

ABSTRACT OF THESIS
CATTLE DIETS ON PINE-BUNCHGRASS RANGE

Forage samples collected by freely grazing ruminal fistulated steers were analyzed chemically and botanically to ascertain the quality of the diets selected by two herds of Hereford range cows managed under separate grazing systems.

The herd grazing native and seeded ranges on an integrated basis was maintained on a high plane of dietary crude protein and phosphorus for a longer period of time than was the herd grazing native ranges only. The response was attributed to earlier initiation of spring growth and later attainment of winter dormancy by the seeded forage species. Seasonal trends in dietary protein and phosphorus indicated that the stage of forage maturity at time of consumption was of major importance in determining the general nutritive quality of the diet of both herds.

Ash in the diets of the two herds differed little and exhibited a slight decline from early spring to late winter. No seasonal trends in dietary calcium were noted.

Botanical compositions of the diets were highly variable, particularly on native ranges. The variability reflected heterogeneity of the ranges sampled rather than changes in animal preference.

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T H E S I S

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Chapter I

INTRODUCTION

Current cost-profit relationships are forcing livestock producers, particularly cow-calf operators, in Colorado and other areas of the mountainous West to seek new methods of increasing efficiency of production. Under present management conditions, effective weight gains in range livestock are limited to the summer grazing season when forage plants are growing rapidly. This period extends from early June to late September in most mountainous areas. The quality, if not quantity, of native range forage is often deficient at other periods of the year. Consequently, calves marketed as feeders in October and November average approximately 385 pounds per head. Only a few herds average 400 pounds or more. Many producers are finding that they cannot operate at this rate of production and continue to meet the challenges of rising costs and prevailing market prices.

Improvements in the nutritional status of range livestock probably offer one of the most logical solutions to the problem. Several alternatives for such improvements are available. Initial results from current studies at the Manitou Experimental Forest indicate that incorporation of seeded forage species into the grazing management system may be highly successful in increasing production efficiency through nutrition. However, little is known about the nutritive value of either native or seeded forage species present in the area. Such

information is fundamental to the researcher who is studying various grazing management systems. Furthermore, it provides the commercial livestock producer with guidelines for the development of sound management practices. To obtain this information, the actual botanical and nutritive composition of the grazing animal's diet must be known.

Definitions

The definitions listed pertain specifically to the present study, conducted at the Manitou Experimental Forest.

Palatability.--Plant characteristics or conditions which stimulate a selective response by grazing animals.

Preference.--The behavioral response exhibited by grazing animals when selecting a particular diet from several alternatives.

Herbage.--Unharvested plant material of any kind available for animal consumption.

Forage.--Material of vegetative origin selected and ingested by grazing animals.

Chapter II

REVIEW OF LITERATURE

Accurate evaluations of the botanical and chemical composition of the diets of grazing livestock continue to be one of the foremost problems in the field of range nutrition (Van Dyne and Torell, 1964; Shumway et al., 1963). Unlike farm animals that are usually fed measured rations of known composition, range cattle select their own diet, usually in a complex mixture of plant species and plant parts (Cook, Stoddart, and Harris, 1954). It is this behavioral characteristic of animal selectivity that makes the study of range cattle nutrition unique and difficult.

The main purpose of this chapter is not to catalog results of previous studies. Such results are usually not directly applicable to the current study because of the wide variety in geographical localities and plant species present where these studies have been conducted. Rather, this chapter will attempt to review some of the factors currently thought to affect the botanical and chemical quality of the diet selected by grazing livestock and the techniques frequently employed in range nutrition studies.

Factors influencing the diet selected by grazing animals

The behavioral response exhibited by grazing animals when selecting a particular diet from several alternatives is termed preference. This discussion of preference follows closely the treatment

suggested by Heady (1964), who recognized palatability, conditions of the ecosystem where herbage is produced, and innate animal characteristics as three broad groups of factors determining the ultimate diets of grazing animals.

Palatability.--Defined as plant characteristics or conditions which stimulate a selective response by animals, palatability is probably one of the foremost factors influencing the selection of certain forage species by grazing animals. However, the factors that determine palatability are largely unknown (Heady, 1964; Garner, 1963). Chemical constituents of plants as they affect palatability have received the most attention. Several workers have found high positive correlations between crude protein content of forage and preference by both cattle and sheep (Cook, 1959; Hardison et al., 1954; Lesperance et al., 1960b; Torell and Weir, 1959; Weir, Meyer, and Lofgreen, 1959). In recent work, however, Denham (1965) found very low correlations between crude protein content of prairie sandreed, blue grama, and needle-and-thread grass and the amounts of these three species in the diets of cattle. Several researchers found corresponding negative correlations between the crude fiber fraction of forage species and the amount of those species selected by grazing animals. Markedly larger amounts of mineral constituents, particularly ash, have been observed in forage samples collected by fistulated animals than in the forage present in the sward (Cook, 1964; Arnold et al., 1964; Lesperance, Bohman, and Marble, 1960a). Most authorities share the opinion that these differences do not represent animal preference but result instead from salivary contamination of the forage samples.

Hardison et al. (1954) reported that high total ether extract in the forage indicated high preference. Similar relationships for total digestible nutrients (TDN) of forage have been reported by Meyer et al. (1957). In a recent review, Heady (1964) cited a variety of other chemical constituents found in forage that have been positively correlated with preference. Included were such factors as sugars, short-chained fatty acids, phosphorus, and potassium. Components reported as having negative relationships were tannin, lignin, coumarins, and nitrates. In general, results of studies conducted to determine the chemical components that affect forage palatability are somewhat inconclusive and often conflicting. Evidence varies from high correlations found for some of the previously mentioned chemical constituents to conclusions that there is no consistent relationship between chemical composition of forage and its relative palatability (Hardison et al., 1954). Probably more important than the amount of any one chemical component is the combination of components (Heady, 1964). Several investigators have indicated that the total nutritive value of a forage species is a better indicator of palatability than is any one chemical constituent (Cook, 1959; Hardison et al., 1954). It is obviously difficult to isolate any one chemical fraction that may influence palatability, as changes in the amount of a particular chemical in a plant are usually accompanied by corresponding changes in other chemical components. The use of partial regression analyses to separate the effects of various chemical components has been suggested for use in future studies (Heady, 1964).

Within any plant, the chemical composition varies with plant parts (Heady, 1964), and animal preference for certain plant parts is a

well documented phenomenon. Fruits and seedheads are generally higher in crude protein, fats, and soluble carbohydrates than are other plant tissues (Cook and Harris, 1950a). Similarly, leaves are higher in crude protein than are stems. Sheep and cattle have both been found to select leaves in preference to stems when physically possible (Arnold, 1960; Heady and Torell, 1959). A study performed by Cook (1959) illustrated that plants on unfavorable sites were preferred over those on more favorable sites because of a higher proportion of leaves to stems on the unfavorable sites. During a summer's grazing season on mature annual range, sheep showed preference for forb heads, whereas, cattle tended to select grass heads (Van Dyne and Heady, 1965a). Some researchers have conjectured that the parts of the plant at the time of consumption are, in fact, more important in determining the nutritive value of the diet than is the species of plant consumed (Connor et al., 1963). Heady (1964) found it difficult to rationalize whether preference for certain plant parts is due to their chemical content or if other factors are involved.

Forage maturity is another often suggested factor influencing palatability, and it is inevitably associated with changes in chemical composition and plant parts. As a plant matures, protein and moisture decrease markedly with accompanying increases in the lignin and cellulose components, as well as increases in other carbohydrates (Hart, Guilbert, and Goss, 1932; Wallace, Rumburg, and Raleigh, 1961). Indeed, Cook and Harris (1950b) found that chemical changes as a result of advancing maturity were greater than those arising from any other factor. Reductions in plant succulence seemed to be the most important factor affecting palatability of several species of seeded grasses in

the ponderosa pine zone of New Mexico (Springfield and Reynolds, 1951). Sufficient evidence is not available to evaluate whether these factors of plant maturity affect palatability through a taste response or through some other stimulus such as touch (Heady, 1964).

Recent evidence seems to indicate that forage maturity is indirectly related to the appetite of the grazing animal and the quantity of forage that it consumes (Balch and Campling, 1965). Inverse relationships between the maturity of ingested forage and the rate at which it is digested by the animal have been elucidated (Tayler and Deriaz, 1963; Garner, 1963; Denham, 1965). Forage decreases in digestibility with advancing maturity due to the encrustation of cellulose particles by the indigestible component lignin, thus presenting a mechanical barrier to the digestive microorganisms in the rumen (Halliwell, 1963; Dehority and Johnson, 1961). There is considerable evidence in support of the hypothesis that appetite in the ruminant is controlled mainly by the rate of digestion and removal of the bulky material from the rumen and reticulum (Campling, 1964). If this hypothesis is valid, the indirect effect of forage maturity upon appetite becomes evident. Appetite and its influence upon animal selectivity will be discussed in a later section.

Cattle and sheep are known to select forage that is more digestible than that they reject (Garner, 1963; Van Dyne and Weir, 1964). Denham (1965) stated that it is likely that the more digestible forage is preferred because it is less fibrous and therefore easier to consume.

Associated species and herbage availability.--Preference for a given species is contingent upon the availability of other associated

species from which to choose (Heady, 1964). Species of secondary palatability, specifically big sagebrush (Artemisia tridentata) and yellowbrush (Chrysothamnus stenophyllus), were noted by Cook, Taylor, and Harris (1962) to receive heavier grazing use on good range sites where they occurred sparsely than on poor range sites where the less palatable species were more abundant. These authors concluded that sheep selected the less palatable species for the sake of variety. Further evidence has been presented illustrating that the relative abundance of a particular plant species in a community of mixed vegetation does not necessarily determine the quantity of that species in the diet. Steers grazing sagebrush-grass ranges in northeastern Nevada selected diets containing an average of 68 per cent grass throughout the summer even though grass constituted less than 15 per cent of the vegetative cover (Connor, 1962).

The quantity of herbage available to the grazing animal also influences relative preference. Van Dyne and Heady (1965a) observed that sheep grazing a mature annual range in California preferred forbs or parts of forbs in early summer when there was ample forage of numerous species available, but as the degree of utilization increased in late summer, the animals tended to eat much more grass. Workers in Utah found that sheep grazing a sagebrush-grass range changed their selectivity from browse to greater quantities of both grass and forbs as the degree of range utilization increased (Cook, Kothmann, and Harris, 1965). A good example of forage availability and its effect on animal selection was exhibited in Arizona. There cattle grazing desert grassland ranges selected rapidly growing annual forbs and

grasses when they were available but turned their attention to species of doubtful palatability such as mesquite and catclaw during periods of low rainfall when herbage was scarce (Shumway et al., 1963). Similar responses have been observed in numerous other studies (Ridley et al., 1963; Springfield and Reynolds, 1951; Arnold, 1960). Indeed, Hardison et al. (1954) concluded from their studies that herbage availability was the major factor influencing animal preference.

The availability of forage and its effect upon animal preference for plant species and parts also exerts a marked influence on the nutritive quality of the diet. Most researchers have found significant negative correlations between herbage availability and crude fiber content of the diet (Weir et al., 1959; Weir and Torell, 1959; Lesperance et al., 1960b). The dietary crude fiber increase with increased utilization was generally accompanied by a corresponding drop in dietary crude protein. Undoubtedly, part of this protein decrease can be attributed to increasing forage maturity, since most of the studies mentioned were conducted over periods of one to several months. However, much of the decrease in diet quality was probably due to less opportunity for animal selection. Connor (1962) reported that cattle used in his investigation were able to maintain their dietary protein levels by seeking out portions of the range that had remained moist, avoiding the more mature plants, and consuming more browse plants which tended to maintain their protein levels longer than did grass. Edlefsen, Cook, and Blake (1960) also reported that animals grazing mixtures of species were able to maintain the nutritive quality of their diet by shifting from species to species. Obviously, for any of the above

alternatives to exist, ample opportunities for animal preference must also exist, both in the number of species present and the quantity of herbage present.

Soil, climate, and topography.--These components of the ecosystem in which forage is produced exert several indirect effects upon the diets consumed by grazing animals (Heady, 1964). Cook and Harris (1950a) observed that the chemical content of herbage on a particular site was influenced by soil and plant development, water runoff, intensity of shading, and other environmental factors. Furthermore, variations in animal movements and grazing behavior are induced by several factors on the environment. Cattle in the ponderosa pine zone of New Mexico were found to alter their grazing habits with changes in the weather, grazing less discriminately when mature grasses were wet from rain or dew (Springfield and Reynolds, 1951). The same cattle grazed for longer periods during cloudy weather and were less selective during the morning and evening than they were at other periods of the day. Reppert (1957) observed that cattle on the eastern plains of Colorado selected large quantities of sand sagebrush and needle-and-thread grass during periods of snow cover. These two relatively tall species were the most accessible at that time and had perhaps been softened by the moisture.

