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Title: THE EFFECTS OF VEGETATION TYPE AND GRAZING SYSTEM ON THE PERFORMANCE, DIET AND INTAKE OF YEARLING CATTLE

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Martin Vavra

Research was conducted at the Starkey Experimental Range and Forest in northeastern Oregon to determine cattle performance, diet quality, botanical composition of forage ingested and forage intake on two vegetation types and under three grazing systems. These parameters were evaluated during the years of 1976, 1977 and 1978. Grazing was conducted on forest and grassland vegetation types. The applied grazing systems were rest-rotation, season-long and deferred-rotation grazing systems. The grazing season lasted from June 20 to October 10 of each year. Cows equipped with esophageal fistulas were used to evaluate diet quality and diet botanical composition. Steers equipped with fecal bags were used to evaluate forage intake on forest and grassland vegetation types. Fistulated cows equipped with fecal bags and urine deflection devices were used to evaluate forage intake under deferred-rotation, rest-rotation and

season-long grazing systems in 1977 and 1978.

Grasses were the most important forage class consumed by cattle on both begetation types. However, more grass was consumed on the grassland than the forest. Forb consumption was the same on the two vegetation types. Browse was heavily utilized on the forest when little green grass was available.

Crude protein and <u>in vitro</u> dry matter digestibility (IVDMD) values for diet samples were not significantly different ($P > .05$) on the forest and grassland in the late spring (June 20-July 18). However, in the summer (July 19-September 12), diet samples collected on the forest were significantly higher ($P < .05$) in crude protein and IVDMD than those from the grassland. When forage regrowth was available on the grassland vegetation type in 1976 and 1977 in the fall (September 13-October 10), grassland cattle diets were significantly higher ($P < .05$) in crude protein and IVDMD than those from the forest. Crude protein and IVDMD values were significantly higher ($P < .05$) from diet samples collected on the forest in 1978 when very little regrowth was available on the grassland.

Forage intake and livestock performance data were consistent with diet quality data. Predicted digestible energy and crude protein intake accounted for 82% of the variation in livestock performance on the two vegetation types.

The results from the study indicate that the grassland can be most efficiently utilized by cattle during the spring until mid-July. Cattle should be moved to the forest in mid-July because phenology of the primary forage species is less advanced and more shade is available than on the grassland. In years when summer precipitation occurs, cattle can be moved back to the grassland in mid-September to make use of forage regrowth.

Trends in diet botanical composition on the grazing system pastures were similar to those on the forest pasture used in the complementary grazing study. Browse was heavily utilized when green grass was unavailable. Idaho fescue, bluebunch wheatgrass, Kentucky bluegrass and common snowberry were the most important species found in cattle diets on the grazing system pastures. Cattle diet botanical composition did not differ significantly ($P < .05$) between grazing systems when diet samples were pooled across years and periods.

Crude protein, acid detergent fiber, lignin and IVDMD values of diet samples collected on the rest-rotation and season-long grazing systems were not significantly different ($P > .05$) in any year of study when samples were pooled across periods. Forage intake and livestock performance data were consistent with diet quality data under all three grazing systems. Cattle performance was not significantly different ($P > .05$) under the two grazing systems when weights were pooled across years and periods or for any of the individual years.

The movement of cattle during mid-season in 1977 under the rest-rotation grazing system resulted in significantly ($P < .05$) improved livestock performance in the following period. In 1976 and 1978 one rest-rotation pasture was grazed while the other was rested. Livestock performance on the heavy use rest-rotation pastures did not differ significantly ($P > .05$) from a season-long pasture which received fifty percent less grazing pressure.

No conclusion can be made concerning cattle diets or performance under the three grazing systems evaluated in this study because vegetational changes may be taking place. This could influence livestock performance in future years.

The Effects of Vegetation Type and Grazing System on the Performance, Diet and Intake of Yearling Cattle

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THE EFFECTS OF VEGETATION TYPES AND GRAZING SYSTEM ON THE PERFORMANCE, DIET AND INTAKE OF YEARLING CATTLE

INTRODUCTION

In the next decade the production of red meat on rangelands in the United States must be increased to meet the projected demand of an increased population at home and abroad (Commission on Population Growth and the American Future, 1972; Long, 1974). Grazing systems (Wambolt, 1974) and complementary grazing (Vavra and Phillips, 1979) are potential means of increasing livestock and forage production on native rangelands.

A number of studies have been conducted which show the effects of grazing systems on range condition, but very little information is available regarding the effects of grazing systems on livestock production. Care must be taken to insure that any grazing management system is compatible with livestock production.

There are nutritional differences among various plant communities (Cook and Harris, 1968). Red meat production from rangelands could be increased if each plant community was used when forage quality was highest. The efficiency of livestock production could be improved if grazing was integrated among specific plant communities to take advantage of different peaks in forage quality.

This study was conducted to evaluate the effects of three different grazing systems and three different vegetation types on livestock performance and diet quality at the Starkey Experimental Range in Northeastern Oregon. The applied grazing systems were rest-rotation, deferred-rotation and season-long systems. Grazing was conducted on forest, grassland and meadow vegetation types. Samples collected from esophageal fistulated cows were used to estimate the quality and botanical composition of the diet. The total dry matter intake of cattle during the grazing season was determined for each grazing system and vegetation type. Cattle were weighed periodically on all pastures to determine their performance.

The specific objectives of this investigation were:

1. To determine cattle performance, diet quality, botanical composition of forage ingested and forage intake on forest, grassland and meadow vegetation types;
2. To determine cattle performance, diet quality, botanical composition of ingested forage and forage intake of cattle among three different grazing systems;
3. To determine if advance of season affects diet quality, botanical composition of ingested forage and forage intake differently among vegetation types and grazing systems;
4. To determine if seasonal changes in animal response occur within grazing treatments and vegetation types;

5. To determine the effect of year on cattle performance, diet quality, botanical composition of ingested forage and forage intake within grazing systems and vegetation types.

LITERATURE REVIEW

The primary problems facing the range nutritionist concern the determination of diet quality, daily intake, and the botanical composition of diets of range herbivores. Because rangelands are composed of diverse plant communities and terrain is often rugged, both accuracy and precision of range nutrition methods are a problem. This section will give a comprehensive discussion of range nutrition problems and methods. A review will be given of procedures for determining diet quality and forage intake. Available information concerning the affects of different grazing strategies on livestock and vegetation productivity will be reviewed. Recently much information has been published concerning livestock diets and methods for determining diets. This information will be summarized and discussed.

The Effects of Grazing Systems on Livestock Production

Currently, information concerning the influence of different grazing systems on livestock production is limited. Many of the studies that have been conducted were of relatively short duration. Because vegetational changes often occur over long time periods, several years may be required before vegetational change affects livestock performance.

The effect of grazing system on livestock production has been variable. Skovlin et al. (1976) found little difference in calf weights in a replicated study in northeastern Oregon comparing season-long and deferred-rotation grazing. In Texas, calf production was greater from deferred-rotation grazing than from continuous grazing at the same stocking rate (Kothman et al., 1971). McIlvain and Shoop (1969) compared rotation to continuous grazing at Woodward, Oklahoma. There was no difference in cattle performance between the two systems. On irrigated pasture continuous grazing consistently resulted in higher daily gains and more beef per hectare than rotational grazing (Hull et al., 1971). Herbel and Anderson (1959) found that deferred-rotation grazing did not increase livestock production in the Flint Hills of Kansas. Eight years of deferred-rotation grazing on bluebunch wheatgrass (Agropyron spicatum) resulted in a doubling of the stocking rate and improved calf weights (Dillon, 1958). Malechek et al. (1978) found that sheep did not perform significantly different between short term rotational grazing and season-long grazing on big game range in Utah. The rotation of grazing on crested wheatgrass (Agropyron desertorum) did not significantly increase beef production when compared to continuous grazing (Frischknecht and Harris, 1968). Livestock gains were higher from pastures grazed season-long than from pastures grazed only part of the season under rest-rotation grazing (Woolfolk, 1960; Rader, 1961; Ratliff and

Rader, 1962). This was attributed to the fact that season-long grazing follows rest under rest-rotation grazing. Therefore, forage reserves are higher in the season-long pastures. The three-herd and four-pasture grazing plan gave increases in livestock production after several years of tests at the Sonora Experimental Station in Texas (Keng and Merrill, 1960). Calving percentages and weaning weights have been found to be higher under the four-pasture system (Waldrip and Marion, 1963; Waldrip and Parker, 1967; Mathis and Kothman, 1968). Heady (1961) reported that the 120-day weights of lambs were higher under continuously grazed pastures than on deferred-rotation pastures in the annual grassland of California. A rotation grazing schedule did not increase cattle gains when compared to season-long grazing in Wyoming (Smith et al., 1967). Smoliak (1960) reported lower cattle gains under rotation grazing than under continuous grazing in Alberta. A new grazing system is presently being tested in Texas (Rittenhouse, 1979; Heitschmidt, 1979). This system involves rapid rotation of animals from one pasture to another. Livestock performance was lower under this system than under continuous grazing (Heitschmidt, 1979). However, this system needs more investigation.

The literature indicates that cattle response to grazing systems is variable, and that it depends on the vegetation type (Heady, 1961; Heady, 1975; Driscoll, 1967). An advantage of season-long grazing is that the quality of the forage being consumed does not change drastically in a short period of time (Smoliak, 1960). Forced movements of cattle can result in weight losses (Smoliak, 1960). Hormay (1970) did not recommend forced cattle movement when using a rest-rotation grazing system for this reason. Loss of nutrient quality on deferred pastures is a disadvantage when using a deferred-rotation system (Sheflet and Heady, 1971). It is well established that livestock gain is less on mature forage than on young growth (Heady, 1975).

Grazing System Effects on Vegetation

There are several important considerations when selecting a grazing system for a particular range. Stoddart et al. (1975) pointed out the primary consideration should always be the forage resource. Other important considerations include the physiography of the range, the kind of animals and the objectives of management. No single grazing system is best under all conditions (Wambolt, 1974).

Season Long Grazing

Season long or continuous grazing is the simplest system of grazing. Under this system, livestock grazing is unrestricted throughout the grazing season (Heady, 1975). The primary problem with continuous grazing is that preferred species and sites receive excessive use. On certain range types where degree of range use and livestock distribution have been controlled, continuous grazing has been beneficial to the vegetation. The shortgrass prairie and the California annual grassland have responded well to continuous grazing (Hyder, 1969; Duncan and Heady, 1969; Heady, 1961). Continuous grazing appears to be best suited to grasslands with few species of extreme palatability differences (Stoddart et al., 1975). This grazing system is often used during the early growing season when forage supplies and growth rates are low (Heady, 1975).

Rotational Grazing

The need for a grazing system to replace continuous season-long use has long been discussed. Sampson (1913) was probably the first to recognize the need for a period of non-use to allow plants to regain vigor.

Rotational grazing has generally been used where forage growth rates are fast and forage production is high. The main assumption with rotation grazing is that selective grazing is reduced because larger numbers of animals are on the range for shorter periods of time (Heady, 1975).

In South Africa rotational grazing has improved the botanical composition and forage production of native rangeland (Acocks, 1966; Howell, 1967). A two-pasture switch back arrangement has been effective in managing crested wheatgrass (*Agropyron desertorum*) (Frischknecht and Harris, 1968). Under this system each pasture is grazed early and late spring in alternate years. Hull et al. (1967) found evidence that rotational grazing of cattle on irrigated pastures changed pasture composition toward a higher proportion of legumes and fewer grasses. McIlvain and Savage (1951) found only a slight improvement in vegetation density and vigor from a rotation system. Dickson et al. (1948) and Fisher and Marion (1951) obtained more range improvement from continuous grazing than from a rotation system.

Deferred Rotation Grazing

Deferred grazing specifies that grazing is delayed. Deferred pastures are usually not grazed until seed maturity (Heady, 1975). This provides a better opportunity for old plants to gain vigor and new plants to become established. Deferred grazing is often rotated among two or more pastures. This is called deferred-rotation grazing.

Sampson and Malmsted (1926) found that more seedlings were established under deferred-rotation grazing than on unused ranges. Continuous grazing required more acres per animal unit than deferred-rotation grazing in North Dakota (Sarvis, 1923). Skovlin et al. (1976) found deferred-rotation grazing was superior to season-long grazing for improving ground cover on mountain grasslands in northeastern Oregon. Climax bunchgrass plants increased under a deferred-rotation grazing system in southeastern Oregon (Hyder and Sawyer, 1951). Hubbard (1951) obtained improved range conditions with a deferred-rotation system. The effects of drought were reduced by using a deferred-rotation grazing system in Oregon (Hyder and Sawyer, 1951). Deferred-rotation grazing has improved range condition on mountain ranges in Wyoming (Johnson, 1965).

Rest-Rotation Grazing

Rest-rotation grazing is a system where part of the range is rested for the entire year. This system is similar to deferred-rotation grazing but differs mainly by having a longer rest period and heavier use of one pasture yearly (Wambolt, 1974). In regions where seasonal grazing is practiced and cool season grasses make up most of the vegetation, rest-rotation grazing has been effective in vegetation improvement (Hormay, 1956; Johnson, 1965; Ratliff et al., 1972). In California, bunchgrass range was less severely affected by drought under rest-rotation grazing (Ratliff and Rader, 1962).

The primary advantages of rest-rotation grazing are that all plants are given opportunity to grow and reproduce, a substantial portion of the range is rested each year and becomes available for other uses, and the rest pasture provides a forage reserve in drought years (Hormay, 1970; Ratliff and Rader, 1962; Woolfolk, 1960). However, increased grazing pressure on the grazed portion of the range may do harm that will exceed the benefit of rest (Heady, 1975).

The Four-Pasture System

The Merrill four-pasture system, developed at Sonora, Texas, has given vegetation improvement on ranges grazed the entire year (Merrill and Young, 1952; Merrill, 1954; Keng and Merrill, 1960). This system involves the use of four pastures of equal carrying capacity (Stoddart et al., 1975). Animals are divided equally among three of the pastures and grazed for 12 months. The fourth pasture is rested four months and then rest is rotated to another pasture. This system has been most successful in areas where rainfall is evenly distributed throughout the year.

Plant Community Integration to Increase Livestock Production

Information dealing directly with the integration of plant communities to increase efficiency of livestock production is rare. The few studies reporting such data indicate that livestock productivity can be increased by plant community integration.

Cook and Harris (1968) studied livestock performance and forage quality on desert, foothill and mountain ranges in Utah. They reported that foothill ranges could be most efficiently used by livestock in the spring while mountain ranges should be used during the summer because of delayed plant phenology and less susceptibility to grazing damage. Desert ranges were found to be ideally suited to winter grazing because they are at low elevations where the weather is less severe. Also the high quality of browse on desert ranges are found to be desirable as winter forage because it retains a higher percentage of crude protein than mature herbaceous forage. They showed that the seeding of introduced grasses on foothill ranges could be an effective tool in increase forage quantity and prolong the period of adequate forage quality.

Vallentine (1968) reported that the integration of plant communities and ranges in different condition classes on the Jornada Experimental Range produced considerable increases in livestock production. The magnitudes of the increases were not given. Smoliak (1968), in Alberta, found that the integration of native range, crested wheatgrass and Russian wildrye pastures greatly increased livestock production. Those animals on a rotation free choice system produced 2.2 times more than those animals on native range alone. The integrated use of the three pastures reduced the per animal acreage requirements from 24.8 to 11.4 acres (Lodge, 1970).

The addition of seeded ranges for fall and spring grazing, to complement native ranges, resulted in an additional two months of adequate dietary protein for range cows at the Manitou Experimental Range in Colorado. Another study at Manitou revealed that combining grazing use of meadow, crested wheatgrass and native range plant communities increased calf weaning weights 33 pounds over those from native range alone (Currie, 1969).

When grazed by yearling cattle, a combination of seeded pastures and native range in Wyoming gave daily gains similar to those on native range (Long and Lander, 1960). However, the combined use of all plant communities increased grazing capacity and gains per acre two to three fold.

The Importance of Dietary Preferences in Range Management

Animals are highly selective in regard to the species and parts of plants they eat (Laycock and Price, 1970). When overgrazing occurs, palatable species tend to be the most severely injured while unpalatable species may actually be benefited because competition is reduced (Raleigh and Lesperance, 1972). Knowledge of dietary preferences of livestock and game animals is valuable to the range manager in determining if competition exists between different types of range animals, selecting types of grazing animals compatible with the forage resource, selecting species for reseeding on deteriorated ranges, predicting the outcome of overgrazing by different animals in terms of vegetational changes, balancing livestock and game numbers with forage availability, and in determining the suitability of exotic animals for a particular range type.

Until recent years information has been lacking concerning dietary preferences of different animal species that might be grazing a particular area. Techniques employing esophageal and rumen fistulated cattle and sheep have introduced a fairly accurate means of quantifying forage preferences (Torrell, 1954; Lesperance et al., 1960). Unfortunately, fistulation techniques for forage sampling have not successfully been applied to wild ruminants (Raleigh and Lesperance, 1972). However, fistulas have been established in deer. Studies using microscopic examination of rumen contents have given reliable estimates of game forage selection. This data is limited because of the difficulty and costliness of animal sacrifice. Microscopic analysis of fecal material will probably add considerably to the knowledge of dietary preferences of game animals in future years. Presently more information is needed concerning the reliability of fecal analysis. This method of determining the botanical composition of animal diets will be discussed in a later section.

With certain exceptions, animal selection by forage types is limited to the broad classification of grass, browse and forbs. Raleigh and Lesperance (1972) presented a compilation of the more complete references on dietary preferences of ruminant animals common to the intermountain areas (Table 1).

The data presented in Table 1 indicate that cattle and elk are primarily grass consumers while deer and antelope make heavy use of browse. Sheep appear to prefer forbs when they are available, but they will readily consume grass or browse. It should be pointed out that the kind and amount of different species selected by grazing animals is variable from area to area and may vary considerably during the grazing season (Heady, 1964).

Heady (1964) listed several factors that influence plant selection by grazing animals which include chemical composition of the plant, morphology of the plant, soil factors, growth stage of the plant, weather conditions and past grazing use. This factor probably has more influence of dietary preferences during the grazing season than any other factor. A comprehensive review of environmental influences on nutritional value of forage plants is given by Laycock and Price (1970).

Animal Production and Forage Quality on Rangeland

The Components of Forage Quality

Forage quality is usually expressed in relation to some animal response such as weight gain or production of milk or wool. Dietz (1970) gave six characteristics of a high-quality forage for ruminant

TABLE 1. Forage Selection by Several Important Animal Species in the Intermountain Area.

Species		grass	browse	forbs	Vegetation Region	Source
Cattle	(1)	98	1	1	bunchgrass-sage-aspen	Ansoteguie et al. (1972)
	(2)	75	1	24	bunchgrass-coniferous for.	Stevens (1966)
	(3)	80	8	12	pinon-juniper, desert shrub	Cook, Harris (1968)
	(4)	73	19	8	pinon-juniper, desert shrub	Lesperance et al. (1973)
	av.	82	7	11		
Sheep	(1)	36	17	47	pinon-juniper, desert shrub	Cook, Harris (1968)
	(2)	70	27	3	northern desert shrub	Anon. (1968)
	(3)	29	1	70	bunchgrass-coniferous for.	Stevens (1966)
	av.	45	15	40		
Deer	(1)	9	77	14	bunchgrass-sagebrush-aspen	Ansoteguie et al. (1972)
	(2)	6	80	13	pinon-juniper, desert shrub	Lesperance et al. (1973)
	(3)	35	18	47	bunchgrass-coniferous for.	Morris, Schwartz (1957)
	av.	17	58	25		
Antelope	(1)	3	92	5	northern desert shrub	Anon. (1968)
	(2)	6	63	31	northern desert shrub	Beale, Scotter (1968)
	av.	4	78	18		
Elk	(1)	77	0	23	bunchgrass, Con. forest	Stevens (1966)
	(2)	94	0	6	bunchgrass, Con. forest	Morris, Schwartz (1954)
	av.	85	0	15		

animals which include the following: (1) High palatibility to the animal, with resultant high feed intake, (2) Optimum levels of various nutrient components in proper ratios during the period of animal use, (3) High apparent digestibility of the nutrient components with an optimum ratio of nitrogenous to non-nitrogenous components, (4) Volatile fatty acids in optimum proportions for efficient energy production, (5) Adequate levels of minerals, vitamins and trace elements, and (6) Efficient convertibility into components necessary for the animal body over sustained periods. Forages on rangelands are usually evaluated on the basis of chemical analyses and digestibility. Important chemical components and digestibility of range forage will be discussed briefly.

Protein is considered the most important nutrient to the animal body (Church, 1974). Even a slight deficiency adversely affects reproduction, growth, lactation, and fattening processes (Morrison, 1957).

Both protein and nonprotein nitrogen is represented by the term crude protein. Since ruminant animals do not require specific amino acids, determination of the crude protein level of a plant can give a reasonably reliable indication of its feeding value (Sullivan, 1962).

Ruminant animals obtain most of their protein to form new cells essential for body maintenance, growth, reproduction, and lactation from digestion of rumen microorganisms (Church and Pond, 1974).

The ruminant animal needs protein for the rumen microorganisms to effectively digest and metabolize carbohydrates and fats. If protein levels fall below a minimum, rumen function becomes severely impaired. However, very high protein levels are both unnecessary and inefficient for ruminant animals.

The term crude fat includes all of the various plant substances soluble in ether (Dietz, 1970). Rumen microorganisms synthesize the various fatty acids in the rumen (Church and Pond, 1974), but require the carotenes in ether extract.

The bulk of the plant material eaten by range animals consists of some form of carbohydrate (Dietz, 1970). Carbohydrates in the forage are broken down by rumen microorganisms. Volatile fatty acids are produced in the process of rumen fermentation which provide most of the energy needed by the animal (Annison and Lewis, 1969).

Under the system set up by Van Soest and Wine (1968), the carbohydrate fraction of a forage is separated into the components readily available carbohydrates, cellulose, and lignin. The readily available carbohydrate fraction includes hemicellulose and soluble carbohydrates such as glucose, sucrose, maltose, and starch which can be easily digested. Cellulose is resistant to weak acids and alkalies but it can be hydrolyzed by strong acids to form glucose (Dietz, 1970). Rumen microorganisms can also break it down into more soluble carbohydrates. Cellulose is important nutritionally to the ruminant because it provides the major source of energy when only low quality forage is available. Lignin represents the fibrous, indigestible portion of the diet (Maynard and Loosli, 1956). The digestibility of a forage is strongly affected by the lignin content since the more lignified cellulose becomes, the less digestible it is to ruminants.

The presence of ash indicates the total mineral content of a forage (Sullivan, 1965). Often it is an advantage to know the ash content of a forage because many measurements of digestibility and of certain substances which relate to digestibility are made on an ash free basis.

Calcium and phosphorus are the primary minerals that may cause problems on western ranges. Calcium supplies are usually ample in most range forage, and may be high enough to adversely affect the metabolism of phosphorus (Morrison, 1957). Phosphorus is deficient in many forage species on western and southern ranges during the winter (Dietz, 1970). Cook and Harris (1968) recommended phosphorus supplementation when animals are on winter ranges since the forage is almost always deficient in this mineral. Phosphorus supplementation is also recommended when a wide calcium-phosphorus ratio may prevent metabolism of phosphorus.

Sodium, potassium, chlorine, magnesium, iron, sulfur, iodine, manganese, copper, cobalt, and zinc are other minerals required by range animals (Dietz, 1970). Because these minerals are usually supplied in adequate amounts in common forage plants, concentrations are not normally reported in routine feed analyses.

Vitamins are organic compounds which play a catalytic role in normal body functioning (Church, 1976). The water-soluble vitamins --C and the B complex-- can be synthesized by rumen bacteria so they are not required in forage consumed by ruminant animals. The fat-soluble vitamins--A, D and E--must be present in the forage ingested by ruminant animals.

Plant carotenes are converted to vitamin A by animals (Church, 1976). A deficiency of vitamin A may develop when animals are on ranges devoid of green material for prolonged periods (Dietz, 1970). Unsuccessful reproduction, retarded growth, death of young, night blindness, eye lesions, and a general degeneration of the nervous system are symptoms of vitamin A deficiency (Morrison, 1957).

Vitamins D and E are usually not a problem on rangelands (Dietz, 1970). The ruminant animals' need for vitamin D is usually satisfied when sun cured forage is available or when the animals are exposed to the direct effect of sunlight. Range forage usually has an adequate amount of vitamin E to meet the requirements of ruminant animals.

Energy is a very important measure of the nutritive value of feeds. With the exception of phosphorus and protein deficiencies, lack of either available energy, digestible energy or both is one of the most common nutritional deficiencies affecting range animals (Dietz, 1970). Overused winter ranges and early spring ranges at the time animals switch to watery green grass and forbs are often energy deficient.

Chemical analyses indicate the probable nutritive value of plants but forage digestibility provides a more definitive reference. Digestibility refers to the amount of a feed that can actually be utilized by the animal's body. A routine feed analysis alone has been shown to be unreliable as an indicator of nutritive value of a feed (Atwood, 1948). Digestion trials have shown that older, more mature fall and winter forage is less readily digested than succulent spring growth (Burzlaff, 1971; Wallace and Denham, 1970; Cook and Harris, 1968). Therefore, any protein deficiency in the fall and winter may be greater than shown by routine chemical analysis. Some of the measurements employed in digestibility studies are described in a later section.

The Effect of Season Upon Forage Quality

Range forage varies tremendously in nutritional qualities during the grazing season (Raleigh and Lesperance, 1972). Range plants are most nutritious during the growth stages. After maturity, grasses and forbs decline rapidly in nutritive value. Shrubs, however, have a longer growing season and maintain their nutritive value longer.

New growth has a high percentage of carbohydrates, crude protein, vitamins and water (Heady, 1975). It is low in fiber, lignin and ash which are associated with poor nutritional qualities. These two groups of substances gradually reverse their positions as plants approach maturity (Stoddart et al., 1975). Tall and coarse grasses do not cure as well as fine and short grasses which retain greater nutritional quality during dormancy. The quality of the feed for large herbivores decreases on all range types after plant maturity. Raleigh (1970) presented data showing the change in chemical composition of three range grasses at different stages of maturity (Table 2). Trends in forage quality in the different topographic regions of the western United States were reviewed by Vavra and Raleigh (1976).

Most shrubs retain higher crude protein contents during the latter part of the growing season and dormancy than grasses (Raleigh and Lesperance, 1972). Grasses, however, usually have lower lignin values than shrubs at all stages of maturity. Cook and Harris (1950) presented data showing crude protein and lignin values of grasses, forbs and shrubs at different stages of growth (Table 3).

As forage quality declines with maturity, livestock performance also decreases. Raleigh and Wallace (1963) found gains by cattle were

TABLE 2. Chemical Composition and *in vitro* Cellulose Digestion of Range Grasses at Various Stages of Growth During 1959 and 1960. Raleigh (1970).

Growth Stage	air-dry matter	N	ether extract	crude fiber	P	Ca	*in vitro* cellulose digestion
Agropyron spicatum							
pre-boot	34	2.6	1.6	21	.22	.23	70
boot	36	2.3	2.1	22	.23	.26	69
head	43	1.8	2.4	25	.17	.23	57
early flower	43	1.6	2.4	26	.18	.22	55
early seed	60	1.2	3.3	27	.18	.16	47
mature	79	0.9	3.5	28	.18	.24	41
Koeleria cristata							
pre-boot	33	3.1	1.8	20	.26	.31	74
early boot	30	2.4	2.9	21	.25	.24	77
early head	33	2.1	2.2	21	.22	.28	71
head	38	1.8	2.8	25	.23	.27	74
flower	40	.15	2.9	28	.19	.25	62
seed stage	58	1.4	4.9	23	.23	.31	61
mature	80	1.2	4.6	24	.20	.24	63
Agropyron desertorum							
pre-boot	30	3.0	2.1	16	.22	.23	75
boot	34	2.3	2.0	17	.21	.21	69
late boot	34	2.2	2.3	20	.21	.28	73
early head	40	1.7	2.1	19	.18	.18	68
head	42	2.0	5.1	23	.18	.24	69
seed stage	51	.14	1.9	22	.14	.18	53
mature	65	0.7	3.0	27	.22	.26	48

TABLE 3. Seasonal Changes in Crude Protein and Lignin of Three Classes of Forage in Northern Utah (Cook and Harris, 1950).

