin et al. 1937, Dietz et al. 1962, Tew 1970).

**Calcium and Phosphorus**

Calcium and phosphorus are highly important dietary components; they make up about 90 percent of the mineral content in the skeletons of animals and about 75 percent of the minerals in their bodies. Both elements perform essential roles in skeleton and antler development, as well as in metabolism and reproduction (Dietz 1970, Halls 1970). Calcium usually occurs in ample quantities on western range lands, but phosphorus deficiencies in forage show up quite commonly throughout the United States (Halls 1970). Swank (1956) stated that phosphorus deficiencies in animals retard growth, depress appetite, reduce milk production, cause irregularities in ovulation, and result in poor hygiene in females during parturition.

Domestic herbivores need more calcium than phosphorus during early growth stages, but the ratio between the two compounds decreases as maturity nears (Maynard and Loosli 1969). Requirements for wild herbivores probably equal or exceed those for domestic animals, especially those which produce antlers annually (Halls 1970).

Calcium and phosphorus requirements for wild ungulates have not been well worked out, but a few studies have attempted to define these requirements for deer. Calcium and phosphorus levels needed by other antler-producing big game probably closely approximate those required by deer (Halls 1970). Magruder et al. (1977) showed that white-tailed deer survived or rations containing 0.25 percent phosphorus and 0.30 percent calcium, antler growth was best at levels of 0.56 percent phosphorus and 0.64 percent calcium. Swank (1956) felt that 0.25 percent phosphorus was a minimum needed by Arizona deer, and Boeker et al. (1972) stated that pregnant mule deer does in New Mexico needed at least 0.16 percent phosphorus.

Almost as important as the levels of calcium and phosphorus in the ungulate diet is the ratio between these two nutrients and the presence of vitamin D, which facilitates their uptake and absorption by the body. A suitable calcium-phosphorus ratio lies between 2 parts calcium : 1 part phosphorus and 1 part calcium : 2 parts phosphorus. The presence of sufficient vitamin D allows a somewhat wider ratio (Halls 1970, Dietz 1970). Diets containing excessive amounts (greater than 10:1) of either calcium or phosphorus inhibits phosphorus metabolism and results in a deficiency of this element (Maynard and Loosli 1969).

**VITAMINS**

Only the oil-soluble vitamins cannot be synthesized by rumen bacteria and must be present in the diet.

**Vitamin A**

Rumen microbes convert plant carotenes to vitamin A. While animals have very small vitamin A requirements, they also possess quite limited abilities to store this substance. Deficiencies most often develop in winter after green material has been unobtainable for long periods; they result in unsuccessful reproduction, retarded growth, infant mortality, night blindness and general nervous system deterioration (Dietz 1970).

**Vitamin D**

This vitamin is usually available in sun-cured forage or from the effect of sunlight on the animal's body. Young animals may develop vitamin D deficiencies on diets of green forage or during periods of low sunlight. Young animals deficient in this vitamin develop rickets, and all animals show inhibited calcium and phosphorus uptake (Dietz 1970).

**Vitamin E**

Normal feeds usually supply sufficient vitamin E, and as adult animals rarely show deficiencies of this vitamin. Young animals, however, may develop muscular dystrophy on diets inadequate in vitamin E. High nitrite levels may cause deficiencies of this vitamin. Vitamin E serves as an important component of enzyme systems, effects hormone production by the pituitary, adrenal and thrycoid glands, and improves utilization of vitamin A (Dietz 1970).

Appendix IV DETERMINATION OF FORAGE QUALITY

**Chemical Analysis Systems**

Students of nutrition have used the Weende system of proximate analysis since the late Nineteenth Century to determine the nutritional value of foods. In this method, food is broken down into chemically separable fractions—crude protein, ether extract, crude fiber, nitrogen-free extract, and ash. Results, expressed as percentages of dry weight material, are calculated by subtraction from the other fractions.
The Weende system presents some problems to the investigator because it does not break down food substances in the same way an animal's body does. For example, the ether extract fraction, designed to measure the percentage of fat in the food, actually includes all substances soluble in ether, including fats, some plant pigments, waxes, phospholipids and essential oils—and only half this total may consist of nutritional fats (Sullivan 1962). In fact, plants which contain large amounts of essential oils not only give a falsely high ether extract value, but essential oils and only half this total may consist of nutritional fats (Sullivan 1962). In fact, plants which contain large amounts of essential oils not only give a falsely high ether extract value, but actually may inhibit digestive function within the rumen (Dietz 1970). But since the ether extract values of ruminant feeds is generally low, it doesn't often present a great problem in evaluating the nutrient value of the food (Crampton and Harris 1969).

Recently, researchers have attempted to replace the crude fiber and nitrogen-free-extract methods of the Weende system. The crude fiber fraction was long regarded as representing non-nutritive residues, while the nitrogen-free-extract (NFE) indicated digestible carbohydrates. But this simple methodology of the crude fiber test has allowed much of the lignin and hemicellulose to be extracted into the NFE, giving a false picture of the nutritional level of plant carbohydrates (Van Soest 1967).

Sullivan (1962) felt that the proximate analysis system should be considered obsolete, but acknowledged that crude protein fractions provided an acceptable measure of feed quality. Crampton and Harris (1969) admitted the flaws in the Weende system but felt that it could be used as a useful index of nutritive value in conjunction with other nutritional knowledge and judgment. Regelin (1969) felt that the proximate system would be retained in general use due to its widespread acceptance and to the large amount of data that already exist from the use of this method.