Methodology--The grazed sample method of dietary evaluation

The botanical and nutritive evaluation of the diet of grazing animals is a perplexing problem involving a complex of plant, animal, and environmental factors. Literature relative to the subject is often contradictory or poorly supported with facts, because of inadequate

techniques for studying the problem (Sell et al., 1959). Methods based on hand sampling are of questionable validity, as hand clipping does not accurately simulate the grazing of animals under range conditions (Van Dyne, 1963; Hardison et al., 1954; Lesperance et al., 1960b; Weir et al., 1959). Observation techniques employing close watch of the grazing animal have been used in determinations of relative preference (Reppert, 1957). Cook, Harris, and Stoddart (1951) used a combination observation and hand sampling technique to obtain samples representative of forage being grazed by sheep. However, observation techniques are subject to criticism because of the possibility of personal bias by the observer (Van Dyne and Torell, 1964).

The most recent techniques of obtaining samples representative of the diet selected by grazing animals employ collector animals fitted with esophageal or ruminal fistulae (Van Dyne and Heady, 1965a; Cook, 1964). The development and use of the esophageal fistula for range nutrition studies has been discussed thoroughly in a recent review (Van Dyne and Torell, 1964). The present discussion shall be limited to the use of the ruminal fistula, as such information is pertinent to the current study.

The rumen evacuation technique.--The technique most frequently employed when ruminal fistulated animals are used in dietary evaluation studies is termed the "rumen evacuation technique" (Lesperance et al., 1960a). The technique involves completely emptying the rumen through the fistula and cleaning the rumen wall with the hand, then allowing the animal to graze a desired period of time, followed by collecting the sample from the animal, and finally returning the original contents to the rumen so as not to deprive the animal of its microbiota.

When used in forage digestibility determinations, ruminal fistulated animals are more advantageous than those fitted with esophageal fistulae, as the ruminal fistulated animals provide a ready source of rumen liquor inocula for in vitro or in vivo digestibility determinations. Ruminal fistulated animals and the rumen evacuation technique have several distinct disadvantages for diet determinations under range conditions, however. Van Dyne and Torell (1964) enumerate the following disadvantages of the rumen evacuation technique: it is not suitable for repeated sampling; the technique is more difficult and time consuming than that of the esophageal fistula and presents disadvantages on cold, open winter range; direct comparisons between sheep and cattle through this method are difficult.

Lesperance and Bohman (1963) observed a depressing effect upon forage digestibility when the rumen was emptied as few as three times a week. Therefore, repeated samplings within a period of several days could exert detrimental effects upon the animal's grazing performance. If there is validity in the hypothesis that appetite is regulated by the degree of ruminoreticular fill (Montgomery and Baumgart, 1965a, 1965b; Campling, 1964), apparently the complete evacuation of the rumen may exert a profound influence upon the animal's appetite. This immediately raises the question of the importance of appetite of the animal at the time the forage sample is collected. Arnold et al. (1964) have demonstrated that the practice of fasting animals overnight exerts an influence upon their forage selectivity the following morning. Tayler and Deriaz (1963) only partially emptied the rumen of their fistulated steer when collecting pasture forage samples. While the

steer grazed, a collector inserted his arm through the fistula and collected boluses of ingested forage in the palm of his hand as they reached the cardia. Such a procedure has obvious disadvantages for use under range conditions. Although several researchers have used the rumen evacuation technique (Lesperance et al., 1960a; Connor, 1962; Tayler and Deriaz, 1963), none have mentioned the apparent effect of rumen evacuation upon appetite or grazing performance per se.

Contamination of fistula samples.--An undesirable property of forage samples collected through either esophageal or ruminal fistulae is contamination by saliva. Although such contamination has little effect on botanical analysis of the samples, the effect upon analysis for chemical components is noteworthy. Bath, Weir, and Torell (1956) observed that salivary contamination increased the ash content of samples but did not appreciably affect other chemical constituents. Lesperance et al. (1959, 1960a) also noted salivary ash contamination and stated that the degree of contamination would depend upon the type of herbage sampled. In their comparisons of the chemical content of fistula samples to forage fed, coarse, fibrous feeds collected through fistulae tended to contain more ash contamination than did lush, succulent feeds. A greater amount of saliva was possibly secreted during ingestion of the coarser feeds. The above investigators also found significantly more phosphorus and slightly more calcium in rumen samples than was present in the forage offered to the animals. Contamination by these two minerals may have resulted to a certain extent from the rumen wall, since rumen samples contained more phosphorus and calcium than did samples of identical forage collected from animals with esophageal fistulae. Shumway et al. (1963) investigated the effects of

salivary contamination on crude protein of fistula samples. They found slight but statistically insignificant increases in crude protein of some ruminal fistula samples and attributed the increase to salivary nitrogen.

Although some investigators (Cook et al., 1962) have attempted to correct fistula forage samples for added nitrogen, ash, and phosphorus from salivary contamination by calculating the amount and chemical composition of the added saliva, Van Dyne and Torell (1964) maintain that such corrections are not completely reliable. They state that unless accurate correction measures (e.g., isotope dilution technique) are available, chemical analysis data should be presented on either a silica-free or ash-free basis.

Sampling variability.--Results of previous investigations employing fistulated animals to study forage quality are not directly applicable to the present study at Manitou Experimental Forest because of the different techniques and different plant species involved. Some insight into the nature of sampling variability encountered in previous work may be helpful, however.

Van Dyne and Heady (1965a) found considerable variation in sampling dietary botanical components of mature annual forage in California. The most important differences in dietary composition existed between three amounts of forage available, between classes of livestock (sheep and cattle), and between morning and evening samples collected during the same day. Differences between samples collected on consecutive days of the 5-day sampling periods by each class of livestock were minor, however. When individual animal data for the five esophageal fistulated steers used in the study were averaged over

the entire study period, highly significant differences ($P < .01$) were found to exist between individual steers in their selection of all grasses as a group and significant differences ($P < .05$) between their selection of all forbs as a group. Calculations of the number of animals necessary to estimate a particular dietary botanical constituent within 10 per cent of the mean with 90 per cent confidence showed that at least 10 animals were necessary for sampling such broad categories as grasses, forbs, and shrubs in early summer. In late summer, however, as few as four animals could have been used to obtain estimates of the same constituents with equal precision. Earlier studies by Lesperance et al. (1960b) using ruminal fistulated steers to estimate botanical composition of the diets of grazing cattle also demonstrated high variability with highly significant differences among grazing periods and days. Less variability was encountered by Ridley et al. (1963) who used ruminal fistulated steers to sample orchard grass and tall fescue pastures. They calculated that to estimate mean botanical composition within a 20 per cent confidence interval at the 90 per cent level of significance during any one day, five rumen samples would have been required from the tall fescue mixture and 11 samples from the orchard grass mixture. This greater uniformity among samples than exhibited in the California study was probably a result of the uniform mixture of a few species sampled (Van Dyne and Heady, 1965a).

Estimations of the chemical components of the diet selected by grazing animals tend to be less variable than estimations of the botanical components (Van Dyne and Heady, 1965b; Connor, 1962). A coefficient of variation of 30 per cent was calculated for the dietary protein component of samples collected from esophageal fistulated

heifers grazing bunchgrass ranges in Montana (Van Dyne, Thomas, and Van Horn, 1964). Using ruminal fistulated steers to sample desert range forage in southern Nevada, Connor (1962) calculated that ten samples per monthly sampling period were necessary to estimate dietary crude protein within four per cent of the mean at the 90 per cent level of significance. He noted that 13 samples would have been required to estimate the same dietary constituent with equal precision at another study area located in northeastern Nevada, where a more complex mixture of herbage species were available for selection.

Laboratory analysis of grazed forage samples.--Forage samples taken from ruminal fistulated animals by the rumen evacuation technique have been subjected to analyses for several chemical constituents, including crude protein, ether extract, nitrogen-free extract, energy, crude fiber, ash calcium, phosphorus, and lignin (Shumway et al., 1963; Lesperance et al., 1960b; Connor, 1962). Several investigators have also successfully subjected rumen samples to in vitro digestibility determinations (Connor, 1962; Ridley et al., 1963). Cook and Harris (1950), Cook, Stoddart, and Harris (1956), and Cook et al. (1954) have repeatedly pointed out that forage evaluation by chemical analysis without corresponding digestibility data is not entirely reliable. However, they conceded that such chemical assays provide valuable comparative information and serve to show what constituents are deficient or present in excess. The lack of digestibility information and the inability to correct for salivary contamination of samples undoubtedly encumbers interpretation in the present study.

The botanical analysis of the diet selected by grazing animals has been conducted through several methods. Norris (1943) hand

separated recognizable botanical constituents of rumen samples from slaughtered sheep that had previously been fed known weights of various forages. He found wide variability between the amounts of forage identified in the rumen samples and amounts fed in the rations. The variability was attributed to differential rates of digestion of the various forages. He suggested that the only value of the technique might lie in an indication of preference.

The point analysis technique of studying natural vegetation was later adapted for use in botanical analysis of forage samples collected from fistulated animals (Torell, 1956). Using hand-made two- and three-species mixtures of forages, Torell (1956) recorded the nearest plant fragment under a crosshair of a binocular microscope. He systematically observed 600 points per sample and found that the per cent of points identified for a certain species closely approximated the weight of that species in the sample. Harker, Torell, and Van Dyne (1964) later designed an experiment to study observer variation and required sample size when using the microscopic point analysis technique. They observed two-species mixtures of varying proportions of grass and sweet potato vines and calculated regression equations for use in prediction of forage weights from percentage points. Calculated regression equations more complex than the direct $X = Y$ equation added so little accuracy to the analysis that the investigators concluded that the percentage weight of a particular species in fistula forage samples could be predicted directly from the percentage points observed for that species. Their calculations also indicated that, when averaged across four different observers, 400 microscopic points were necessary to estimate within 20 per cent of the mean at the 90 per cent level of probability.

Several other workers have successfully used this technique, or slight modifications thereof, for the botanical analysis of both esophageal and ruminal fistula forage samples (Heady and Torell, 1959; Lesperance et al., 1960b; Connor, 1962; Van Dyne and Heady, 1965a; Lusk et al., 1961; Cook et al., 1958).

All of the above workers analyzed forage samples as they were collected from the fistulated animals. They have used few preparatory treatments, other than mixing the samples and spreading them over suitable surfaces for the point analysis procedure. Identification of particles was on the basis of gross morphological features such as leaf margins, pubescence, venation, and other macroscopic features commonly used in taxonomic work. Cook et al. (1958) reported that much material in esophageal fistula samples collected on winter range could be distinguished by its color; however, identification of material in samples collected during the growing season was difficult, due to the masticated condition of the forage. Grimes, Watkin, and May (1965) reported that variability encountered in microscopic point analysis procedures could be reduced extensively through pre-treatment of the samples by maceration in a Waring blender. Such pre-treatments yield samples composed of particles relatively homogeneous in size, but the need for identification techniques based on characteristics other than gross morphological features of the particles becomes evident.

As early as 1939, workers used histological features of plant material found in stomachs of herbivorous animals to determine their food habits (Baumgartner and Martin, 1939). Researchers in North Dakota used histological characteristics of plant epidermis to study

food habits and preferences of grasshoppers (Brusven and Mulkern, 1960). Their technique required the collection and preparation of known plant material anticipated in the diet. This material was later used as a reference during the analysis of the crop contents of the grasshoppers. Although they found epidermal characteristics of grasses and forbs to be highly variable with different stages of maturity, such histological features as size and shape of epidermal cells, presence or absence of hairs, and shape of hairs provided diagnostic characteristics for identification of forb species. Species of grass were identified by the occurrence and position of such specialized epidermal cells as cork cells, silica cells, silico-suberose couples, and asperities. Similar techniques based on microscopic features of plant epidermis have been used in food habit investigations of herbivorous animals ranging from cottontail rabbits (Dusi, 1949) to pocket gophers (Ward and Keith, 1962).

The microtechnique described above was recently adapted for possible use in the botanical analysis of forage samples collected by fistulated cattle (Denham, 1965). Although he was not able to obtain samples from his fistulated steer, Denham (1965) investigated the use of the microtechnique on hand-compounded forage samples made to simulate fistula forage samples. Samples were prepared for analysis by first oven-drying, then by grinding through a one millimeter mesh, and finally, by mounting small subsamples of the material on microscope slides. The analysis procedure was executed by observing and identifying material at approximately 100 locations on each of two slides prepared from each mixed sample. Fragments that could not be recognized as epidermal fragments were disregarded in the final analysis.

Reference slides and photomicrographs of plant species anticipated in the samples were used to facilitate identification of the plant fragments. When all six species observed were correlated with the percentage weight of each expected in the sample, a very significant correlation of $r = 0.97$ resulted. The researcher conjectured that equally high degrees of accuracy should be achieved from analyses of samples collected through esophageal fistulae.