	Protein			Lignin		
	Early	Middle	Late	Early	Middle	Late
Grasses						
stems	5.02	3.62	3.16	10.99	11.16	12.98
leaves	14.60	11.68	10.21	7.87	8.50	10.30
heads	13.76	15.20	---	8.20	8.22	---
entire plant	8.22	6.02	4.49	9.95	10.48	12.48
Forbs						
stems	4.73	4.31	4.48	11.73	11.78	13.59
leaves	15.66	13.45	13.25	8.05	7.64	9.86
entire plant	10.62	9.18	8.79	9.74	9.36	11.54
Shrubs						
stems	6.50	6.00	6.46	22.72	16.03	22.95
leaves	13.77	12.91	12.45	13.88	11.09	12.01
current growth	12.26	11.71	10.76	16.20	13.76	15.08

1.0 kg or more during May and June, 0.7 kg or less during July, less than 0.5 kg during August and very little gain was made in September at the Squaw Butte Experiment Station at Burns, Oregon. If the nutritional quality of forage is known throughout the grazing season, protein and energy supplements can be provided to maintain livestock performance. Raleigh et al. (1967) and Raleigh and Wallace (1964) showed that supplementation with protein and energy to yearlings was economical on bunchgrass range in southeastern Oregon. On

Oklahoma range, protein supplementation increased average daily gains (Gallup et al., 1953). Southern ranges are deficient in digestible protein much of the year (Shepherd and Hughes, 1970). In Louisiana, protein supplementation on bluestem ranges from October to May produced profitable calf crops (Duvall and Whitaker, 1963). Most western ranges dominated by grasses have sufficient energy to meet the maintenance requirements of wintering livestock except during periods of heavy snow (Shepherd and Hughes, 1970). However, energy supplementation is recommended for browse ranges during the winter (Cook and Harris, 1968). Southern wiregrass and bluegrass ranges are deficient in energy during the spring and winter (Shepherd and Hughes, 1970). Energy supplementation has been found to improve calf crops on these ranges (Halls and Southwell, 1956; Shepherd et al., 1953).

Considerable data are available concerning the digestibility of range forage. During early growth, range grasses are highly digestible (40 to 70 percent), but they decline sharply as the season advances to less than 40 percent (Burzlaff, 1971). Wallace and Denham (1970) found that the digestibility of all the chemical components of the diet selected by cattle decreased as the grazing season advanced (Table 4).

TABLE 4. Digestibility of Forage Selected by Cattle (Wallace and Denham, 1970).

Component	June	July	September	December
		percent digestibility		
Organic matter	73	68	56	49
Crude fiber	67	63	52	45
Gross energy	70	63	50	43
Crude protein	69	59	34	2
Ether extract	40	24	23	14

Sample Collection Problems and Techniques

Several methods are available for collecting forage samples representative of the grazing animal's diet for chemical analysis which include:

1) bulk sampling by mowing or clipping.
2) collection of current years growth by clipping new leaders on browse or separating green from old shoots on herbaceous forage.
3) hand plucking of samples believed to represent the grazing animal's diet.
4) use of caged or microplots which exclude grazing animals and can be clipped to represent the grazing animal's diet.
5) the use of fistulated animals.

Herbage available for grazing may be different in chemical composition than forage ingested by grazing animals due to selective grazing (Hardison et al., 1954; Weir and Torell, 1959; Lesperance et al., 1960; Galt et al., 1969; Lesperance et al., 1974). Because of the problem of selective grazing, animals with esophageal or rumen fistulas have been widely used in recent years to obtain samples of forage for chemical analysis. Forage samples obtained with fistulated animals should represent the diet selected by the grazing animal. Theurer (1969) listed several factors which determine the exactness with which fistula forage samples will represent the chemical composition of the diet. These factors include losses in fistula sample collection, chemical changes during mastication and in salivation, and chemical changes during sample preparation for laboratory analysis.

Salivary contamination has been suggested as a factor which may change the chemical composition of fistula forage samples (Cook, 1964). It has been shown that animal ingestion markedly affects forage chemical composition (Lesperance et al., 1960; Bath et al., 1956; Barth and Kazzal, 1971).

The nitrogen content of fistula forage samples has been found to be higher than that contained in the forage fed to the animal in some investigations (Blackstone et al., 1965; Lesperance and Bohman, 1964). Other studies have shown no differences between forage fed to the animal and forage samples collected from fistulated animals (Lesperance et al., 1960; Barth et al., 1956). In a study conducted by Galt and Theurer (1972), there was no difference in the nitrogen content of forage offered versus fistula forage. This investigation indicated little nitrogen was lost from rumen fistula samples by leaching.

Many investigations have shown that mastication and salivary contamination increased the ash and phosphorus contents of esophageal fistula forage but had variable effects on other chemical parameters (Scales et al., 1972; Wallace et al., 1972; Scales et al., 1974; Lesperance et al., 1974). These results agreed with those of Cundy and Rice (1968) who presented evidence that salivary contamination increases the ash content of esophageal fistula forage. In this study nitrogen levels were not affected by saliva. Scales et al. (1974) concluded that with the exception of minerals and possibly crude protein, the chemical composition of diet samples obtained with the esophageal fistula gave a reasonable estimate of the chemical composition of the grazed forage.

Lesperance et al. (1974) presented evidence that salivary contamination is the most important factor altering the chemical composition of fistula samples. Datawere presented showing that saliva will contribute significant amounts of ash, phosphorus and nitrogen to alter sample composition. It was reported nitrogen contamination may be minimized by maintaining fistulated animals on diets of similar nitrogen content to the forage being sampled.

The magnitude of the increase in ash and phosphorus from salivary contamination of fistula samples has been studied (Lesperance et al., 1974). Ash is usually increased from one to four percent while the increase in phosphorus ranges less than 0.1 to over 0.3 percentage units. Apparently fistulated animals should not be used to study the phosphorus content of the diet.

Attempts have been made to reduce salivary contamination of fistula samples by hand squeezing or using collection bags with screen bottoms (Lesperance et al., 1974; Hoehne et al., 1967). Both techniques reduce salivary contamination but introduce the possible loss of soluble nutrients. Methods of saliva removal need further investigation. In many studies, problems of ash contamination have been minimized by presenting data on an ash free basis.

Considerable change in carbohydrates of fistula samples compared to feed have been reported (Lesperance et al., 1974; Rice, 1970). Fistula samples are generally higher in crude fiber and lignin while nitrogen free extract values tend to be lower. However, Lascano et al. (1970) found that the acid detergent fiber and lignin content of esophageal fistula samples were not different from the original feed.

Sample preparation can affect the chemical content of fistula forage samples (Theurer, 1969). The addition of water or artificial saliva to hay samples followed by drying increased crude fiber and lignin while nitrogen free extract was decreased (Lesperance and Bohman, 1964). This study also indicated that drying temperature had a significant influence on lignin and carbohydrate composition of the hay samples. Lignin values were greater for samples oven dried (65°C) compared to samples vacuum-dried (25°C). Smith et al. (1967) found that crude fiber and acid detergent lignin were significantly higher in oven-dried (65°C) forage samples as compared to freeze-dried samples, while nitrogen free extract was lower. Van Dyne and Torell (1964) also reported increased fiber and lignin values by drying samples at high temperatures. Apparently a combination of high temperature and moisture causes a nonenzymatic browning reaction that increases the fiber content of feeds (Van Soest, 1962).

Research conducted in Wyoming showed esophageal samples of forage dried at 60°C were significantly lower in ash than samples frozen after collection (Rice, 1970). The nitrogen, cellulose and acid-detergent lignin contents were not significantly affected by sample preparation:

	Frozen Percent	Dried Percent
Ash[2]	19.3[a]	12.3[b]
Nitrogen[2]	2.9	2.8
Cellulose[2]	32.2	29.9
Acid detergent lignin	2.3	2.4

1 means with different superscripts are significantly different (PL.01).

2 dry matter basis.

Rice (1970) reported dry matter was significantly reduced and ash was significantly increased when samples of alfalfa were collected by esophageal fistulated steers. Lignin values also tended to be higher. Rinsing the esophageal samples with tapwater resulted in further reduction in dry matter. Significantly higher cellulose, lower ash, and lower nitrogen were found in rinsed samples when compared to unrinsed samples.

The chemical composition of forage samples has been shown to vary between rumen and esophageal fistula samples (Lesperance et al., 1974). However, when the rumen was completely evacuated, contamination from rumen contents was greatly reduced. Rumen contamination of esophageal fistula samples was found to also occur but was usually not a problem.

Rumen fistula samples have been found to be generally higher in crude fiver and lignin than esophageal fistula samples (Lesperance et al., 1974). The exact mechanisms causing these values to be higher in the rumen is currently unknown.

Techniques for Determining Chemical Composition

The chemical composition of range forage plants has been studied by numerous investigators. Methods of analysis of crude protein, gross energy, ash and dry matter are standardized (A.O.A.C., 1960). However several techniques have been used to determine fiber and lignin values, and will be discussed.

Crude fiber commonly refers to the cell wall contents of plants, and is comprised primarily of plant structural carbohydrates such as cellulose and hemicellulose (Church and Pond, 1974). It also contains lignin which is a highly indigestible material associated with the fibrous portion of plant tissues.

The nutritional value of crude fiber in the diet varies between animals. Crude fiber has low value to the monogastric, but is utilized to a higher degree of ruminants because they have cellulolytic bacteria (Church, 1976). Forbes et al. (1937) cited evidence that suggested cattle digest crude fiber more efficiently than sheep. However, when the proportion of concentrate to roughage was high, sheep were more efficient. Short (1963) found white-tailed deer digested fibrous material better than a steer. In another experiment, alfalfa hay was feed to deer and sheep by Smith (1952). Similar digestibility coefficients were found for all components except ether extract. Cowan et al. (1970) found small differences in the ability of deer and sheep to digest timothy hay (Phleum pratense).

Crude fiber is composed of cellulose, hemicellose, lignin and silica (Crampton and Harris, 1969). The kind and maturity of plant as well as the age and species of animal determine the nutritional availability of these components. Lignin is a polymer which has a negative effect on digestibility (Van Soest, 1964). Sullivan (1959) showed that as lignin increased, digestibility decreased. Therefore it has received more attention than other cell wall constituents. Lignin is highly resistant to chemical degradation and enzymatic digestion (Albersheim, 1965). As the plant approaches maturity, the lignin polymer increases in size. Lignin is thought to be indigestible because it is the result of a non-enzymatic spontaneous reaction.

Wallace and Van Dyne (1970) reviewed several studies concerning lignin, and reported that apparent digestibility of lignin ranged from -40 to +64% at varying stages of maturity. Methods used were those of Crampton and Maynard (1938); Davis and Miller (1939); Ellis, Matrone and Maynard (1964); Kalb (1932); Norman and Jenkins (1934); Sullivan (1959); and Van Soest (1963). The calculated lignin digestibility values ranged from 46% to 4% for esophageal fistula samples taken in June, July, September and December. The highest lignin digestibility values were reported in June and the lowest in December.

Some of the problems of lignin analysis were discussed by Van Soest (1964). Lignin may be partially dissolved when the pH exceeds seven. The involvement of lignin in the browning reaction may also confound the percent lignin when forage samples are dried at high temperatures. Lignin values of 15.5 and 14.4%, respectively, were obtained when the same sample was dried at 20 and 100 degrees Centigrade for 16 hours.

Techniques that are now widely accepted for the determination of cell wall constituents and cellular contents have been developed by Van Soest (1963) and Van Soest and Wine (1967, 1968). In the original technique, lignin is determined as the loss of organic matter upon ashing. In the newer method, lignin is dissolved with potassium permanganate. Cellulose is not affected by permanganate. Therefore this technique has the advantage of allowing for determination of cellulose. One value is obtained from cell contents and hemicelluloses with this technique. Percent lignin, cellulose, and silica are individually obtained as well as total acid detergent fiber. In other lignin methods cutin is excluded. Because of this, the permanganate method is more reliable than the method of Van Soest (1963).

Procedures for Determining Digestibility

Several procedures have been used to determine the digestibility of range forage. Because of the time and effort required to collect sufficient forage for a classic digestion trial, most of these methods involve *in vitro* or *in vivo* digestion of small samples. Indirect techniques involving indicator or regression techniques have also been widely used.

Micromethods for nutritive evaluation of forages have been reviewed by Annison and Lewis (1959); Barnett and Reid (1961); Johnson (1963); Van Dyne (1968); and Johnson (1969). The application of micromethods to the nutritive value of range forages is discussed by Van Dyne (1962) and Johnson (1969). The *in vitro* and *in vivo* techniques are the two primary microdigestion methods.

In vivo procedures for evaluating forages have been used for more than forty years (Barnett and Reid, 1961). The advantage of this procedure is that conditions in the rumen are closely duplicated, and the complexities of duplicating ruminal conditions, are avoided (Short, 1970). Samples of several forages can be simultaneously suspended in a single rumen without greatly changing the ruminal environment.

The *in vivo* procedure is discussed by Short (1970). This technique involves leaving the forage to be analyzed in the rumen of a fistulated animal for a prescribed time period. Nylon bags are used to hold the forage. The forage is weighed when it is put in the rumen and after it is removed. Digestion is calculated by subtracting the weight after removal from the intact weight.

There are some problems with this procedure which have been discussed by Van Dyne (1968). A major problem is that retention time needed to maximize microdigestion varies with size, grind and type of sample. Results are also affected by movement of particles into and out of the bag; the chemical nature of the bag itself; the present diet of the animal; and the age, health and species of animal used for digestion. Further, repeatability has been a problem in some investigations, and only a small number of samples can be run at one time. These disadvantages are why *in vitro* techniques have largely replaced this method in recent years.

The *in vitro* digestion technique simulates natural ruminant digestion under laboratory conditions (Pearson, 1970). This procedure involves innoculating a forage sample placed in a test tube having appropriate buffers with rumen fluid from a fistulated animal. After an appropriate period of time, digestion is calculated by subtracting the weight of the digested sample from the original sample.

A number of artificial rumen techniques are available, and have been described by El-Shazly et al. (1960); Van Dyne (1962); Tilley and Terry (1963); and Johnson (1970). Specific methods vary greatly between laboratories, and the more common techniques have been compared by Scales et al. (1974); Meyer et al. (1971); Oh, Baumgardt and Scholl (1966); and Handl and Rittenhouse (1975). Several investigations have shown the modified two-stage Tilley and Terry method to be the most reliable predictor of digestibility (Pearson, 1970). Van Soest (1967) considered this technique superior to other in vitro methods because it involves essentially an enzymatic preparation of undigested cell walls. Tilley and Terry (1963) state that it is difficult to duplicate in vitro data with in vivo data because of variation between animal species, age and health of the animals, level of feed intake and feed preparation method. These problems can be corrected by the calculation of a regression equation between a standard sample of known in vivo digestibility and in vitro samples.

Several variables affect results from in vitro fermentation studies. These variables have been discussed by Van Dyne and Harris (1968) and were placed in four categories as follows:

(1) Variations in microbial populations

a. diet of host animal

b. animal to animal differences

c. inoculum processing differences

(2) Variations due to different storage, grinding and processing techniques in sample preparation.

(3) Differences attributable to medium

a. sample: inoculum ratio

b. buffer used

c. nutrient medium

(4) Procedural variations such as length of fermentation, criteria of digestibility and laboratory errors.

The inoculum is the largest source of error or variability in the *in vitro* system (Johnson, 1970). Factors which can contribute to variability are:

(1) diet of the animal.

(2) feeding system (time, etc.).

(3) time of removal of rumen contents.

(4) method of processing rumen contents.

(5) handling of rumen liquor between animal and *in vitro* vessel.

(6) treatment in the laboratory prior to inoculation.

Although there are many sources of error, the *in vitro* acid pepsin digestion of Tilley and Terry (1963) can produce relatively high correlations with apparent *in vivo* dry matter digestibility on forages exhibiting a wide range of digestibilities. This has been demonstrated in studies conducted by Scales et al. (1974), Tilley and Terry (1963), Van Soest et al. (1966), and Wilson et al. (1971).

Several fecal indexes or regression techniques have been used to determine the digestibility of range forage. In recent years, the fecal nitrogen index, originated by Lancaster (1949), has received considerable attention. The basis of this method is that total fecal nitrogen is directly proportional to nitrogen content of the diet. Comprehensive discussions of this method are given by Lambourne and Reardon (1962); Lancaster (1954); Greenhalgh and Corbett (1960); and Van Dyne (1968). This method does require a digestion trial to develop the relation between forage and fecal nitrogen for the forage under question. A serious problem with this procedure is reduced accuracy when total collections are not taken.

The assumptions behind the fecal nitrogen technique are: (1) the herbage fed to the animal is similar to that grazed by the animal, and (2) the penned and grazing animals digest herbage to the same degree (Wallace and Van Dyne, 1970). The regressions have been found to vary between first growth and aftermath herbage (Greenhalgh and Corbett, 1960), for leaf and stem components of the herbage (Lambourne and Reardon, 1962), from year to year (Topps, 1962), and for different varieties of the same herbage species (Minson and Milford, 1967). However, the method has given useful results even when a general rather than specific regression was used (Holmes et al., 1961; Langlands, 1967).

Chromogens and lignin are the two most common internal indicators used to determine digestibility.

Van Dyne (1968) presented the following general equation for digestibility using internal indicators such as lignin or chromogens:

$$\text{Digestible Dry Matter} = 100 - \frac{\%\ \text{indicator in forage}}{\%\ \text{indicator in feces}} \times 100$$

Short (1970) gave an equation which has been used in many range studies when internal indicators are used to determine the digestibility of a particular nutrient. This equation is as follows:

$$\text{Digestibility} = 100 - \left[100 \times \frac{\%\ \text{indicator in feed}}{\%\ \text{indicator in feces}} \times \frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in feed}} \right]$$

The lignin ratio technique for determining digestion has been reviewed by Salo (1957a, 1957b, 1958); Milford (1957); and Van Dyne (1968). In a review of the lignin ratio procedure, Milford (1957) gives a number of disadvantages. These include: 1) lignin is not a distinct chemical entity, 2) impurities may become attached to lignin during chemical analysis, 3) methods of lignin analysis are tedious and expensive, 4) selective grazing can introduce high errors in sampling of forage actually consumed, 5) lignin may be partially digestible, and 6) changes in the chemical composition of lignin may occur through the digestive tract. Because lignin may be partially digestible in immature forages, it appears that the lignin ratio method should be reserved for evaluating digestibility on winter or browse ranges where lignin values of consumed forage are over five percent.

Chromagens are recoverable, naturally occurring plant substances used to a limited degree as internal indicators. Chromagens have given best results with grasses and new growth which have a high chromogen content (Lindahl, 1963). Extraction is a primary problem with mature forages when chromagens are used (Greenhalgh and Corbett, 1960). Cook and Harris (1951) found that when the animals diet was high in ether extract there was considerable variation in digestion estimates. Negative digestion coefficients were occasionally reported because less chromagen occurred in the feces than in the feed.

The use of silica as an internal indicator was reviewed by Van Dyne (1968). This method has not been successful because it has been impossible to sample the same forage as does the animal. Soil contamination is also a problem due to the high silica content in the soil. Even a small amount of soil contamination of herbage or fecal samples gives variable and invalid results in digestion trials.

Chromic oxide is the primary external indicator which has been used to calculate digestion. The chromic oxide method involves administering a known amount of the indicator substance and then measuring the amount recovered in the feces (Church and Pond, 1974).

The calculation for apparent digestibility using this method is the same as the one previously given for internal indicators.

The primary problem with the chromic oxide technique is the wide variation in fecal recovery (McCann and Theurer, 1967; Weir et al., 1959; Lambourne, 1957; Van Dyne, 1968; and Pidgen and Minson, 1969). It has been shown that there is less variation when chromic oxide impregnated paper is used rather than the powdered form (Streeter and Clanton, 1964; Corbett et al., 1958). Studies with sheep have indicated that chromic oxide should be administered for five consecutive days before feces collection for analysis (Crampton and Lloyd, 1951). Rice et al. (1974) administered 10 grams of Cr_2O_3 twice daily for 10 days before taking grab samples. Grab samples were then taken twice daily for five days and chromic oxide administration was continued. Error in fecal recovery has been reduced by collecting grab samples twice daily at 6 am and 4 pm (Hardison and Reid, 1953; Smith and Reid, 1955). Smith and Reid (1955) reported a mean rate of recovery of 100.58 $\pm$ .87% when grab samples were collected daily at these two time periods. The correlation between total fecal collection and grab sample estimation was 0.98 in this study.

Consistent results were not obtained using chromic oxide and grab sampling by Weir et al. (1959). Changes in the diurnal excretion rates under grazing conditions may cause considerable error

(Lambourne, 1957; Van Dyne, 1968). If the investigator needs to know the amplitude of this diurnal variation, he can sample when the average is expected or sample twice, once below average and once above. Periodically, total collections are necessary to check the accuracy of the sampling pattern and to obtain data for correction factors to prevent biased sampling.

Forage Intake Determination

Information on the quantitative forage intake by range animals is currently limited. The lignin ratio, chromogen ratio, fecal nitrogen index, and chromic oxide procedures have been widely used to determine forage intake by range livestock. All these methods have limitations which have already been discussed. Fecal collections have been used in addition to external indicators to determine fecal output. Intake can be calculated when total fecal output and the digestibility are known with the following equation:

$$\text{Dry matter intake} = \frac{\text{total fecal excretion (100)}}{\text{100 - percent digestibility}}$$

(Van Dyne, 1968). For determining quantitative intake of grazing livestock, it appears that relatively accurate estimates could be obtained using a Tilley and Terry (1963) *in vitro* system in conjunction with total fecal collection (Van Dyne, 1968).

The different approaches utilized to estimate forage intake are

1) relating animal performance to intake (Davis et al., 1970; Knott et al., 1934); 2) relating water to forage intake (Hyder, 1970); 3) observing numbers of mastications in deer (Crawford and Whelan, 1973; Wallmo and Neff, 1970) and in domestic livestock (Bjugstad et al., 1970); 4) using fecal index techniques (McManus et al., 1967); 5) feeding clipped forage in conventional digestion trials (Short, 1970); 6) using an agronomic approach with clipping before and after grazing to estimate herbage removal (Martin, 1970); and 7) relating forage intake to fecal output and forage digestibility (excretion to indigestibility ratio) (Van Dyne, 1968).

Comparison of Forage Intake Methods

Van Dyne (1968) stated that an ideal method for determining forage intake of grazing animals should: (1) be applicable to individual animals rather than groups, (2) be based on measurement of dietary or fecal components which can be easily and accurately analyzed, (3) not depend on harvesting range herbages for dry-lot digestion trials, (4) be applicable to both cattle and sheep, and (5) be useable on all types of ranges in all seasons. Unfortunately, none of the indicator methods meet all these criteria.

There are also a number of problems associated with external marker methods (chromic oxide) which do not involve total fecal collection (Lambourne, 1957) which include:

1) the marker must be fed as a discrete dose once or twice daily at an arbitrary time, regardless of changing patterns of grazing behavior;

2) fecal samples from individual animals can be obtained only at arbitrary times and no more than 2 - 5% of the total feces will generally be obtained;

3) handling of stock must be kept to a minimum and it will generally be necessary to take fecal samples at dosing times;

4) since individual animals within a herd may vary greatly in appetite and selectively under natural grazing conditions, the technique adopted must be satisfactory over a wide range of feed intake and quality.

Total fecal excretion is calculated from external markers with the following equation:

$$\text{Total fecal output/day} = \frac{\text{amount of indicator administered per day}}{\text{amount of indicator in grab sample}} \times \text{weight of grab sample}$$

Chromic oxide has been the most commonly used indicator.

When total fecal collections are made per 24-hour period, microdigestion can be utilized (Van Dyne, 1968). It is assumed that microdigestion equals the true total digestibility of the forage. Techniques utilizing microdigestion are somewhat more tedious than the chromagen or lignin ratio methods but less so than the fecal nitrogen index method (Van Dyne and Meyer, 1964). The micro-digestion procedure was superior to the lignin ratio method when forages were immature and lignin was partially digestible in a study conducted by Wallace and Van Dyne (1970). Because interfering substances can prevent accurate determination of chromagens, microdigestion was better than the chromagen method (Cook and Harris, 1951). As with other techniques, the microdigestion method does require an accurate sample of the animal's diet.

In recent years there has been much interest in using water intake as a measure of forage intake. This interest was stimulated by Winchester and Manis (1956) who gave water intake rates (in gallons of water consumed per pound of forage dry matter consumed) as a function of ambient temperature. Hyder (1970) equated the data in the following form:

$$F = \frac{H}{K}$$

In this equation, F represents the forage intake (pounds of dry matter eatern per day), H represents the total amount of water consumed (gallons) and K represents the water-intake rate (gallons of water per pound of dry matter consumed at any given mean air temperature in degrees F). This method requires that a table be compiled to take the water in the forage and water consumption levels at different mean air temperatures into account. Drinking water is measured by metering and air temperatures are recorded by a thermograph. The moisture contents of the forage can be estimated from hand-plucked samples representing the animal's diet or from samples collected from esophageal fistulated animals.

Hyder et al. (1966, 1968) gave evidence that the water intake method was more accurate than a clipping method. This technique shows considerable promise in determining forage intake on range animals, but further evaluation is needed comparing it with conventional methods.

Clipping before and after grazing has been used extensively to measure forage utilization and intake (Martin, 1970). Unaccounted losses due to such things as trampling and consumption or destruction by wildlife and insects are a major fault with this technique. Sampford (1960) discusses several of the statistical problems related to this method. This method appears to give best results when relative intake between treatments is desired and the level of use is heavy (Martin, 1970). Usually it should be avoided when a quantitative intake measurement is needed.

Diet Botanical Composition Determination

Dietary Sampling Procedures

One of the most basic problems confronting the range nutritionist is that of determining precisely the botanical composition of the grazing animal's diet. Range animals usually graze large areas where plant communities are quite diverse, and they usually exhibit a preference for certain species. Information on the botanical composition of the grazing animal's diet is essential for devising optimal grazing and supplementation plans (Cook and Harris, 1950). A number of techniques have been utilized to determine the botanical composition of the range herbivores diet although in recent years esophageally fistulated animals have been widely used. This discussion will deal primarily with the esophageal fistula. Other methods will be mentioned.

A number of procedures are available for determining the diet of the grazing animal which include:

1. Fistula techniques
2. Direct observation of wild animals
3. Utilization studies
4. Fecal analysis
5. Stomach analysis
6. Cafeteria trials
7. Direct observation of captive animals
8. Stomach analysis using trocar samples

Unfortunately all of these methods are either inaccurate or very expensive. In all cases, the choice of method depends on the information desired and the particular situation involved.

The various clipping techniques have been reviewed by Smith et al. (1962) and Martin (1970). Many problems seriously affect accuracy when using clipping techniques. Consumption by other animals and insects or destruction by the physical forces of the environment can be easily confused with removal by domestic livestock (Martin, 1970). Another limitation is that past forage use is not always visible. When fistula samples were compared with plot clipping, it has been found that selective grazing made the clipping method unsatisfactory (Lesperance et al., 1960; Ridley et al., 1963; Connor et al., 1963). Lesperance et al. (1960) found that there was little agreement between utilization data and esophageal fistula samples on irrigated pasture with only three forage species. McInnis (1977) found that utilization data by the ocular-estimate-by-plot method gave lower estimates of graminoids and higher estimates of forbs in sheep diets when compared to fistula samples.