The determination of lignin and cellulose fractions of forage plants offers a way to replace the crude fiber and nitrogen-free-extract portions of the proximate system. An accurate determination of lignin is important, because of the highly significant negative correlation found to exist between lignin percentages and digestibility of both dry and organic matter. A high negative correlation also exists between lignin content and digestible energy, digestible cellulose, dry matter digestibility, protein (Sullivan 1962). Van Soest (1963) and Goering and Van Soest (1970) developed the detergent method of analysis, based on the division of forage dry matter into two fractions of differing nutritional availability. These fractions are: cell contents, essentially completely available, and cell walls, having non-uniform nutritive availability (Van Soest 1967). The neutral detergent method (Goering and Van Soest 1970) makes it possible to determine cell wall percentage and the large amount of cell-soluble by subtraction. Cell wall constituents may be separated by several methods: lignin, lignified nitrogen compounds, keratin and silica by their insolubility in an acid detergent solution; hemicellulose by its insolubility in an acid detergent solution, and, hence by difference of cell wall and acid detergent fiber values; and attached protein by its insolubility in a neutral detergent solution. Cell contents include lipids, carbohydrates, non-protein nitrogen and soluble protein, all dissolves in neutral detergent solutions. This method is superior to the crude fiber method because it separates totally digestible, partially digestible and indigestible partials of plants (Van Soest 1966).

Although the detergent analyses may eventually replace the proximate system as the standard comparative procedure, they are still relatively new and subject to their own inherent weaknesses. The neutral-detergent extraction can remove significant quantities of the lignin and cutin reported in the acid-detergent procedure, and results may occur when attempting to estimate the true digestibility of the acid-detergent fiber/cutin/lignin difference (Robbins et al. 1975).

Presently, animal nutrition workers do not agree on which methods are most useful in evaluating forage quality, but the techniques advance the future will surely be used until a standard method becomes adopted in the future.

Digestion Trials

Once chemical analysis systems define the nutrient composition of forage species, digestion trials serve to evaluate nutrient availability to the animal. Two types of digestion trials exist.

In vivo tests utilize live animals and various methods to quantify digestion values as they occur within the rumen. These trials, quite expensive and time-consuming, require large amounts of food which must be laboriously hand-gathered (Barnes 1965, Pearson 1970). Wild ruminants do not temporally lend themselves to confinement in a metabolic cage required for the tests (Cowan et al. 1969). However, a successful fistulation of white-tailed deer has been achieved (Short 1963), researchers have failed with some other wildlife species (Hoover 1971) and the trauma of repeated sampling of rumen contents may affect survival (Palmer 1975, Short 1964b).

In vitro trials simulate natural rumen digestion in the laboratory. The Tilley and Terry (1963) technique involves fermentation of forage material with rumen microorganisms in a buffered medium under standard of temperature, pH and anaerobiosis designed to simulate rumen conditions, followed by an acid-pepsin digestion.


A few studies have attempted to determine the validity of comparing results of in vivo and in vitro research on North American deer. Buggiero and...
Whelan (1976) used Pearson's (1970) in vitro method with white-tailed deer and concluded that the in vitro technique gave accurate estimates of in vivo digestion, and that their results appeared repeatable. They experienced errors of 15 percent in predicting in vivo digestibility using Pearson's method. Robbins et al. (1975) found that in vitro digestibilities in white-tailed deer were higher than in vivo values, and attributed the lower in vivo values to metabolic fecal excretion (MFE). Although they did not clearly state how MFE values were calculated, they concluded that in vitro and in vivo digestibilities were nearly identical after MFE values were taken into account. Urense et al. (1977), working with mule deer in Arizona, employed the two-stage Tilley and Terry (1963) method as modified by Alexander and McGowan (1961). They compared in vitro results with in vivo data, but used different forage samples for each trial, even though attempts were made to duplicate plant phenological development and season of use in the compared forages. They determined that the in vitro method employed in the study provided reasonable, but conservative, estimates of apparent digestibility for deer foods that were 35 percent or more digestible in vitro. Below 35 percent in vitro digestibility, forage digestibility values varied markedly from in vivo estimates and raised the question whether deer consume plants lower than this in digestibility, given reasonable choice.

Oh et al. (1966) and Scales et al. (1974) found the two-stage Tilley and Terry method to be the best in vitro digestibility technique when compared with various other methods of estimating in vivo digestibility. Nevertheless, arguments regarding in vitro digestion trials center around the inoculum or not the inoculum used in the test should come from an animal of the species being studied, whether the inoculum employed should come from a ham that has been on a diet containing the forage sample being tested, and whether the inoculum should come from only one, or from two or more animals (see: Short 1963, Van Dyne and Weir 1964, Nagy et al. 1967, Ward 1971, Scales et al. 1974, Palmer 1975, Alexander and McGowan 1966).

The collection of rumen fluid at equivalent post-feeding times also becomes a factor in attempts to standardize in vitro tests, because number and species composition of rumen microbes undergo diurnal cycles related to feeding time (Church 1969). While the use of standardized in vitro methods would enable the direct comparison of results from different studies, it is doubtful whether a single technique could be developed which would apply to all species and situations.

Appendix V METHODS OF DETERMINING FORAGE INTAKE

A number of methods, some direct and some indirect, have come into use for estimating rates of forage intake for domestic and wild ungulates. Each method has its drawbacks, and no technique can be used without the need for some sort of estimation on the part of the researcher.

Clipping Method

In this technique, investigators mow strips over a given study area or clip sample strips nearby, and weigh the clipped samples. Then animals are allowed to graze the experimental plot. Forage remaining after grazing is clipped and weighed, with the difference between the before and after weights equaling the amount of forage consumed.

When forage is mowed, consideration must be given to the rate of growth of the mowed area during the grazing study. If forage plants are in mature growth stages, experimental error will be small, but errors can reach 10 percent using immature plants in the study. Furthermore, strips mowed may not accurately represent plant composition of the entire study area. The amplitude of error could be such that more forage would appear to be available after grazing than before, resulting in a negative consumption measurement (Garrigus and Rusk 1939).