Chapter III

METHODS AND MATERIALS

The study area

The study was conducted at the Manitou Experimental Forest, 28 miles northwest of Colorado Springs, Colorado. The Experimental Forest is situated in the ponderosa pine zone at approximately 8,000 feet elevation. Climate of the area is relatively cool and semi-arid; the mean annual temperature is approximately 45 F. Mid-summer temperatures seldom exceed 90 F, and overnight temperatures frequently go below freezing early or late in the growing season. Cold, but open winters are common, with minimum temperatures as low as -40 F. Precipitation during the past 25 years has averaged 15.73 inches, with 11.25 inches of this amount falling predominantly as rain from April through August. Rain showers of high intensity and short duration are common during the late spring and summer months.

Soils of the area are texturally classified as sandy loams or sandy clay loams and are developed from an alluvial parent material of decomposed Pikes Peak granite. Surface horizons are generally quite shallow, ranging in depth from 8 to 10 inches. They either lack a subsoil or overlie a coarse gravelly loam subsoil that grades into unconsolidated parent material at a depth of 3 to 4 feet. These soils are acid in reaction and are low in fertility and organic matter. Most of the soils are unstable and erode extensively when exposed.

The grazing units on which the study was conducted consist of both native and seeded ranges. Their respective locations and acreages are presented in Figure 1.

Native range grazing units.--The native bunchgrass ranges designated I-7 and I-8 are typical of the ponderosa pine-bunchgrass type and are used for early spring and late fall grazing, respectively. Both ranges are in good condition. The major forage species in the units are Arizona fescue (Festuca arizonica Vasey)^{1/} and mountain muhly (Muhlenbergia montana (Nutt.) Hitchc.). Less common gramineous species are blue grama (Bouteloua gracilis (H.B.K.) Lag.), little bluestem (Andropogon scoparius Michx.), Parry danthonia (Danthonia parryi Scribn.), and sleepygrass (Stipa robusta (Vasey) Scribn.). Several species of meadow grasses and sedges occur along drainages. Mountain muhly is the major forage producer of the two units. Three cover types common to both units are a grassland type, an open timber type, and a dense timber type. The major portion of the area is occupied by the grassland and open timber types, with the dense timber type restricted to a few isolated locations.

The native bunchgrass unit I-4 is used for summer grazing. It is similar in cover types and species association to the spring and fall ranges described above. The area is generally good condition range.

Grazing units I-1 and I-5 are native meadow ranges. Unit I-5 is grazed in the fall following hay cutting and has a vegetative cover of typical native meadow species. Kentucky bluegrass (Poa pratense L.), timothy (Phleum pratense L.), sedge (Carex nebraskensis Dewey), and wire

^{1/}Scientific names from nomenclature by Harrington, H.D. 1954. Manual of the plants of Colorado. Sage Books, Denver, Colorado. 666p.

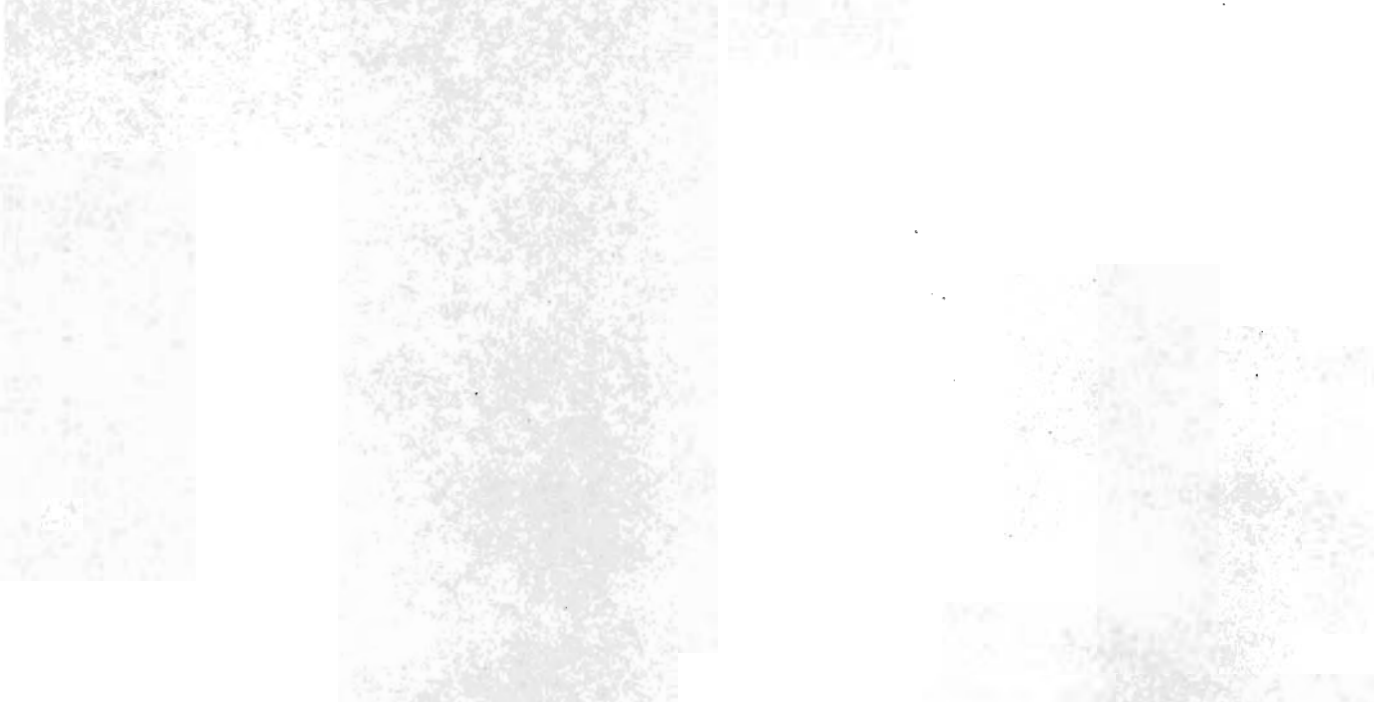


Figure 1. Map of a portion of the Manitou Experimental Forest showing locations and acreages of grazing units used in the study.

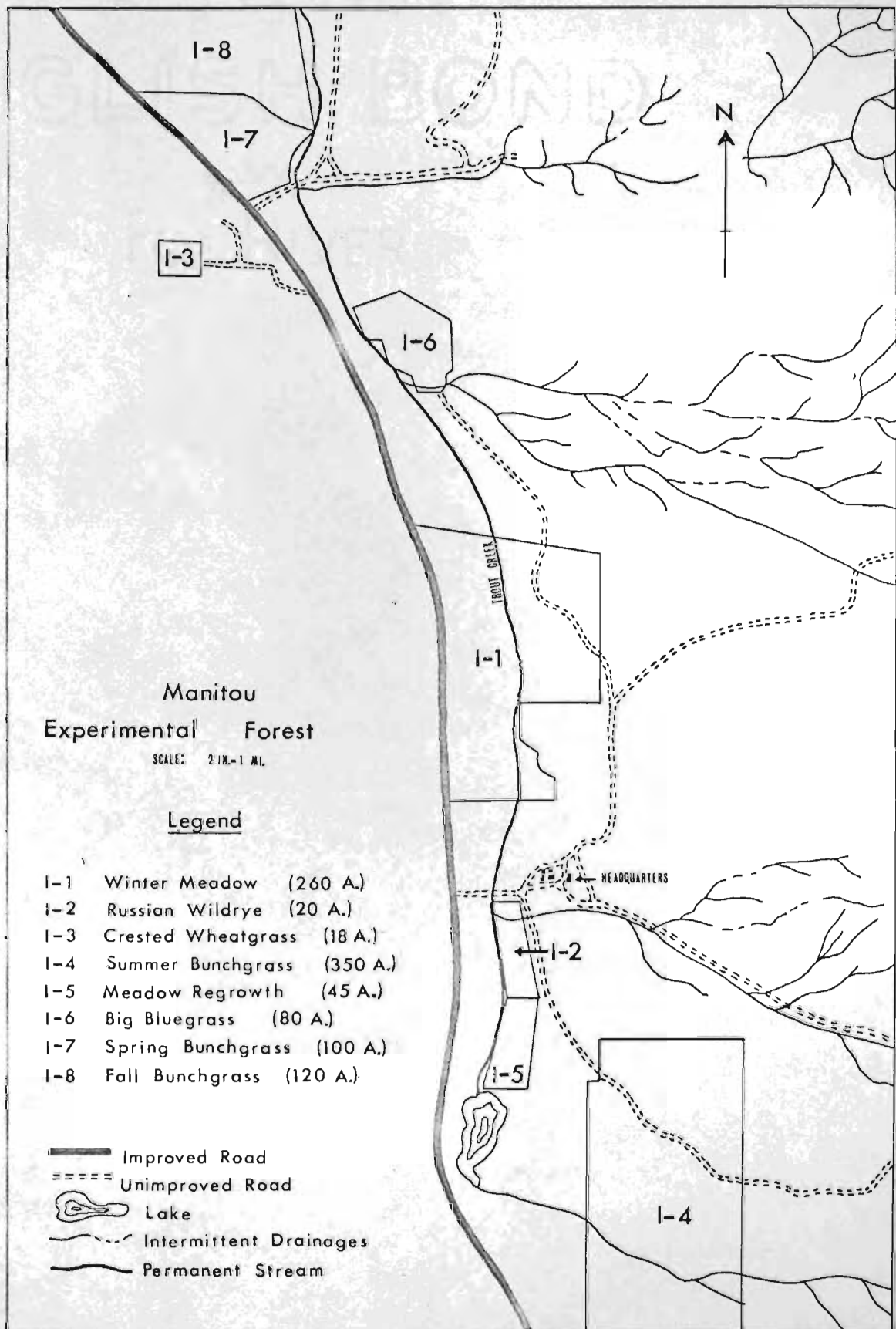


Figure 1

rush (Juncus balticus Willd.) are predominate species on the hydric sites. On drier sites, western wheatgrass (Agropyron smithii Rydb.) and slender wheatgrass (Agropyron trachycaulum (Link) Malte) are common.

Unit I-1 is used for winter range. Trout creek traverses the entire length of the unit in a north-south direction and divides the area into two approximately equal portions. The low-lying areas immediately adjacent to the stream support native meadow vegetation similar in species association to that of the I-5 unit, with the exception of dense patches of willows (Salix exigua Nutt. and Salix sp.) along the stream banks. The low-lying hydric meadow type adjacent to the creek grades into a pine bunchgrass type on the slopes and terraces to the east and west.

Seeded range grazing units.--The Sherman's big bluegrass (Poa ampla Merr.) unit I-6 and the Russian wildrye (Elymus junceus Fisch.) unit I-2 are used for late fall and early spring grazing, respectively. Both units were seeded in 1954. The Russian wildrye unit supports a nearly pure stand of that species. Kentucky bluegrass, wire rush, and a few species of forbs are interspersed infrequently throughout the stand. On the other hand, the Sherman's big bluegrass unit has sustained considerable invasion by several species of grasses and forbs. Sleepygrass, needle-and-thread grass (Stipa comata Trin. and Rupr.), slender wheatgrass, and bluegrama are several of the more abundant gramineous species present. Fringed sagebrush (Artemisia frigida Willd.), lambsquarter (Chenopodium album L.), field bindweed (Convolvulus arvensis L.), and several other species of forbs are also common.

Unit I-3 is a seeded pasture supporting a nearly homogeneous stand of crested wheatgrass (Agropyron cristatum (L.) Gaertn.). Some

invasion by fringed sagebrush has occurred. The unit is used for late spring grazing.

Collection of dietary forage samples with fistulated steers

This study had as its major objectives the chemical and botanical evaluation of the diets of cattle grazing ranges of the Manitou Experimental Forest. Of particular interest was the dietary evaluation of two herds of cattle. One herd grazed native vegetation only (native range herd); the other grazed both native and seeded vegetation on an integrated basis (integrated-use herd). The annual grazing management plan used to regulate the two cow herds is presented in Figure 2.

Fistulated collector animals.--Two ruminal fistulated Hereford steers (Figure 3) were used to collect samples of forage representative of that consumed by each of the above cow herds. The steers were fitted with 4-inch outside diameter plexiglass fistula cannulae with removable threaded lids. Both animals were approximately 2 years of age at the initiation of the study. The first steer ready for use after fistulation (steer A) was introduced to the study area in late February, 1965. Rumen sample collections were initiated March 17, 1965, at which time both cow herds were grazing together in the native meadow unit I-1 (Figure 2). Steer A was used to collect samples of forage representative of that consumed by both herds until April 15, 1965, when the cattle were removed from the grazing unit and the two herds were separated. At that time, the other steer (steer B) was incorporated into the integrated-use cow herd and steer A remained with the native range cow herd. Steer B was a nervous, excitable animal and by the August 10 collection period he had become completely unmanageable and was no longer

Figure 2. Grazing management plan used to regulate the integrated-use and native range cow herds and their respective fistulated steers.