Wildlife researchers have commonly used stomach and intestinal tract analysis (Chippendale, 1962; Chamrad and Box, 1964; Korschgen, 1966; Talbot and Talbot, 1962). The problem with this method is that the animals must be sacrificed.

Direct visual observation or "bite-count" procedures have also been used (Bjugstad et al., 1970; Wallmo and Neff, 1970; Reppert, 1960). With this technique, the observer must be able to identify individual species and plant parts in all growth stages at distances up to 10 feet (Free et al., 1971). The problem with this method is that intake of the different species cannot be quantified.

A new method offering promise for sampling stomach contents involves the use of tranquilization to immobilize animals in conjunction with the use of a trocar to take rumen samples (Wilson et al., 1977). The wound resulting from sample collection is sown shut. The main problems with the trocar method include parasites in warm climates, tranquilization of animals, and layering of rumen contents which may bias the sample.

In recent years fecal analysis has been used in many investigations. Fecal analysis requires fewer samples than rumen analysis and allows practically unlimited sampling (Anthony and Smith, 1974). Additional advantages are that fecal analysis does not interfere with the normal habits of the animal, places no restrictions on the movement of the animal, has particular value where animals range extensively over mixed plant communities, and is the only feasible procedure to use when studying secretive and/or endangered species (Crocker, 1959; Anthony and Smith, 1974). Fecal analysis is also advantageous when the same range is used by two or more animals (Korfhage, 1974).

Although fecal analysis does have several advantages, the disadvantages deserve discussion. Ward (1970) presented the following disadvantages of fecal analysis:

1. Where the food was eaten cannot be determined.
2. Much equipment and labor are required.
3. There may be a problem in identifying the animal feces.
4. An extensive reference plant collection is required.
5. Food items passed in feces might not be proportional to those consumed.
6. Plant identification is difficult at the species and sometimes at the genus level.
7. Considerable time is required in plant identification.
8. Some plant species may be destroyed in slide preparation.
9. Sample collection procedures may further bias the results.
10. Aging of fecal material before collection further complicates identification.

Vavra et al. (1970) found that during the growing season, fecal sampling for diet composition tended to underestimate the incidence of forbs and over-estimate the occurrence of grasses. In the winter months when plants were mature, fecal samples were more comparable to esophageal samples. McInnis (1977) fed synthesized diets to sheep. Esophageal, rumen and fecal samples were compared to the synthesized diet. Fecal samples were significantly higher in their composition of grasses and significantly lower in their composition of forbs than the actual diet.

It is generally acknowledged that the sampling methods which have been discussed have serious limitations for accurately evaluating the herbage grazed (Van Dyne, 1968). The use of the esophageal and rumen fistula methods have become widespread (Rice, 1970; Theurer, 1969; Free et al., 1971). The esophageal fistula was found to be superior to the fecal analysis procedure in studies conducted by Vavra et al. (1970) and McInnis (1977). Esophageal fistula samples were found to be more representative of the grazing animal's diet than clipping procedures in a study conducted by Kiesling et al. (1969). The use of the esophageal fistula is preferable to the use of rumen fistula because rumen evacuation (1) subjects animals to unphysiologic conditions, (2) is limited to large animals, and (3) is more laborious (Rice, 1970). McInnis (1977) found esophageal samples were more representative of synthesized diets fed to sheep than rumen samples.

Rumen fistulas are more easily established and maintained than esophageal fistulas (Lesperance et al., 1960; Rice, 1970). Rumen fistulated animals require less care during sampling than esophageal fistulated animals (Theurer, 1969). Sampling involves removal of rumen contents, allowing the animal to graze, removing the collected sample and replacing the original contents (Lesperance et al., 1960a). Rumen fistula samples contain all the forage the animal has consumed during the collection period. This is not necessarily so with the esophageal fistulated animals as forage can be lost from the collection bags (Lesperance et al., 1974).

There are a number of restrictions to the use of the rumen fistula (Rice, 1970). Much time and effort are required to empty and wash the rumen and then replace the contents after sampling. Removal of rumen contents may adversely affect the animal's physiology because there is an influx of fluids from the body. An empty rumen may stimulate the animal to fill it and graze haphazardly decreasing normal selectivity. Repeated emptying of the rumen also depresses digestibility (Lesperance and Bohman, 1963; Connor et al., 1963). Even though the rumen fistula has certain limitations some investigators have used it successfully to study diet composition (Galt et al., 1969; Lesperance et al., 1960b; Connor et al., 1963).

The esophageal fistula has been used for many years. It was first used on horses (Magendi and Ryer, 1847), and later on dogs (Pavlov, 1897). Van Dyne and Torrell (1964) reported that Goldman (1939) was the first to use the esophageal fistula on cattle. The technique has been used widely in ruminant nutrition only for the last two decades.

Descriptions concerning the surgical technique of fistulation for large animals have been published by Torrell (1954); Cook et al. (1958); Hamilton et al. (1960); McManus (1962a); McManus et al. (1962b); Chapman and Hamilton (1962); and Cook et al. (1963). Reviews on the development and use of the esophageal fistual include

Van Dyne and Torrell (1964); Theurer (1969); and Rice (1970). Success with surgery and maintenance of fistulated animals has been reported by Lesperance et al. (1960a); Torrell (1954); Cook et al., (1958); Cook et al. (1963); Van Dyne and Heady (1965); Jeffries and Rice (1969); and Lake and Clanton (1972). Refinement in surgical procedures, pre- and post-operative care, and cannula types have reduced animal mortality in recent years. Descriptions of the care of animals is given by Cook et al. (1958) and Hoehne et al. (1965).

The primary problems with esophageal fistula sampling are salivary contamination, rumen contamination, and incomplete recoveries. Since salivary contamination has already been discussed, only sample contamination from rumen contents and incomplete recovery will be reviewed. Known mixtures of collected herbage were fed by Grimes and Watkins (1965). Although recovery was only 53 to 73%, ingested forage was the same as the forage offered. In a similar study, conducted by Campbell et al. (1968), a recovery range of 84 to 94% was reported on a concentrated ration. Recoveries on other feeds ranged from 34 to 81%. One of the primary causes of incomplete recovery was plugging of the fistula opening with a bolus of forage. Collection periods of longer than 30 minutes increase the chance of regurgitation of rumen contents into the collection bag (Bath et al., 1956). Samples with this source of contamination cannot be used for botanical or chemical analysis.

Botanical Analysis of Fistula Samples

Quantitative analyses for species composition of masticated forage mixtures presented difficulty during initial use of the esophageal fistula for diet determination. In the last decade, techniques have been developed which reduce this problem.

Four methods of dietary botanical analysis of esophageal fistula material are available which include visual appraisal, manual separation, microhistological techniques and microscopic point techniques. These will be discussed.

Only qualitative estimates of botanical components of the diet of grazing animals can be obtained by visual appraisal (Theurer et al., 1976). Cook et al. (1958) found most browse plants in fistula forage samples could be identified visually by texture and color differences. Grasses, however, were frequently masticated beyond recognition.

Hoehne, Shuster and Clanton (1965) and Obioha (1967) manually separated plants into groups or specific species. In both of these investigations a detailed discussion was given of the separation procedures used. Personal error was the greatest problem in obtaining reproducible results in these investigations. The greatest precision occurred when only one individual performed all separations.

In recent years microhistological techniques have been used by many investigators to identify plant material in fistula samples.

Baumgartner and Martin (1939) first described this technique. It was later refined by Dusi (1947).

A microhistological technique for determining dry weight composition of forage mixtures was reported by Sparks and Malechek (1968). Known amounts of grasses and forbs were artificially mixed, oven-dried and ground through a 1 mm screen to reduce all plant fragments to a uniform size. Five slide mounts of mixed samples were examined under a compound binocular microscope. A microscope field using 125X magnification was defined as a location. Epidermal characteristics were used to identify each species. A conversion of frequency percentages was used to determine the percent composition by weight (number of locations that the species occurred per 100 locations). Dry weight percentages were predicted directly from relative density. A 1: 1 regression ratio was observed. The authors stated the 1: 1 relationship between estimated dry weight percentages and actual dry weight percentages may not be consistent with species or at other maturity stages. If the species are similar, it was concluded that little accuracy could be gained by a prediction equation.

Correlations have been made between species fragments of known composition and composition determined by the microhistological technique. Denham (1965) obtained a highly significant value of r = .97 when the expected and observed values of six species were correlated. The correlation between expected and observed values was .99 when 15 mixtures of plants commonly found in herbivore diets were examined using microhistological techniques in a study conducted by Sparks and Malechek (1968). This correlation coefficient was highly significant.

One important assumption of the microhistological technique is that the percent identifiable material is constant for each species. Havstad and Donart (1978) found ratios of identifiable to nonidentifiable fragments were neither equal to one nor equal between grass and forb fragments. Their data indicate that individual values for percent composition for a species of a diet should be interpreted cautiously.

The microscopic point technique was first used for identifying species composition of pastures by Levy and Madden (1933). This technique was further developed by Heady and Torrell (1959) and illustrated by Harker, Torrell and Van Dyne (1964). This technique involves placing clipped forage of fistula samples on a tray. The tray is then passed under a binocular microscope (16X magnification) equipped with a cross hair and a stage with established stops. The plant which appears immediately under the cross hair is identified and recorded at each point location. Regression equations are used to estimate the percent species composition by weight from data points. Several investigators have used methods similar to those of Heady and Torrell (1959) to determine species composition of fistula samples collected from animals (Lusk et al., 1961; Chamrad and Box, 1964; Van Dyne and Heady, 1965; Galt et al., 1969; Bedell, 1968; Rice et al., 1971; Strasia et al., 1970; Galt, 1972).

Workers in Arizona have modified the point technique to estimate volume of species identified since the ratio of percent points to percent weight was not 1:1 for all species identified in fistula forage samples (Galt, 1972). This method was derived from the procedure of Chamrad and Box (1964). In this study a density constant (weight/volume) was applied to point estimates to determine the percent weight of species in masticated forage samples. Measurements of weight per volume were then determined for various masticated species of grasses and forbs which had been individually fed and recovered from rumen fistulated steers.

It has been found that slopes for regression of percent volume on percent microscope points were closer to unity for most species than the regression slopes of percent weight on percent points (Galt, 1972). In this study only two grass species did not approach a 1:1 ratio for the percent volume:percent point comparisons. Theurer et al. (1976) suggested that relating volume, rather than weight, to points may be better for quantifying diets. This was because the interaction between those species with weight point regression slopes that do not approach unity is reduced.

THE STUDY AREA

Location

The study area is located on the 11,735 hectare Starkey Experimental Range and Forest in the Blue Mountains of northeastern Oregon. The experimental area is in Union County, Oregon, with primary access from Oregon State Highway 244. The city of La Grande, Oregon is approximately 50 kilometers northeast of the experimental area. The exact location of the study area lies within Township 3 South, Range 31 East of the Willamette Meridian. Sections 19, 26-29 and 32-35 are occupied by the experimental area (Figure 1). Meadow Creek drains the area, and flows to the Grande Ronde River.

History of the Area

Livestock have used the Starkey area since the middle 1860's. Cattle and sheep use was quite heavy from 1885 to the early 1900's when it was designated as a sheep range. In 1935 use was converted from sheep to cattle. When the Starkey Experimental Range was established in 1940, range condition was poor to fair. A two-unit deferred rotation grazing system was applied in 1942 with a stocking rate of 3.2 hectares per animal unit month (Strickler, 1966). Range condition gradually improved under this management until it was fenced in the summer of 1975.

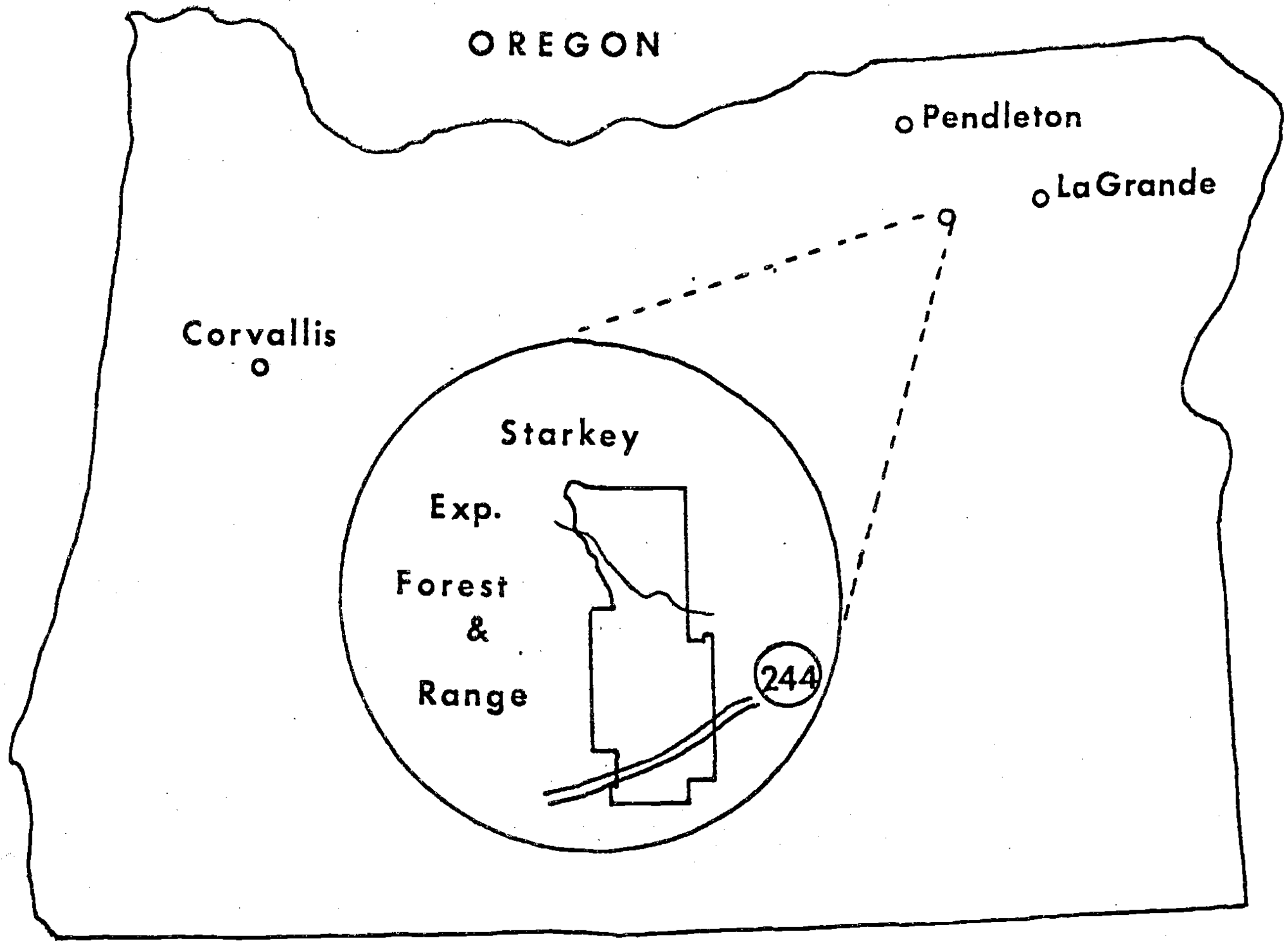


Figure 1. Location of the Starkey Experimental Forest and Range.

The Starkey area provides spring and fall range for Rocky Mountain elk (Cervus canadensis nelsoni) (Ganskopp, 1978). Mule deer (Odocoileus hemionus hemionus) are found on the area throughout the year. Skovlin et al. (1968) reported deer use on the area averages 6.92 days per hectare and elk use averages 3.7 days per hectare annually. Big game have steadily increased on the study area since about 1920. Presently about one-fourth of the local forage supply is utilized by big game animals.

Topography

Moderately deep canyon drainages separating broad rolling uplands characterize the topography of the Starkey range (Skovlin et al., 1976). Elevations range from 1,070 to 1,525 m (Skovlin et al., 1968).

The Starkey Experimental Range lies within the Blue Mountains of northeastern Oregon and southeastern Washington. The overall structure of the Blue Mountains is a large, asymmetric anticline with a steep north flank and a gentle south flank (McKee, 1972). Therefore, the Blue Mountains rise sharply from the Columbia Basin, but merge gradually into the high desert country of southeastern Oregon. The experimental area lies just south of the Blue Mountain Anticline (Walker, 1973).

Soils

A description of the soils of the study area is given by Strickler (1966). Five soil series are found on the study area (Burr, 1960). These include the Tolo, Klicker, Veazie, Rock Creek and Snipe series. The Tolo and Klicker series are found under the timbered areas. The Veazie, Rock Creek and Snipe series are common to the upland grasslands and meadows. Tolo soils are medium to fine textured, well drained, and developed from Volcanic ash. The Klicker series is a "Western" brown forest soil (spodosol in new classification system) developed in neoduum found on moderate slopes of south aspect. The Rock Creek soils are characterized by shallow depth and mixture stoniness. The Snipe series is closely associated with the Rock Creek and Klicker series. This series is found on moderate to very steep south facing slopes. The primary soil found along the level bottom-lands is the Veazie series. This is a moderately to well-drained, alluvial soil of medium texture.

Climate

The overall climate at the Starkey Experimental Range and Forest is continental with cold winters and warm summers. Annual precipitation averages 59 cm (Skovlin et al., 1976). Winter snowfall accounts for two-thirds of the total precipitation, with spring and fall rains contributing the remaining amount. The mean temperature for July is 18°C and for January is -4°C (Strickler, 1966). Precipitation data for 1976, 1977 and 1978 is given in Table 5. Total precipitation during the 1976 growing season was near normal. However, July and December were exceptionally dry while August was unusually wet. This resulted in a great deal of forage growth on grassland areas during September.

Precipitation during the winter and spring of 1977 was much below average. This resulted in a reduction in forage production during the growing season. However, late summer rainfall gave some fall regrowth on grassland areas.

The total precipitation in 1978 greatly exceeded the average. Much of the precipitation in 1978 accurred during the growing season. This resulted in above average forage production. The late summer and early fall of 1978 were very dry, and there was little forage regrowth available on grassland areas.

Vegetation

Vegetation on the Starkey Experimental Range and Forest is characterized by ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*) forest intermingled with bunchgrass openings (Driscoll, 1955; Franklin and Dyrness, 1973; Hall, 1973). A complete description of the vegetation on the experimental area is given

TABLE 5. Summary of Precipitation Data (cm) at the Starkey Experimental Forest and Range.

Month	25-year $\bar{X}$	1976	1977	1978
January	6.48	6.86	1.02	5.08
February	4.27	2.29	2.54	4.06
March	4.57	2.54	2.11	3.56
April	4.42	5.08	2.79	6.68
May	5.44	4.39	4.80	4.01
June	4.72	3.71	1.83	3.12
July	1.57	0.05	0.13	2.54
August	2.01	6.86	7.42	3.43
September	2.72	3.71	9.42	4.11
October	4.52	2.67	3.76	7.11
November	5.66	4.06	7.75	4.06
December	6.68	0.00	9.40	--
Total	53.06	42.22	53.00	--

by Ganskopp (1978).

Vegetation types included in the experimental area are grassland, forest and meadow. The grassland vegetation type is primarily a bluebunch wheatgrass and sandberg bluegrass (Agropyron spicatum-Poa sandbergii) habitat type. The forest vegetation type consists of ponderosa pine-Idaho fescue (Pinus ponderosa-Festuca idahoensis), Douglas fir-snowberry (Pseudotsuga menziesii-Symphoricarpos albus) and Douglas fir-ninebark (Pseudotsuga menziesii-Physocarpus malvaceus) habitat types as described by Daubenmire (1970) and Daubenmire and Daubenmire (1968). The meadow vegetation type consists primarily of a combination of introduced and native grasses. Sedges dominate the wetter portions of the meadow vegetation type. Important grass species in this community are timothy (Phleum pratense), orchard grass (Dactylus glomerata), smooth brome (Bromus inermis), meadow foxtail (Alopecurus pratense), Kentucky bluegrass (Poa pratense), and several species of bentgrass (Agrostis spp.).

The principal herbage species on the study site was Idaho fescue. Sandberg bluegrass, bluebunch wheatgrass and elk sedge are other common grasses found on the study area. Important forbs include western yarrow (Achillea millefolium lanulosa), heartleaf arnica (Arnica cordifolia) and several species of lupine (Lupinus spp.). Ninebark and snowberry were the most common shrubs found on the study pastures.

Ganskopp (1978) presented data showing the percent cover of the primary species found in the different plant communities on the study area in 1976. These data were combined with data giving the amount of area of each plant community on the different pastures. An estimate was obtained of the relative percent plant cover for the primary herbage species found on the different pastures. These data are presented in Tables 6 and 7.

TABLE 6. Percent Relative Canopy Cover of the Primary Species on the Forest and Grassland. Data were Collected in the Summer of 1976. (Ganskopp, 1978)

Species	Forest	Grassland
Bluebunch wheatgrass	1-5	20-30
Elk sedge	5-10	1
Pinegrass	0-5	1
One-spike danthonia	1-5	1-5
Idaho fescue	10-20	10-20
Western fescue	1-5	1
Prairie junegrass	1-5	1-5
Kentucky bluegrass	1-5	1
Sandberg bluegrass	5-10	20-30
Total Graminoids	44	70
Western yarrow	1-5	1-5
Heartleaf arnica	1-5	1
Balsamroot	1	1-5
Wyeth eriogonum	1-5	5-10
Lupine	1-5	1-5
Cluster tarweed	1-5	1
Total Forbs	31	20
Snowberry	5-10	1-5
Ninebark	5-10	1
Spiraea	5-10	1
Total Shrubs	25	6

TABLE 7. Percent Canopy Cover of the Primary Species on the Grazing System Pastures in 1976 (Ganskopp, 1978).

Species [a]	RR(1)	RR(2)	SL	DR
Bluebunch wheatgrass	10-20	5-10	5-10	10-20
Idaho fescue	5-10	10-20	10-20	5-10
Elk sedge	5-10	5-10	5-10	5-10
One-spike danthonia	1-5	1-5	1-5	1-5
Western fescue	1-5	1-5	1-5	1-5
Kentucky bluegrass	5-10	5-10	5-10	5-10
Sandberg bluegrass	5-10	10-20	10-20	10-20
Cheatgrass	5-10	1-5	1-5	1-5
Total Graminoids	50	50	50	50
Heartleaf arnica	1-5	1-5	1-5	1-5
Balsamroot	1	1	1	1
Lupine	1-5	1-5	1-5	1-5
Wyeth eriogonum	1-5	1-5	1-5	1-5
Cluster tarweed	1-5	1-5	1-5	1-5
Milkvetch	1-5	1-5	1-5	1-5
Total Forbs	30	30	30	30
Western yarrow	1-5	1-5	1-5	1-5
Snowberry	5-10	5-10	5-10	5-10
Ninebark	5-10	5-10	5-10	5-10
Spiraea	1-5	1-5	1-5	1-5
Twinflower	1-5	1-5	1-5	1-5
Total Shrubs	20	20	20	20

[a] Only species found on the upland areas are given.
RR = Rest Rotation; SL = Season Long; DR = Deferred Rotation.

METHODS

This study involved two separate experiments which included the complementary grazing experiment and the grazing system experiment. Since the procedures for the two experiments are somewhat different, they will be discussed separately.

The Complementary Grazing Experiment

Grazing and Livestock Management

Cattle from the Eastern Oregon Agricultural Research Center were used on the forest and grassland pastures. Cooperator cattle were used on the meadow pastures. Total livestock numbers on the forest and grassland pastures were the same for all three years of study. Because of improper fence placement and variation in the forage commodity, livestock numbers on the meadow were adjusted from year to year. The forest and grassland pastures were both grazed by 18 head of yearling heifers. In addition, eight head of experimental animals were grazed on each vegetation type. Table 8 gives the grazing treatments for the grassland, forest, and meadow pastures during the three years of study.

The grazing season lasted 120 days during each of the three years of study. Cattle were placed on the pastures on June 20 and removed on October 10. The forest and grassland pastures were

TABLE 8. Pasture Stocking Rates for the Three Vegetation Types. (Yearling = .6 AU).

Pasture 1/	1976 AUMs	1977 AUMs	1978 AUMs	Total AUMs
F - RR - 1	62.4	31.2	0	73.6
		*		
F - RR - 2	0	31.2	62.4	73.6
G - RR - 3	62.4	31.2	0	73.6
		*		
G - RR - 4	0	31.2	62.4	73.6
M - 1	8	8	8	24
M - 2	8	8	8	24

1/ F = Forest
G = Grassland
M = Meadow
RR = Rest Rotation

* Refers to one group of cattle. Twenty-six head in pastures i until August 15 then moved to pasture j.

delineated so that the same amount of forage was available on each vegetation type.

A portable scale and corral system was used to handle and weigh livestock. The performance of all animals used in both the complementary grazing and grazing system experiments was evaluated at four periods during each year of study. The time intervals for periods 1, 2, 3, and 4 were June 20 to July 18, July 19 to August 15, August 16 to September 12, and September 13 to October 10, respectively. These time periods will be referred to as late spring, early summer, late summer and fall, in future discussion and apply to all data. These periods correspond to plant phenological development rather than to calendar dates.

Fistula and Fecal Collections

Yearling heifers equipped with esophageal fistulas were used to collect diet samples during the 1976 grazing season. The techniques of Van Dyne and Torrell (1964) were used for fistulation. The esophageal opening was closed with a removable plate and plug similar to the one described by these investigators. During the 1977 and 1978 grazing seasons, fistulated cows were used for diet sample collection.

A total of 11 fistulated heifers were used on the complementary grazing study during each year of study. Four heifers were used on both the forest and grassland pastures. An additional three head were placed on the meadow pastures.

Each pasture was sampled twice every other week. Collections were initiated in the second week of the grazing season to allow animals time to adjust to their surroundings. The same pattern of sample collection was used during all three years of study.

Fistula collections on the pastures were rotated between morning and evening. This was done because Van Dyne and Heady (1965) found a difference in chemical composition of samples collected at different times of the day. An attempt was made to drift the cows through several plant communities during collections. When possible, animals were grazed with the rest of the herd. Fistulated cows were usually allowed to graze a half hour or more so a large volume of forage could be collected. An attempt was made to graze fistulated animals in parts of a pasture that the rest of the herd appeared to be using during a given week. After gathering, the fistulated cows were held two to three hours before sampling was initiated.

Immediately after collection, diet samples were placed in plastic bags and frozen. As time permitted, they were thawed, placed in paper bags and oven dried at 40°C for seven days. Upon drying, the samples were ground separately in a Wiley laboratory mill with a 40 mesh (1 mm openings) screen to reduce fragments to a uniform size (Sparks and Malechek, 1968). These samples were stored in plastic bags until preparation for chemical and botanical analysis.

A total of eight steers (four steers per vegetation type) were allotted to the forest and grassland vegetation types for fecal collection. The apparatus described by Lesperance and Bohman (1961) was used for total fecal collection. Collections were made on each of the two vegetation types bi-weekly. A 24-hour period of total collection was used. Individual fecal collections were weighed, and a sample was retained for analysis.