Direct Observation of Grazing Animals

The obvious disadvantage of this method lies in its difficulty of application to wild animals under field conditions. Animals used in such trials must either be reared in captivity or otherwise acclimated to human presence. This technique is more useful in determining diet than intake.

Bjugstad et al. (1970) described three techniques of direct observation for use on domestic animals—mainly cattle—which probably have limited application to wild ungulates. The first method, known as the cafeteria or free-choice method, allows animals to select foods from equally accessible plant species available in roughly equivalent amounts. The food is offered in pure stands, in bunks, or in dry lot, time spent feeding on each species is observed, and consumption measured by weight. The relative preference value of each forage species can be identified, although the number of species which may be offered is limited. Also, since forage plants are grown in pure stands in grazing trials, the results of the studies cannot be applied to field conditions where grazing areas may show highly varied plant composition. However, rate of intake varies with animal skill and direct observation might not account for this. Observers may also modify animal feeding behavior (Hurd and Blyler 1962). Jones (1952) criticized this method because grazing time might correlate poorly with the amount eaten, since some foods are actively grazed while others are only nibbled. But Smith and Huber (1966) found no significant difference between precision ranking of 15 browse species based on the time deer spent foraging and the weight of each forage species they consumed.

In the feeding-minutes method, grazing time for each species in a mixed stand provides the index to preference and consumption, with the time spent grazing each plant assumed to be proportional to the amount each species contributes to the diet. The observer must watch and time the animal as it feeds on each plant. Except at very close range, it is difficult to distinguish between nibbling and active feeding (Bjugstad et al. 1970). Kautz and Van Dyne (1978) hand-collected 100 simulated pronghorn bites for each forage species to provide a basis for converting field data on percent bites to percent weight of the diet.
Bjugstad et al. (1970) describe a third technique, the evaluation of grazing patterns method. It relies on the knowledge of grazing use on various range types in good condition during different seasons. Deviations from established grazing use patterns indicate increasing scarcity of desired plants or deficient in nutrients and that animals are forced to spend more time seeking out adequate forage. This method requires the use of an experienced observer and can only obtain qualitative but not quantitative value. It is useful for determining range quality (Bjugstad et al. 1970).

### INTERNAL AND EXTERNAL INDICATOR RATIO METHODS

#### Fecal Indicator Methods

Fecal indicator methods use indirect techniques to arrive at intake estimates. They depend on the use of two indicators: one internal to estimate the digestibility of the consumed forage, and the other external and completely indigestible to determine fecal output (Reid and Kennedy 1956). Internal indicators are components of the food itself; the most commonly used is lignin (Reid and Kennedy 1956), but indigestible protein may also be employed (Forbes 1950). External indicators include chrome oxide (Reid and Kennedy 1956), barium sulfate (Kane et al. 1956), or polyethylene or Cerium-144 (Snakpa et al. 1967). The internal indicator is used in equation (1) to calculate dry matter (DM) digestibility:

\[
\text{DM digestibility} = \frac{100 - \left(\frac{\text{DM in feces}}{\text{DM in feed}}\right) \times 100}{\text{internal indicator in feed}}
\]

When digestibility is known, dry matter consumption using the external indicator is calculated with equation (2):

\[
\text{DM consumption} = \frac{\text{total indicator in feed}}{\text{DM in feces sample}} \times \text{DM digestibility}
\]

Since a feces sample is used, total fecal collection is not necessary, and a grab sample taken at intervals is used to determine the amount of indicator (Skiles et al. 1980).

When lignin is used as an indicator, widely variable intake rates may result. This is because grazing animals may digest lignin to a larger extent in immature plants than they are able to in mature plants (Wallace and Van Dyne 1970). The major disadvantage of this method for estimating intake rates of wild species is that subject animals must be allowed to eat only foods to which the external indicator has been added. This requirement virtually precludes the use of the indicator method under field conditions.

#### Fecal Nitrogen Index

In the fecal nitrogen index method, standard feeding trials are conducted with forages of varying digestibilities being offered to the subject animal. Equation (3) is used to relate the concentration of an index substance in the feces (X) to the digestibility, or feed-to-feces ratio (Y):

\[
Y = a + bX
\]

where b is the slope of the regression curve and a is the y intercept. Fecal samples from foraging animals are analysed to determine the concentration of the index substance. That concentration is substituted into the equation (at X) and the digestibility or feed-to-feces ratio predicted (Cordova et al. 1978, Skiles et al. 1980).

The fecal nitrogen index requires the measurement of the fecal nitrogen content, and assumes that fecal nitrogen is of body origin and that the body excretes metabolic fecal nitrogen in proportion to the amount of dry matter consumed or digested (Cordova et al. 1978). The most difficult aspect of using fecal indices lies in the initial formulation of the regression equation; for it to be accurate, the forage offered the subject animal must be identical in species composition, proportion and physiological development to forage found on the range. Ideally, once established, a regression equation may be employed for all similar animals and pastures, but in reality, fecal nitrogen indices vary with season (Streeter 1969). Furthermore, differences in species, age and physiological condition and the fact that this method is used mostly on pastures and not on rangeland, add to potential inaccuracies. All in all, the fecal nitrogen method is more applicable to digestibility, rather than intake, studies (Cordova 1977).

#### Total Fecal Collection

This method requires, in addition to total collection of feces, complete records of the feed or forage consumed. By then combining measurements of fecal output with determinations of digestibility of the forage plants, forage consumption is calculated (Cordova et al. 1978). Digestibility may be calculated by samples collected from fistulated animals or from the fecal nitrogen index, if a suitable regression equation is available.