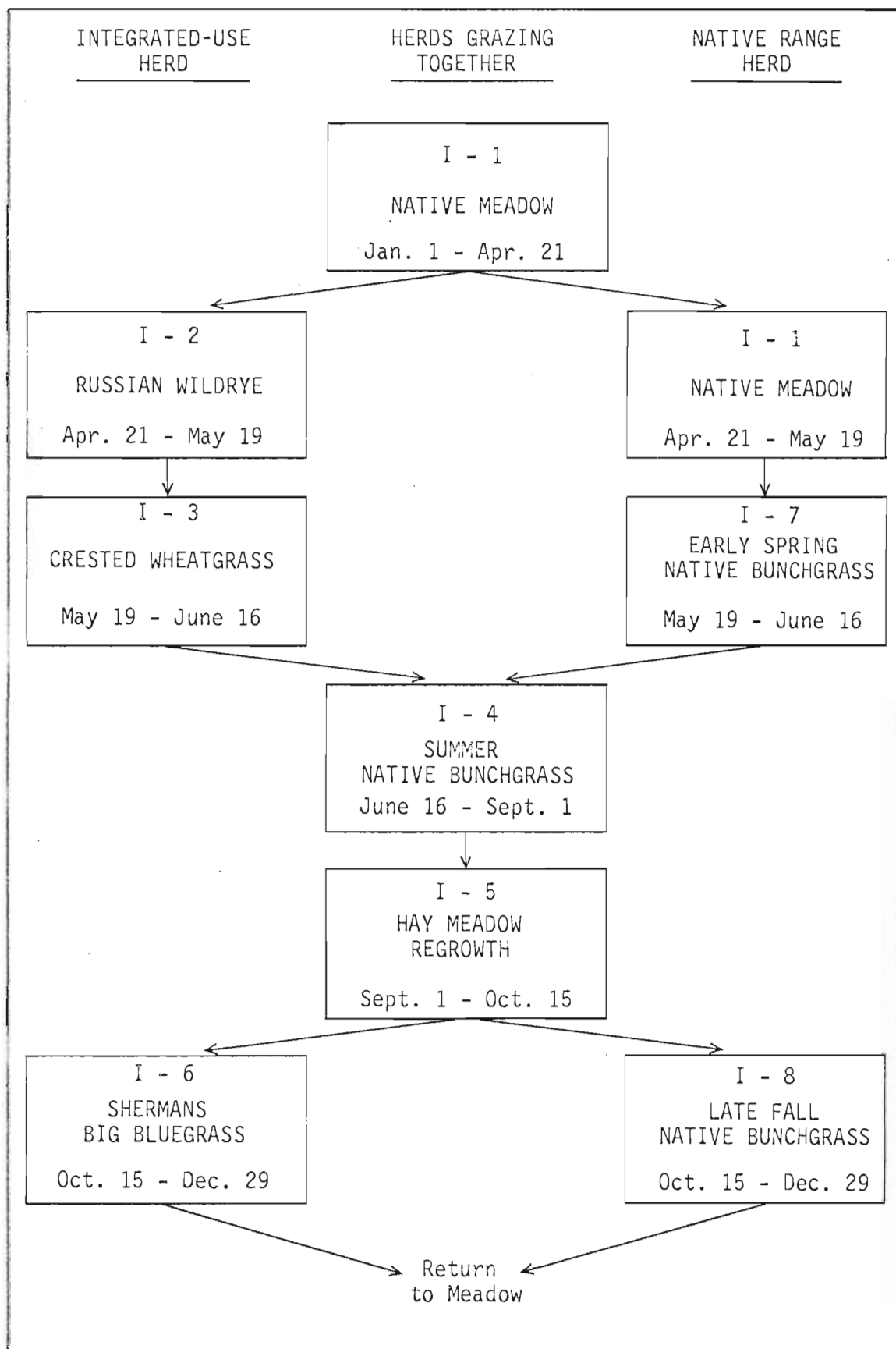


Figure 3. Ruminant fistulated steer with open fistula cannula.

Figure 4. Insulated chest used for storing rumen contents during sample collection period.

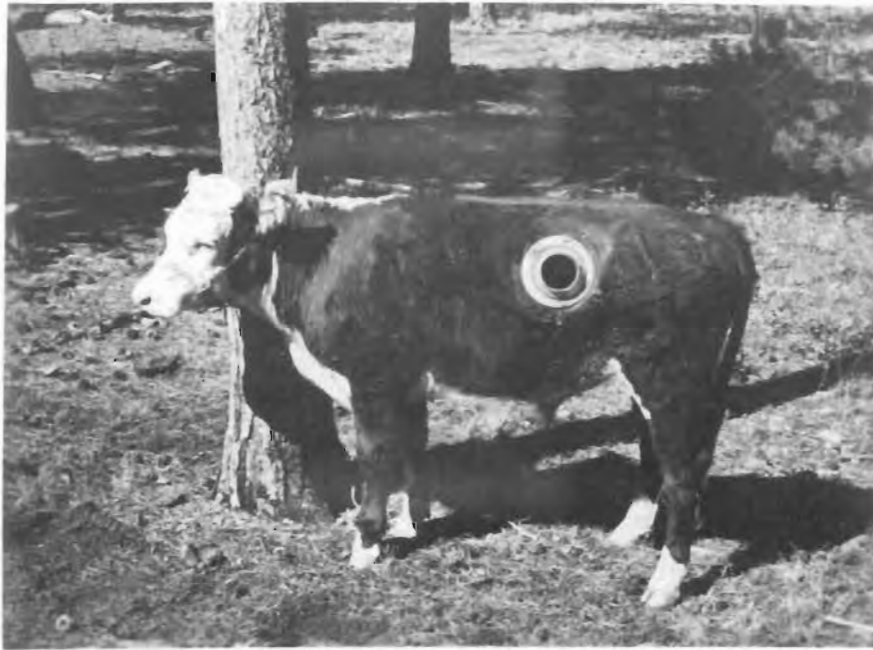


Figure 3



Figure 4

useful for sample collection purposes. Steer A was therefore used for all subsequent sample collections. When the two cow herds were grazing in separate units, the steer was alternated between units to obtain samples representative of the diets of each herd. Upon introduction into a new pasture, the fistulated steer was allowed an adjustment period of at least 5 days before samples were collected.

Sampling scheme.--Rumen sample collection periods were scheduled at approximately monthly intervals with more frequent collections during months of rapid vegetational change. Table 1 is a summary of dates during the study when samples were collected. Initially, one sample per collection period was taken. However, when use of steer B was discontinued, the sampling scheme was altered to include, when possible, two samples per collection period. Usually, the first sample of a particular period was collected during the afternoon and the other during the following morning. On two occasions, August 14 and September 14, both morning and afternoon samples were collected during the same day.

Rumen evacuation technique.--On a typical sampling day, the fistulated animal was caught by hand in the grazing unit and restrained with a halter. The rumen and reticulum were then evacuated through the cannula and the removed ingesta was stored temporarily in a large pre-warmed insulated chest (Figure 4). All semi-liquid ingesta that could not be evacuated from the rumen with the hand was removed by swabbing the rumen floor with a large, soft synthetic sponge. Immediately following evacuation, the animal was released in the proximity of the area where he was initially found grazing and was allowed to graze at will for a period of time sufficient to obtain a sample approximately

Table 1.--Dates of forage sample collections from fistulated steers in each grazing unit.

Grazing Units							
I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8
Mar. 17	<u>May 1</u>	<u>May 25</u>	Jul. 8 ^{1/}	Sept. 14*	Oct. 21	May 25	Nov. 4
Apr. 17	<u>May 15</u>	June 16	Aug. 10	Sept. 30	Oct. 22	June 15	Nov. 5
Jan. 8			Aug. 14*	Oct. 1	Dec. 2		Dec. 13
Jan. 9			Aug. 31	Oct. 14	Dec. 3		
Feb. 12			Sept. 1	Oct. 15	Dec. 19		

^{1/}Samples collected from both fistulated steers grazing in same grazing unit.

Underlined dates refer to samples collected by steer B.

*Both morning and afternoon samples collected on same date.

4 quarts in volume. He was then recaptured and the grazed sample was removed. Copious quantities of saliva that usually collected in the rumen and reticulum during the grazing period were partially removed from the sample by squeezing the material lightly by hand. Finally, the original contents were returned to the rumen, the rumen cannula was reclosed securely, and the animal was set free. The collected rumen samples were placed in polyethylene bags and were frozen until they could be analyzed. The length of the grazing period necessary to obtain a sample of sufficient size varied from 30 minutes to 1 hour and depended upon the amount of herbage available and the time the steer actually spent in the process of grazing. The grazing animals were observed during the collection period and the plant species present in the grazing area were noted. These species lists were a valuable reference aid during the botanical analyses of the grazed samples.

Laboratory analysis of the grazed forage samples

The frozen rumen samples were prepared for laboratory analysis by first drying at 150 F in a forced-air oven and then by grinding in a Wiley mill equipped with a 1-mm screen.

Chemical analysis.--Duplicate aliquots were taken from the ground rumen samples and were subjected to analyses for crude protein, oven-dry moisture, phosphorus, calcium, and ash. The analytical procedures were in accordance with the "Official Methods of Analysis of the Association of Official Agricultural Chemists."

Botanical analysis.--The botanical composition of the rumen samples was determined by a microscopic analysis procedure similar to that used by Denham (1965). The first phase of the procedure included

preparation of reference microscope slide mounts of tissue from all plant species anticipated in the diet. These slides were constructed according to the procedure outlined by Denham (1965). The reference slides were then studied intensively to discover and learn diagnostic histological characteristics of each species. Particular attention was given to such features as cell wall characteristics, presence and shape of specialized cells, cell dimensions, presence and characteristics of micropubescence (asperities), and characteristics of stomatal cells. Illustrations of the various diagnostic properties were sketched for ready reference during this phase.

The botanical analysis phase was performed by observing under a binocular microscope five slide mounts prepared from each of the finely ground rumen samples. Twenty locations were systematically observed on each slide and all recognizable fragments at a location were counted and recorded. A location was considered as the area of the slide delineated by a microscope field using 125 magnifications. Only those fragments that were recognized as epidermal tissue were considered in the analysis. The fragments were identified to species when possible. They were otherwise identified to genera, or, if this was not possible, as grass or forb. The total number of fragments of a particular species or category was then tabulated for all five slides. The relative proportion each species contributed to the sample was then calculated from the above totals.

Chapter IV

PRESENTATION OF RESULTS

Nutritive composition of the diet

The nutritional evaluation of the annual diets selected by the "integrated-use" cow herd and the "native range" cow herd was based on the relative amounts of four chemical constituents present in forage consumed by each herd. Representative forage samples were collected by ruminal fistulated steers, and the 32 samples obtained were analyzed for crude protein, calcium, phosphorus, and ash. The results of the analyses are presented in this section under a separate subheading for each of the four chemical components studied. The limited number of samples obtained and the lack of replication in both grazing treatments and collector animals preclude statistical analyses of the data. Consequently, presentation and interpretation are based largely upon graphical representations of the data (Figures 5 through 8). Under each of the four subheadings, the annual mean, seasonal trends, and various levels of the chemical component in the diet of the native range herd are first discussed. Then, the various levels and trends of the component in the diet of the integrated-use herd are presented by way of comparison. It should be remembered that native forage in grazing units I-1, I-4, and I-5 contributed to the diets of both herds. Reference to the annual grazing management plan (Figure 2) may aid in understanding the results.

Dietary crude protein.--Samples of forage grazed by the native range herd averaged 9.08% crude protein for the 1-year study period. Quantities of the nutrient found in fistula-forage samples varied about the mean in definite seasonal patterns (Figure 5). There was a distinct rise in the level of protein throughout the spring to the annual maximum of 15.4% in early July. An orderly decline throughout the summer and autumn then followed. The levels tended to become stabilized about the annual minimum of 5.5% during the mid-October to January grazing season. In January, the forage selected by animals grazing in the winter meadow unit I-1 contained appreciably more protein than did either native or seeded forage grazed during the two preceding months. However, February samples from the unit indicated that a slight decline had occurred. Although sampling was terminated with the February collection, data from March and April of the previous year indicated an appreciable decline during the latter part of the grazing period in the unit. A similar decline possibly occurred during the 1966 grazing period in the unit.

Samples of the forage grazed by the integrated-use herd averaged 9.78% crude protein during the 1-year study period. This mean value was not significantly ($P < .05$) different from the annual mean of the native range herd. However, the short-term differences induced by the three grazing periods on seeded ranges are of considerable importance. The annual maximum percentages furnished by seeded and native ranges were not greatly different in magnitude, but Russian wildrye and crested wheatgrass furnished high levels of dietary protein approximately 30 days earlier in the spring than did native forage.