Laboratory Analysis

Chemical analysis of esophageal samples included the determination of crude protein, acid detergent fiber, lignin, and dry matter digestibility. Crude protein was determined by the methods set forth by the A.O.A.C. (1960). Acid detergent fiber and lignin were determined by the permangamate technique of Van Soest and Wine (1968). A modification of the *in vitro* digestion technique of Tilley and Terry (1963) was used to determine dry matter digestibility. The original technique calls for the centrifuging of the samples at the termination of pepsin digestion. This was modified by filtering samples through scintered glass crucibles and determining the final weight. Digestible energy was predicted using an equation developed by Rittenhouse et al. (1971). This equation is as follows:

$$\text{DE, Mcal / kg DM} = .038\ (\%\ \text{DM digestibility}) + 0.18$$

Although this equation was developed with forages from the Great Plains, it is thought to have application on other range types (Rittenhouse et al., 1971).

In vitro digestion values and total fecal weights were used to estimate forage intake. Intake was calculated by using the equation of Van Dyne (1968):

$$\text{Intake} = \frac{(100)\ \text{Total fecal excretion}}{100 - \%\ \text{digestibility}}$$

The procedure of Sparks and Malechek (1968) was used to prepare fistula samples for botanical analysis. Fistula samples were mascerated with an osterizer, washed on a 200 mesh sieve and a small portion of the mascerated material was spread over microscope slides. Hertwig's cleaning solution was used on each slide to aid in identification of fragments. Hoyer's mounting medium was used to seal the cover slip on slides. The formulae for these two solutions is given in Appendix A.

Plant fragments were identified using the technique of Sparks and Malechek (1968). The frequency of occurrence of individual species of plants in 60 microscope fields was recorded. Samples collected from each animal were pooled by collection period. This resulted in reducing the number of samples examined by one half. The relative density of each species was determined on a percentage basis using the following formula (Sparks and Malechek, 1968):

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

Percent dry weight composition of each species was assumed to be the same as its calculated relative density (Sparks and Malechek, 1968).

During sample preparation some species undergo greater destruction than others (Dearden et al., 1975; Vavra and Holechek, 1979). Vavra and Holechek (1979) developed an equation to correct common snowberry for destruction during sample preparation, which is as follows:

$$Y = 4.86 + 1.29\,X$$

Y = % common snowberry by weight in diet corrected for sample preparation

X = % common snowberry in diet by weight determined by the Sparks and Malechek (1968) method

This equation was used to correct estimated percent by weight of common snowberry in the diet.

Statistical Analysis

All data were analyzed according to the methods set forth by Steel and Torrie (1960). The meadow vegetation type was not compared to the forest and grassland vegetation types because it was grazed during only the latter half of the grazing season of each year and management was different.

A modified split plot design was used to analyze diet quality, forage intake and livestock performance data on the forest and grassland vegetation types. Analysis of covariance was used to determine if a relationship existed between initial weights at the beginning of each period and average daily gain during the period. The procedures of Neter and Wasserman (1974) were used in covariance analysis.

Cattle diets were analyzed using multivariate techniques described by Cooley and Lohnes (1971). Multivariate analysis of variance was used to compare cattle diets between vegetation types, years and periods. Redundancy was calculated using the procedures of Cooley and Lohnes (1971). Individual species and forage classes were analyzed using a randomized factorial design (Steel and Torrie, 1960).

Multiple regression and correlation procedures were used to determine if a relationship existed between diet quality, forage intake and livestock performance. The procedures set forth by Neter and Wasserman (1974) were used.

Levels of significance used for the botanical data were .10, .05, and .01. Chemical, digestibility, intake and livestock performance data were tested at the .05 and .01 levels. Where applicable and where significant differences were observed, Duncan's New Multiple Range Test was applied to rank treatment means.

The Grazing System Experiment

Grazing and Livestock Management

Yearling heifers belonging to a private cooperator, Lewis Umbarger, were used to evaluate livestock performance in this experiment. Total livestock numbers used each year on the rest rotation, deferred rotation and season long grazing systems were 20, 20, and 10 animals, respectively. Three animals on each pasture belonged to the Eastern Oregon Agriculture Research Center. These animals were cows equipped with esophageal fistulas. Table 9 gives the grazing treatments for the three grazing systems during the three years of study.

The grazing season lasted 120 days as with the plant community study. Cattle were placed on the pastures on June 20 and removed on October 10. The pastures were delineated so that the stocking rate was the same for each grazing system. Esophageal fistulated animals were included as part of the stocking rate on each pasture.

Fistula and Fecal Collections

Procedures used in collecting fistula samples were the same as used in the complementary grazing study. However, fecal collection procedures differed because fistulated cows were used instead of yearling steers. Fecal collections were not made on the grazing

TABLE 9. Grazing System Pasture Stocking Rates.
6 AU/pasture/season. Yearling = .6 AU

Pasture 1/	1976 AUMs	1977 AUMs	1978 AUMs	Total AUMs
RR	0	24.0	48	72.0
RR	48	24.0 *	0	72.0
SL	24	24	24	72
DR	24	24	24	72

1/ RR = Rest Rotation; SL = Season Long; DR = Deferred Rotation

* Refers to one group of cattle. Twenty head in pasture i until August 15 and then moved to pasture j.

system pastures in 1976.

The device described by Kartchner (1975) was used to prevent urine contamination of feces when fecal collections were made. Fecal collections were initiated during the early part of the grazing season in 1977. One collection was made per sampling period.

In 1978, fecal collections were made bi-weekly on each pasture throughout the grazing season. Methods of quantification and sample care were the same as described for the complementary grazing experiment.

Laboratory Analysis

Laboratory analysis procedures are the same as described for the complementary grazing experiment.

Statistical Analysis

Statistical procedures were similar to those used for the plant community experiment. The deferred rotation grazing system was not included in the analysis of variance because grazing was conducted for only half the grazing season of each year.

A modified split plot design was used to compare diet quality data. Forage intake and livestock performance data were analyzed using a completely randomized design. The least squares analysis of variance was used because subclass numbers were unequal (Steel and Torrie, 1960; Neter and Wasserman, 1974). Covariance analysis was used to determine if initial weights at the beginning of each period were affecting average daily gains during the period. Diet botanical composition data were analyzed using the same procedures as in the complementary grazing study.

RESULTS AND DISCUSSION: COMPLEMENTARY GRAZING STUDY

Botanical Analysis

Cattle Diets on the Forest and Grassland

During the three years of study, 25 grasses, 27 forbs, and 10 shrubs were consumed by cattle on the forest and grassland. However, of the grasses and grass-like species consumed, only Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass, elk sedge (*Carex geyeri*), and Sandberg bluegrass were of importance (important species are those that comprise 5% or more of the diet by weight). The primary forbs consumed included western yarrow, heartleaf arnica and Wyeth eriogonum (*Eriogonum heracleoides*). Other forbs were taken in small amounts or only for a short time. Snowberry, spiraea (*Spiraea betulifolia lucida*) and Pacific ninebark were the principal shrub species consumed. The mean percent weights of all species comprising one percent or more of diet samples during the three year period are listed in Appendix B-C.

Considerable variability was encountered between animals within sampling periods. Large standard errors were recorded and are listed in Appendix B-C. Due to the large standard errors encountered, when statistical analyses were applied, the 10%, 5%, and 1% levels were accepted as significant.

TABLE 10. The Mean Percent Weight of Grasses, Forbs and Shrubs in the Diet of Cattle on the Forest and Grassland Pooled by Year.

Period[1]	Forest[2]			Grassland[3]		
	Grasses	Forbs	Shrubs	Grasses	Forbs	Shrubs
Late spring	46[b]	29[a]	25	66[a]	17[a]	7
Early summer	66[a]	13[b]	21	79[b]	15[b]	6
Late summer	65[a]	11[b]	23	90[b]	5[c]	5
Fall	69[a]	9[b]	21	89[b]	5[c]	6
Average	61	16	23	80	14	6

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only within columns.

The difference between cattle diets on the forest and grassland was significant ($P < .01$). The degree of redundancy between the primary species on the two vegetation types was 27%.

Grass consumption was significantly higher ($P < .01$) on the grassland than on the forest during all three years of study (Tables 10 and 11). Shrubs, on the other hand, were significantly ($P < .01$) more important in cattle diets on the forest. Forb consumption did not vary significantly ($P > .10$) between vegetation types or years.

Grasses were the most important forage component by percent

TABLE 11. The Mean Percent Weight of Grasses, Forbs and Shrubs in the Diet of Cattle on the Forest and Grassland Pooled by Period.

Year[1]	Forest[2]			Grassland[2]		
	Grasses	Forbs	Shrubs	Grasses	Forbs	Shrubs
1976	64	18	18	82	12[b]	6
1977	63	13	24	82	12[b]	6
1978	57	16	27	77	17[a]	6
Average	61	16	23	80	14	6

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only within columns.

weight in cattle diets on the forest and grassland in all three years of study. Several other investigators have reported preferences for grass by cattle (Cook et al., 1963; Ridley et al., 1963; Van Dyne and Heady, 1965; Galt et al., 1969; Smith et al., 1968; Free et al., 1970; Thetford et al., 1971; Ansotegui et al., 1972; Vavra, 1972). In Nevada, grass comprised 60% to 80% of the diet in the spring even though shrubs were much more available (Lesperance et al., 1970).

Grassland and forest diet samples differed significantly ($P < .01$) in mean percent weights of the important forage species with the exception of Idaho fescue. This species made up 23% of forest diet samples and 29% of samples collected from the grassland. Other important species and their respective contribution to cattle diets on the grassland and forest were bluebunch wheatgrass (28%, 5%), elk sedge (1%, 12%), Sandberg bluegrass (8%, 1%), junegrass (Koeleria cristata) (6%, 1%), western yarrow (5%, 2%), snowberry (4%, 11%), spiraea (0, 5%), and ninebark (0, 5%).

Cattle Diets on the Grassland

Cattle diets on the grassland did not vary significantly ($P > .05$) between years but they did differ significantly between periods ($P < .05$). The redundancy values for years and periods were 74% and 66%, respectively.

Although diet samples pooled by year revealed a shift towards more grass and fewer forbs with seasonal advance, there were no trends in shrub consumption (Table 12). The reduction in the forb content of the diet as the grazing season advanced is probably a reflection of reduced forb availability and palatability. However, standing crop data were not available for the different grazing periods.

Several other studies are available showing a decrease in forb consumption with advance of plant phenology when cattle were used as the grazing animal (Jefferies, 1969; Pickford and Reid, 1948; Scales et al., 1971; Thetford et al., 1971; Van Dyne and Heady, 1965;

TABLE 12. The Percent by Weight of Important Species Found in Cattle Diets on the Grassland Pooled by Year.

Species 1/	Period 2/			
	late spring	early summer	late summer	fall
Idaho fescue	23^{b}	32^{a}	33^{a}	28^{a}
Bluebunch wheatgrass	21^{b}	26^{b}	31^{ab}	34^{a}
Sandberg bluegrass	8	7	8	9
Prairie junegrass	2	2	2	5
Total grasses	66^{a}	79^{b}	90^{b}	88^{b}
Western yarrow	6^{a}	3^{b}	3^{b}	3^{b}
Wyeth eriogonum	2	5	1	T
Arrowleaf balsamroot	5^{a}	1^{b}	T	T
Total forbs	27^{a}	15^{b}	5^{c}	6^{c}
Snowberry	5	4	3	5
Total shrubs	7	6	5	6

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

T = Trace

Vavra, 1972). Both reduced palatability and availability were mentioned as reasons for this trend in forb and grass consumption.

Cattle diets were significantly ($P < .05$) higher in forbs on the grassland in 1978 than during the other two years of study (Table 13). However, fewer forb species were found in the diet in 1978. This was probably because the preferred species were more available. Vavra (1972) reported fewer forb species occurred in cattle diets in a wet year. He attributed this to higher availability of preferred species.

Sandberg bluegrass was the most common plant species on the grassland (Table 6). However, this species comprised only 8% of cattle diets. Bluebunch wheatgrass and Idaho fescue made up 28 and 29 percent of cattle diets, respectively. These species were much more highly preferred than Sandberg bluegrass. Idaho fescue was less common on the grassland pastures than bluebunch wheatgrass (Table 6). It appears that cattle preferred this species more than bluebunch wheatgrass during all three years of study.

Cattle diets were significantly higher ($P < .05$) in Sandberg bluegrass in 1978 than during other years. This species matured much earlier than bluebunch wheatgrass and Idaho fescue in 1976 and 1977. However, it remained green during much of the grazing season in 1978. In addition, production of this species was much higher in

TABLE 13. The Percent by Weight of Important Species Found in Cattle Diets on the Grassland Pooled by Period.

Species 1/	Year 2/ 1976	1977	1978
Idaho fescue	31[a]	33[a]	25[b]
Bluebunch wheatgrass	29[a]	35[a]	21[b]
Sandberg bluegrass	3[b]	5[b]	16[a]
Prairie junegrass	3	2	3
Total grasses	82	82	77
Western yarrow	3	2	4
Wyeth eriogonum	T	3	3
Arrowleaf balsamroot	1	1	3
Total forbs	12[b]	12[b]	17[a]
Snowberry	3	4	4
Total shrubs	6	6	6

1/ Means followed by the same letter are not significantly different (P > .05) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

T = Trace

1978 than in the other two years (Strickler, personal communication, 1978). Increased palatability and availability probably explain why more of this species was consumed in 1978. Pickford and Reid (1948) reported Sandberg bluegrass was highly unpalatable after it reached maturity.

Many forage species matured much earlier in 1977 than in the other two years. This was particularly true of the forbs. Cattle may have increased consumption of Idaho fescue and bluebunch wheatgrass during the early part of the grazing season to compensate for the lack of palatable forbs. The latter half of the grazing season in 1977 was much wetter than during the other two years. Sandberg bluegrass showed considerable regrowth after the rainfall which could explain why consumption of this species was significantly ($P < .10$) higher during the fall of 1977 than in other periods. Pickford and Reid (1948) reported increased utilization of Sandberg bluegrass after late summer rainfall.

During the first half of 1978, three forbs were important in cattle diets that were minor species in 1976 and 1977 (Tables 14 - 16). These species included Wyeth eriogonum, lupine (Lupinus spp.) and arrowleaf balsamroot (Balsamorhiza sagittata). Western yarrow was was the most important forb found in cattle diets on the grassland during all three years of study.

In 1977, cattle were moved from one grassland pasture to the other at mid-season. This resulted in no significant ($P < .01$) change in cattle diets although cattle had the opportunity to be more selective after movement.

Cattle were grazed on different grassland pastures in 1976 and 1978. This had little effect on cattle diets.

Although livestock use of different plant communities on the grassland could not be quantified, it does merit a qualitative discussion. An attempt was made to expose fistulated cattle to several plant communities during sample collection. However, cattle would usually graze only in a few communities. The ponderosa pine/Idaho fescue plant commonly appeared to be highly preferred. This community received repeated use throughout the grazing season in all three years of study. The bluebunch wheatgrass/Sandberg bluegrass plant community, however, was the most available and heavily used community. Other plant communities were used very lightly or avoided. No trend in plant community use was observed within grazing seasons during the three years of study.

Differential use of plant communities within the grassland pastures probably explains why the occurrence of minor species in cattle diets was so variable. Heady (1964) reported that species associated with a particular plant may greatly influence its

TABLE 14. The Percent by Weight of Important Species Found in Cattle Diets on the Grassland in 1976.

Species 1/	Period 2/ late spring	early summer	late summer	fall
Idaho fescue	18[b]	36[a]	35[a]	34[a]
Bluebunch wheatgrass	16[b]	28[a]	34[a]	36[a]
Prairie junegrass	3	4	3	4
Subalpine needlegrass	5	2	4	3
Sandberg bluegrass	2	5	3	1
Total grasses	64[b]	86[a]	90[a]	85[a]
Western yarrow	5	1	4	3
Wyeth eriogonum	T	T	T	T
Lupinus species	4	T	T	--
Arrowleaf balsamroot	3	T	T	--
Total forbs	28[a]	8[b]	7[b]	7[b]
Snowberry	7[a]	4[a]	4[b]	7[a]
Total shrubs	8	6	3	8

1/ Means followed by the same letter are not significantly different (P >.05) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

T = Trace

TABLE 15. The Percent by Weight of Important Species Found in Cattle Diets on the Grassland in 1977.

Species [1/]	Period [2/] late spring	early summer	late summer	fall
Idaho fescue	41^{a}	34^{b}	32^{b}	23^{c}
Bluebunch wheatgrass	28^{b}	33^{ab}	38^{a}	39^{a}
Sandberg bluegrass	2^{b}	2^{b}	5^{b}	12^{a}
Prairie junegrass	2	1	2	4
One-spike danthonia	1	1	4	1
Total grasses	78^{b}	79^{b}	90^{a}	91^{a}
Western yarrow	3	3	1	1
Wyeth eriogonum	3	4	1	T
Arrowleaf balsamroot	2	2	--	T
Total forbs	16^{a}	14^{a}	5^{b}	4^{b}
Snowberry	5	4	4	4
Total shrubs	6	7	5	5

[1/] Means followed by the same letter are not significantly different (P > .05) using Duncan's Multiple Range Test.

[2/] Statistical tests apply only across column.

T = Trace

TABLE 16. The Percent by Weight of Important Species Found in Cattle Diets on the Grassland in 1978.

Species [1/]	Period [2/] late spring	early summer	late summer	fall
Idaho fescue	11[b]	26[a]	33[a]	28[a]
Bluebunch wheatgrass	15[b]	18[b]	22[ab]	28[a]
Sandberg bluegrass	18	16	15	14
Prairie junegrass	2[b]	1[b]	1[b]	7[a]
Cheatgrass	1	2	3	5
Total grasses	54[c]	70[b]	90[a]	89[a]
Western yarrow	10[a]	4[b]	2[b]	1[b]
Wyeth eriogonum	3[b]	10[a]	T	T
Arrowleaf balsamroot	10	T	--	T
Lupinus species	4	5	--	T
Mules ear	3	2	T	T
Total forbs	41[a]	25[b]	4[c]	5[c]
Snowberry	3	4	5	5
Total shrubs	5	5	6	6

1/ Means followed by the same letter are not significantly different (P > .05) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

T = Trace

attractiveness to a grazing animal. Also, availability and growth stage were mentioned as playing important roles in diet selection.

It does appear that animals select plant communities as well as species for grazing. This selection may be governed more by factors such as animal comfort or access to an area than by the availability of palatable plants. A very palatable plant found in a plant community little used by grazing animals may receive very heavy use when animals are on the plant community (Pickford and Reid, 1948). This could explain why a particular species will often make up a large part of an animal's diet during a given collection but may be present in other samples collected during the same period in trace amounts.

Cattle Diets on the Forest

Cattle diets on the forest showed much more variation between years and periods than diets on the grassland. This is attributed to more diversity in vegetation and terrain. Differences in cattle diets on the forest between years and periods were significant ($P < .01$). The redundancy in cattle diets between years was 62% compared to 54% between periods.

Most of the variation in cattle diets during different years occurred between 1978 and the other two years. Cattle were grazed on different pastures in 1976 than in 1978. In 1977, cattle were grazed on each rest-rotation pasture for one-half the grazing season. Although the vegetation was very similar in structure and composition on the two pastures, there were some differences in topography which may have affected animal behavior. Also, the heavy rainfall during the grazing season in 1978 probably had considerable effect on species availability, palatability and cattle behavior. Climatic conditions in 1976 and 1977 were much different (Table 5). In 1977, cattle were moved at mid-season which gave the cattle the opportunity to be more selective in the late summer and fall than in 1976 and 1978. However, cattle diets in 1976 and 1977 did not differ significantly ($P > .05$). The percent by weight of important species found in cattle diets on the grassland pooled across periods is given in Table 17.

Other studies have been reported in which the botanical composition of the diet of animals grazing the same range varied considerably from year to year (Bohman and Lesperance, 1967; Buchanan et al., 1972; Streeter et al., 1968; Vavra, 1972). Bohman and Lesperance (1967) reported the average botanical composition of rumen fistula forage samples collected on a Nevada range varied from 68-93% grass, 4-17% forbs and 0-24% browse during a five-year period. Precipitation largely influenced diets in their study because it determined grass availability.

Trends in cattle diets on the forest were similar to those on

TABLE 17. Mean Percent Weights of Important Species Found in Cattle Diets on the Forest Pooled Across Periods.

Species 1/	Year 2/ 1976	1977	1978
Idaho fescue	22	26	21
Elk sedge	10	14	11
Bluebunch wheatgrass	9[a]	3[b]	2[b]
Pinegrass	4	4	4
Western fescue	4[ab]	2[b]	7[a]
Kentucky bluegrass	4	4	4
Total grasses	64	63	57
Western yarrow	2	1	2
Heartleaf arnica	6[a]	2[b]	6[a]
Total forbs	18	13	16
Snowberry	12	13	8
Spiraea	5[b]	3[b]	7[a]
Ninebark	T	6	7
Total shrubs	18	24	27

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

T = Trace

the grassland as the grazing season advanced. When diet samples were pooled by year, forb consumption dropped significantly ($P < .05$) during the early summer and then stabilized (Table 18). Grass consumption varied inversely with forb consumption but there was little change in shrub consumption.

The interaction between year and period was significant ($P < .05$) for the three forage classes and several individual species. Therefore, a discussion will be given of cattle diets within individual years.

Cattle Diets on the Forest in 1976

In 1976, fistulated heifers showed no preference for any particular plant community during collections in the late spring (Table 19). In the early summer, animals displayed a definite preference for the more open areas associated with the ponderosa pine/Idaho fescue plant community. Although fistulated animals were given the opportunity to graze other plant communities on the pasture, they would drift, grazing somewhat randomly, until they reached open areas associated with the ponderosa pine/Idaho fescue plant community. Then serious grazing would begin. This community showed much heavier use at the end of the grazing season than other plant communities.

TABLE 18. Mean Percent Weights of Important Species Found in Cattle Diets on the Forest Pooled Across Years.

Species[1]	Period[2]: late spring	early summer	late summer	fall
Idaho fescue	19[b]	26[a]	25[a]	20[b]
Elk sedge	5[c]	8[bc]	12[b]	21[a]
Bluebunch wheatgrass	2[b]	7[a]	6[a]	3[b]
Pinegrass	2	4	1	3
Western fescue	3[b]	8[a]	3[b]	2[b]
Kentucky bluegrass	4	3	4	4
Total grasses	46[b]	66[a]	65[a]	69[a]
Western yarrow	2	2	2	2
Heartleaf arnica	8[a]	3[b]	2[b]	2[b]
Total forbs	29[a]	13[b]	11[b]	9[b]
Snowberry	14	10	9	12
Spiraea	5	4	7	4
Ninebark	3	6	4	5
Total Shrubs	25	21	23	23

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

Idaho fescue and elk sedge were the most important forage species in the diet in 1976. These species made up 22% and 10% of the diet, respectively. Consumption of Idaho fescue was significantly ($P < .05$) lower during the late spring than in the other periods. Cattle exhibited considerable preference for forbs in the late spring which probably explains why Idaho fescue consumption was reduced. Consumption of elk sedge was erratic although significantly more ($P < .10$) elk sedge was consumed during the fall than in other periods. Pickford and Reid (1948) reported elk sedge was a preferred species by cattle during the latter part of the grazing season at the Starkey Range because it remained green after other graminoids had matured.

Two forbs appearing consistently in cattle diets in 1976 included heartleaf arnica and western yarrow. Western yarrow is fairly common in several forest plant communities although heartleaf arnica is found only in the heavily forested areas. Individual cows consumed large amounts of heartleaf arnica while other cows totally rejected it. Vavra (1972) reported that there was considerable difference between cattle in the selection of certain forb species on shortgrass range. Pickford and Reid (1948) reported that heartleaf arnica was a preferred forb species on the Starkey Experimental Range.

A large number of unknown forbs were present in diet samples during the early spring in 1976. Because more than 200 forbs are found on the Starkey area, cellular identification of all forb species

TABLE 19. Mean Percent Weight of Important Species Found in Cattle Diets on the Forest in 1976.

Species 1/ 2/	Period 2/			
	late spring	early summer	late summer	fall
Idaho fescue	9 c	28 a	29 a	20 b
Elk sedge	9 b	10 b	4 c	17 a
Bluebunch wheatgrass	3 b	14 a	13 a	6 a
Pinegrass	2	1	2	1
Western fescue	4	4	4	3
Kentucky bluegrass	4 a	6 a	4 a	1 b
Total grasses	49 b	73 a	76 a	58 b
Western yarrow	3	1	3	1
Heartleaf arnica	14 a	6 b	3 b	1
Lupinus species	3	1	--	--
Total forbs	36 a	14 b	11 b	12 b
Snowberry	9 b	8	9	20 a
Spiraea	5	3	1	5
Ninebark	--	--	--	3
Total shrubs	15 b	12 b	13 b	30 a

1/ Means followed by the same letter are not significantly different (P> .05) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

in the diet would be very difficult if not impossible. Another problem encountered was that certain forbs were very similar in appearance of epidermal fragments. An attempt was made to identify those species making up more than 2% of the diet during a given period.

The most important shrub found in the diet was snowberry. Consumption of this species was highest in the fall when the consumption of elk sedge was highest. In the fall, fistulated animals showed a definite preference for ponderosa pine/snowberry/elk sedge and Douglas fir/snowberry/elk sedge plant communities. Elk sedge and snowberry were still green after most other forage species on the forest had matured, which probably explains why these two communities were preferred.

Cattle Diets on the Forest in 1977

Livestock use of forest plant communities was somewhat different in 1977 than in 1976. Cattle showed a definite preference for the ponderosa pine/Idaho fescue areas during the first two grazing periods. At mid-season, cattle were moved to the other forest pasture. During the latter half of the grazing season, cattle did much of their grazing in the ponderosa pine/snowberry/elk sedge and ponderosa pine/Idaho fescue plant communities. Mean percent weights of important dietary components on the forest in 1977 are given in Table 20.

As in 1976, Idaho fescue and elk sedge were the most important species found in diet samples. These two species made up 26% and 14%, respectively, of the diet when samples were pooled by period. During the first half of the grazing season much more Idaho fescue occurred in diet samples than elk sedge. However, during the latter part of the grazing season, there was no difference in consumption of the two species.

Forb consumption during the late spring in 1977 was significantly ($P < .10$) less than in 1976. The precipitation during the winter and spring in 1977 was much below that in 1976. Many species of forbs appeared to be less available and maturity was reached earlier, which may explain why forb consumption was reduced. Heartleaf arnica was the most important forb occurring in cattle diets. This species made up 5% of the diet in the late spring although little of this species was consumed during the rest of the grazing season.

Shrub consumption during the first half of the grazing season in 1977 was significantly ($P < .05$) higher than in 1976. Shrubs may have been substituted for forbs in the late spring. Snowberry was the most important species in diet samples in the late spring. Other important shrubs consumed by cattle included ninebark and spiraea.

Grasses comprised 79% of cattle diets during the latter half of the grazing season. Cattle were on a different pasture than during

TABLE 20. Mean Percent Weights of Important Species Found in Cattle Diets on the Forest in 1977.

Species [1]	Period [2]: late spring	early summer	late summer	fall
Idaho fescue	18^{b}	28^{a}	29^{a}	27^{a}
Elk sedge	2^{b}	7^{b}	23^{a}	24^{a}
Bluebunch wheatgrass	2	2	5	2
Pinegrass	2^{b}	6^{a}	2^{b}	3^{b}
Western fescue	2	3	1	1
Kentucky bluegrass	3	3	5	4
Total grasses	36^{c}	57^{b}	83^{a}	76^{a}
Western yarrow	1	2	2	2
Heartleaf arnica	5^{a}	1^{b}	1	1
Lupinus species	4	1	--	1
Total forbs	26^{a}	13^{b}	7^{c}	6^{c}
Snowberry	24^{a}	13^{b}	9^{bc}	7^{c}
Spiraea	8^{a}	4^{b}	1	1^{b}
Ninebark	5^{b}	12^{a}	1	8^{b}
Total shrubs	38^{a}	30^{b}	10^{d}	18^{c}

[1] Means followed by the same letter are not significantly different (P > .05) using Duncan's Multiple Range Test.