This method requires huge labor expenditures—as many as 70 man-hours per fecal output measurement (Karchner 1975, Cordova et al. 1978). Aberrant feeding behavior by harnessed animals may be another disadvantage to this technique (Skiles et al. 1980).

#### Radioisotope Studies

Radiation fallout studies are the only methods used to date to infer forage intake rates of free-ranging wild ungulates. These estimates utilize available data of fallout cesium-137 concentrations in the wild ungulate and its inferred diet, and employ the convolution of an intake function and a retention function (Allredge et al. 1974). Calculations are complex and rely on sufficient data concerning radionuclide concentrations and behavior on the study area. The two studies completed, one on mule deer (Allredge et al. 1974) and one on caribou (Hanson et al. 1975) relied on fallout nuclides, but while convenient, they are not necessary to this type of study. In fact, since in most areas fallout levels are much lower than they were when these studies were conducted, it may be more feasible to artificially contaminate food supplies with radioisotopes to determine intake rates. Such a study would require access to radiation detection equipment and computing capability adequate
to perform the necessary mathematical calculations. For a more detailed description of methods involved, see Allredge et al. (1974) and Hanson et al. (1975).

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**ANNOTATED BIBLIOGRAPHY**


Forage intake rates of Colorado mule deer were estimated using available data on fallout Cesium-137 concentrations in the deer and their inferred diet. Method employed involved the convolutions of an intake function and a retention function. Ingestion rates reported and analyzed by sex, season and age class.


Data from this study indicate that white-tailed deer are able to maintain a constant energy balance, close to the maintenance requirements of fawns, by adjusting dry matter intake when fed diets of medium to high digestibility.


Counts of mule deer fecal groups on three north-central Colorado winter range study areas were related to mean forage yields in pounds per acre and mean utilization per plot of three major forage species. Counts of fecal groups were not significantly correlated with yield and utilization of mountain mahogany and antelope bitterbrush.

_____. 1972b. Mule deer fecal group counts related to site factors on winter range. J. Range Mgmt. 25:66-68.


During periods of drought in Arizona, deer use evergreen and drought resistant plant species more than at other times. The hot, dry season (April-June) appears to be the most critical period of the year for deer herds of the desert southwest.


Fecal analysis appears to be a useful technique for studying deer diets in the arid southwest. The utility of this technique for other areas and species is discussed as are sampling rates and suggestions for successful use of fecal analysis.


Two winter feeding trials of hand-reared mule deer fawns showed that dry matter digestibility was not affected by level of intake, ambient temperature or physiological condition. Body weight change was linearly related to feed and energy intake. Fawns in these trials required a metabolizable energy intake of 157 kcal/kg of ADG/day to maintain body weight homeostasis.


Observations on distribution of pronghorns in Alberta revealed that over 60 percent of all winter sightings were in Artemisia cana vegetation complexes. Utilization of A. cana in winter was 25 percent. Pronghorn winter densities in the type should not exceed 15 pronghorns per day per acre; mean daily intake of A. cana is 2.45 lb. per animal per day.


Two groups of two calf elk each were tested on bare maintenance rations. One group received 5.5 lbs. alfalfa hay and 5.5 lbs. grain per animal per day. The other group received 5.5 lbs. alfalfa hay, 0.5 lb. grain, and 0.5 lb. browse clippings per animal per day. The group without the browse supplement remained in the best condition.


Changes in voluntary dry matter intake, body weight, and resting metabolic weights at 10 and -10°C were measured in adult bighorn sheep from October until May. Voluntary intake in mid-February decreased to 0.55 of that in mid-October. Body weights increased until January, after which stasis or slight declines occurred. Resting metabolic weight at 10°C fluctuated without a consistent pattern over winter. Wind speeds from 4 to 8 m/s increased metabolic rates only at temperatures below -20°C.


Objectives of study were to investigate competition for food between mule deer and bighorn sheep, to evaluate the effect of increased numbers of deer on the sheep of Rock Creek, and to predict the effect of mule deer on any recovery of the sheep population.

Colorado ponderosa pine-bunchgrass range during the spring-summer-fall grazing season. Management of the timber stand increased forage for both types of animals and resulted in short-term availability of dried pine needles, a preferred deer food.


Discusses recent developments and findings concerning deer and elk nutrition, particularly as they relate to malnutrition and supplemental feeding.


Trained mule deer used to determine botanical composition and relative preference of mule deer diets on five habitat segments in the lodgepole pine ecosystem of northeastern Utah. Diets were statistically analyzed according to estimated weight consumption per unit of time spent feeding on the different segments.


Protein content of some plant species were significantly higher in seasons following low-intensity fires, but no effects could be determined the second year. High intensity fires produced significant protein content increases in all four species studied, and effects were still apparent at the end of two years.


A Review of nutritional components of feeds, chemical analysis systems, and forage quality indices.


A survey of nutrient components and digestibility measurements for shrub plants. Carrying capacity can be estimated when nutrient content and dry matter production are compared to daily dietary requirements of animals.


Deer nutrition and range plant utilization are probably both directly and indirectly associated with the possible mule deer decline. Many important browse plant communities are (1) the result of past site disturbances, (2) near the end of their lifespan, and (3) may not be replaced because present land management factors prevent fire, intensive grazing and severe timber harvesting.


Five key species of deer browse were collected seasonally from the Mesa Verde region of Colorado to determine their proximate chemical analysis. Deer on the study areas were observed to choose browse containing the highest amounts of important nutrients during each season, especially in the case of protein.


Water potential of big sagebrush shows great seasonal variation. While starch content did not significantly change in water-stressed plants, sugar increased in leaf, stem and roots. Leaf nitrogen content decreased during water stress, but stem nitrogen content increased. Sugar increases in leaves, stem and roots and nitrogen accumulation in stem of water-stressed plants may be of adaptive significance.