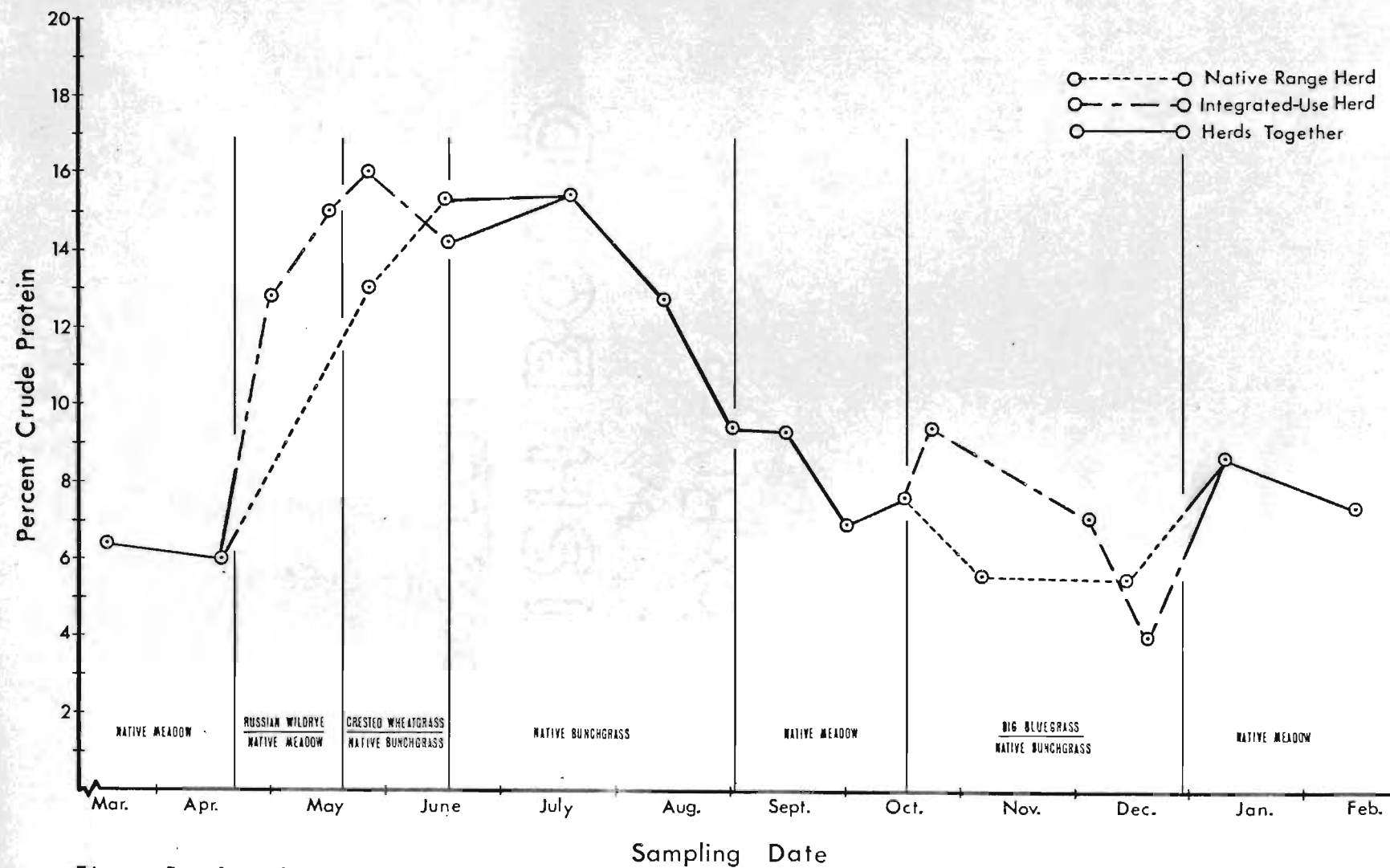


Figure 5. Annual trends of dietary crude protein.

The annual minimum level observed in fistula-collected samples of native forage was approximately 1.6% greater than the corresponding minimum in samples of seeded forage. However, the annual minimum in the native forage was observed approximately 40 days earlier in the year. Therefore, through utilizing seeded species in the early spring and again in the late autumn, the dietary crude protein levels of the integrated-use herd were maintained on a higher plane for a longer period of time than were those of the native range herd, even though the annual mean values of the two herds were not significantly different.

A close scrutiny of the seasonal trends in dietary crude protein (Figure 5) reveals that as the cow herds were shifted from one grazing unit to the next and forage samples were taken, initial samples from a particular unit usually contained higher levels of protein than samples collected during the latter part of the previous grazing period. The only exceptions to this response were observed when both herds were shifted from the native bunchgrass in unit I-4 to hay meadow aftermath in unit I-5 and when the native range herd was shifted from unit I-5 to native bunchgrass in unit I-8. Within a particular grazing unit, crude protein percentages in the samples tended to decline with the advancement of the grazing season. This response was not observed in any of the native or seeded range units used for spring grazing, but it was particularly evident in the big bluegrass used for fall grazing. Indeed, the last sample obtained from that unit contained the least amount of crude protein (4.0%) observed during the study.

Dietary calcium.--Samples of forage grazed by the native range herd averaged 0.61% calcium for the 1-year study period. Variations of

the percentages about the mean were not particularly indicative of seasonal trends (Figure 6). The maximum quantity (0.87%) was in samples collected in January from the native meadow winter range unit I-1. Percentages of the nutrient were often found to diminish in subsequent samples collected within a particular grazing unit, but two exceptions to this response were observed. An appreciable increase occurred throughout the grazing period in the meadow regrowth unit I-5, and a relatively static condition was maintained throughout the grazing period in the fall bunchgrass unit I-8.

Samples of integrated native and seeded forage representative of that grazed by the integrated-use herd averaged 0.64% calcium. A statistical comparison of this annual mean to that of the native range herd indicated no significant ($P < .05$) difference. However, a graphical representation of the data (Figure 6) indicated that marked short-term differences in dietary calcium levels of the two herds occurred during periods of grazing separate ranges. Russian wildrye apparently supplied greater amounts of dietary calcium than did the corresponding native forage, but crested wheatgrass forage was appreciably lower in the nutrient than was the comparative native forage. Indeed, the lowest quantity of calcium encountered in dietary samples of either herd occurred in the last sample from the crested wheatgrass unit. Comparisons between the dietary calcium furnished by big bluegrass and that furnished by native bunchgrass are difficult because of the unusually high level (1.30%) of the nutrient observed during the December 3 sampling period in the big bluegrass unit.

Dietary phosphorus.--Samples of forage grazed by the native range herd averaged 0.34% phosphorus. A graphical analysis of the data

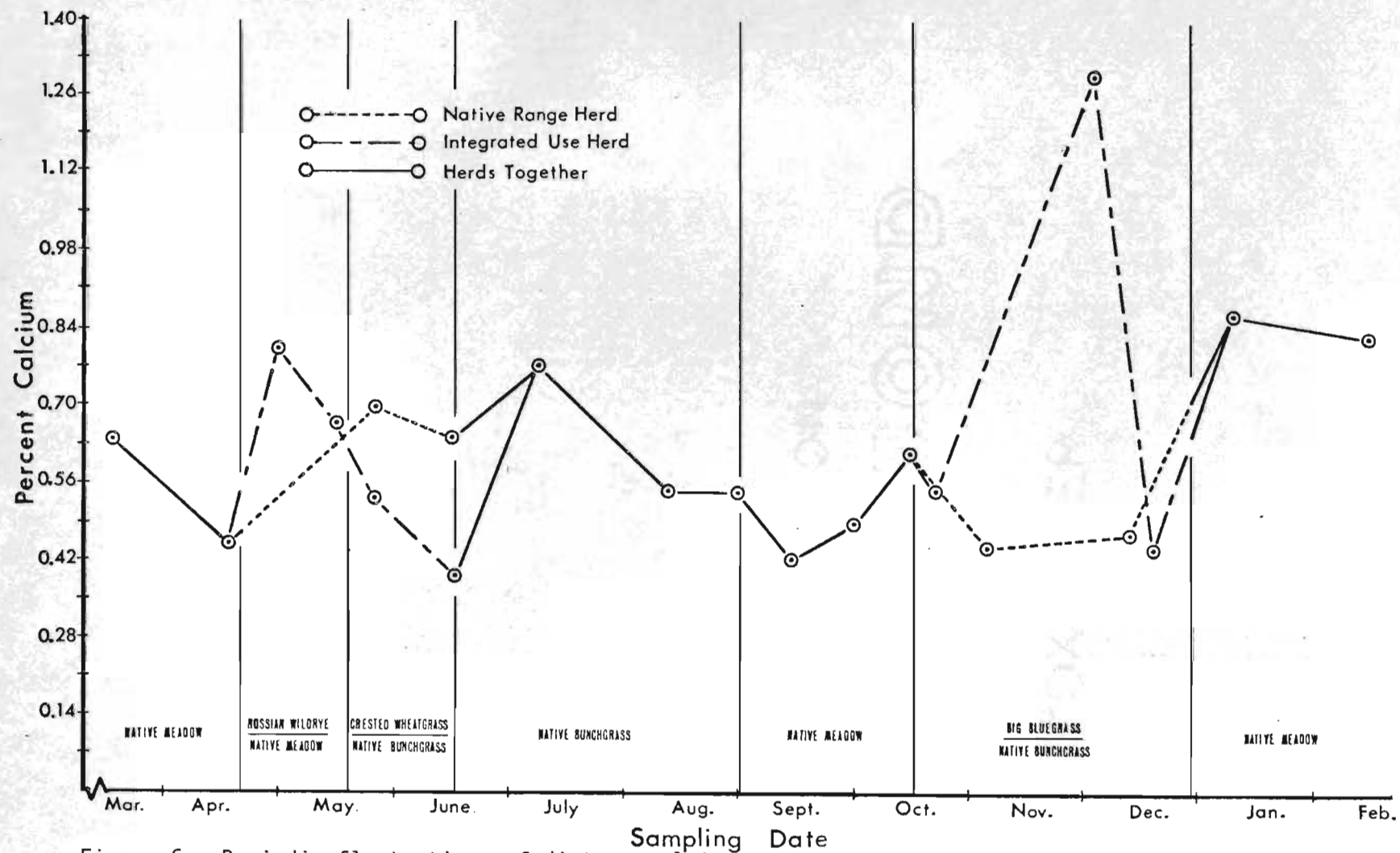


Figure 6. Periodic fluctuations of dietary calcium.

indicated that the levels of the nutrient in the fistula-forage samples varied about the mean in definite seasonal trends (Figure 7). A comparison of Figures 5 and 7 illustrated a striking similarity between the seasonal trends followed by phosphorus and protein in the native range forage. The annual peak occurred in mid June and was followed by a general decline throughout the summer and early autumn. The annual minimum was observed in the November 5 sample from the fall bunchgrass unit I-8, but subsequent samples indicated that the nutrient again increased during the latter part of the grazing period in the unit. Samples from the native meadow unit I-1 in January, 1966, contained appreciably more phosphorus than did samples from either native or seeded ranges grazed during the preceding autumn months. A further increase was indicated in the February sample, but March and April data from 1965 suggested a possible decline during the latter part of the grazing period in the unit.