[2] Statistical tests apply only across columns.

the first half of the grazing season and the weather was much different. Heavy rainfall occurred in the latter part of August and September which resulted in limited green-up of grasses in the more open plant communities. The palatability of grasses on these communities may have been increased by the softening effect of the rains.

Cattle Diets on the Forest in 1978

As in 1977, fistulated cows showed a preference for the ponderosa pine/Idaho fescue plant community when diet samples were collected during the late spring. Other plant communities were used moderately. During the early summer, cattle displayed little preference for any plant community. In the latter half of the grazing season, the more heavily forested areas received considerable use. This may have been because these communities provided more shade, and forage species were less advanced in maturity. This part of the grazing season was quite warm and dry. The important species found in cattle diets and their contribution to the diet by weight are given in Table 21.

As in 1976 and 1977, Idaho fescue and elk sedge were the primary forage species in cattle diets. More Idaho fescue was consumed during the late spring in 1978 than in other years. This species was less advanced in maturity during the late spring in 1978 than in the other two years which may explain why it recieved

TABLE 21. Mean Percent Weights of Important Species Found in Cattle Diets on the Forest in 1978.

Species 1/ 2/	Period: late spring	early summer	late summer	fall
Idaho fescue	31^{a}	22^{b}	17^{bc}	13^{c}
Elk sedge	5^{b}	8^{b}	8^{b}	22^{a}
Bluebunch wheatgrass	1	5	2	1
Pinegrass	2	2	1	5
Western fescue	3^{b}	3^{b}	3^{a}	3^{a}
Kentucky bluegrass	4^{b}	1	2^{b}	8^{a}
Total grasses	52^{b}	67^{a}	37^{c}	74^{a}
Western yarrow	1	1	2	2
Heartleaf arnica	4	2	2	2
Lupinus species	3	1	1	--
Total forbs	25^{a}	12^{b}	16^{b}	10^{b}
Snowberry	8	8	9	6
Spiraea	3^{b}	5^{b}	18^{a}	3^{b}
Ninebark	7^{b}	6^{b}	12^{a}	3^{b}
Wax currant	2	1	6	3
Total shrubs	23^{b}	21^{b}	47^{a}	16^{b}

1/ Means followed by the same letter are significantly different (P < .05) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

heavier use.

Diet samples in the early part of 1978 were significantly ($P < .10$) lower in forbs than in 1976. Although more forb species occurred in cattle diets in 1978 than in the other two years, no single forb made up an important part of the diet. Heartleaf arnica was the most common forb in cattle diets during the 1978 grazing season.

Shrub consumption during the late summer in 1978 was higher than in any other period during the three years of study. Cattle diets were comprised of 47% browse. Shrubs were highly available in the heavily forested areas that fistulated cattle seemed to prefer during sample collection. It is probable that animals used these areas because both shade and green forage were available. Snowberry, spiraea, and ninebark were important shrub species found in cattle diets.

It appears that on some vegetation types cattle will switch from grass to browse when little green grass is available. Studies are available showing heavy browse consumption after grasses reached maturity (Connor et al., 1963; Cook and Harris, 1968; Lesperance, 1970). In contrast, Galt et al. (1969), Galt (1972), and Ansotegui et al. (1972) reported cattle did not switch to browse even though it was available. The species of shrubs available probably influence how heavily they will be utilized by cattle.

Cattle Diets on the Meadow

Cattle diets on the meadow did not differ significantly between years or periods at the 1% level. Grasses, forbs, and shrubs comprised 80%, 12%, and 8% of the diet, respectively, when samples were pooled across years and periods. Kentucky bluegrass (*Poa pratensis*) was the most important species found in cattle diets during all three years of study. The average percent by weight of important species found in diet samples collected on the meadow during the three years of study is presented in Table 22.

Significantly ($P < .10$) more grasses were consumed during the fall than in the late summer. However, significantly ($P < .10$) more forbs and shrubs were found in diet samples in the late summer. Cattle, during all three years of study, were rotated to a fresh pasture at the end of the third period. Therefore, it appears availability was nearly the same in both periods. However, seasonal advance may have resulted in reduced forb palatability. Pickford and Reid (1948) reported a decrease in forb consumption at Starkey as the grazing season advanced.

TABLE 22. The Average Percent by Weight of Important Grasses, Forbs, and Shrubs in Cattle Diets on the Meadow in 1976, 1977, and 1978.

Forage Class	1976		1977		1978		
	Period		Period		Period		
	3	4	3	4	3	4	$\bar{X}$
Kentucky bluegrass	12	15	10	8	12	15	12
Western fescue	7	6	7	13	7	6	8
Small fruited bulrush	10	6	9	6	8	6	8
Spike bentgrass	9	4	6	13	9	3	8
Timothy	5	5	2	3	5	5	6
Meadow foxtail	4	7	1	3	5	7	7
Mountain brome	T	4	2	4	T	4	3
Idaho fescue	6	12	4	7	6	11	8
Carex species	3	1	7	4	4	2	5
Juncus species	2	3	5	2	T	1	3
Total grasses	75	86	72	85	73	86	80
Western yarrow	2	4	T	T	T	4	2
Trifolium species	4	1	1	T	2	2	2
Total forbs	18	12	14	10	18	12	12
Snowberry	3	T	13	2	2	4	6
Total shrubs	7	2	14	5	10	2	8

Diet Quality

Crude protein, in vitro dry matter digestibility, acid detergent fiber and lignin data are presented for the grassland, forest and meadow in this section. The meadow was not included in the statistical analysis because management was different from that on the forest and grassland.

Crude Protein

The crude protein content of cattle diets did not differ significantly ($P > .05$) between the forest and grassland when samples were pooled across years and periods (Table 23). There was significantly more ($P < .05$) crude protein in diet samples from the forest than on the grassland in the late summer.

Vegetation type, period and year interacted significantly at the 1% level. The percent crude protein in diet samples on the forest, grassland and meadow in 1976, 1977 and 1978 is presented in Table 24.

Differences in crude protein between the forest and grassland in 1976 were relatively small. The protein requirements for growing heifers, as outlined by the National Research Council (N. R. C.) (1976), indicate that 350 kg. heifers require 8.2% crude protein for a 0.5 kg daily gain. The requirement for lactating cows is 9.2%

TABLE 23. Percent Crude Protein Diet Samples on the Forest, Grassland, and Meadow Pooled Across Years.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
Late spring	10.6	11.1	
Early summer	8.5	9.4	
Late summer	8.4[b]	10.1[a]	8.7
Fall	8.9	9.8	8.5

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in statistical analysis.

TABLE 24. Percent Crude Protein in Diet Samples on the Meadow, Forest and Grassland in 1976, 1977, and 1978.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
	1976 Grazing Season		
Late spring	12.4[a]	11.0[b]	
Early summer	9.1	9.1	
Late summer	11.0	11.7	9.5
Fall	9.3[b]	10.6[a]	9.3
	1977 Grazing Season		
Late spring	9.5	10.6	
Early summer	7.4[b]	8.8[a]	
Late summer	7.2[b]	9.4[a]	8.0
Fall	8.4	9.1	7.7
	1978 Grazing Season		
Late spring	9.8[b]	11.6[a]	
Early summer	9.1[b]	10.2[a]	
Late summer	7.0[b]	9.3[a]	8.5
Fall	9.1	9.7	8.1

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

crude protein. This requirement was satisfied on the three vegetation types throughout the 1976 grazing season for both classes of cattle.

Crude protein percentages on the grassland were below the N.R.C. recommended value for 350 kg yearling heifers and lactating cows during the summer in 1977. Diet samples collected on the forest were inadequate for lactating cows in the early summer. The relatively low crude protein content of diet samples in 1977 is attributed to the dry winter and spring which resulted in forage maturing nearly three weeks earlier in 1977 than in 1976. The increase in crude protein in diet samples from the grassland in the fall is attributed to the fact considerable regrowth was available.

Precipitation during the spring and early summer of 1978 was higher than 1976 or 1977. Crude protein values for 350 kg yearling heifers on the grassland were below the N.R.C. recommended requirement in the late summer. Crude protein in diet samples collected on the forest never fell below the N.R.C. requirement for heifers or lactating cows.

Regression and correlation analysis was used to determine if a linear relationship existed between forage class level in individual diet samples from the forest and crude protein. The highest correlation coefficient was between browse and crude protein ($r = .51$).

This relationship was not significant (P > .05).

Many studies are available showing a crude protein decline in range cattle diets with seasonal advance (Van Dyne and Heady, 1965b; Cook and Harris, 1968; Wallace et al., 1972; Vavra, 1972; Rosiere et al., 1975). On the forest, cattle in this study were able to maintain higher crude protein levels in the diet than on the grassland by altering their selection of forage species. Snowberry, ninebark, spiraea, and elk sedge were heavily used after other forest species had matured. Cook and Harris (1950) reported browse species retain higher crude protein levels after reaching maturity than did grasses. Elk sedge was found to be higher in crude protein during the latter part of the grazing season at Starkey than bluebunch wheatgrass, Idaho fescue, pinegrass or Sandberg bluegrass (Pickford and Reid, 1948; Skovlin, 1967). Other factors may also explain why crude protein was higher in diet samples collected on the forest. Plants growing in the shade usually have higher crude protein percentages than the same species growing in the sun (Roberts, 1926; McEwen and Dietz, 1965). This is because stage of development is often retarded in shaded areas (McEwen and Dietz, 1965). Reduced leaching because of interception of rain by overstory species might also be a factor (Laycock and Price, 1970).

Acid Detergent Fiber

Acid detergent fiber (ADF) values were not significant ($P > .05$) for the main effect of vegetation type. The year and vegetation type interaction was significant ($P < .05$). The forest and grassland differed only in 1978 when percent ADF values were 48.8 and 51.4, respectively.

Pasture, period and year interacted significantly at the 5% level. The percent ADF values in diet samples in 1976, 1977 and 1978 are presented in Table 25.

The primary value of ADF data is that they help explain IVDMD values. There was a significant negative correlation between IVDMD and ADF at the 5% level. However, the coefficient of determination was only .50. Acid detergent fiber is difficult to interpret because it is a summation of separate entities that may be highly variable in their own digestibility (Van Soest, 1971).

Lignin

Lignin values on the forest were significantly higher ($P < .05$) than on the grassland when samples were pooled across years and periods (Table 26). Diet samples from both the forest and grassland increased progressively in lignin content with seasonal advance.

The interaction between pasture, period, and year was highly

TABLE 25. Percent Acid Detergent Fiber in Diet Samples on the Meadow, Forest and Grassland in 1976, 1977 and 1978.

Sampling Period[1/] [2/]	Grassland	Forest	Meadow[3/]
	1976 Grazing Season		
Late spring	48.2	42.1	
Early summer	41.1[a]	44.2[b]	
Late summer	51.3	50.5	51.6
Fall	53.4	54.0	53.2
	1977 Grazing Season		
Late spring	49.7	49.4	
Early summer	49.8	49.5	
Late summer	52.7	48.8	50.1
Fall	55.4	50.7	52.3
	1978 Grazing Season		
Late spring	47.5	46.2	
Early summer	49.8	49.5	
Late summer	52.7[a]	48.8[b]	50.1
Fall	55.4[a]	50.7[b]	52.3

[1/] Means with different letters are significantly different ($P < .05$).

[2/] Statistical tests apply only across columns.

[3/] The meadow was not included in the statistical analysis.

TABLE 26. Percent Lignin in Diet Samples on the Meadow, Forest and Grassland Pooled Across Years.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
Late spring	10.4	11.6	
Early summer	10.6	11.9	
Late summer	11.2[b]	14.5[a]	12.4
Fall	12.1[b]	14.6[a]	12.0

[1/] Means with different letters are significantly different ($P \leq .05$).

[2/] Statistical tests apply only across columns.

[3/] The meadow was not included in the statistical analysis.

significant ($P < .01$) (Table 27). The higher lignin content of diet samples from the forest compared to the grassland is attributed to two factors. Cook and Harris (1950) found shrubs were higher in lignin than grasses. Van Dyne and Heady (1965) found plants grown in the shade were higher in lignin than when the same species grew in the sun.

The coefficient of determination between lignin and IVDMD on diet samples collected from the grassland was .10; this value was .36 on the forest. When samples with less than 15% lignin were excluded from the analysis, the correlation coefficient was improved ($r = -.86$). It has been found that high correlations exist within species and forage classes between lignin and apparent digestibility (Tomlin, 1965). However, when forage classes are mixed together this relationship decreases considerably (Van Soest, 1971). This is related to morphological differences in grasses, forbs and shrubs. Van Soest (1971) explained that in grasses, lignin influences the digestibility of the available fraction of cellulose whereas, in forbs and shrubs, lignin influences the amount of the available cellulose. Tomlin et al. (1965) showed lignin had much less effect on the digestibility of legumes than grasses. This indicated that lignin data are difficult to interpret when more than one forage class occurs in the diet.

TABLE 27. Percent Lignin in Diet Samples on the Meadow, Forest and Grassland in 1976, 1977, and 1978.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
	1976 Grazing Season		
Late spring	10.9	12.5	
Early summer	12.6	10.3	
Late summer	11.9[b]	15.3[a]	13.3
Fall	13.2[b]	17.0[a]	14.7
	1977 Grazing Season		
Late spring	10.3	11.3	
Early summer	10.0	14.2	
Late summer	11.0	11.5	10.4
Fall	9.2[b]	13.1[a]	10.5
	1978 Grazing Season		
Late spring	10.0	11.1	
Early summer	9.1	11.2	
Late summer	11.4[b]	16.7[a]	13.4
Fall	13.9	12.4	10.7

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

In vitro Dry Matter Digestibility

In vitro dry matter digestibility differed significantly ($P < .05$) between vegetation types when samples were pooled across years and periods. The interaction between vegetation type and year was highly significant ($P < .01$). The percent IVDMD values for diet samples collected on the forest pooled across periods in 1976, 1977 and 1978 were 51.7, 46.3, and 48.4, respectively. These values were 49.3, 42.9, and 45.9, respectively, on the grassland. During all three years of study, IVDMD values were higher on the forest than on the grassland.

There was considerable difference in IVDMD values between the two vegetation types during the four periods when samples were pooled across years (Table 28). IVDMD values were significantly higher ($P < .05$) on the forest during the late spring and summer. Forage on the forest compared to the grassland tended to be less advanced in maturity which explains why IVDMD values were higher on the forest.

In 1976 and 1977 when forage regrowth was available on the grassland in the fall, IVDMD values of diet samples collected on the grassland were significantly higher ($P < .05$) than on the forest. Little regrowth was available on the grassland in 1978. Cattle diets on the forest were significantly higher ($P < .05$) in IVDMD than those

TABLE 28. Percent *in vitro* Dry Matter Digestibility of Diet Samples on the Forest and Grassland Pooled Across Years.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
Late spring	50.2[b]	52.8[a]	
Early summer	47.2[b]	49.8[a]	
Late summer	43.3[b]	46.6[a]	45.1
Fall	43.7	42.8	43.6
Average	46.1	48.0	

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

on the grassland.

The interaction between vegetation type, period and year was highly significant ($P < .01$). IVDMD values for diet samples collected on the forest and grassland pastures in 1976, 1977 and 1978 are presented in Table 29.

Regression analysis was used to determine if a relationship existed between forage class level and IVDMD values of individual forage samples on the forest. The highest correlation was between the percent by weight of shrubs and IVDMD ($r^2 = .48$). Generally, diet samples containing over 30% browse were lower in IVDMD than those with a lower browse content although there were exceptions. Diet samples high in elk sedge were, in many cases, higher in IVDMD than other samples but, again, there were exceptions. Diet samples high in grasses collected on the forest were generally higher in IVDMD than those collected on the grassland. It appears that the higher IVDMD values on the forest can be attributed to forage being less advanced in maturity than on the grassland. However, little can be concluded regarding the influence of forage class level or species on IVDMD.

IVDMD and crude protein values were examined to see if a relationship existed between these two parameters on the forest and grassland. On the grassland, the correlation between crude protein and IVDMD was highly significant ($P < .01$) ($r^2 = .87$). The linear

TABLE 29. Percent in vitro Dry Matter Digestibility of Diet Samples on the Meadow, Forest and Grassland in 1976, 1977 and 1978.

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
	1976 Grazing Season		
Late spring	50.8[b]	55.4[a]	
Early summer	51.3	52.4	
Late summer	49.0	47.8	44.9
Fall	46.3[a]	41.8[b]	48.2
	1977 Grazing Season		
Late spring	49.0	51.4	
Early summer	40.1[b]	44.6[a]	
Late summer	37.5[b]	47.7[a]	45.6
Fall	45.2[a]	41.3[b]	38.5
	1978 Grazing Season		
Late spring	50.7	50.8	
Early summer	49.7[b]	52.3[a]	
Late summer	43.5	45.0	44.7
Fall	39.6[b]	45.0[a]	44.1

1/ Means with different letters are significantly different ($P \leq .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

regression equation between crude protein and IVDMD was as follows:

$$y = 26.36 + 2.14 X$$

$$Y = \text{IVDMD} \quad X = \text{crude protein}$$

All three years' data were used in developing the equation. It appears IVDMD could satisfactorily be estimated on the grassland using this equation. On the forest the relationship between IVDMD and crude protein was not nearly so strong ($r^2 = .60$). Therefore, any estimate of IVDMD using crude protein could be highly inaccurate.

Brown et al. (1968) and Rosiere et al. (1975) reported coefficients of determination of .85 and .56, respectively, in studies evaluating the relationship between crude protein and digestibility. Rosiere et al. (1975) reported their relatively low correlation coefficient was probably caused by large quantities of browse and weathered grass in the diet. Their results concur with the findings of this investigation on the forest. Rao et al. (1973) studied cattle diets on tallgrass prairie and developed similar regression equations for predicting in vitro digestibility. They found digestibility was most closely correlated to crude protein and fiber ($r = .87$). Rosiere et al. (1975) found lignin and digestibility were poorly correlated ($r = -.59$). Their correlation coefficient was very similar to the correlation coefficient on the forest in this study ($r = -.62$). Lignin determinations are considerably more tedious and time-consuming than nitrogen analyses; thus as a single indicator for nutritive value of cattle diets, crude protein is preferred over lignin.

Moir (1961) reported a high correlation (r = .98) between digestible energy and dry matter digestibility. Rittenhouse et al. (1971) developed a regression equation to predict digestible energy (DE) from dry matter (DM) digestibility using forage species grazed by cattle on Great Plains grassland:

$$\text{DE in Mcal/kg DM} = .038\ (\%\ \text{DM digestibility}) + 0.18$$

This equation was developed with several different forages and should be applicable on other range types. DE values may be compared to the requirements (N.R.C., 1976) by converting metabolizable energy (ME) values to DE using the NRC conversion:

$$\text{DE in Mcal/kg} = \text{ME in Mcal/kg} \times 1.22$$

This gives a DE level for a 350 kg pregnant yearly heifer to gain 0.5 kg of 2.3 Mcal/kg. Lactating cows require 2.5 Mcal/kg.

Diets on the forest and grassland were inadequate in digestible energy for 350 kg yearling heifers and lactating cows throughout the grazing season in all three years of study based on the N.R.C. (1976) requirements (Table 30). The predicted digestible energy values reported in this study are very similar to those reported by Rosiere et al. (1975). They reported a value of 1.80 Mcal/kg for esophageal fistual samples collected from steers on summer range on semi-desert grassland in New Mexico.

TABLE 30. Estimated Digestible Energy (Mcal/kg) in Diet Samples in 1976, 1977 and 1978 Predicted by the Equation of Rittenhouse et al (1971).

Sampling Period [1/] [2/]	Grassland	Forest	Meadow [3/]
	1976 Grazing Season		
Late spring	2.29[a]	2.11[b]	
Early summer	2.11	2.13	
Late summer	2.00	2.04	1.89
Fall	1.77[b]	1.94[a]	2.01
	1977 Grazing Season		
Late spring	2.13	2.04	
Early summer	1.87[a]	1.70[b]	
Late summer	1.99[a]	1.61[b]	1.91
Fall	1.75[b]	1.90[a]	1.64
	1978 Grazing Season		
Late spring	2.11	2.11	
Early summer	2.17[a]	2.07[b]	
Late summer	1.89	1.83	1.88
Fall	1.89[a]	1.68[b]	1.86

1/ Means with different letters are significantly different ($P < .05$)

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

Forage Intake

Forage intake data were collected on the forest and grassland in 1976, 1977 and 1978. Because the size of the steers used for intake evaluation differed between years, intake is expressed in grams of forage intake on a dry weight basis per kilogram of body weight to the 0.75 power.

Forage intake was significantly lower ($P < .05$) in 1976 than in 1977 or 1978 when samples were pooled across periods and pastures. The relatively low intake in 1976 is attributed to a water quality problem on both the forest and grassland pastures in the late spring. When this problem was corrected with a pumping system, intake was substantially increased on both pastures.

When years and periods were pooled, intake values did not differ significantly ($P > .05$) on the forest and grassland. The interaction between pasture and period was significant at the 5% level. In the late spring forage intake was significantly higher ($P < .05$) on the grassland than on the forest (Table 31). During the summer, significantly more ($P < .05$) forage was consumed on the forest. The two vegetation types did not differ significantly ($P > .05$) in the fall.

The interaction between vegetation type, year and period was significant ($P < .01$). Forage intake during 1976, 1977 and 1978 is presented in Table 32.

TABLE 31. Daily Forage Intake (gm/kg $BW^{.75}$) on the Forest and Grassland Pooled Across Years.

Sampling Period [1/] [2/]	Grassland	Forest
Late spring	88.6	86.3
Early summer	83.9[b]	89.3[a]
Late summer	78.0[b]	82.2[a]
Fall	92.6	93.6
Average daily forage intake	85.7	86.7

[1/] Means with different letters are significantly different ($P < .05$).

[2/] Statistical tests apply only across columns.

TABLE 32. Daily Forage Intake (gm/kg BW$^{.75}$) on the Forest and Grassland in 1976, 1977 and 1978.

Sampling Period [1/] [2/]	Grassland	Forest
	1976 Grazing Season	
Late spring	65.7[a]	50.4[b]
Early summer	81.4[b]	93.0[a]
Late summer	87.1[b]	91.9[a]
Fall	88.2[a]	83.8[b]
Average daily forage intake	80.7	78.6
	1977 Grazing Season	
Late spring	98.5	97.9
Early summer	85.6	87.1
Late summer	79.6[b]	87.7[a]
Fall	102.9[a]	92.6[b]
Average daily forage intake	91.7[a]	87.7[b]
	1978 Grazing Season	
Late spring	101.8[a]	90.4[b]
Early summer	84.8[b]	87.6[a]
Late summer	67.0	66.1
Fall	86.0[b]	106.5[a]
Average daily forage intake	84.9[b]	92.4[a]

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

Forage intake was higher on the grassland than on the forest in the late spring during all three years of study. The difference was significant ($P < .05$) in 1976 and 1978. Diet quality on the two vegetation types was very similar in the late spring. However, forage species consumed were different on the forest and grassland which may explain the difference in consumption.

More forage was consumed on the forest than on the grassland during the summer in all three years of the investigation. These differences were significant ($P < .05$) with the exception of the early summer in 1977. Diet quality may explain why intake was higher on the forest in the summer. Forage consumed on the forest was higher in nutritive value compared to the grassland. Forage intake of medium and low quality roughages is positively related to forage quality and succulence (Conrad et al., 1964). Comfort may also account for the higher consumption of forage on the forest since much more shade was available. Cattle on the forest were observed to spend much of their time grazing during the middle part of the day in the summer while grassland cattle spent most of their time resting.

Considerable regrowth was available on the grassland during the latter part of the grazing seasons in 1976 and 1977 which probably explains why intake was higher on the grassland than on the forest. In 1978, there was very little regrowth available in the fall and the weather was quite warm. Lower diet quality and lack of shaded areas for grazing may both account for the lower forage intake on the grassland compared to the forest.

Cattle were moved to a fresh pasture at mid-season in 1977 on both vegetation types. Forage intake on the forest did not change after the movement but intake on the grassland was reduced.

The dry matter intake requirement for a 350 kg steer to gain 0.5 kg per day is 86.5 gm/kg $BW^{.75}$ (N.R.C., 1976). This requirement was met during all three years on the forest with the exception of late summer in 1978. Intake values on the grassland were inadequate in the summer on the grassland during all three years of study.

Crude protein and digestible energy intake requirements for a 350 kg heifer to gain 0.5 kg per day are 0.63 kg and 16.1 Mcal, respectively (N.R.C., 1976). A 350 kg lactating cow requires .75 kg of crude protein and 20.7 Mcal of digestible energy.

Crude protein consumption was adequate on the forest in all three years of study although requirements on the grassland were not satisfied during the summer in 1977 and 1978 (Table 33). Digestible energy intake was more limiting to livestock performance than crude protein intake on both the forest and grassland. When vegetation types, years and periods were pooled, heifers consumed 106% of their crude protein requirements but only 88% of their digestible energy requirements. Lactating cows would have consumed 89% of their

TABLE 33. Total Crude Protein and Digestible Energy Consumed in 1976, 1977 and 1978.

Sampling Period[1/] [2/]	Crude Protein (kg) Grassland	Crude Protein (kg) Forest	Digestible Energy (Mcal) Grassland	Digestible Energy (Mcal) Forest
	1976 Grazing Season			
Late spring	0.66[a]	0.45[b]	13.7[a]	11.4[b]
Early summer	0.60	0.68	17.1[b]	19.9[a]
Late summer	0.78[b]	0.87[a]	17.6[b]	18.2[a]
Fall	0.66	0.72	16.9[a]	14.7[b]
	1977 Grazing Season			
Late spring	0.76	0.84	19.9	20.6
Early summer	0.51[b]	0.63[a]	14.4[b]	16.1[a]
Late summer	0.47[b]	0.66[a]	12.6[b]	17.2[a]
Fall	0.70	0.67	19.3[a]	16.0[b]
	1978 Grazing Season			
Late spring	0.80	0.85	21.3[a]	18.8[b]
Early summer	0.63[b]	0.72[a]	17.3[b]	18.7[a]
Late summer	0.38[b]	0.50[a]	12.1	12.4
Fall	0.63[b]	0.84[a]	14.3[b]	19.9[a]

[1/] Means with different letters are significantly different ($P < .05$).

[2/] Statistical tests apply only across columns.

crude protein requirements but only 66% of their digestible energy requirements. Because steers used for estimating intake were under stress during fecal collections, estimates of digestible energy and crude protein intake could be low. However, the estimated values do allow comparison of the relative importance of digestible energy and crude protein intake in determining livestock performance.

Livestock Performance

Livestock performance data were collected on forest, grassland and meadow pastures in 1976, 1977 and 1978. However, statistical analysis was applied to only the forest and grassland pastures.

The main effect of vegetation type was highly significant ($P < .01$). Average daily gains on the forest and grassland pooled across years and periods were 0.40 and 0.33 kg, respectively.

When weights were pooled across pastures and periods, the effect of year was significant at the 5% level. Average daily gains for 1976, 1977 and 1978 were 0.39, 0.29, and 0.36 kg, respectively. Cattle gains were significantly lower ($P < .05$) in 1977 than in 1976 or 1978. The relatively poor performance in 1977 is attributed to reduced forage quality. The spring of 1977 was quite dry and forage matured much earlier than in 1976 or 1978. A water quality problem existed on both the forest and grassland in the first period of 1976, and was corrected by the installation of a pumping system in early July. If this problem had not existed, gains would probably have been much higher in 1976.

The interaction between vegetation type and period was highly significant ($P < .01$). Livestock performance for the forest, grassland and meadow pastures pooled across years is presented in Table 34. Cattle performance was significantly higher ($P < .05$) on the grassland than on the forest in the late spring. However, in the summer, cattle performed significantly better ($P < .01$) on the forest. There was no significant difference ($P < .05$) between the two vegetation types in the fall.