Discusses value of protein in deer forage and the need to identify and use areas of high-quality forage.


A review of seasonal energy requirements and utilization of food by moose, along with reference to other wild and domestic species, is presented. The value and practical application of using various parameters of rumen function to evaluate nutritional status of ruminants and quality of the habitat is discussed.


The sense of taste is important in animal nutrition because it is involved in motivating and regulating ingestive behavior. Variables affecting taste response include: nature and temperature of taste medium, visual clues, age, disease, nutritional deficits, genetic constitution, experience, sex and psychological factors. The procedure used to assess taste reactions may importantly influence the value obtained.


The most significant chemical difference between "good" and "poor" forages seems to be in crude protein content. Protein content varies seasonally, from a high level in summer to a low level in winter. Insufficient or low protein digestion may further augment the protein deficiency ordinarily encountered by the deer in their late winter diet.


Compiles nutritional data for beef cattle, sheep and deer; discusses requirements for dry weight intake, energy, protein, water and important minerals and vitamins. Nutrient requirements are not
exact but are useful as standards for selecting forage species for evaluating carrying capacity and nutritional value of ranges.


Lichen forage ingestion rates of free-roaming caribou herds in northern Alaska during 1963-70 were estimated by applying a two-compartment, eight parameter cesium-137 kinetics model to measure fallout concentrations in lichen and caribou. Estimates for winter equilibrium periods for each year ranged from 3.7 to 6.9 kg dry weight lichens per day for adult female caribou.


Moisture, crude protein, ash, calcium, phosphorus, calcium:phosphorus ratio, crude fiber, crude fat, and apparent digestibility were determined for 15 species in three vegetal classes on seven vegetation types. These measurements were contrasted by classes, species, and type, and ungulate management inferences were drawn.


The preference by reindeer for five species of lichens commonly found on Central Alaska rangelands was tested under controlled laboratory conditions. Results indicate that reindeer are strongly species-selective in their lichen grazing habits.


Digestibility and protein values of clipped grasses and sedges were compared to fistula samples from yearling steers. In a dry year clipped forages contained protein levels comparable with those found in fistula samples. In a year with abundant early moisture, grazed forbs brought about higher protein levels and dry matter digestibilities in fistula samples than in clipped samples, especially during early parts of the grazing season.


Spring livestock grazing by cattle and sheep on deer-elm winter ranges where primary browse species was bitterbrush caused little forage competition with big game when grazing was restricted to early growing season before rapid shrub growth.


Compares estimation of browse use by twig counts and by estimation of browse units. First method enables identification of key species in the diet while second gives proportion of each by weight.


Presents thesis summarizing the relationship between heart-rate and energy expenditure for three mule deer fawns.


An evaluation of the nutritional status of bighorn sheep on existing ranges was undertaken to measure the adequacy or inadequacy of these ranges to meet the nutritional requirements of bighorn sheep at all times of the year.


Trace mineral formulations were developed and tested for animal preference. As a result of these tests a trace mineral mix was developed and is in use throughout many areas of Colorado as a supplement to the nutritional requirements of animals for essential trace minerals.


Forage samples were collected from atoposed fritculated sheep in morning and evening. There was significantly more total protein and gross energy in the diet in the evening than in the morning.


Kuck, L. 1973. Seasonal food habits of mountain goats and winter food habits of mule deer on the study area. Idaho W-144-R-03/Wk. Pl. 02/Job 02. Idaho Fish and Game Dept., Moscow. 9 p.


Weather, soil, competition and grazing are highly interrelated factors influencing chemical composition and nutritive value of grazed plants. Direct and indirect effects of these factors on forage plants are discussed and evaluated.


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Leedy, D. L. Highway-wildlife relationships (continued)

This study assesses, primarily through literature review, knowledge of highway-wildlife relationships and suggests research and management approaches to protect and enhance fish, wildlife and environmental quality.


Food intake of three tame moose was observed during summer on normal range and during winter and spring on normal and depleted range. Food eaten varied between summer and winter, and moose ate a greater variety of forage than previously realized. Availability of under-story forage species during part of the winter is probably an important factor in supporting the high moose densities found on this range.


Evaporated milk, a commercial milk replacer, pasteurized, homogenized milk, and raw Jersey milk were fed to four groups of white-tailed deer fawns over a seven-week period to compare the efficacy of these diets for raising fawns to weaning age. Average body weight gains in pounds for fawns fed the various rations were evaporated milk, 19.5; milk replacer, 15.3; pasteurized homogenized milk, 18.0; and raw milk, 25.0.


Olfaction is the primary sense used by deer to discern preferred plants. Good correlation has been found between plants' palatability and the extent to which they inhibit the growth of rumen microorganisms. Different species of ruminants, harboring different complements of rumen microorganisms, digest plants at different rates.
Relative abilities to digest certain forages are thought to influence animals' preference to particular forages.


Lyon, L. J. and P. F. Stickney. 1966. Two forest fires and some specified implications in big game habitat management. West Assoc. State Game and Fish Comm. 1966;


Types and uses of fencing described, viewpoints of rancher and land manager discussed.


Field observation of deer in the 3 Bar vicinity.


The heat production of two caribou, during fasting, 91 kcal/kg/hr per 24 hr. was 20 to 30% higher than the quoted interspecific mean of 70 kcal/kg/hr per 24 hr. The mean heat production values of two female caribou at the maintenance level of feeding were 107.0 kcal and 124.5 kcal/kg/hr per 24 hr.


Relations between energy intake and body weight of reindeer and caribou are summarized. Caloric intake was 15-45% lower in winter than during summer growth period. Relation between heat production and body weight also exhibited a cyclical pattern. Estimated metabolizable energy requirement for maintenance of a 70 kg reindeer in


Types and uses of fencing described, viewpoints of rancher and land manager discussed.