Samples of forage grazed by the integrated-use herd averaged 0.35% phosphorus for the year of the study. Apparently, the annual phosphorus consumption of the herd was not greatly altered by the three grazing periods on seeded range. Statistical comparisons of the annual means of the two herds indicated no significant difference. However, the short-term differences observed when the two herds were separated are noteworthy. Russian wildrye provided higher levels of dietary phosphorus earlier in the year than did native forage, but this advantage was short-lived. When the integrated-use herd was shifted to crested wheatgrass range, samples from the two herds indicated that native bunchgrass was supplying considerably more phosphorus than was

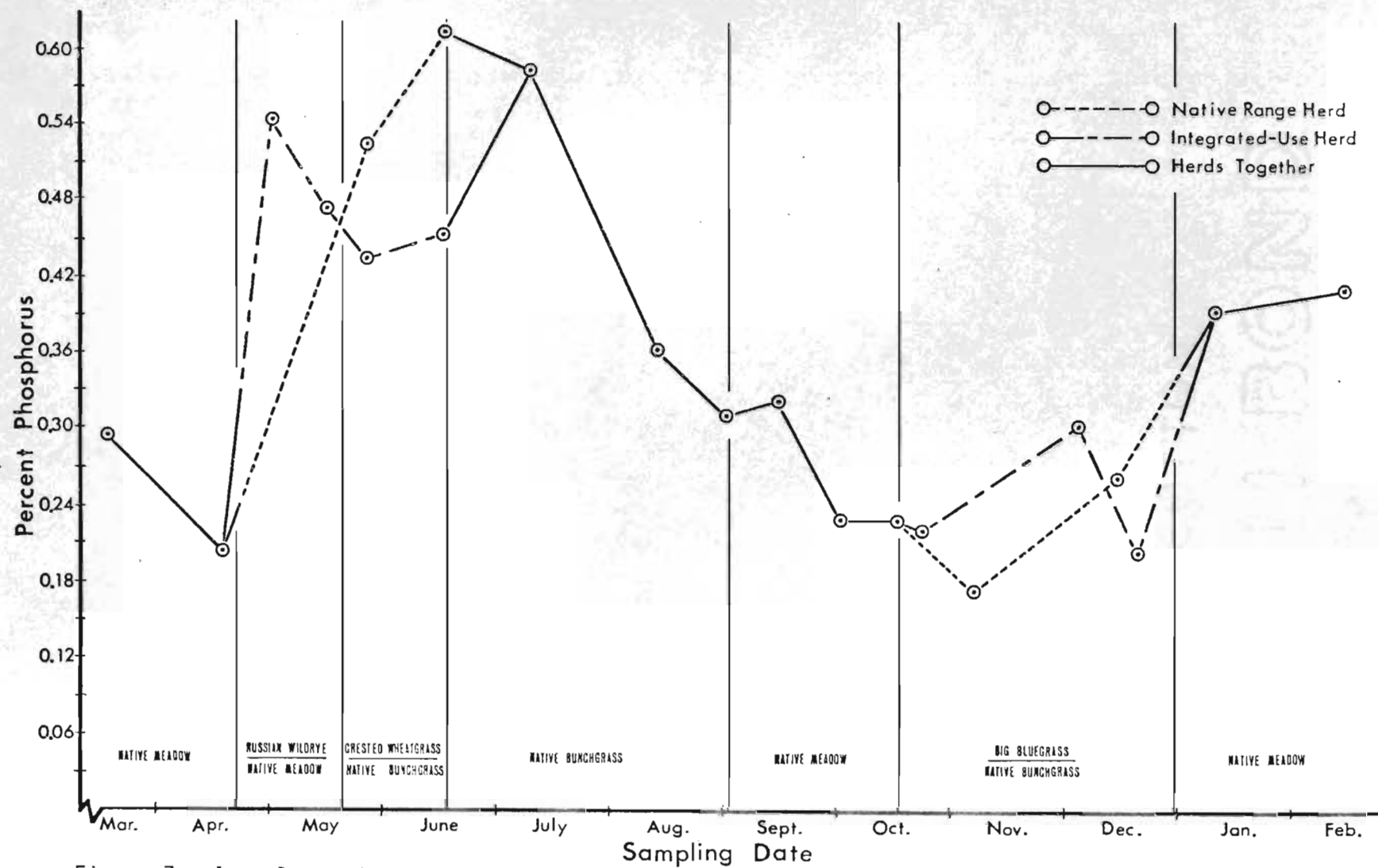


Figure 7. Annual trends of dietary phosphorus.

the crested wheatgrass. Comparisons for the late autumn period when the herds were again grazing separately are difficult, as considerable variation was observed in both the native bunchgrass unit and the big bluegrass unit used by the two respective herds at that time.

Dietary ash.--Samples of forage grazed by the native range herd averaged 11.9% ash for the 1-year study period. Ash in the native forage was the least variable of the four chemical constituents studied (Figure 8). The most notable fluctuation was the continual increase throughout spring and early summer to the annual maximum of 15.4% on June 15. The period from July 1 to October 15 was characterized by a slight overall decline with minor rises near the ends of the grazing periods in the two units (I-4 and I-5) occupied during that time span. Ash levels changed little throughout the subsequent mid-October to January grazing period on native bunchgrass in unit I-8. January, 1966, samples from the native meadow unit I-1 indicated a slight decline in the annual trend of the component. Data from February, 1966, coupled with March and April data from the previous year suggested that the decline continued throughout the grazing period in the unit.

Samples of forage grazed by the integrated-use herd averaged 11.7% ash for the year of the study. This mean value was not significantly different from that in the forage grazed by the native range herd. The short-term differences induced by the three grazing periods on seeded forage were not great, but several interesting fluctuations in dietary ash were observed in samples obtained from the seeded range units. Ash in the ingested forage tended to increase as the grazing period progressed in each of the two seeded range units used for spring grazing (Figure 8). The overall effect was a 9% increase during the

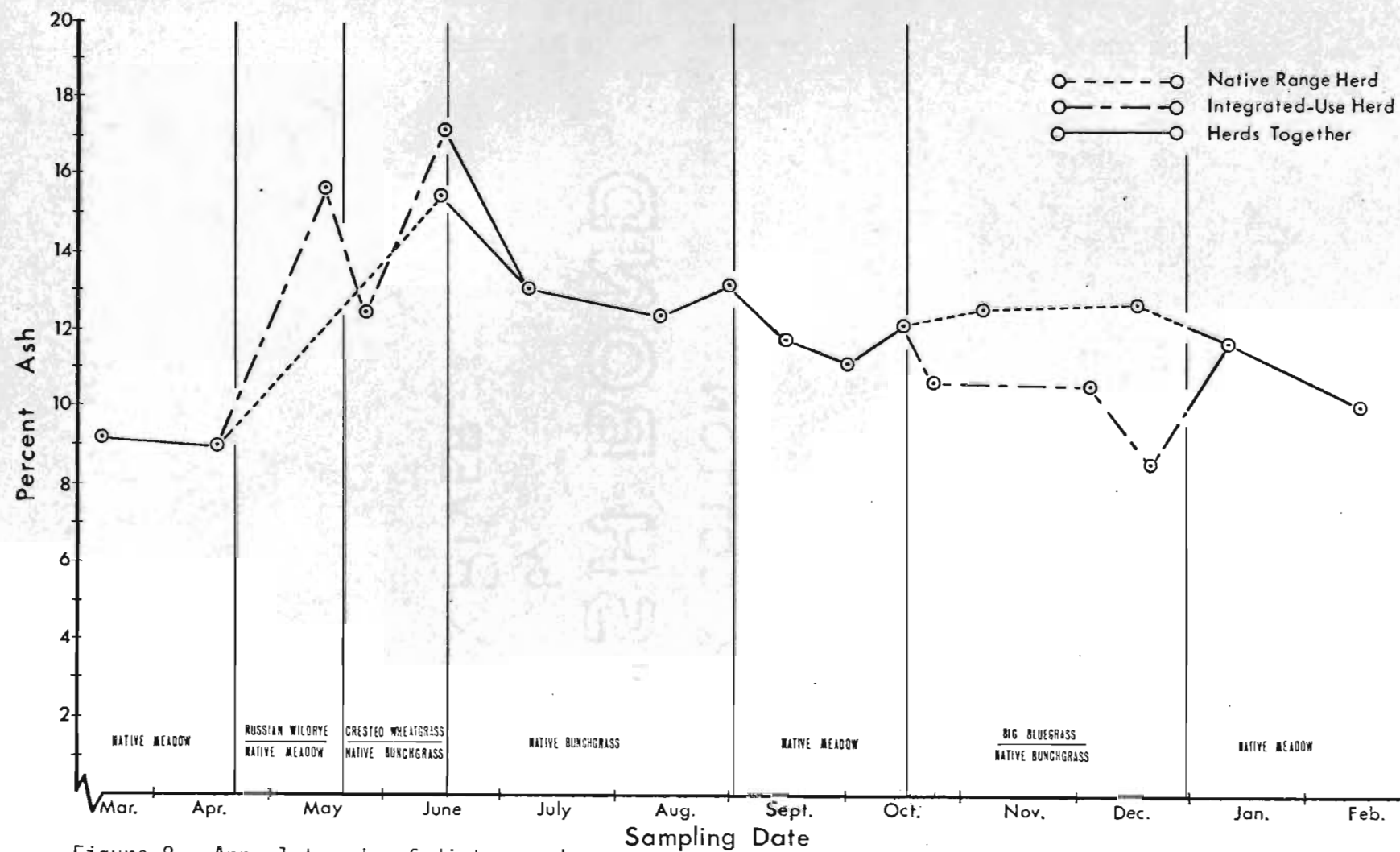


Figure 8. Annual trends of dietary ash.

period extending from mid April to mid June. The peak level of the component in seeded forage samples occurred in the June 16 sample from the crested wheatgrass unit. This maximum level was slightly greater than the annual maximum observed in native forage samples. Both maximums were detected during the same collection period. When the two herds were again separated in late autumn, samples from the native bunchgrass range I-8 contained slightly, but consistently, more ash than did the comparative samples from the big bluegrass range. The December 19 sample from the big bluegrass unit contained the least amount of ash observed during the study.

Botanical composition of the diet

The forage samples collected by the fistulated steers were analyzed microscopically in an attempt to discern the botanical composition of the diets selected by each of the two cow herds. The analyses indicated that, in most cases, the collector steers were highly variable in their selectivity. Samples collected during consecutive sampling periods in a particular grazing unit were usually characterized by large and inconsistent differences in botanical components. In addition, samples collected on consecutive days within a period were often extremely variable. Presentation of such data in the form of mean values or yearly trends would be meaningless. Therefore, the data are presented in the form of actual values obtained in the analysis of each separate sample. To facilitate presentation and interpretation, the data were grouped into three categories based on the three general types of range herbage grazed by the two herds during the year-long study.

Botanical composition of samples collected from seeded ranges.--

Seeded species comprised the forage available to the integrated-use herd during a total of 18 weeks in the spring and autumn of the study period. The botanical compositions of the dietary samples collected from each of the seeded range units are presented in Table 2. Dietary samples collected during the grazing seasons on these ranges tended to be considerably less variable in species composition than samples collected during grazing periods on native range. Obviously, the animals were limited in selectivity to the relatively small number of species available in these units. Samples from the big bluegrass unit contained a somewhat wider variety of plant species than did samples taken from either the Russian wildrye or crested wheatgrass units.

In all but one case, the seeded species under study contributed 73% or more to the composition of the samples. The exception was observed in the December 3 sample from the big bluegrass unit. Only 20.7% of that sample was composed of big bluegrass. The remainder of the material was primarily lambsquarter. Field observations during that collection period also indicated large quantities of lambsquarter seeds in the rumen samples. It is interesting to recall that an unusually high level of calcium was also observed during that sampling period.

The only possible trend of botanical components observed in the samples from these seeded range units was a marked increase in fringed sagebrush consumption as the grazing season in the crested wheatgrass unit progressed. The validity of this observation is questionable, as it is based on only two single-sample periods.

Botanical composition of samples collected from native bunchgrass ranges.--Native bunchgrass ranges I-7 and I-8 were utilized by the

Table 2.--Percentage botanical composition of grazed forage samples from seeded ranges.

Species or group	Grazing units and sample collection dates								
	I-2		I-3		I-6				
	Russian wildrye		Crested Wheatgrass		Big Bluegrass				
	May 1	May 15	May 25	June 16	Oct. 21	Oct. 22	Dec. 2	Dec. 3	Dec. 19
Grasses and grass-like species:									
Agropyron cristatum.....	...	...	97.30	79.60	...	...	...	...	...
Agropyron smithii.....	...	...	...	...	0.46	...	0.38	...	...
Carex heliophila.....	...	...	...	...	...	...	<0.10	...	...
Elymus junceus.....	81.50	73.00	...	...	...	...	...	...	...
Juncus balticus.....	8.00	1.61	...	...	...	...	...	...	...
Muhlenbergia richardsonis.....	...	...	...	...	...	...	<0.10	...	0.30
Poa ampla.....	...	...	...	...	81.55	84.41	75.23	20.86	92.17
Poa pratensis.....	1.20	3.23	...	...	...	...	...	...	...
Stipa comata.....	...	...	...	...	4.35	5.69	0.58	...	...
Unidentifiable grasses.....	...	16.40	...	...	8.23	5.88	...	0.72	0.60
Total grasses.....	90.70	94.24	97.30	79.60	94.58	95.98	76.19	21.58	93.07
Forbs:									
Artemisia frigida.....	1.20	...	1.61	20.39	0.46	...	0.58	1.44	0.60
Chenopodium album.....	...	...	...	...	...	...	21.94	74.10	6.32
Potentilla pennsylvanica.....	...	0.92	...	...	...	...	...	...	...
Taraxacum officinale.....	...	...	...	...	...	<0.10	...	...	...
Unidentifiable forbs.....	8.00	3.00	0.73	...	4.12	3.58	0.38	2.88	...
Total forbs.....	9.20	3.92	2.34	20.39	4.58	3.58	22.90	78.42	6.92

native range cow herd in early spring and late autumn, respectively. The native bunchgrass unit I-4 was utilized by both herds grazing together during the summer. The botanical compositions of the samples collected from these three units are presented in Table 3.