TABLE 34. Average Daily Gains (kg) for Cattle on the Meadow, Forest and Grassland Pooled Across Years.

Sampling Period [1/] [2/]	Forest	Grassland	Meadow [3/]
Late spring	+0.39[b]	+0.50[a]	
Early summer	+0.61[a]	+0.43[b]	
Late summer	+0.27[a]	+0.03[b]	+0.47
Fall	+0.32	+0.38	0.41
Average Daily gain	+0.40	0.33	0.41

1/ Means with different letters are significantly different ($P < .05$).
2/ Statistical tests apply only across columns.
3/ The meadow and control were not included in statistical tests.

During the fall, livestock performance on the grassland compared to the forest depended on the availability of forage regrowth. In 1976 and 1977 when regrowth availability on the grassland was high, cattle performed significantly better ($P < .05$) on the grassland (Table 35). The summer and fall of 1978 were relatively dry compared to the other two years. Cattle performance on the forest was significantly better ($P < .05$) than on the grassland.

Crude protein and digestible energy intake values were consistent with livestock performance during the three years of study with one exception. In the early summer of 1977 livestock performance was significantly higher ($P < .05$) on the grassland although digestible energy and crude protein intake values were significantly higher ($P < .05$) on the forest. Cattle were weighed much later in the day on the forest than on the grassland because of a gathering problem. Results may have been changed because of a difference in water and forage fill on the two vegetation types. This could explain why there was a high rate of gain on the forest in the late summer of 1977 although crude protein and predicted digestible energy intake were relatively low.

In the late summer of 1978, cattle performance on both the forest and grassland were lower than in any other period during the three years of study. This is explained by low diet quality and forage intake. Fecal collection steers consumed only 80% of the N. R. C.

TABLE 35. Average Daily Gains (kg) for Cattle on the Meadow, Forest and Grassland in 1976, 1977 and 1978.

Sampling Period [1/] [2/]	Forest	Grassland	Meadow [3/]
	1976 Grazing Season		
Late spring	-0.06[b]	+0.22[a]	--
Early summer	+0.61[a]	+0.43[b]	--
Late summer	+0.51	+0.41	+0.99
Fall	+0.42[b]	+0.57[a]	+0.13
$\bar{X}$ Daily gain	+0.38	+0.40	+0.56
	1977 Grazing Season		
Late spring	+0.63	+0.50	
Early summer	0.00[b]	+0.33[a]	
Late summer	+0.72[a]	+0.08[b]	+0.46
Fall	-0.01[b]	+0.27[a]	+0.16
$\bar{X}$ Daily gain	+0.33	+0.29	+0.31
	1978 Grazing Season		
Late spring	0.58[b]	0.80[a]	
Early summer	1.10[a]	0.41[b]	
Late summer	-0.37	-0.40	-0.04
Fall	0.54[a]	0.28[b]	+0.74
$\bar{X}$ Daily gain	0.46[a]	0.27[b]	+0.35

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The meadow was not included in the statistical analysis.

(1976) recommended digestible energy requirement for maintenance on both pastures. High lignin values on the forest and low crude protein values on the grassland explain why forage intake was so low.

Cattle on both vegetation types were moved to a fresh pasture at mid-summer in 1977. It is hard to evaluate how much influence this had on cattle performance on the forest because the gathering problem may have confounded mid-summer weight gains. Cattle performance on the grassland was significantly lower ($P < .05$) in late summer after the movement compared to the early summer before movement.

Analysis of covariance was used to determine if a relationship existed between weights at the beginning of each period and average daily gains during the three years of study. The regression was not significant ($P < .05$) for any of the 12 periods. Therefore, corrected weights were not used in the analysis of variance.

Regression and correlation were used to determine if a relationship existed between cattle performance and diet quality (Table 36). Cattle performance data from the forest in the early and late summer of 1977 were not used in the analysis because of the problem mentioned earlier involving gathering.

Only IVDMD and crude protein were significantly ($P < .05$) correlated average daily gain. Multiple regression was used to determine the relationship between average daily gain with crude

TABLE 36. Coefficients of Determination Between Average Daily Gain and the Components of Diet Quality on the Forest and Grassland.

	CP	ADF [1/]	Lignin [1/]	IVDMD
Forest	0.37	0.03	0.44	0.51*
Grassland	0.68*	0.13	0.06	0.56*
Forest & Grassland & Meadow	0.53*	0.29	0.29	0.54*

[1/] Correlation coefficients were negative for ADF and lignin.

* Significant at $P < .05$.

protein and IVDMD. The equation is as follows:

$$Y = 0.109\,X_1 + 0.012\,X_2 - 1.203$$

Y = average daily gain

X_1 = crude protein

X_2 = IVDMD

The coefficient of determination for this equation was significant ($P < .05$) ($R^2 = .69$).

Crude protein and predicted digestible energy intake values were regressed against livestock performance to determine if correlation coefficients could be improved. More variation in livestock performance was accounted for by these variables than when percent data were used (Table 37). When both independent variables were

TABLE 37. Coefficients of Determination Between Average Daily Gains with Crude Protein and Digestible Energy Intake.

	CP	DE
Forest	0.49	0.75*
Grassland	0.82*	0.83*
Forest & Grassland	0.65*	0.78*

* Significant at $P < .05$.

used the multiple regression equation was as follows:

$$Y = 0.125\,X_1 + 0.104\,X_2 - 1.182$$

$\hat{Y}$ = average daily gain (kg)

X_1 = crude protein intake (kg)

X_2 = predicted digestible energy intake (Mcal)

The coefficient of determination was significant ($P < .01$) ($R^2 = .83$). When simple linear regressions were run with crude protein and predicted digestible energy intake as independent variables, the coefficients of determination were .66 and .77, respectively.

Livestock performance on the forest and grassland during the three years of study was determined primarily by the intake of digestible energy and crude protein. Digestible energy intake was more important than crude protein consumption in determining livestock performance. This was because cattle more nearly met their crude protein requirements than their digestible energy requirements. The procedures used in the evaluation of diet quality and forage intake gave a very good explanation of livestock performance when data were expressed on the basis of predicted digestible energy and crude protein intake.

RESULTS AND DISCUSSION: GRAZING SYSTEMS STUDY

Botanical Analysis

Cattle Diet Main Effects

Diet botanical composition was determined under rest-rotation, deferred rotation, and season-long grazing systems. The deferred rotation grazing system will be discussed separately because grazing only lasted half the grazing season in each year.

During the three years of study 25 grasses, 29 forbs and 11 shrubs were consumed by cattle on the grazing system pastures. The important grasses and grass-like plants consumed included Idaho fescue, bluebunch wheatgrass, elk sedge, Kentucky bluegrass (*Poa pratensis*) and Sandberg bluegrass. The primary forbs consumed included western yarrow and several clover species (*Trifolium* spp.) which were lumped together because of identification problems. Snowberry and ninebark were the primary shrubs consumed. The mean percent weights of all species occurring in diet samples during the three periods are listed in Appendix E-G.

Grasses made up 62% of the cattle diets on the season-long and rest-rotation grazing systems when samples were pooled across pastures, periods and years. Forbs and shrubs contributed 20% and 18% of the diet, respectively. The mean percent weight of each forage class and important species in the diet pooled by grazing system and period are presented in Table 38.

Idaho fescue and bluebunch wheatgrass made up 18% and 14%, respectively, of the diet by weight when samples were pooled across grazing systems, periods and years. They were the most important species found in cattle diets on all the pastures.

Clover and western yarrow made up 2% and 4% of the diet, respectively. A large number of other forb species were found in cattle diets early in the grazing season. Many of these species were not identified because they were not in the reference slide collection. Their contribution to cattle diets is unimportant since none of these species made up over 1% of the overall diet.

Snowberry was the most common shrub found in cattle diets under both the season-long and rest-rotation grazing systems. This was also the most common shrub found on the pastures (Table 7), and comprised 12% of the overall diet.

Elk sedge was the fourth most important species found in cattle diets, and accounted for 8% of the overall diet. This species was very common in the forested parts of all the grazing system pastures.

Grass consumption did not differ significantly ($P > .05$) between

TABLE 38. The Percent by Weight of Important Species Found in Cattle Diets Pooled Across Periods and Grazing Systems.

Species [1/] [2/]	Year 1976	1977	1978	$\bar{X}$
Idaho fescue	17	20	15	18
Bluebunch wheatgrass	16	12	15	14
Sandberg bluegrass	9[a]	4[b]	5[b]	6
Kentucky bluegrass	5	4	4	4
Elk sedge	4[b]	9[ab]	12[a]	8
Total grasses	64	56	61	62
Trifolium species	2	2	3	2
Western yarrow	5	3	4	4
Total forbs	23[a]	14[c]	19[b]	20
Snowberry	6[c]	18[a]	14[b]	12
Ninebark	3	7	4	5
Total shrubs	13[c]	30[a]	20[b]	18

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across columns.

years although the shrub and forb content of cattle diets varied considerably. The highest forb consumption was in 1976, while the lowest was in 1977. In contrast, the shrubs were most important in cattle diets in 1977 and least important in 1976.

Grass consumption was significantly higher ($P < .05$) in the second half of the grazing season than in the first half. Forb consumption declined as the grazing season advanced. Shrubs were highest in diets during the middle part of grazing season. The mean percent by weight of important species found in cattle diets pooled across grazing systems and years is given in Table 39.

Cattle diets under the season-long and rest-rotation grazing systems did not differ significantly at the 5% level. The degree of redundancy in diets under the two systems was 77%. However, significantly ($P < .05$) more bluebunch wheatgrass was consumed under the rest-rotation grazing system. Cattle diets were higher in Idaho fescue on the season-long pasture.

Cattle diets were pooled across grazing systems to examine the degree of redundancy in cattle diets between years and periods. The redundancy values for years and periods were 28% and 72%, respectively.

The interaction between grazing system, period, year and the three forage classes was significant ($P < .01$). Several species also interacted significantly ($P < .01$) with grazing system, pasture and

TABLE 39. The Percent by Weight of Important Species Found in Cattle Diets Pooled Across Years and Grazing Systems.

Species[1/] [2/]	Period			
	Late Spring	Early Summer	Late Summer	Fall
Idaho fescue	13^{b}	15^{b}	21^{ab}	25^{a}
Bluebunch wheatgrass	5^{c}	12^{b}	18^{ab}	21^{a}
Sandberg bluegrass	5^{a}	4^{b}	5^{b}	9^{a}
Kentucky bluegrass	9^{a}	5^{b}	2^{b}	2^{b}
Elk sedge	3^{c}	7^{bc}	10^{ab}	12^{a}
Total grasses	51^{c}	50^{c}	65^{b}	78^{a}
Trifolium species	7^{a}	1^{b}	T	T
Western yarrow	5^{a}	6^{a}	4^{a}	1^{b}
Total forbs	43^{a}	22^{b}	9^{c}	4^{c}
Snowberry	5^{b}	17^{a}	14^{a}	8^{b}
Ninebark	T	4^{b}	8^{a}	3^{b}
Total shrubs	6^{c}	28^{a}	26^{ab}	18^{b}

1/ Means followed by the same letter are not significantly different ($P > .05$) using Duncan's Multiple Range Test.

2/ Statistical tests apply only across column.

year. Therefore, a separate discussion will be given for each of the three years.

Cattle Diets in 1976

Management under the rest-rotation system involved grazing pasture 2 all season and resting pasture 1. This resulted in double grazing pressure on the rest-rotation pasture compared to the season-long pasture.

Grazing habits of cattle under the two grazing systems were very similar. In the early part of the grazing season, the meadow received heavy use. After the more palatable plants on the meadow had been consumed, the cattle moved on to the south-facing slope. During the middle part of the grazing season, use appeared to be divided between the ponderosa pine and Douglas fir plant communities. In the final grazing period, the open grassland areas were preferred. Very little use was made of the north-facing slope, perhaps due to the steep slopes and lack of forage.

Cattle on the season-long pasture consumed significantly ($P < .05$) more Idaho fescue than cattle on the rest-rotation pasture (Table 40). However, significantly ($P < .05$) less bluebunch wheatgrass was found in diet samples from the season-long pasture. The availability of these two species was approximately the same on both pastures (Table 6). However, the stocking rate on the rest-rotation

TABLE 40. The Percent by Weight of Important Species Found in Cattle Diets Under the Season-Long and Rest-Rotation Grazing Systems in 1976.

	Period							
	1		2		3		4	
Species[1/][2/]	RR	SL	RR	SL	RR	SL	RR	SL
Idaho fescue	15	15	10	15	16[b]	41[a]	21	29
Bluebunch wheatgrass	6	2	12	14	20	14	38[a]	15[b]
Sandberg bluegrass	T	10	7	3	12[a]	4[b]	14[a]	8[b]
Kentucky bluegrass	5	6	5	9	3	4	1	6
Elk sedge	6	T	T	1	9	1	10	4
Total grasses	47	42	55	53	65	78	85	85
Trifolium species	4	10	1	1	T	--	T	1
Western yarrow	2[b]	8[a]	1[b]	11[a]	2	6	2	1
Total forbs	47	52	25	32	10	10	5	5
Snowberry	4	3	12	6	7	8	4	6
Ninebark	1	--	2	2	16	--	2	T
Total shrubs	6	6	20	15	25[a]	12[b]	10	10

1/ Means with a and b are significantly different ($P < .05$).

2/ Statistical tests apply only across columns and within each period.

pasture was twice as heavy as on the season-long pasture. During the last half of the grazing season, bluebunch wheatgrass consumption increased progressively on the rest-rotation pasture. It may be that cattle used more bluebunch wheatgrass on the rest-rotation pasture because Idaho fescue became less available as grazing progressed. This is substantiated by the fact that significantly ($P < .05$) more Sandberg bluegrass was found in diet samples from the rest-rotation pasture. Pickford and Reid (1948) reported that Sandberg bluegrass was a relatively unpalatable grass at the Starkey range. Another possibility is that cattle used more bluebunch wheatgrass and Sandberg bluegrass on the rest-rotation pasture because these two species were very responsive to the precipitation received in early August. Since grazing was much lighter on the season-long pasture, much more old growth may have been present on these two plants which would decrease palatability.

Trends in forb consumption were very similar on both pastures. In the first grazing period, forbs comprised nearly half the diet. However, forb consumption declined rapidly in the early summer. This agrees with data presented in the complementary grazing study. Both availability and palatability probably account for this trend. Western yarrow was significantly higher ($P < .05$) in cattle diets using the season-long pasture. This appears to be a preferred forb species. It is possible that western yarrow availability was reduced much sooner on the rest-rotation pasture because of the heavier stocking rate.

Cattle under rest-rotation grazing used the north slope more heavily than cattle under season-long grazing. This was particularly true in the late summer, and accounted for the higher consumption of ninebark and elk sedge on the rest-rotation pasture. Both these species were much more available on the north slope. Pickford and Reid (1948) reported cattle use of the north slope increased as the stocking rate was increased at the Starkey range.

Grass consumption on both pastures was highest in the fall. The heavy rainfall in August resulted in much regrowth and may have softened the mature grasses.

Cattle Diets in 1977

In 1977, grazing was initiated on rest-rotation pasture 1 and at mid-season cattle were moved to pasture 2. Consequently, grazing pressure was the same under the season-long and rest-rotation grazing systems.

General trends in cattle diets in 1977 were similar to 1976. The percent by weight of important species found in cattle diets under the two grazing systems in 1977 is presented in Table 41. Forb consumption was significantly higher ($P < .01$) under the rest-rotation grazing system than under the season-long grazing in the

TABLE 41. The Percent by Weight of Important Species Found in Cattle Diets Under the Season-Long and Rest-Rotation Grazing Systems in 1977.

	Period							
	1		2		3		4	
Species [1/] [2/]	RR	SL	RR	SL	RR	SL	RR	SL
Idaho fescue	14	17	16[a]	9[b]	23	22	35	29
Bluebunch wheatgrass	2	9	8	3	18	16	25	19
Sandberg bluegrass	3	5	4	4	3	4	12	7
Kentucky bluegrass	10	9	2	5	T	1	2	T
Elk sedge	1	6	14[a]	4[b]	11	14	15[a]	5[b]
Total grasses	41[b]	72[a]	46[a]	32[b]	53[a]	75[a]	80	85
Trifolium species	7	2	--	2	--	T	--	1
Western yarrow	5	2	6	4	7	1	--	1
Total forbs	52[a]	22[b]	14	15	11	10	2	6
Snowberry	7	5	25	30	24[a]	9[b]	9	4
Ninebark	--	--	12[a]	4[b]	8	5	6	T
Total shrubs	7	6	40	53	36[a]	15[b]	18[a]	9[b]

1/ Means with a and b are significantly different ($P < .05$).

2/ Statistical tests apply across columns and within each period.

late spring. This is hard to explain since availability during the first half of the grazing season should have been less under the rest-rotation system because of heavier stocking. However, data presented by Ganskopp (1978) indicate that there is considerable difference in the proportions of the plant communities found on the two pastures. This could and probably did greatly influence cattle diets under the two systems. Another factor was that the terrain was much different on the pastures which appeared to have considerable influence on how the plant communities were used. Therefore, it is probable that the effect of grazing system is partially confounded by vegetation and terrain differences between the pastures.

Rest-rotation pasture 2 and the season-long pasture were very similar in terrain and vegetation. However, the south slope of rest-rotation pasture 1 was composed primarily of a bluebunch wheatgrass-Sandberg bluegrass plant community. On rest-rotation pasture 2 and the season-long pasture, the south slope was dominated by the ponderosa pine/Idaho fescue and Sandberg bluebunch/bluebunch/wheatgrass plant communities. The terrain on rest-rotation pasture 1 was much steeper and appeared to influence animals' use of the different plant communities. However, utilization data were not collected.

As in 1976, shrub consumption on both pastures was highest during the middle part of the grazing season. More browse was found in cattle diets in 1977 than in 1976 or 1978. The relatively dry spring and summer in 1977 compared to the other two years is a possible explanation. Forage matured in the early part of July in 1977 on the grassland areas. Forage phenology was less advanced in the forested areas and shrubs were highly available. Leaves on snowberry and ninebark remained green after the grasses had dried which may explain why these two shrub species were heavily used.

When rest-rotation cattle were moved at mid-season, their diets did not change significantly ($P > .10$). The redundancy in cattle diets between early and late summer was 91%.

Cattle diets on the season-long pasture differed significantly ($P < .01$) between early and later summer. The degree of redundancy between the two periods was only 20%. Browse consumption decreased significantly ($P < .01$) in the late summer. This appears to have been caused by lack of availability. Snowberry and other shrubs showed very heavy use by the end of the early summer period on the season-long pasture.

Heavy rainfall occurred in the middle part of August, and much green growth was available on the grassland areas of both pastures by the end of the summer. Cattle showed a definite preference for these areas during collections in September and October which explains the large amount of grass found in diet samples.

Cattle Diets in 1978

Cattle were grazed all season on rest-rotation pasture 1 in 1978. This pasture, as previously mentioned, was somewhat different in vegetation composition than the season-long pasture and rest-rotation pasture 2.

The spring and early summer of 1978 were much wetter than in 1976 or 1977. However, the general trends in cattle diets were very similar to 1976 and 1977 on both pastures. Forb consumption was significantly ($P < .05$) higher on the rest-rotation pasture than on the season-long pasture in the late spring in 1978 (Table 42). Whether this was the result of the heavier stocking rate on the rest-rotation system or was caused by a difference in pasture vegetation and terrain is unknown.

In the early summer, significantly more ($P < .05$) snowberry was consumed on the rest-rotation pasture compared to the season-long pasture. Snowberry was available on both the north and south slopes of the pastures. Plant communities dominated by snowberry were more accessible on the rest-rotation pasture, perhaps accounting for the large amount of this species in diet samples collected from this pasture.

Significantly more ($P < .01$) bluebunch wheatgrass was found in cattle diets on the rest-rotation pasture than on the season-long

TABLE 42. The Percent by Weight of Important Species Found in Cattle Diets Under the Season-Long and Rest-Rotation Grazing Systems in 1978.

Species [1/] [2/]	Period 1 RR	Period 1 SL	Period 2 RR	Period 2 SL	Period 3 RR	Period 3 SL	Period 4 RR	Period 4 SL
Idaho fescue	11	9	10[b]	28[a]	10	13	8[b]	29[a]
Bluebunch wheatgrass	7	5	24[a]	8[b]	33[a]	3[b]	22[a]	10[b]
Sandberg bluegrass	2	6	5	2	10[a]	2[b]	7[a]	2[b]
Kentucky bluegrass	6[b]	15[a]	1	3	T	3	5	1
Elk sedge	1	1	10	9	6[b]	20[a]	18	25
Total grasses	44[b]	62[a]	53	63	64	54	64[b]	79[a]
Trifolium species	10	5	2	1	--	T	--	2
Western yarrow	6	7	2	11	2	4	1	1
Total forbs	49[a]	33[b]	20	27	7	8	5	2
Snowberry	6	4	21[a]	6[b]	18	19	19	12
Ninebark	T	--	1	1	6	12	4	2
Total shrubs	7	5	27[a]	10[b]	29	38	31[a]	19[b]

1/ Means with a and b are significantly different ($P < .05$).

2/ Statistical tests apply only across columns and within each period.

pasture with the exception of the late spring period. About 50% of the south-facing slope on the rest-rotation pasture was occupied by a bluebunch wheatgrass/Sandberg bluegrass plant community. This community was nearly absent from the season-long pasture. Therefore, availability may account for the higher consumption of bluebunch wheatgrass on the rest-rotation pasture.

Sandberg bluegrass was also more available on the rest-rotation pasture than on the season-long pasture, which is probably why more of this species was consumed on the rest-rotation pasture. However, it is possible that this species received heavier use on the rest-rotation pasture because the stocking rate was heavier.

Shrub consumption in the fall was significantly higher ($P < .05$) on the rest-rotation pasture compared to the season-long pasture. Cattle on the rest-rotation pasture used the north slope much more in this period than those on the season-long pasture. Therefore, the north slope on the rest-rotation pasture was more heavily sampled than on the season-long pasture. The north slope may have received heavier use on the rest-rotation pasture because of reduced forage availability on the south-facing slope.

More browse was found in cattle diet samples collected on both pastures during the fall of 1978 than in 1976 or 1977. The summer and fall of 1978 were very dry compared to the other two years and lack of green grass may explain the high consumption of browse.

Cattle Diets on the Deferred Rotation Pasture

Cattle diets on the deferred-rotation pasture did not differ significantly ($P > .10$) from those on the season-long and rest-rotation pastures. Only those periods in which the deferred-rotation pasture was grazed were used in the analysis. The percent by weight of important species found in cattle diets on the deferred rotation pasture is presented in Table 43.

Consumption of individual species on the deferred-rotation pasture was very similar to the rest-rotation grazing system. The degree of redundancy between the two systems was 93%. The vegetation composition of the deferred-rotation pasture was very similar to rest-rotation pasture 1. As on rest-rotation pasture 1, the bluebunch wheatgrass/Sandberg bluegrass plant community was the dominant community of the south-facing slope. This probably accounts for the high consumption of bluebunch wheatgrass on this pasture.

TABLE 43. The Percent by Weight of Important Species Found in Cattle Diets Under the Deferred-Rotation Grazing System During the Three Years of Study.

Species	1976		1977		1978		
	1	2	3	4	1	2	X
Idaho fescue	13	10	16	16	10	6	10
Bluebunch wheatgrass	4	13	10	32	6	30	16
Sandberg bluegrass	2	3	5	2	2	1	T
Kentucky bluegrass	9	8	1[b]	7	13	6	5
Elk sedge	--	9	25	15	1	15[a]	11
Total grasses	44	53	60	81	48	64	60
Trifolium species	10	--	1	--	12	2[b]	4
Western yarrow	7	1	3	T	4	2	3
Total forbs	48	17	25	3	45	9	23
Snowberry	8	28	12	13	7	24	16
Ninebark	--	--	--	T	1	1	T
Total shrubs	8	29	15	16	7	27	17

Diet Quality

Crude protein, *in vitro* dry matter digestibility, acid detergent fiber, and lignin data are presented for the rest-rotation, season-long and deferred-rotation grazing systems in this section. The deferred-rotation pasture was not included in the statistical analysis because it was grazed for one-half the grazing season of each year.

Crude Protein

Cattle diets on the rest-rotation and season-long pastures did not differ significantly ($P < .05$) in crude protein when samples were pooled by period and year. The average percent crude protein values on the rest-rotation and season-long pastures were 8.5 and 8.8, respectively. The main effect of year was significant at the 5% level. The mean percent crude protein values in diet samples pooled across pastures and periods in 1976, 1977 and 1978 were 10.0, 8.7, and 9.1, respectively. In 1976, crude protein was significantly higher ($P < .05$) than in 1977 or 1978.

When samples were pooled across pastures and years, the main effect of period was significant at the 5% level. The percent crude protein in diet samples was significantly higher ($P < .05$) in the late spring than in the other three periods. Crude protein values for the late spring, early summer, late summer and fall were 11.5%, 9.1%, 8.3%, and 8.2%, respectively.

The only significant (P < .05) two factor interaction was between year and period. The percent crude protein in diet samples pooled across pastures is given in Table 44. In the late summer, crude protein in diet samples was significantly higher (P < .05) in 1976 than in 1977 or 1978. There was considerable regrowth available on the pastures in the late summer in 1976 which probably explains the relatively high level of crude protein in the diet.

TABLE 44. Percent Crude Protein in Diet Samples Pooled Across Rest-Rotation and Season-Long Grazing Systems.

	Year		
Sampling Period 1/ 2/	1976	1977	1978
Late spring	11.7	12.0	10.8
Early summer	9.0	8.6	9.8
Late summer	10.7[a]	6.8[b]	7.3[b]
Fall	8.7	7.5	8.5

1/ Means with different letters are significantly different (P < .05).

2/ Statistical tests apply only across columns.

The interaction between grazing system, period and year was not significant at the 5% level. The percent crude protein in diet samples on the grazing system pastures in 1976, 1977 and 1978 is presented in Appendix H.

The N.R.C. recommends that 350 kg yearly heifers and lactating cows receive 8.2% and 9.2% crude protein, respectively. Diet samples were inadequate for lactating cows in the summer and fall of 1977 and in the late summer of 1978. Crude protein concentrations were inadequate for heifers in the late summer of 1977 and 1978.

Acid Detergent Fiber

Acid detergent fiber (ADF) values in cattle diet samples were not significantly different ($P > .05$) for rest-rotation and season-long grazing systems when samples were pooled by period and year. The main effect of both year and period were significant at the 5% level.

Cattle diets were significantly lower ($P < .05$) in ADF during the 1976 grazing season than in the other years. ADF values for 1976, 1977 and 1978 were 46.9%, 51.7%, and 49.6%, respectively, when samples were pooled across pastures and periods.

The ADF content of diet samples increased as the grazing season advanced. The percent ADF values for the late spring, early summer, late summer, and fall across years and pastures were

45.6, 47.3, 52.1, and 52.5, respectively.

The two and three factor interactions between grazing system, period and year were not significant at the 5% level. The percent ADF in diet samples collected on the grazing systems pastures in 1976, 1977 and 1978 is presented in Appendix I.

Lignin

The main effects of grazing system and year were not significant ($P > .05$) for the percent lignin in cattle diets. However, the effect of period was significant ($P < .01$).

Lignin values for diet samples pooled across years and grazing systems were 12.4, 16.0, 13.8 and 12.3, respectively, for the late spring, early summer, late summer and fall. The high lignin content of diet samples collected in the summer is explained by the fact shrubs comprised over 20% of the diet. Cook and Harris (1950) reported shrubs were higher in lignin than grasses.