Field observation of deer in the 3 Bar vicinity.


The heat production of two caribou, during fasting, 91 kcal/kg/hr per 24 hr. was 20 to 30% higher than the quoted interspecific mean of 70 kcal/kg/hr per 24 hr. The mean heat production values of two female caribou at the maintenance level of feeding were 107.0 kcal and 124.5 kcal/kg/hr per 24 hr.


Relations between energy intake and body weight of reindeer and caribou are summarized. Caloric intake was 15-45% lower in winter than during summer growth period. Relation between heat production and body weight also exhibited a cyclical pattern. Estimated metabolizable energy requirement for maintenance of a 70 kg reindeer in
winter amounted to 5.5 Mcal/day, or about 200 kcal/W^0.75 per day.


Greatest skeletal and muscular growth were attained on a ration containing approximately 17 percent protein, 0.64 percent calcium and 0.56 percent phosphorus. Deer fed a level of 4.5 percent protein were extremely stunted in size and barely survived.


Discusses the nature and extent of competition on a pinyon-juniper range between cattle, sheep and mule deer in fenced enclosures under various grazing intensities during 1952-1965. It discusses vegetative and animal responses measured between 1952 and 1968.

The conclusion is that cattle, sheep and mule deer can be grazed singly or in combination if kept at moderate rates, as described for each animal, without serious competition and accompanying range regression.


Milchunas, D. G. In vivo — in vitro relationships (continued)

Morphological and phenological differences in forage in vitro digestibility were observed in species examined from mule deer spruce-fir summer range and sagebrush winter range in Middle Park, Colorado. Large differences occurred between in vitro digestible dry matter and in vitro digestible organic matter in forages of high ash content. Non-protein nitrogen supplementation experiments suggest that nitrogen stimulates rumen microbes, but that associative effects are not observed unless the material also increases carbon structure exploitation potential. Caution must be used when relating in vivo to in vitro digestible dry matter for species combinations or diets.


This investigation attempted to determine which factors influence vegetal response to supplemental moisture gained from floodwater spreaders. Forage was established and produced only on sites that received at least one flooding per year. Production was less where water ponded and could not drain thoroughly from soil surface. Total moisture retention capacity of the A and B horizons had more influence than soil texture on amount of forage produced.


White-tailed deer exhibited seasonal rhythms in heart rate activities, and metabolism, with the lowest metabolism occurring in winter and the highest in summer, as an adaptation for energy conservation. Highest energy expenditure is for a female with two fawns; lowest for deer in midwinter.


"Since forage quality, as reflected by its rate of digestion, usually controls voluntary intake within the limits set by availability, the rate of forage digestibility is probably the single most important attribute of any pasture."


Nutritional parameters of major mule deer winter forage species and maximum potential forage production of herbaceous plants were evaluated within each of four different habitat types on the west slope of the Bridger Mountains in southwestern Montana.


Discusses volatile plant oils, their composition, location in the plant, and effects on animals feeding on plants containing volatile oils.


Presents and discusses the importance of rumen microbes in the digestive processes of domestic and wild ungulates. Evaluates host responses to varied conditions in the rumen.


Sagebrush essential oils showed inhibitory action on several gram-positive and gram-negative bacteria. The addition of 0.05-ml amounts of essential oils of sagebrush inhibited the growth of deer rumen microbes in 9-ml amounts of agar media. Appetite and rumen movements ceased completely following the introduction of 21 pounds of sagebrush in 7-pound daily portions through the rumen fistula of a steer.


Discusses effects of stage of maturity, soil types and their physical and chemical properties, climate, plant species, livestock and range condition.


A review of evaluations of forage quality for wild ungulates is presented. The amount and variability of carbohydrates, fats, proteins, energy and digestibility of forage are discussed. Results of in vitro digestion of three species palatable to moose on the Kenai Peninsula, Alaska, are presented.


Alder and willow ranked as the best summer browse plants and lowbush cranberry as the poorest; in winter, aspen and lowbush cranberry ranked best and paper birch poorest. But since the different browse species provide different nutrients, sufficient quantities of all 5 species studied could better meet the needs of moose than any one.


Olsen, F. W. Food relations (continued)

A large percentage of the diets of wild horses, cattle and elk were the same species of grasses and sedges. Sagebrush was the major food in antelope diets regardless of season.


Mule deer occupying deer management units 53 and 54 in south-central Utah were studied to determine food habits, caloric requirements, dietary nutritional levels, and productivity.


In vitro techniques are discussed in detail. While lack of standardized methods are presently a disadvantage, in vitro techniques may in the future become the accepted method for analyzing the nutritive value of forage for domestic animals and wildlife.


Major goals of this study were to perfect an in vitro digestibility technique for use under field experimental conditions, and secondly, to apply this technique to the evaluation of the nutritional quality of range plants consumed by caribou and reindeer.


Two microdigestion techniques for estimating dry matter digestibility were compared for 31 plant species consumed by reindeer and caribou.
Reasons for differences between in vitro DMD values are discussed. Comparison of in vitro and nylon-bag estimates of digestibility can be used to screen forages for digestive inhibitors.


Summarizes characteristics and methods of handling several exotic and native shrub species in reseeding operations.


Six plant species of known preference to black-tailed deer were used to evaluate several factors thought to influence preference: chemical composition, in vitro fermentation of dry matter and cellulose, and effects of essential oils and water and methanol extracts on rumen microbial activity in vitro.


Esophageally fistulated steers were used to determine organic matter intake and digestibility of bluestem pastures during the summer grazing season. Nutrient levels of forages from fistulas are compared with clipped forage samples.