Only two samples were obtained from the early-spring bunchgrass unit. Although no meaningful trends or preferences could be established from only two samples, the data indicated that fringed sagebrush and cinquefoil (Potentilla pennsylvancia L.) were important constituents in both samples. The cinquefoil decreased markedly from the first to the second sample, thus indicating that it may have been highly preferred during that season and was selected while it was available. Forbs as a whole were more important during these two sampling periods than they were at any other time of the year.

Three samples were collected while the native range herd was grazing in unit I-8. Two of the samples were obtained during the same collection period and the remaining sample was collected slightly more than a month later. The relative amounts of several of the species differed extensively in the two samples collected during the same sampling period. The only possibly meaningful trend observed was an apparent increase in the quantity of fringed sagebrush in the samples as the grazing season in the unit progressed.

The seven samples obtained while the two herds were grazing together in unit I-4 were generally highly variable, but a grouping of all species as either grass or forbs indicated that the collector animals preferred forbs early in the grazing season while they were available. However, at no time did forbs constitute more than 35% of any one sample. Fringed sagebrush was the only individual component

Table 3.--Percentage botanical composition of grazed forage samples from native bunchgrass ranges.

Species or group	Grazing units and sample collection dates											
	I-7		I-4							I-8		
	Spring Native Bunchgrass		Summer Native Bunchgrass							Fall Native Bunchgrass		
	May 25	June 15	July 8*	July 8*	Aug. 10	Aug. 10	Aug. 14	Aug. 31	Sept. 1	Nov. 4	Nov. 5	Dec. 13
Grasses and grass-like species:												
Agropyron smithii.....		< 0.10	49.15	51.31	...	< 0.10	1.72	0.74	22.61	9.45	49.86	5.72
Blepharoneuron tricholepis.....		...	< 0.10	0.56	0.22	...	...	...	...	...	...	...
Bouteloua gracilis.....		...	< 0.10	< 0.10	...	33.06	5.86	7.15	13.40	4.26	0.54	...
Calamagrostis inexpansia.....		...	...	...	...	...	...	...	...	10.97	...	...
Carex heliophila.....	< 0.10	0.99	...	...	4.89	1.89	1.03	2.83	1.00	7.92	14.82	13.08
Danthonia parryi.....		...	...	...	1.55	0.67	...	1.49	5.02	...	...	...
Festuca arizonica.....	4.32	1.49	...	0.56	25.80	7.12	16.55	21.01	20.60	...	...	4.90
Koeleria cristata.....	3.63	< 0.10	...	...	3.45	2.44	8.45	7.60	5.19	3.66	0.80	3.27
Muhlenbergia montana.....	1.82	14.64	...	5.26	29.70	25.47	11.03	19.82	12.23	3.96	2.69	35.42
Poa pratensis.....	2.73	...	...	0.75	...	...	11.72	3.72	2.34	13.11	7.81	0.81
Stipa comata.....	< 0.10	4.96	...	...	1.00	0.54	4.31	4.32	...	1.52	...	...
Stipa robusta.....	3.86	3.72	< 0.10	...	0.33	...	...	...	...	8.53	1.61	2.45
Unidentifiable grasses.....	25.00	23.32	10.82	11.09	25.47	16.53	18.79	6.41	7.54	11.89	7.00	3.27
Total grasses.....	41.36	49.22	59.97	69.53	92.41	87.98	79.46	75.09	89.93	75.25	85.13	68.95
Forbs:												
Arenaria fendleri.....	...	...	2.00	...	1.67	0.95	2.76	2.08	0.33	...	...	...
Artemisia frigida.....	19.77	23.32	...	...	...	2.98	8.96	10.73	7.70	8.53	9.43	15.80
Astragalus striatus.....	...	...	...	...	...	...	...	...	...	...	...	4.08
Chenopodium album.....	...	...	< 0.10	...	...	...	...	...	...	...	...	...
Chrysothamnus viscidiflorus.....	...	...	...	...	...	...	...	...	0.16	...	...	...
Erigeron flagellaris.....	...	...	...	...	...	...	...	...	...	1.52	...	...
Geranium parryi.....	...	< 0.10	...	...	...	...	...	...	...	...	...	...
Melilotus officinalis.....	< 0.10	...	< 0.10	< 0.10	...	...	...	1.19	...	...	...	...
Polygonum aviculare.....	...	...	8.96	1.88	...	...	...	...	...	...	...	...
Potentilla pennsylvanica.....	32.39	12.40	...	3.19	...	...	...	...	...	0.61	2.42	1.36
Unidentifiable forbs.....	5.91	15.13	24.42	23.68	5.89	7.86	10.34	10.73	1.84	14.02	2.96	9.81
Total forbs.....	57.91	50.75	35.38	30.44	7.56	11.79	22.06	24.73	10.03	24.68	14.81	31.05

* Samples collected by steers A and B, respectively.

indicative of a trend throughout the grazing period. It apparently increased in the samples as the grazing period in the unit progressed. This increase was reflected as a rise in the total forbs category near the end of the season.

The July 8 collection period was the only time samples were obtained from both fistulated steers grazing in the same unit. It is evident from Table 3 that the two animals selected forage strikingly similar in botanical composition. The forb Polygonum aviculare L. and mountain muhly were the only species exhibiting noteworthy differences in the two samples.

Botanical composition of samples collected from native meadow ranges.--The two native meadow grazing units were utilized by both cow herds. The cattle grazed in unit I-5 in the early autumn following hay harvest, and they wintered on the herbage present in unit I-1. The botanical compositions of the forage samples collected from these two units are listed in Table 4.

The sample collection phase of the study was initiated during the latter part of the 1965 grazing period in unit I-1; consequently, only two samples were obtained from the unit during that year. The remaining three samples were collected during the 1966 grazing season in the unit. Therefore, approximately a 1-year interim existed between the first three and the last two samples listed under unit I-1 in Table 4. The two samples obtained during the January 8 and 9 collection period differed markedly in the amounts of several species present. The first sample collected during the period contained considerably more forbs than did the sample collected on the following day. Although most of the forbs observed in the sample were not identifiable to either

Table 4.--Percentage botanical composition of grazed forage samples from native meadow ranges.

Species or group	Grazing units and sample collection dates										
	I-1					I-5					
	Native Meadow Winter Range					Hay Meadow Regrowth					
	Jan. 8*	Jan. 9*	Feb. 12*	Mar. 17	Apr. 17	Sept. 14	Sept. 14	Sept. 30	Oct. 1	Oct. 14	Oct. 15
Grasses and grass-like species:											
<i>Agropyron smithii</i>	...	...	...	...	...	1.76	<0.10	1.22	<0.10	...	...
<i>Agropyron trachycaulum</i>	0.86	45.66	17.65	2.64	3.71	...	...	...	...	...	...
<i>Agrostis scabra</i>	...	...	...	...	6.81	...	...	...	...	...	...
<i>Andropogon scoparius</i>	...	...	...	0.90	...	...	...	...	...	...	...
<i>Bouteloua gracilis</i>	...	...	...	4.29	...	...	...	...	...	...	...
<i>Calamagrostis inexpansia</i>	11.42	0.58	10.41	9.24	8.98	4.52	16.07	16.33	32.68	38.78	28.32
<i>Carex nebraskensis</i>	5.71	4.04	18.55	37.62	54.48	10.55	57.14	28.24	8.79	16.12	19.94
<i>Festuca arizonica</i>	...	...	2.26	3.63	...	...	...	...	...	...	...
<i>Glyceria striata</i>	...	...	...	...	0.62	...	...	...	...	...	...
<i>Juncus balticus</i>	2.28	...	9.50	...	0.93	19.09	1.65	1.06	<0.10	1.31	1.73
<i>Muhlenbergia montana</i>	...	...	...	12.21	...	...	...	...	...	...	...
<i>Phleum pratense</i>	...	...	...	...	0.62	5.02	2.33	3.81	4.04	3.48	4.05
<i>Poa pratensis</i>	20.00	27.45	20.36	4.95	7.43	59.04	19.09	44.42	47.98	32.02	40.75
Unidentifiable grasses.....	2.57	5.20	3.17	11.55	7.74	<0.10	3.02	3.51	4.39	3.70	2.60
Total grasses.....	42.84	82.93	81.90	87.03	91.32	100.00	99.32	98.63	97.90	95.42	97.40
Forbs:											
<i>Arenaria fendleri</i>	...	...	...	3.30	...	...	...	...	...	...	...
<i>Artemisia frigida</i>	...	1.15	4.07	5.94	...	...	...	...	...	...	...
<i>Chenopodium album</i>	...	11.85	9.05	...	...	...	...	...	...	...	...
<i>Trifolium pratense</i>	...	...	...	...	...	...	0.68	...	...	0.44	...
Unidentifiable forbs.....	57.14	4.04	4.89	3.30	8.67	...	...	1.37	2.10	4.14	2.60
Total forbs.....	57.14	17.04	18.10	12.54	8.67	...	0.68	1.37	2.10	4.58	2.60

* Samples collected during 1966 grazing season. Remainder of data from 1965.

genera or species, their abundance would suggest that the steer was more selective during the first sampling day than he was during the second. Discounting the year's time lapse, other samples indicated that forbs were possibly preferred early in the season when they were available. This observation was based on the slight decline in total forbs present in the samples with advancing time. No meaningful trends were observed in any other botanical component except total grasses. The values presented in this category would naturally increase with advancing time as the total forbs component declined.

Six samples were obtained from unit I-5 during three separate sampling periods. Again, paired samples collected during the first two sampling periods differed considerably. However, the two samples from the third sampling period were not considerably different in their composition. There were indications that northern reedgrass (Calamagrostis inexpansia A. Gray), Kentucky bluegrass, and a sedge (Carex nebraskensis) usually constituted the major portion of the diet selected by the fistulated steer. The disconcerting variation within each of the first two sampling periods masked any trends in preference that may have existed among the three species during the grazing season. Forbs did not contribute more than 4.5% to any of the samples collected from the unit.

Chapter V

DISCUSSION

Nutritive composition of the diet

Dietary evaluations of range forage based on chemical analyses without supplementary digestibility information are notably deficient in revealing the true nutritive value of the forage. However, such evaluations provide valuable comparative information and serve to show which constituents may be deficient or present in excess. Inferences from the results of this study must be made with this thought in mind. Furthermore, the limited number of samples obtained in the study necessitate the use of caution in making inferences from the results presented.

Dietary crude protein.--Forage maturity has often been suggested as one of the major factors influencing the nutritive quality of the diet selected by grazing animals. It is directly responsible for many of the chemical reactions that occur in the forage plants themselves, and it exerts an indirect influence upon the nutritive quality of the diet through its controls of plant palatability and, consequently, animal selectivity. Crude protein in the diet is particularly influenced by forage maturity (Cook and Harris, 1950b).

The quantities of crude protein consumed by each of the two cow herds in this study were largely dependent upon the stage of maturity of the forage at the time of consumption. Annual peaks of crude protein during the spring indicated that both native and seeded species

furnished the largest quantities of the nutrient when plants were young and growing rapidly. Cattle grazing seeded species in the spring encountered these high levels somewhat earlier in the year than did cattle grazing native species. This response is attributable to the earlier initiation of growth in the two seeded species, Russian wildrye and crested wheatgrass.

The decline in dietary protein throughout the July to October grazing seasons on native range is apparently a further reflection of forage maturity. Cook and Harris (1950b) have stated that as plants mature and the reproductive process is initiated, nitrogen from the leaves and stems is translocated to the basal portions and roots. Results of the present study indicate that such a response occurred during the summer grazing season. Mid-August samples were the first to indicate a decline in protein levels. Phenological observations during that period indicated that mountain muhly, the species comprising a large portion of the mid-August samples (Table 3), had entered the reproductive phase the previous week.

Shifting the integrated-use herd from native to big bluegrass range in mid October resulted in an immediate 2% rise in dietary protein levels of the animals, whereas, protein in the diet of the native range herd continued to decline. The condition of the forage as determined by its stage of maturity was possibly responsible for the observed responses. The native herbage had reached complete dormancy by October 27, whereas, big bluegrass still contained large amounts of green tissue at the time.

The marked rise in dietary protein of both herds when they were shifted to the winter meadow unit in January may also be partially

attributed to the physiological condition of the herbage. Field observations during the January 8 collection period showed that several of the herbage species selected by the grazing animals contained green tissue near their bases.