The three factor interaction between grazing system, period and year was significant ($P < .05$). The lignin values for diet samples collected on the grazing system pastures in 1976, 1977 and 1978 are presented in Table 45. Significant ($P < .05$) differences occurred between rest-rotation and season-long pastures during the summer. High lignin values were associated with a high browse content in the diet.

TABLE 45. Percent Lignin in Diet Samples on the Grazing System Pastures in 1976, 1977 and 1978.

Sampling Period [1/] [2/]	Rest-rotation	Season-long	Deferred-rotation [3/]
	1976 Grazing Season		
Late spring	13.9	14.2	13.8
Early summer	16.3	15.0	14.2
Late summer	17.6[a]	13.1[b]	--
Fall	13.2	12.1	--
	1977 Grazing Season		
Late spring	13.1	10.3	
Early summer	18.3[a]	13.2[b]	
Late summer	15.3	15.1	11.8
Fall	12.3	13.6	10.6
	1978 Grazing Season		
Late spring	10.7	10.3	10.9
Early summer	13.0	13.2	12.4
Late summer	10.8[b]	15.1[a]	
Fall	12.8	13.6	

1/ Means with different letters were significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The deferred-rotation pasture was not included in the statistical analysis.

In vitro Dry Matter Digestibility

In vitro dry matter digestibility (IVDMD) values did not differ significantly ($P > .05$) between the rest-rotation and season-long grazing systems when samples were pooled across years and periods. However, the main effects of year and period were significant ($P < .01$). In 1977, IVDMD values were significantly lower ($P < .01$) than in 1976 or 1978. The mean percent IVDMD values pooled across pastures and periods for 1976, 1977 and 1978 were 50.0, 44.7 and 48.7, respectively. The relatively low value in 1977 is attributed to the dry spring and summer which resulted in forage maturing much earlier than in 1976 or 1978.

During the four periods, IVDMD values dropped progressively with seasonal advance. The IVDMD values for late spring, early summer, late summer and fall pooled across pastures and years were 55.5, 47.0, 45.1 and 44.2, respectively. Most of the drop in IVDMD occurred during the early summer when forage reached maturity.

The only significant interaction ($P < .05$) was between vegetation type, period and year. IVDMD values for diet samples collected on season-long and rest-rotation pastures in 1976, 1977 and 1978 are presented in Table 46.

During the 1976 grazing season, IVDMD values were significantly higher ($P < .05$) on the rest-rotation pasture than on the

TABLE 46. Percent *in vitro* Dry Matter Digestibility of Diet Samples on the Season-Long and Rest-Rotation Pastures in 1976, 1977 and 1978.

Sampling Period [1/] [2/]	Rest-rotation	Season-long	Deferred-rotation [3/]
	1976 Grazing Season		
Late spring	58.2	58.0	57.8
Early summer	50.9[a]	47.5[b]	49.8
Late summer	46.8	47.7	
Fall	44.1[b]	46.8[a]	
	1977 Grazing Season		
Late spring	54.3	53.6	
Early summer	39.8[b]	43.1[a]	
Late summer	42.5	42.9	44.4
Fall	44.1	44.5	44.0
	1978 Grazing Season		
Late spring	54.4	54.2	53.9
Early summer	52.6	52.6	53.6
Late summer	44.3	46.2	
Fall	41.1[b]	44.4[a]	

1/ Means with different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ Deferred-rotation pasture was not included in the statistical analysis.

season-long pasture in the early summer. Cattle on the rest-rotation pasture consumed more snowberry than those on the season-long pasture (Table 40). Leaves on snowberry were still green while most of the grasses and forbs had matured. In the fall, IVDMD values were higher on the season-long pasture although diet botanical composition was very similar on the two pastures (Table 40). Reduced forage availability may have forced animals on the rest-rotation pasture to select more stems and fewer leaves.

In the early summer in 1977, IVDMD values were significantly higher ($P < .05$) on the season-long pasture than on the rest-rotation pasture. Grazing pressure on the rest-rotation pasture was twice as heavy as on the season-long pasture which may have forced cattle to select a lower quality diet. This is substantiated by lignin values for diet samples collected on the rest-rotation pasture which were significantly higher ($P < .05$) than those on the season-long pasture.

Cattle diets on the season-long pasture were higher in IVDMD than those on the rest-rotation pasture in the fall of 1978. The botanical composition of cattle diets on the two grazing systems was very similar. However, cattle on the rest-rotation pasture may have been forced to consume more stems than those on the season-long pasture because of the heavier stocking rate.

The equation given by Rittenhouse et al. (1971) was used to convert IVDMD values to digestible energy in Mcal/kg dry matter.

Predicted digestible energy values for samples pooled across grazing systems and years for the late spring, early summer, late summer and fall were 2.3, 2.0, 1.9 and 1.9 Mcal, respectively. The N.R.C. (1976) recommends that a 350 kg pregnant yearling heifer receive 2.3 Mcal/kg of digestible energy for 0.5 kg daily gain and lactating cows receive 2.5 Mcal/kg. This requirement was not met on the pastures in the summer and fall during the three years of study for either class of cattle.

Forage Intake

Forage intake was collected on the grazing system pastures in 1977 and 1978. The deferred-rotation pasture was not included in the statistical analysis because it was grazed for only one-half the grazing season.

Fistulated cows were used for fecal collections. In order to reduce stress on the animals, only one collection was made per period in 1977. Two collections were made per period in 1978. Variation between cows and collections was quite high. Forage intake data are expressed as the grams of forage consumed divided by the cows weight in kilograms to the .75 power (gm/kg $BW^{.75}$) because there was considerable variability in the weight of the cows.

The main effects of year and pasture were not significant ($P > .05$). However, forage intake did differ significantly ($P < .05$)

between the four periods. Intake was significantly higher ($P > .05$) in the late spring than in the other three periods. Forage intake values for the late spring, early summer, late summer and fall pooled across grazing systems and pastures were 97.9, 90.2, 89.0 and 86.4 gm/kg $BW^{.75}$, respectively. The reduction in forage intake in the summer and fall is attributed to decreased forage quality. Forage intake on the grazing system pastures in 1977 and 1978 is presented in Table 47.

Forage intake was combined with diet quality data to determine if predicted digestible energy and crude protein intake requirements were met. The N.R.C. (1976) recommends that a 350 kg pregnant yearling heifer receive 0.63 kg of crude protein and 16.1 Mcal of digestible energy for 0.5 kg daily gain. The requirements for a 350 kg lactating cow are .75 kg of crude protein and 20.7 Mcal of digestible energy. Although the intake data were collected with fistulated cows, it does have application to other classes of animals when converted to gm/kg $BW^{.75}$. When these data were used as forage consumption for 350 kg yearling heifers and lactating cows, crude protein intake values for the late spring, early summer, late summer and fall pooled across years and pastures are 0.91, 0.67, 0.52 and 0.55 kg, respectively. Predicted digestible energy intake values were 18.5, 14.8, 13.6 and 13.4 Mcal, respectively. These data show that heifers were deficient in crude protein in the late summer and fall

TABLE 47. Forage Intake in gms/kg BW$^{.75}$ on the Grazing Systems Pastures in 1977 and 1978.

Sampling Period [1/]	Rest-rotation	Season-long	Deferred-rotation [2/]
	1977 Grazing Season		
Late spring	99.5	92.6	
Early summer	86.9	90.2	
Late summer	92.0	83.1	91.1
Fall	88.9	91.1	83.5
	1978 Grazing Season		
Late spring	101.0	99.9	103.0
Early summer	90.0	93.5	96.3
Late summer	90.0	88.8	
Fall	79.2	86.2	

1/ The rest-rotation and season-long pastures did not differ significantly ($P > .05$) during the four periods.

2/ The deferred-rotation pasture was not included in the statistical analysis.

while digestible energy deficiencies existed during the entire summer and fall. Lactating cows would have been deficient in both crude protein and digestible energy throughout the grazing season. When values were pooled by period, heifers consumed 94% of their digestible energy requirements and 105% of their crude protein requirements. These data are consistent with data from the complementary grazing study which showed digestible energy was probably more limiting to livestock production than crude protein intake. Crude protein and digestible energy intake values in 1976, 1977 and 1978 are given in Appendix U.

Livestock Performance

Covariance analysis was used to determine if a relationship existed between weights at the beginning of each period and average daily gains on the deferred-rotation, rest-rotation and season-long grazing system pastures. The regression was not significant ($P > .05$) for any of the periods of study. Therefore, actual weight gains were used in the analysis of variance. The deferred-rotation pasture was not included in the statistical analysis because it was grazed for only one-half the grazing season of each year.

When average daily gains were pooled across years and periods, the main effect of grazing system was not significant ($P < .05$). However, the main effects of year and period were significant at the

5% level. Average daily gains for three years of study pooled across grazing systems and periods for 1976, 1977 and 1978 were 0.66, 0.53 and 0.54 kilograms, respectively. Average daily gains in 1976 were significantly higher ($P < .05$) than during the other two years. Average daily gains were significantly higher ($P < .05$) in the late spring than in the other periods. Average daily gains for the late spring, early summer, late summer and fall were 0.84, 0.54, 0.43 and 0.46, respectively.

During all three years of study, there was no significant ($P > .05$) difference in cattle performance between rest-rotation and season-long grazing systems. However, there were significant differences ($P < .05$) between the two systems during different periods (Table 48).

Performance on the season-long pasture was significantly ($P < .05$) better than on the rest-rotation pasture in the early summer of 1977. This is attributed to low IVDMD and high lignin values in diet samples collected on the rest-rotation pasture. When rest-rotation cattle were moved to a fresh pasture at mid-season, they performed significantly better ($P < .05$) than season-long cattle. Diet quality improved after movement. This is contradictory to research reported by Smoliak (1960) showing decreased cattle performance after movement under rotation grazing. Data from the present study may be confounded by vegetation differences in the two

TABLE 48. Average Daily Gain (kg) for Cattle on the Grazing System Pastures in 1976, 1977 and 1978.

Grazing Period 1/ 2/	Rest-rotation	Season-long	Deferred-rotation 3/
	1976 Grazing Season		
Late spring	0.73	0.78	0.58
Early summer	0.68[a]	0.53[b]	0.39
Late summer	0.70	0.63	--
Fall	0.56	0.66	--
$\bar{X}$ Daily gain	0.68	0.64	0.48
	1977 Grazing Season		
Late spring	0.95	0.76	
Early summer	0.08[b]	0.70[a]	
Late summer	0.71[a]	0.05[b]	0.74
Fall	0.31	0.31	0.12
$\bar{X}$ Daily gain	0.51	0.55	0.43
	1978 Grazing Season		
Late spring	0.86	0.92	0.71
Early summer	0.65	0.60	0.80
Late summer	0.15[b]	0.30[a]	--
Fall	0.36[b]	0.55[a]	--
$\bar{X}$ Daily gain	0.51	0.57	0.76

1/ Means with different letters were significantly different ($P < .05$).

2/ Statistical tests apply only across columns.

3/ The deferred-rotation pasture was not included in the statistical analysis.

rest-rotation pastures.

Linear regression and correlation analysis was used to determine if a relationship existed between the components of diet quality and average daily gains. Data from the deferred-rotation pasture were used in the analysis. The highest coefficient of determination was between crude protein and average daily gain ($r^2 = .67$). The coefficients of determination for IVDMD, ADF and lignin were 0.55, 0.20, and 0.24, respectively. Multiple regression was used to determine the relationship between average daily gain and all the components of diet quality. The best equation that could be developed is as follows:

$$Y = 0.064 X_1 + 0.015 X_2 - 0.704$$

Y = average daily gain; X = crude protein

X_2 = <u>in vitro</u> dry matter digestibility

The regression was significant ($P < .05$) ($R^2 = .74$).

Livestock performance data in 1977 and 1978 were regressed with predicted digestible energy and crude protein intake. The resulting equation is as follows:

$$Y = 0.911 X_1 + 0.063 X_2 - 1.145$$

Y = average daily gain (kg)

X_1 = crude protein intake (kg)

X_2 = digestible energy intake (Mcal)

This equation accounted for 85% of the variation in livestock performance in 1977 and 1978. When simple linear regressions were run with average daily gain as the dependent variable, the coefficients of determination for crude protein and predicted digestible energy intake were 0.58 and 0.76, respectively. The regression equation for estimation of livestock performance using predicted digestible energy intake is the following:

$$Y = 0.103\ X - 1.061\ X$$

Y = average daily gain

X = digestible energy intake

As on the complementary grazing study, most of the variation in livestock performance on the grazing system pastures was accounted for by predicted digestible energy intake.

SUMMARY AND CONCLUSIONS

The objectives of this investigation were to determine cattle performance, diet quality, botanical composition of forage ingested and forage intake on three vegetation types and three grazing systems. These parameters were evaluated within the 1976, 1977 and 1978 grazing seasons at the Starkey Experimental Range and Forest in northeastern Oregon. The three vegetation types that were evaluated included grassland, forest and meadow types. Rest-rotation, season-long and deferred rotation grazing systems were compared.

Esophageal fistulated cows were used to evaluate diet quality and botanical composition of the diet. Crude protein, acid detergent fiber, lignin and in vitro dry matter digestibility were used to evaluate nutritional quality of esophageal samples. Botanical composition of diet samples was determined with the microhistological technique described by Sparks and Malechek (1968).

Forage intake was evaluated using the method described by Van Dyne (1968). Four steers were used for fecal collections on the forest and grassland vegetation types. Three esophageal fistulated cows were used for fecal collections on each of the grazing system pastures.

Cattle performance was evaluated with a portable scale and corral. Yearling heifers were used for cattle performance evaluation on both investigations during the three years of study. Cattle were weighed onto the pastures, and weight data were collected during four periods. Late spring, early summer, late summer and fall periods were June 20 to July 18, July 19 to August 15, August 16 to September 12 and September 13 to October 10, respectively.

Precipitation conditions were much different in the three years of study. Heavy rainfall occurred in the middle part of the 1976 grazing season which resulted in high regrowth availability on grassland areas in the late summer and fall. The winter and spring of 1977 were quite dry. Forage matured in the early part of July which was about two weeks earlier than in 1976. Heavy rainfall in the late summer resulted in considerable regrowth availability in the fall on the grassland areas. In 1978, precipitation was much higher in the spring and early summer than in 1976 or 1977. However, the latter part of the grazing season was quite dry, and very little regrowth was available on the grassland in the fall.

The Complementary Grazing Study

Botanical Analysis

Diets on the forest and grassland were very different during the three years of study. However, Idaho fescue was the most important species found in diet samples on both vegetation types.

Grasses were the most important forage class consumed by cattle on the two vegetation types. Grasses comprised 80% and 61% by weight of the diet on the forest and grassland, respectively, when samples were pooled by year and period.

Trends in forb consumption were the same on both pastures. During the late spring, forbs comprised 27% of the diet when samples were pooled across vegetation types and years. During the late summer, forb consumption dropped to 14% of the diet, and continued to decrease during the remainder of the grazing season. The reduction in forb consumption with the advance of the grazing season is attributed to decreased palatability and availability.

Browse was much more available on the forest than on the grassland. Browse comprised 23% and 6% of the diet on the forest and grassland, respectively, when samples were pooled across years and periods.

Cattle diets on the grassland were very similar during the three years of study. However, there was considerable variation between the four periods. Diets in the late spring were different than in the other three periods because the forb content of the diet declined drastically during the early summer.

There was considerable difference in cattle diets between both years and periods on the forest. Browse consumption by the cattle was especially erratic; grass and forb consumption was much less variable.

The most important species found in cattle diets on the grassland were Idaho fescue, bluebunch wheatgrass, Sandberg bluegrass and snowberry. Idaho fescue and bluebunch wheatgrass comprised 29% and 28%, respectively, of cattle diets on the grassland. Idaho fescue appeared to be much more preferred since it was less available than bluebunch wheatgrass. Sandberg bluegrass was the most available grass on the grassland although it comprised only 8% of the diet by weight. Sandberg bluegrass matures earlier than most of the other grasses on the study area which may explain why it received little use in relation to its availability.

Idaho fescue, elk sedge and snowberry were the most important species found in cattle diets on the forest. These species comprised 23%, 12% and 10%, respectively, of diet samples pooled across years and periods on the forest. The consumption of Idaho fescue was highest in the middle part of the grazing season, while elk sedge consumption increased as the grazing season advanced. Snowberry consumption was very erratic in different periods and years.

Diet selection was heavily related to plant community use on both the forest and grassland. The most preferred plant community on both vegetation types was the ponderosa pine/Idaho fescue community. This community occupied approximately 15% of each vegetation type. However, it received heavy use on the forest and grassland throughout the grazing season during all three years of study.

The bluebunch wheatgrass/Sandberg bluegrass plant community received considerable use on the grassland. This plant community occupied about 40% of the grassland pastures. Use of this community appeared to be proportional to availability.

Plant communities dominated by Sandberg bluegrass occupied about 30% of the grassland pastures, but these communities recieved very little use.

In the latter half of the grazing season, fistulated cattle on the forest showed a preference for the ponderosa pine/snowberry/elk sedge, Douglas fir/ninebark and Douglas fir/snowberry/elk sedge plant communities. Elk sedge was highly available in these communities, and was very important in cattle diets in the fall period.

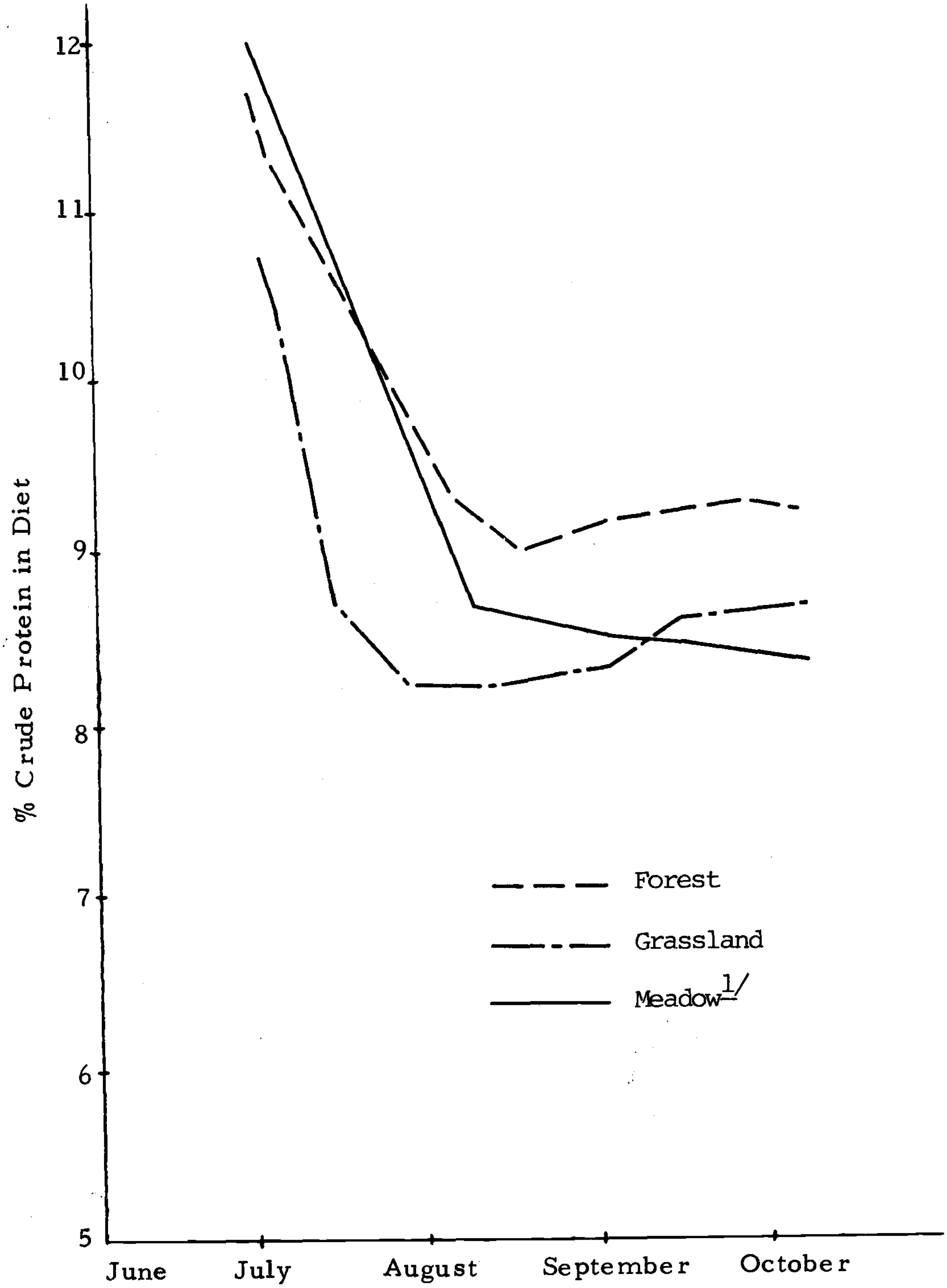
Two plant communities on the forest were avoided by fistulated cattle during the three years of study. These included the Douglas fir/twinflower and the Grand fir/twinflower communities, which together, comprised about 30% of the forest pastures. However, they produced little forage because of shading by the trees. Pickford and Reid (1948) reported these areas were practically worthless for grazing. However, Hedrick et al. (1968) reported that yearling heifers would voluntarily graze these areas but they were avoided by cows and calves. They recommended salting and riding as practices to improve use of heavily forested areas.

Cattle on both vegetation types were moved to an ungrazed pasture of approximately the same vegetation composition and structure at mid-season in 1977. Cattle diets on the grassland showed little change after movement. However, diets on the forest were much different in the late summer than in the early summer. The weather changed and may have influenced cattle use of different forest plant communities. Another possibility is that the fresh pasture provided the opportunity for greater selectivity.

The meadow vegetation type was not compared statistically to the grassland and forest because management was different. Grasses, forbs and shrbus comprised 80%, 12% and 8% by weight of the diet, respectively, on the meadow when samples were pooled across years and periods. Kentucky bluegrass was the most important species found in cattle diets on the meadow. Cattle diets on the meadow showed little variation between years and periods.

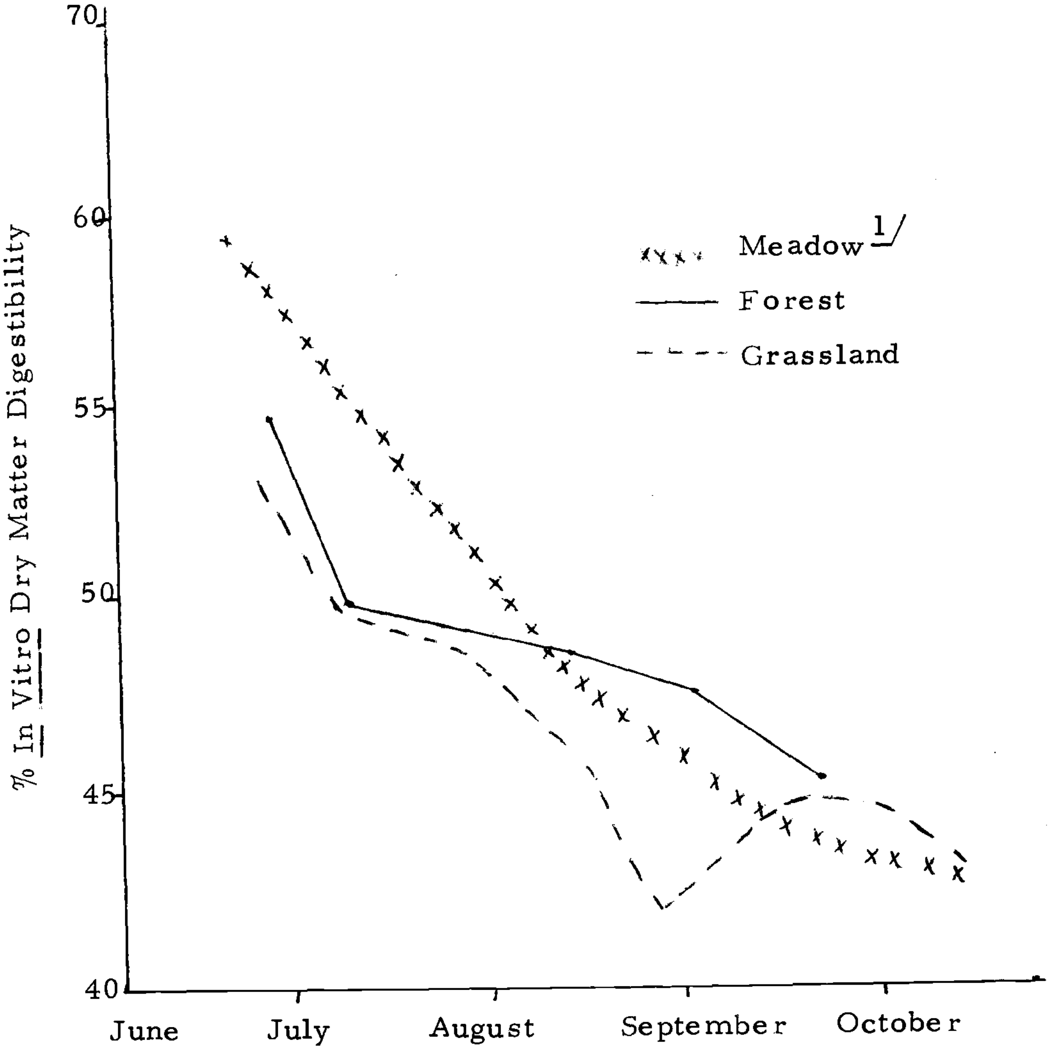
Diet Quality

During the three years of study, there was considerable difference in diet quality on the forest, grassland and meadow. Crude protein and IVDMD gave the most interpretable explanation of diet quality. The trends in crude protein and IVDMD on the forest, grassland and meadow are presented in Figures 2 and 3 when samples were



1/ Values for the meadow in the first period came from the grazing systems pastures.

Figure 2. The trend in crude protein in diet samples collected on the grassland, forest and meadow pooled across years.



1/ Values for the meadow in the first period came from the grazing systems pastures.

Figure 3. The trend in *in vitro* dry matter digestibility of diet samples collected on the grassland, forest and meadow pooled across years.

pooled across years. Diet samples collected on the meadow showed the greatest decline in crude protein and IVDMD with seasonal advance. During the latter half of the grazing season, crude protein and IVDMD values for diet samples were lower on the meadow than on the forest and grassland.

During the late spring, crude protein and IVDMD were very similar on the forest and grassland in all three years of study. However, in the summer, diet samples from the forest were higher in crude protein and IVDMD than those from the grassland. Considerable difference existed between the forest and grassland in the fall during individual years. In 1976 and 1977, when regrowth was available on the grassland, IVDMD values for diet samples collected on the grassland were higher than those from the forest. Crude protein values were similar. Crude protein and IVDMD values were higher on the forest than on the grassland in the fall of 1978 when little regrowth was available.

The protein requirements for growing heifers, as outlined by the N.R.C. (1976), indicate that 350 kg heifers require 8.2% crude protein for a 0.5 kg gain. This requirement was met on both the grassland and forest throughout the grazing season in 1976. However, in 1977 and 1978, grassland cattle diets were deficient in crude protein in the summer and fall. Cattle diets on the forest were deficient in crude protein in the late summer in 1977.

The movement of cattle at mid-season in 1977 did not result in improved diet quality on the grassland. However, crude protein and IVDMD percentages in diet samples were higher on the forest after the movement.

Regression and correlation analysis was used to determine if a relationship existed using individual forage classes as dependent variables and crude protein and IVDMD values as independent variables for individual diet samples collected on the forest. The correlations were not significant ($P > .05$). It appears that diet quality was higher on the forest than on the grassland in the summer because forage was less mature. However, no conclusions can be drawn concerning individual species or forage classes. Pickford and Reid (1948) and Skovlin (1967) did report elk sedge was higher in crude protein at the Starkey Range than Idaho fescue or bluebunch wheatgrass in the latter part of the grazing season. This species was very important in cattle diets on the forest in the late summer and fall periods.