In a pinyon-juniper habitat, tame mule deer with access to unlimited amounts of concentrate feed select the same forage species in a similar proportion of their diet as deer that received no supplemental feed.


Sprout use of shrub live oak, birchleaf mountain mahogany, and Wright slicktassel was heaviest during late spring when herbaceous vegetation was mostly dry, with mountain mahogany preferred. Sprout selection was associated with high moisture and crude protein, low crude fiber, and a comparatively wide calcium-phosphorus ratio.


Response of black-tailed deer to certain browse extracts, non-volatile organic acids, and two odoriferous compounds was determined by use of the two-choice preference test method. Data indicated that six may have a pronounced effect on taste and odor responses of black-tailed deer.


Two captive, rumen-fistulated white-tailed deer were used to evaluate the two-stage in vitro microdigestion technique as an estimator of in vivo dry matter digestibility. The technique provided digestibility percentages that departed only slightly from in vivo values for the artificial ration tested.


Cafeteria feeding trials were used to determine preferences by mule deer among three species of juniper, and for pelleted feeds treated with their volatile oils. Deer exhibited a preference for alligator juniper but did not differentiate between Utah and Rocky Mountain junipers. Preferences were inversely related to concentrations of volatile oil contents of junipers. Forage species most selected had lowest absolute concentration of oxygenated monoterpene.


Lichens were found to be generally low in protein, calcium and phosphorus in relation to the estimated nutrient requirements of caribou, but do appear to supply a major part of the energy needs of this species. Seasonal fluctuations in chemical composition are indicated.


Three artificial diets that varied in cellulose content but were similar in protein and energy levels were fed to three mule deer according to a latin square design. Both digestible energy and digestible dry matter were inversely related to dietary cellulose content. Limited cellulose digestion occurs in mule deer and affects energy and dry matter digestion in foodstuffs.

This paper considers feeding-performance experiments, digestion trials, and rumen assays as techniques for measuring forage quality and utilization for wild ruminants, especially deer.


In vivo techniques are discussed. Results of such investigations, when used in combination with information about range forage quality and animal habits, can help explain how different herbivore species compete on common ranges.


Nine plant species believed important to mule deer on the Cache La Poudre drainage of Colorado were collected at four seasons from five study areas which varied in elevation from 6400 to 10,300 feet. Eleven chemical components were analyzed for each plant sample. Seasonal changes and variations between species are discussed.


In the study area at Ft. Bayard, New Mexico, deer and elk ate evergreen browse extensively during winter. Small clearings within woodlands were readily used by both deer and elk. Extensive clearing of woodlands increased herbage production but may have been sufficiently detrimental to wildlife to negate any additional grazing values for range cattle. Large cuttings and those that isolated undisturbed woodlands from contiguous protective cover were unacceptable wildlife habitat.


--- Deer were confined to digestion crates and fed material from forages that were important on winter ranges. Amounts of material consumed and eliminated were measured and subject to chemical analyses.


--- During three winters mule deer were fed on prescribed diets of browse species common to Utah ranges--sagebrush, juniper and oak. The three species were fed single and in combination. No diets appeared to be adequate in digestible nutrients when compared to recommended allowances for domestic sheep. Plants that have a high value in a mixed diet may be inadequate as the sole source of forage.

On bitterbrush ranges, early spring grazing by cattle on deer-elk winter range caused little forage competition with big game, and even increased moisture available to bitterbrush through removal of herbaceous vegetation around it, significantly increasing browse production for winter use by deer and elk.

Winter feeding tests were conducted on captive deer to determine relative preferences of browse plants common in northern Utah. Data were secured on two bases, time spent browsing such species and amount of forage consumed. No relationship existed between time spent feeding on a given species and the amount of feed obtained from it.

Six antelope were fed sixteen species of browse plants common on Utah desert ranges for a period of six days. Three species, big sagebrush, black sagebrush and juniper provided the major part of the diet; more than half was provided by big sagebrush. Unless competition from livestock seriously reduces the volume of sagebrush available to pronghorn, a low plane of nutrition in winter does not appear to be a factor in the productivity of this species in western Utah.

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Smith, S. H. et al. Protein requirements (continued)

Fawns require maximum growth (body retention of dietary protein), estimated by regression analysis, was 19 g digestible crude protein per kg of metabolic body weight (W^0.75) daily.


1956b. Protein and phosphorus content of browse plants as an influence on southwestern deer herd levels. Trans. N. Amer. Wildl. Conf. 21:141-158.


Chemical composition of aspen leaves, collected on three sampling dates, varied greatly. Calcium, magnesium, sodium and fat contents increased as the season progressed, whereas total nitrogen, phosphorus and potassium content decreased significantly.


Thompson, C. G. et al. Nutrition of white-tailed deer (continued)

Eight hand-reared white-tailed deer fawns were fed a single diet to study their energy requirements. All fawns exhibited normal growth patterns, and reduction in voluntary dry matter intake, below maintenance, in winter. Advanced age and maturation of ruminant digestive processes were accompanied by more efficient utilization of dietary carbohydrates, resulting in increased total digestible nutrients and net energy per unit of dry matter consumed. Mean apparent maintenance metabolizable energy requirement over all time periods and both sexes was 154 kcal/kg body weight b.75 and was highest in August (192) and lowest in January (109).


The effects of weight loss during gestation on reproduction in mature cow elk were examined. Weight loss during pregnancy was significantly and directly correlated to calf weights at birth and at 4 weeks of age, and to calf growth rates through the fourth week. Free-ranging pregnant elk required about 22.7 g/kg body weight of good quality feed daily for maintenance.


Adult does preferred snowbrush, Douglas fir and Rocky Mountain maple...
and avoided Saskatoon serviceberry, big sagebrush and gray rabbitbrush. Juvenile deer preferred Douglas fir, accepted snowbrush and Rocky Mountain maple and avoided Saskatoon serviceberry, big sagebrush and gray rabbitbrush. Adults differed from juveniles in the preference for snowbrush and Douglas fir.