The fluctuations in dietary protein cannot be attributed completely to changes in forage induced by advancing maturity; particularly those fluctuations that occurred over a relatively short period of time. Animal selectivity, as affected by both species and quantity of herbage available, undoubtedly modified the trends. However, it is difficult to ascribe a particular fluctuation to any one cause, as most causes are interrelated. The 2% decline in dietary protein observed during the grazing period in the crested wheatgrass unit could, without close examination, be attributed to increasing limitations on animal selectivity. The decline occurred over a relatively short time interval, in a grazing unit with a restricted area and number of species available, and at a season of the year when no major phenological changes were occurring. However, chemical analyses of hand-clipped, cage protected herbage illustrated that a decline in plant protein paralleled the decline in dietary protein. The marked decline of dietary protein throughout the autumn grazing period on big bluegrass was probably the result of a compound effect of advancing herbage maturity and limited animal selectivity. The particularly low level in the December 19 sample from the big bluegrass unit occurred during a period when a snow cover imposed severe limitations upon animal selectivity. At that time, the grazing animals were forced to consume the coarse, fibrous portions of the bluegrass plants that protruded above the snow.

Forage grazed by the integrated-use herd supplied adequate to excessive quantities of dietary crude protein for 10 months of the 1-year study period.^{2/} However, the quantities in forage grazed by the native range herd were adequate for only 8 months of the year.

Dietary calcium.--The fluctuations of calcium in forage plants are not well understood. Some researchers (Hart et al., 1932) have stated that calcium levels in forage plants follow no particular trends. Others (Cook and Harris, 1950b) have found an increasing trend with advancing stages of forage maturity. Little research relative to calcium in the diet of grazing animals has been reported. Lesperance et al. (1960b) indicated that the level of the nutrient in the diet was probably not contingent upon animal selectivity.

Levels of calcium in dietary samples collected during the present study are difficult to rationalize. Apparently no general factor such as forage maturity was important, as no seasonal trends were evident. Animal selectivity was undoubtedly a factor partially responsible for the unusually high level (1.30%) observed in the December 3 sample from the big bluegrass unit. Lambsquarter, a forb, comprised a large proportion of that particular sample (Table 2). Hand-clipped samples of herbage from the crested wheatgrass unit I-3 indicated that the decline in dietary calcium observed throughout the grazing period in that unit (Figure 6) was paralleled by a corresponding decline in the calcium levels of the herbage per se.

^{2/}Observations based on recommendations by National Research Council Committee on Animal Nutrition. 1958. Nutrient requirements of domestic animals. IV. Nutrient requirements of beef cattle. Nat. Acad. Sci.--Nat. Res. Council Pub. 579. 32p.

Regardless of the factors responsible for the various fluctuations in calcium percentages throughout the year, the nutrient was always present in the samples in quantities far in excess of the recommended minimum levels for animal growth and production.

Dietary phosphorus.--The maturity of herbage plants has been shown to exert a definite influence upon their phosphorus content. Hart et al. (1932), Wallace et al. (1961), and Cook and Harris (1950b) all reported peak levels of the nutrient during the spring, followed by declines throughout the summer to a relatively stable level throughout the autumn and winter. Cook and Harris (1950b) observed that increases of soil moisture in late summer tended to produce slight rises in the levels of the nutrient, even though the additional moisture was not of sufficient quantity to initiate plant regrowth. They also found that such factors as site and vegetation type modified the levels of the nutrient in the herbage they studied.

Results of the present study indicate that forage maturity was partially responsible for the fluctuating levels of dietary phosphorus in the two cow herds studied. Trends generally similar to those previously ascribed to herbage maturity were observed. However, several fluctuations in the levels were observed that cannot be explained by changes induced by advancing forage maturity. Such a response was the declining trend throughout the grazing period on Russian wildrye. This decline occurred during a season of the year when no major phenological changes were taking place. Dietary protein exhibited a marked increase during the same time period, therefore, it is doubtful that the decline was due to limited herbage availability or animal selectivity.

This study offers no explanation for the relatively low levels of dietary phosphorus in the samples from the crested wheatgrass unit. The high percentage of lambsquarter in the December 3 sample from the big bluegrass unit may account for the rise in the level of the nutrient during the grazing period in that unit.

Although the results obtained from this study relative to dietary phosphorus may be useful in depicting general trends, the accurate determination of dietary phosphorus from fistula-forage samples is questionable. Ruminant saliva is particularly rich in phosphorus and correction techniques for its added effects were unavailable in the present study. Van Dyne and Heady (1965b) contend that dietary phosphorus determinations without corrections by the isotope dilution technique are entirely misleading.

Dietary ash.--Ash percentages in the fistula-forage samples from either herd were not characterized by the marked seasonal trends observed in protein and phosphorus, but a slight peak in the early summer was detected (Figure 8). A slight decline throughout the remainder of the year was also indicated. Cook and Harris (1950b) reported similar trends in the ash content of several range herbage species. The relatively high levels of the component in the last samples collected from each of the two seeded range units used for spring grazing possibly resulted as a compound effect of inherently high ash levels in the forage itself at that time of the year, plus contamination by adhering soil particles. By the time terminal samples were collected from each of the two units, the herbage had been grazed to approximately a 1- to 2-inch stubble height. Therefore, the possibility of ingesting appreciable quantities of silica with the forage was enhanced.

The rises in dietary ash noted near the ends of the grazing periods in most units probably reflected an interaction of several factors, but soil contamination and salivary ash contamination were possibly of major importance. If limited availability at these times forced animals to consume coarser, more fibrous forage, an increase in salivary ash would be expected. Large quantities of saliva are produced during the mastication and swallowing of such forage (Lesperance et al., 1959).

Botanical composition of the diet

Results obtained in the botanical evaluation of the diets selected by the two cow herds permit only limited conclusions. With the exception of the July 8 sample from unit I-4, only one collector animal was used to sample the forage grazed by each herd. Therefore, it is impossible to estimate the variability introduced into the data by the collector animals. Van Dyne and Heady (1965a) state that this type of variability is usually extensive. Their calculations indicated that a minimum of 5 animals were necessary to sample dietary botanical composition of cattle grazing native annual range. An equal or greater number would probably have been required in the present study. Furthermore, a maximum of only two samples per collection period were obtained; frequently, only one sample was obtained. Although no "within period" variances were computed for the 2-sample collection periods, the obvious differences between the paired samples were usually of sufficient magnitude to be disconcerting. Therefore, the botanical compositions of the samples are discussed from the aspect of possible causes of some of the larger differences, rather than from the standpoint of inferences that may be made from the results.

Botanical composition of samples collected from seeded ranges.--

Fistula-forage samples from the three seeded range units were obviously limited in their botanical composition to the relatively small number of species available in the units. However, species available in small quantities often contributed appreciably to the samples. A good example was the 8% level of wire rush in the May 1 sample from the Russian wild-rye unit I-2 where wire rush comprised only a trace of the vegetative cover.

A marked increase in the consumption of fringed sagebrush was noted in the last sample obtained from the crested wheatgrass unit. Limited herbage availability near the end of the grazing season in the unit may have forced the animals to alter their selectivity in favor of fringed sagebrush, or other factors influencing palatability may have induced the change. It is interesting to observe that protein and phosphorus in the clipped samples of crested wheatgrass exhibited a sizeable decline during the same time period.

Fistula-forage samples from the big bluegrass unit contained an appreciably larger number of species than did those from the other two units; however, the big bluegrass unit supported a larger number of available species than did either of the other two units. An unusually high percentage of lambsquarter was noted in the December 3 sample from the unit. This sample was collected early in the morning and a heavy dew was present on the plants. The added moisture may have softened the dry tissue of the forb, making it appealing to the collector steer. Field observations during that collection indicated that the remainder of the animals in the herd were also concentrating their grazing in an area where the forb was particularly abundant. A 4-inch snow cover at

the time of collection was responsible for the high percentage of big bluegrass present in the December 19 sample from the unit. Big bluegrass was the only common species protruding above the snow cover at that time.

Botanical composition of samples collected from native bunchgrass ranges.--The extreme "within period" and "between period" differences observed in the botanical compositions of the fistula-forage samples from the native bunchgrass units probably reflect the heterogeneity of the ranges sampled rather than changes in animal preference per se. Range sites in each of the three units vary from swales supporting dry meadow vegetation to ridgetop sites supporting typical pine-bunchgrass vegetation. Although no specific study was made of the cattle's daily movements, incidental field observations indicated that the animals roamed widely throughout a particular grazing unit in a day's time. Therefore, throughout any one day, the cattle grazed over several range sites, each site supporting vegetation somewhat different from the others in species composition. The samples obtained during the 30-minute to 1-hour intervals allowed for sample collection are possibly quite representative of the forage selected in a localized area, but they represent only a small part of the total daily diet. This may explain some of the vast differences often observed between samples collected during the same day or during subsequent days. Frequently, the animals were grazing in widely separated areas within the pastures when each of the two samples were collected.

Botanical composition of samples collected from native meadow ranges.--The botanical evaluation of cattle diets in the two native meadow units was subject to limitations similar to those encountered in

the bunchgrass units. This was particularly the case in the winter meadow unit I-1 where the vegetation varied from a wet meadow type to an upland pine-bunchgrass type. Animals grazing in the meadow regrowth unit I-5 were confined to a relatively small area supporting primarily meadow species. However, the vegetation in the meadow was characterized by localized variation in species composition, and this variation was sometimes reflected vividly in the dietary samples. A case in point was the evening sample collected on September 14. The fistulated steer spent most of the 30-minute sample collection interval grazing in a boggy area left unmowed during hay harvest. This boggy area supported a dense stand of the sedge, Carex nebraskensis. The botanical analysis of the sample showed that over 57% of the material ingested was Carex nebraskensis. A sample collected during the morning of the same day contained only 10% of the sedge, but the steer grazed a slightly different area of the unit during the morning sample collection interval.

Considerations for future studies

Dietary botanical and nutritive evaluations under range conditions such as those encountered in this study are subject to severe limitations. Native range units presented a distinctive problem because of their extensive variability. Obviously, an adequate number of samples was not obtained from any of the grazing units in the present study. However, fistulated animals are expensive to obtain and maintain. Furthermore, sample collection and analysis is time consuming and expensive. Sampling designs employed to reduce the number of samples required should therefore be considered. A stratified sampling

procedure, supplemented with animal movement and behavior data, could possibly be used effectively in the native range units.

Digestibility information would undoubtedly strengthen future nutritive evaluations. Ruminal fistulated animals are almost a necessity if digestibility trials are to be conducted, but their value for use in dietary botanical evaluations is questionable. If appetite is influenced by evacuation of the rumen, the animal's innate selectivity may also be affected. Furthermore, esophageal fistulated collector animals are more advantageous from the standpoint of speed and ease of sample collection.

Chapter VI

SUMMARY

The diets selected by two herds of Hereford range cows were studied in a 1-year investigation at the Manitou Experimental Forest. One herd grazed native forage exclusively (native range herd); the other herd grazed both native and seeded species on an integrated basis (integrated-use herd). Ruminant fistulated steers were used to collect samples of forage representative of that grazed by each herd. The 32 samples collected periodically from March, 1965 to February, 1966 were analyzed both chemically and botanically to evaluate the quality of the diet selected by each herd. Although the number of samples was somewhat limited for inferential purposes, several interesting responses were observed.

Crude protein in the diets of both herds followed definite seasonal patterns. Peak levels were observed in late spring and were followed by a decline throughout the subsequent summer and autumn to annual minimums in late autumn. Although the annual mean crude protein consumption of the two herds did not differ statistically, the herd grazing both native and seeded species was maintained on a high plane of dietary protein for a longer period of time than was the herd grazing native species only. This response was attributed to earlier dates of growth initiation of seeded species in the spring and later dates of dormancy in the autumn. Factors such as herbage availability

and animal selectivity modified the seasonal trends of dietary protein in the two herds, but the condition of the forage as determined by stage of maturity apparently influenced dietary protein more than any other factor.

Calcium in the diets of the two herds followed no seasonal trends and exhibited no consistent fluctuations.

Dietary phosphorus levels of the two cow herds followed seasonal trends generally similar to those of crude protein. Forage maturity was largely responsible for the overall seasonal trends, but various fluctuations in the trends resulted from factors or combinations of factors not perceivable in this study. Such a fluctuation was the decline in dietary phosphorus of the integrated-use herd while grazing spring-use seeded ranges.

Although the general seasonal trends of dietary phosphorus observed in this study are probably quite valid, the accurate determination of dietary phosphorus from the fistula-forage samples is somewhat questionable, as techniques for the correction of salivary contamination were unavailable.

Ash levels in the forage grazed by both herds exhibited a slight overall decline from highs in the late spring to a minimum in late winter. No corrections were made for the added effects of salivary ash, and the degree of contamination may have been of sufficient extent to bias the observed results extensively.

The botanical compositions of the fistula-forage samples from both herds were often characterized by disconcerting variability among subsequent sampling days and among sampling periods. Consequently, only limited conclusions can be drawn from the results. The large

differences in species composition of samples collected from native range units probably reflected the heterogeneity of the ranges sampled rather than changes in animal preference per se. Species of questionable palatability, e.g. fringed sagebrush, were often important constituents in the diet, both on seeded and native ranges.

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