Average estimated daily maintenance for pregnant white-tailed does penned outdoors in late winter was 158 kcal of apparently digestible energy and 131 kcal of metabolizable energy per kgBW0.75.


Mule deer and Covey white-tailed deer have similar intakes of protein, phosphorus, calcium and fiber. Digestibility is somewhat more variable. Data based on chemical analysis and in vitro digestibility of hand-harvested forages comprising seasonal diets combined with diet-composition data.


Urness, P. J. et al. Nutrient content of mule deer diets (continued)

Chemical analysis and in vitro digestibility data were obtained for forages used by mule deer during summer when deer occupied ponderosa pine types. Dietary protein and phosphorus content diminished from 25 and 0.48 percent in May to 10 and 0.19 percent, respectively, in late summer. Dry matter digestibility declined from about 68 percent in May to 46 percent in August.


Chemical analyses and apparent in vitro dry matter digestibilities were obtained for mule deer forages appearing in monthly diets. Relative values among individual forage species were calculated based on nutrient contents and percentage composition in the diet, so that land managers can more precisely assess some impacts of vegetation management practices upon mule deer habitats.


In vivo digestibility percentages from mule deer digestion-balance trials were usually higher than in vitro determinations obtained from the same experimental forage species. Forages with in vitro digestibility values below 35 percent often varied markedly from in vivo estimates. It raises the question whether deer consume species lower than this in digestibility given reasonable choice.


Contains a section detailing mechanical methods for range vegetation control.


A comprehensive review of large herbivore food habits, food selection, intake and digestion processes.


This paper presents the results of experimental studies to determine the effect of various nutritional levels in white-tailed deer on pre- and post-natal growth of the fawn.


Productivity of low-diet yearlings and prime-age animals amounted to 0.62 and 1.36 fawns per doe, respectively, compared to rates of 1.00 and 1.80 for high-diet deer. Males comprised 70 percent of the births from physically mature mothers on low diets, whereas males made up 46.7 percent of the offspring conceived by does on high diets.


A review of deer nutritional studies.


Wallmo, O. C. et al. Evaluation of deer habitat (continued)

Protein and energy requirements of deer and supplies of those nutrients in native forage are synthesized into a model to estimate carrying capacity of seasonal ranges of a migratory mule deer population in north-central Colorado. The model indicates that summer forage will support many times the number of deer present, but winter forage will not sustain deer at any population level. Instead, duration and severity of winter determine the length of time deer can survive on these ranges. Habitat evaluation based on quantification of nutrient supplies and their availability offers a more logical alternative for evaluating deer winter ranges than traditional methods based on measurements of twig lengths of so-called "key" species.


Introduces basic techniques for the identification of stomach and fecal contents.


Energy flow trials with four pronghorn ranging from 108 to 182 days of age produced results similar to those described for other ruminants with the possible exception of total heat production and fasting metabolic rate. The comparatively high heat production may be related to the higher metabolism of younger animals.


Energy metabolism trials conducted at 21°C temperature with pronghorns at four ages from 2 months to 18 months, indicated that 2-month old animals showed higher energy intake, apparent digestible energy, metabolizable energy, energy retention, total, and fasting heat production than animals about 7.5 months of age.

Feeding strategy of large herbivores is aimed at achieving the best nutritional balance within a fixed total bulk of food. If diet selection is dominated by the need to meet nutritional criteria, the response of the diet to availability of particular foods should not be continuous but take the form of a cutoff at very low availability. This implies that as a food becomes rarer in a plant community, grazing pressure on it will increase, at least until the cutoff is reached.


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


Literature on chemical analysis, animal preference, digestibility, and intake of browse and on the production of animals grazing on browse is examined. It is concluded that browse has not yet been shown to make a major contribution to the nutrition of domestic or most game animals and further study of browse-grass comparisons is needed.


The Shiras moose and its winter habitat on the north slopes of the Uinta Mountains, Utah, were studied to determine food requirements for moose, the key browse species during winter, the acreage, density and utilization of the key browse species, and their carrying capacity for moose. The carrying capacity of the key browse species on the winter range was 80,030 moose days or 445 animals for a period of six months. Specifically, the carrying capacity, based on a weighted caloric requirement and annual classification counts, would be 115 bulls, 250 cows, and 136 calves for a period of six months on the winter range.


Three techniques of data collection to determine food preferences of desert bighorn include observing feeding bighorn and recording utilization of plants selected, stomach analysis of harvested bighorn, and microscopic analysis of feces. Biases associated with these techniques are discussed, as are biases which can result when making comparative studies between bighorn and other herbivores. Recommendations are given to reduce bias in data collection and presentation of data.


Discusses nature of land-use changes in North America since 1935 and their implications for big game resources. Includes a brief overview of current state of the arts of habitat management practices for big game animals.


The point-center-quarter and Shafer twig-count methods were used to estimate availability of hardwood browse and consumption by moose on the Tanana River floodplain near Fairbanks, Alaska. In 8- and 15-year old stands, respectively, 38 and 113 kg/ha of available hardwood browse were present. About 55 percent of the available forage was consumed by moose in both areas during the 1974-75 winter. Willows were the most abundant shrubs present and provided the most winter forage for moose.


Contains a section on proper fence construction to allow pronghorn mobility (pp. 55-63).


The results of a study of two groups of white-tailed deer at the Cusino Wildlife Experiment Station in Michigan indicate that acute food shortages during pregnancy do not reduce milk nutritive value but do adversely affect newborn fawns. Deer produce milk of uniform quality regardless of dietary differences during pregnancy.