IVDMD values were converted to digestible energy using the prediction equation of Rittenhouse et al. (1971). Predicted digestible values were below the N.R.C. (1976) required values for 350 kg yearling heifers to gain 0.5 kg throughout the grazing season in all three years of study.

Forage Intake

Forage intake data were consistent with diet quality data. Forage intake was higher on the grassland compared to the forest in the late spring in all three years of study. During the summer, intake was highest on the forest. In the fall, there was little difference in intake between the two vegetation types when collections were pooled across years. However, there was considerable difference during different years. In 1976 and 1977, when forage regrowth was available, intake was highest on the grassland. During the 1978 grazing season, regrowth was not available in the fall and intake was higher on the forest than on the grassland.

The reduced intake on the grassland compared to the forest in the middle part of the grazing season is attributed to both reduced diet quality and animal comfort. Cattle on the forest spent much time grazing in the shaded areas during the summer. In contrast, cattle on the grassland spent most of their time resting.

When cattle were moved to a fresh pasture at the end of the early summer period in 1977, intake did not change on the forest. However, it decreased on the grassland. The decreases in intake on the grassland is attributed to the reduction in diet quality that occurred during this period.

Crude protein intake was sufficient on the forest during all three years to meet the N. R. C. (1976) requirement for a 350 kg heifer to gain 0.5 kg per day. However, cattle on the grassland did not satisfy this requirement during the summer in 1977 and 1978. Cattle on both the forest and grassland did not consume enough digestible energy in any period of study to meet the N. R. C. (1976) requirement. Because steers used for estimating intake were under stress during fecal collections, estimates of digestible energy and crude protein intake could be low.

Livestock Performance

Cattle performance was significantly higher ($P < .05$) on the forest than on the grassland when average daily gains were pooled across years and periods. However, there was considerable difference in livestock performance in different years and periods.

Livestock performance was significantly higher ($P < .05$) on the grassland than on the forest during the first period when gains were pooled across years. However, during the summer, average daily gains were significantly higher ($P < .05$) on the forest than on the grassland. There was no difference in the performance of cattle on the forest and grassland in the fall.

In the fall, considerable difference existed between the two vegetation types within individual years. In 1976 and 1977, cattle performed significantly better ($P < .05$) on the grassland than on the forest. This is attributed to the high availability of regrowth on the grassland. The latter part of the grazing season in 1978 was quite dry and little forage regrowth was available on the grassland. Average daily gains were significantly higher ($P < .05$) on the forest than on the grassland.

The movement of cattle at mid-season in 1977 resulted in improved livestock performance on the forest. However, average daily gains on the grassland were reduced. Diet quality and forage intake were lower on the grassland after movement. The reverse was true on the forest. These two factors probably explain why cattle on the forest and grassland responded differently to the pasture change.

When crude protein and predicted digestible energy intake values were used as independent variables and average daily gain was used as a dependent variable, the coefficient of determination was .83. Predicted digestible energy intake accounted for more variation in livestock performance than crude protein intake.

Livestock Management Recommendations

In most parts of the Blue Mountains of northeastern Oregon, forest and grassland vegetation types occupy large enough areas that it is practical to fence them as discrete units. The data presented on diet quality, forage intake and livestock performance indicate the grassland vegetation type should be used in the spring and early summer. In the middle part of July, cattle should be moved onto the forest vegetation type because more shade is available and forage is less advanced in phenological development. During years with precipitation in August and/or September, cattle should be moved back to the grassland in mid-September to make use of forage regrowth. When there is no late summer rainfall, cattle should remain on the forest until the end of the grazing season. If this grazing program had been used during the three years of study, average daily gains would have been 0.46 kg under the integrated system compared to 0.40 kg with forest use only and 0.33 kg with grassland use only. Total beef production under the integrated system would have been increased 15% over forest use only and 40% over grassland use only. If the selling price for a kg of beef was $1.54, the increase in value per animal per grazing season based on the three years of data would be $11 when the integrated system is compared to forest grazing only and $14 when the integrated system is compared to grassland use only.

Crude protein intake on the grassland was inadequate between the middle of July until the end of the grazing season in the early part of October in 1977 and 1978. Average daily gains were less than 0.5 kg. Protein supplementation may be a practical way to improve livestock performance in dry years on the grassland. However, this needs investigation.

The relatively low predicted digestible energy intake values on both vegetation types between the middle of July and early October indicated digestible energy may be more limiting to livestock performance than crude protein. However, energy supplementation would probably not be practical because of logistical problems. In addition, it may result in less efficient use of range forage.

Harris (1968) reported supplying deficient protein may increase the digestibility of other nutrients in the diet. Where browse comprises much of the diet, protein supplementation is less advantageous because desirable browse species usually contain adequate protein (Cook and Harris, 1968).

Wallace et al. (1963) reported protein supplementation extended gains of calves and yearlings on spring and summer range in the Northwest, but it was not always profitable. On summer and fall range in Utah, a protein supplement increased gains of lactating cows but not of calves or yearlings (Harris et al., 1963). Obviously, if protein supplementation is to be profitable, increased weight must be marketed.

Average daily gains were above 0.50 kg throughout the grazing season on the forest and grassland in 1976 when there was heavy late summer rainfall. Diet quality and forage intake during the 1976 grazing season were much higher than in 1977 or 1978. It appears that late summer rainfall is essential for sustained livestock performance in the latter part of the grazing season on the Starkey Range. When heavy late summer rainfall occurs, it may be economical to extend the grazing season. However, in dry years, it may be practical to terminate grazing in September.

Because yearling heifers were used to evaluate livestock performance, it is possible that the results would have been different if cows and calves had been used. However, the trends in diet quality, forage intake and livestock performance were consistent with each other. In addition, the differences in these parameters between the forest and grassland were reasonably similar during the three years of study. Although more data would be useful, it is believed that the management recommendations could be successfully applied to a cow-calf operation.

The Grazing Systems Study

Botanical Analysis

Grasses comprised 62% of cattle diets by weight on the rest-rotation and season-long pastures when samples were pooled across grazing systems, periods and years. Forbs and shrubs contributed 20% and 19% of the diet, respectively.

Idaho fescue, bluebunch wheatgrass, elk sedge and snowberry were the most important species found in cattle diets on the grazing system pastures. The percentages by weight of these species in the diet when samples were pooled across years, periods and pastures were 18%, 14%, 8% and 15%, respectively.

The amount of grass in diet samples increased with seasonal advance when samples were pooled across years. In contrast, forb consumption decreased with seasonal advance. The consumption of shrubs was highest in the middle part of the grazing season.

Cattle diets under the season-long and rest-rotation grazing systems did not differ significantly ($P > .05$). However, there were significant differences ($P < .05$) in the consumption of individual species. More bluebunch wheatgrass and less Idaho fescue were consumed under the rest-rotation system than under the season-long system. This is attributed to a difference in plant community structure on the pastures rather than to a grazing system effect.

When cattle diets were pooled across grazing systems and periods, a high degree of redundancy existed between years. However, there was considerable variation in diets during the four periods. Diets in the late spring were poorly correlated with the other periods. This is attributed to the rapid decline in forb consumption in the early summer period.

Diets on the deferred-rotation pasture were not compared statistically to the other pastures because this pasture was grazed for only one-half the grazing season in each year. However, when it was grazed, diets on this pasture were very similar to the season-long and rest-rotation pastures.

During collections, the south slope of the pastures was more heavily sampled than the north slope because cattle use on the north slope was light. The ponderosa pine/Idaho fescue plant community appeared to be highly preferred throughout the grazing season on the pastures where it was available. The bluebunch wheatgrass/Sandberg bluegrass plant community received considerable use on the deferred-rotation pasture and rest-rotation pasture 1. This community was nearly absent on the other pastures.

The north slope appeared to be more heavily used under the rest-rotation system than under the season-long system. However, because utilization data were not collected, no conclusions can be made.

Cattle were moved to a fresh pasture at mid-season under the rest-rotation system in 1977. The change of pasture did not result in a significant ($P > .05$) change in cattle diets.

In 1976 and 1977, forage regrowth was available on the grassland areas of the grazing system pastures in the fall. Cattle on all the pastures made heavy use of the regrowth. In 1978, very little regrowth occurred in the latter half of the grazing season. The forested plant communities received considerable use in the fall.

Cattle diets contained a large amount of elk sedge and snowberry on both the rest-rotation and season-long pastures when cattle used the forested communities.

Diet Quality

There was little difference in cattle diet quality under the season-long and rest-rotation grazing systems during the three years of study. When diet samples were pooled across years, crude protein and IVDMD values did not differ significantly ($P > .05$) between the two grazing systems in the four periods. However, the interaction between period and year was significant ($P < .05$) for both crude protein and IVDMD. During the late summer in 1977 and 1978, crude protein and predicted digestible energy values on all the grazing system pastures were below the value recommended by the N. R. C. (1976) for lactating cows and yearling heifers to gain 0.5 kg per day.

The movement of cattle at mid-season in 1977 under the rest-rotation system did not result in any significant ($P > .05$) change in the crude protein or IVDMD values of diet samples. Crude protein and IVDMD values did not differ significantly ($P > .05$) between the rest-rotation and season-long pastures in the late summer following movement.

In 1976 and 1978, grazing pressure on the rest-rotation pasture was twice that on the season-long pasture. However, there was no difference in crude protein and IVDMD values on the two pastures when diet samples were pooled across periods. It may be that the stocking rate was too light on the pastures to greatly reduce forage selectivity. Forage production in both 1976 and 1978 was above average and results may have been different in a year of reduced forage availability.

Forage Intake

Forage intake was evaluated on the grazing systems pastures in 1977 and 1978. There were no significant ($P < .05$) differences in forage intake under the two systems in either year of study. When collections were pooled across pastures and years, intake was significantly higher ($P < .05$) in the early spring than in the other three periods. Reduced diet quality probably accounts for the lower intake values in the summer and fall.

When cattle under the rest-rotation system moved to a fresh pasture at mid-season in 1977, forage intake did not change in the late summer after movement.

Grazing pressure was twice as heavy on the rest-rotation pasture as on the season-long pasture in 1978. When collections were pooled across periods, there was no significant difference ($P > .05$) in intake under the two systems.

Livestock Performance

Average daily gains did not differ significantly ($P < .05$) between the season-long and rest-rotation grazing systems in any of the three years of study. The mean overall daily gains for the rest-rotation, season-long, and deferred-rotation grazing systems were 0.56, 0.57, and 0.53 kg, respectively.

Average daily gains were significantly higher in the late spring than in the other periods when samples were pooled across years and pastures. The decline in diet quality and forage intake are probable reasons for the reduction in livestock performance as the grazing season advanced.

The movement of cattle to a fresh pasture under the rest-rotation system at mid-season in 1977 resulted in a significant increase ($P < .05$) in livestock performance. Smoliak (1966) and Hormay (1970) reported forced movements of cattle to another pasture can result in weight losses. More data will be needed from the pastures in this study before any conclusions can be drawn concerning the effect of pasture change on livestock performance.

Grazing pressure was twice as heavy on the rest-rotation pasture as on the season-long pasture in 1976 and 1978. However, there was no difference in livestock performance between the two systems when average daily gains were pooled across periods.

Predicted digestible energy and crude protein intake accounted for 85% of the variation in livestock performance in 1977 and 1978. As on the complementary grazing study, predicted digestible energy intake accounted for more variation in livestock performance than crude protein intake.

Conclusions

It appears that there was no difference in diet quality, forage intake and average daily gains between a rest-rotation and season-long grazing system at the Starkey Experimental Range during the 1976, 1977 and 1978 grazing seasons.

Livestock diets were very similar under the two systems although there were some differences in consumption of individual species on the grazing systems pastures. More bluebunch wheatgrass and less Idaho fescue were consumed under the rest-rotation grazing system probably because vegetation structure was different on the season-long and rest-rotation pastures.

No conclusions can be made concerning livestock performance or diet quality under the deferred-rotation, rest-rotation and season-long grazing systems used in this study. The effect of grazing system was partially confounded by differences in topography and vegetation structure on the grazing system pastures. Several years are usually required for vegetation change to take place. Vegetation availability has been shown to influence both diet quality and livestock performance (Klipple and Costello, 1960; Vavra, 1972; Launchbaugh, 1957). A heavier stocking rate may have resulted in diet quality, forage intake and livestock performance differences between the rest-rotation and season-long pastures. The fact cattle diet quality and performance on the heavy use rest-rotation pasture and the season-long pasture did not differ significantly ($P < .05$) in 1976 or 1978 suggests the stocking rates used in this study were light. However, little can be concluded regarding stocking rate because utilization data were not collected. It is recommended that in the future forage availability and utilization data be collected from the primary plant communities found on each pasture. These data would allow more meaningful interpretation of diet quality, diet botanical composition, forage intake and livestock performance data. Until additional treatment time has passed and any resultant changes in vegetative structure and/or composition have occurred, it is impossible to recommend any particular grazing system over another based upon animal performance and diet characteristics.

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APPENDICES

APPENDIX A

Formulae for Hoyer's Mounting Medium and Hertwig's Clearing Solution (Ward, 1970)

Hoyer's Mounting Medium

20% gum arabic

35% distilled water

12% glycerin

30% chloral hydrate

3% glucose

Hertwig's Clearing Solution

19 cc HCl added to 150 cc water

60 cc glycerine

270 g chloral hydrate crystals

APPENDIX B. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Grassland

Species	Year	PERIOD 1	2	3	4
Bluebunch wheatgrass	1976	16 (4.1)	28 (2.8)	34 (4.8)	36 (4.8)
Agropyron spicatum	1977	28 (2.6)	33 (4.3)	38 (5.8)	39 (3.7)
	1978	11 (2.9)	26 (3.3)	33 (4.2)	28 (3.3)
Idaho fescue	1976	18 (4.9)	36 (4.7)	35 (6.8)	34 (7.0)
Festuca idahoensis	1977	41 (3.9)	34 (6.0)	32 (6.0)	23 (4.1)
	1978	11 (2.4)	26 (5.4)	33 (2.4)	28 (3.3)
Prairie junegrass	1976	3 (1.3)	4 (2.1)	3 (1.7)	4 (1.2)
Koeleria cristata	1977	2 (1.5)	1 (0.5)	2 (1.2)	4 (2.4)
	1978	2 (1.2)	1 (0.5)	1 (0.3)	7 (1.9)
Subalpine needlegrass	1976	5 (2.1)	2 (1.3)	4 (1.2)	3 (1.4)
Stipa occidentalis	1977	T	--	T	T
	1978	T	--	--	T
Sandberg bluegrass	1976	2 (1.6)	5 (1.5)	3 (1.8)	1 (0.6)
Poa sandbergii	1977	2 (0.5)	2 (1.0)	5 (1.6)	12 (4.2)
	1978	18 (5.1)	16 (4.8)	15 (5.1)	14 (3.6)
Cheatgrass brome	1976	1 (0.7)	3 (2.3)	3 (2.7)	1 (0.6)
Bromus tectorum	1977	T	--	--	T
	1978	1 (0.7)	2 (0.7)	3 (1.5)	5 (1.2)
Onespike-danthonia	1976	1 (0.9)	3 (2.6)	1 (0.6)	2 (0.9)
Danthonia unispicata	1977	1 (0.3)	1 (0.4)	4 (2.1)	1 (0.5)
	1978	T	T	T	2 (1.02)
Total grasses	1976	64 (8.8)	86 (6.6)	90 (7.0)	85 (5.4)
	1977	78 (3.7)	79 (6.0)	90 (2.6)	91 (2.6)
	1978	54 (8.0)	70 (6.5)	90 (4.2)	89 (3.0)
Western yarrow	1976	5 (1.8)	1 (0.5)	4 (1.5)	3 (1.2)
Achillea millefolium	1977	3 (1.0)	3 (1.0)	1 (0.9)	1 (.45)
lanulosa	1978	10 (4.6)	4 (2.4)	2 (1.2)	1 (0.5)
Wyeth eriogonum	1976	T	T	T	T
Eriogonum hieracleo-	1977	3 (1.2)	4 (1.2)	1 (1.1)	T
ides	1978	3 (1.8)	10 (3.6)	T	T

APPENDIX B. continued

Species	Year	PERIOD 1	2	3	4
Arrowleaf balsamroot	1976	3 (1.5)	T	T	--
Balsamorhiza	1977	2 (0.9)	2 (0.9)	--	T
sagittata	1978	10 (3.8)	T	--	T
Lupine	1976	4 (1.8)	T	T	--
Lupinus spp.	1977	T	--	T	--
	1978	4 (1.3)	5 (2.7)	--	T
Mules ear	1976	1 (0.6)	T	--	--
Wyethia amplexicaulis	1977	T	--	--	--
	1978	3 (2.4)	2 (2.1)	T	T
Total forbs	1976	28 (4.6)	8 (1.5)	7 (1.8)	7 (1.5)
	1977	16 (1.8)	14 (1.8)	5 (2.0)	4 (1.2)
	1978	41 (6.4)	25 (5.7)	4 (1.5)	5 (2.4)
Snowberry	1976	7 (2.7)	4 (0.8)	4 (1.6)	7 (3.3)
Symphoricarpos albus	1977	5 (1.2)	4 (1.8)	4 (2.1)	4 (1.5)
	1978	3 (1.8)	4 (1.5)	5 (1.2)	5 (1.8)
Total shrubs	1976	8 (3.3)	6 (0.9)	3 (0.6)	8 (3.3)
	1977	6 (1.2)	7 (3.4)	5 (1.9)	5 (1.8)
	1978	5 (2.8)	5 (2.1)	6 (3.0)	6 (1.8)

T = Trace

APPENDIX C. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Forest.

Species	Year	PERIOD 1	2	3	4
Idaho fescue	1976	9 (2.6)	28 (5.3)	29 (4.8)	20 (2.0)
Festuca idahoensis	1977	18 (3.8)	28 (3.9)	29 (5.1)	27 (4.2)
	1978	31 (8.4)	22 (5.1)	17 (6.1)	13 (2.8)
Elk sedge	1976	9 (1.8)	10 (3.8)	4 (0.7)	17 (2.1)
Carex geyeri	1977	2 (0.7)	7 (3.2)	23 (5.7)	24 (5.6)
	1978	5 (0.9)	8 (2.9)	8 (2.2)	22 (5.8)
Bluebunch wheatgrass	1976	3 (0.8)	14 (5.2)	13 (3.6)	6 (2.4)
Agropyron spicatum	1977	2 (0.7)	2 (0.9)	5 (2.0)	2 (0.8)
	1978	1 (1.1)	5 (1.8)	2 (0.6)	T
Pinegrass	1976	2 (0.4)	T	2 (5.3)	1 (0.5)
Calamagrostis rubescens	1977	2 (0.9)	6 (2.2)	2 (0.7)	3 (0.8)
	1978	2 (1.2)	2 (1.1)	T	5 (2.7)
Western fescue	1976	4 (1.4)	4 (1.4)	4 (1.7)	3 (1.3)
Festuca occidentalis	1977	2 (0.9)	3 (1.5)	1 (0.7)	T
	1978	3 (0.9)	3 (1.6)	18 (4.8)	3 (1.5)
Kentucky bluegrass	1976	4 (1.2)	6 (2.0)	4 (1.4)	1 (0.6)
Poa pratensis	1977	3 (1.7)	3 (0.9)	5 (2.7)	4 (2.4)
	1978	4 (1.9)	T	2 (1.4)	8 (6.1)
One-spike danthonia	1976	3 (1.3)	1 (0.5)	5 (1.4)	2 (0.5)
Danthonia unispicata	1977	T	T	T	2
	1978	2 (0.9)	4 (1.9)	1 (0.5)	1 (0.6)
Tall oatgrass	1976	T	T	T	--
Arrhenatherum elatius	1977	T	--	T	--
	1978	2 (1.5)	T	T	2 (0.9)
Sandberg bluegrass	1976	T	T	T	1
Poa sandbergii	1977	2 (1.1)	T	4 (2.1)	T
	1978	1 (0.6)	--	--	T
Total grasses	1976	49 (4.2)	73 (8.2)	76 (3.3)	58 (4.8)
	1977	36 (5.3)	57 (6.8)	83 (4.4)	76 (4.3)
	1978	52 (6.1)	67 (2.5)	37 (9.3)	74 (5.6)

APPENDIX C. continued

Species	Year	PERIOD 1	2	3	4
Western yarrow	1976	3 (1.3)	1 (0.6)	3 (1.5)	1 (0.5)
Achillea millefolium	1977	T	2 (1.1)	2 (1.3)	2 (1.1)
lanulosa	1978	1 (0.7)	1 (0.8)	2 (1.1)	2 (1.5)
Heartleaf Arnica	1976	14 (3.0)	6 (3.5)	3 (1.5)	T
Arnica cordifolia	1977	5 (2.4)	1 (1.1)	T	T
	1978	3 (0.9)	1 (0.7)	1 (0.6)	--
Western hawkweed	1976	2 (1.3)	2 (1.5)	T	--
Hieracium spp.	1977	2 (1.1)	T	T	T
	1978	2 (1.5)	2 (1.4)	T	T
Lupine	1976	3 (1.8)	T	--	--
Lupinus spp.	1977	4 (2.1)	T	--	T
	1978	3 (1.6)	1 (0.6)	1 (0.5)	1 (0.6)
Total forbs	1976	36 (2.1)	14 (5.7)	11 (1.7)	12 (2.2)
	1977	26 (3.3)	13 (4.6)	7 (2.3)	6 (2.3)
	1978	25 (4.0)	12 (2.0)	16 (5.7)	10 (4.0)
Snowberry	1976	9 (2.3)	8 (2.0)	9 (2.8)	20 (5.7)
Symphoricarpos albus	1977	24 (4.5)	13 (3.9)	9 (3.3)	7 (1.8)
	1978	8 (2.4)	8 (2.5)	9 (1.8)	6 (4.0)
Spiraea	1976	5 (1.6)	3 (1.7)	1 (0.5)	5 (1.3)
Spiraea betulifolia	1977	8 (2.4)	4 (2.1)	T	1 (0.6)
lucida	1978	3 (1.1)	5 (1.7)	18 (5.9)	3 (1.1)
Ninebark	1976	--	--	--	3 (1.1)
Physocarpus malvaceus	1977	5 (3.8)	12 (7.9)	T	8 (5.4)
	1978	7 (6.0)	6 (2.2)	12 (5.4)	3 (3.7)
Wax Currant	1976	T	1 (0.5)	1 (0.6)	1 (0.4)
Ribes cereum	1977	--	--	T	2 (1.1)
	1978	2 (1.1)	1 (0.4)	6 (2.5)	3 (1.1)
Total shrubs	1976	15 (3.9)	12 (3.0)	13 (2.7)	30 (4.6)
	1977	38 (7.0)	30 (7.7)	10 (3.0)	18 (5.6)
	1978	23 (6.0)	21 (3.1)	47 (10.5)	16 (6.7)

T = Trace

APPENDIX D. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Meadow.

Species	Period	YEAR 1976	1977	1978
Kentucky bluegrass	3	12 (2.0)	10 (4.4)	12 (2.3)
Poa pratensis	4	15 (3.5)	8 (0.6)	15 (4.0)
Western fescue	3	7 (1.3)	7 (1.6)	7 (1.5)
Festuca occidentalis	4	6 (2.4)	13 (2.6)	6 (2.8)
Small fruited bulrush	3	10 (2.1)	9 (3.2)	8 (1.0)
Scirpis microcarpus	4	6 (2.3)	6 (1.9)	6 (2.7)
Spike bentgrass	3	9 (2.5)	6 (1.1)	9 (3.0)
Agrostis exarata	4	4 (1.2)	13 (1.0)	3 (1.6)
Timothy	3	4 (2.2)	2 (0.9)	5 (2.5)
Phleum pratense	4	5 (1.4)	3 (0.9)	5 (1.6)
Meadow foxtail	3	4 (1.9)	1 (0.4)	5 (2.9)
Alopecurus pratensis	4	7 (2.4)	3 (1.2)	7 (2.8)
Idaho fescue	3	6 (0.8)	4 (1.7)	6 (0.9)
Festuca idahoensis	4	12 (4.2)	7 (1.74)	11 (4.3)
California brome	3	T	2 (1.0)	T
Bromus carinatus	4	4 (2.2)	4 (1.4)	4 (2.6)
Carex species	3	3 (1.05)	7 (2.3)	4 (1.0)
Carex spp.	4	1 (0.3)	4 (2.0)	2 (0.7)
Juncus species	3	2 (1.0)	5 (1.5)	T
Juncus spp.	4	3 (0.4)	2 (0.7)	1 (0.7)

APPENDIX D. continued

Species	Period	YEAR 1976	1977	1978
Total grasses	3	75 (3.1)	72 (9.0)	73 (3.2)
	4	86 (3.3)	85 (2.2)	86 (2.5)
Western yarrow *Achillea millefolium lanulosa*	3	2 (1.2)	T	T
	4	4 (1.1)	T	4 (1.4)
Trifolium species *Trifolium* spp.	3	4 (1.3)	1 (0.6)	2 (1.3)
	4	1 (0.5)	T	2 (1.0)
Total forbs	3	18 (3.1)	14 (3.3)	18 (2.3)
	4	12 (1.8)	10 (2.0)	12 (1.8)
Snowberry *Symphoricarpos albus*	3	3 (1.2)	13 (9.0)	2 (1.6)
	4	T	2 (0.9)	4 (1.8)
Total shrubs	3	7 (2.3)	14 (6.30)	10 (2.5)
	4	2 (1.2)	5 (0.6)	2 (0.8)

T = Trace

APPENDIX E. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Rest-Rotation Pastures.

Species	Year	PERIOD 1	2	3	4
Idaho fescue	1976	15 (1.7)	10 (3.0)	16 (4.1)	21 (2.0)
Festuca idahoensis	1977	14 (3.1)	16 (2.5)	23 (3.6)	35 (5.3)
	1978	11 (3.21)	10 (2.5)	10 (3.5)	8 (2.5)
Bluebunch wheatgrass	1976	6 (1.2)	12 (4.3)	20 (3.3)	38 (4.6)
Agropyron spicatum	1977	2 (1.2)	8 (1.4)	18 (2.5)	25 (5.8)
	1978	7 (2.3)	24 (2.9)	33 (3.5)	22 (6.0)
Kentucky bluegrass	1976	5 (1.7)	5 (3.4)	3 (2.4)	1 (0.6)
Poa pratensis	1977	10 (3.8)	2 (0.9)	T	2 (0.7)
	1978	6 (1.5)	1 (0.7)	T	5 (1.0)
Sandberg bluegrass	1976	T	7 (2.4)	12 (1.5)	14 (2.1)
Poa sandbergii	1977	3 (1.5)	4 (1.6)	3 (0.4)	12 (1.2)
	1978	2 (1.7)	5 (1.7)	10 (1.7)	7 (1.0)
Elk sedge	1976	6 (1.6)	T	9 (2.5)	10 (2.5)
Carex geyeri	1977	1 (0.6)	14 (3.5)	11 (2.7)	15 (4.4)
	1978	1 (0.7)	10 (3.9)	6 (1.2)	18 (5.1)
Total grasses	1976	47 (1.5)	55 (3.2)	65 (3.1)	85 (3.1)
	1977	41 (5.5)	46 (4.2)	53 (3.5)	80 (2.2)
	1978	44 (4.7)	53 (4.2)	64 (1.5)	64 (5.2)
Trifolium species	1976	4 (1.1)	1 (0.6)	T	T
Trifolium spp.	1977	7 (1.9)	--	--	--
	1978	10 (1.0)	2 (2.0)	--	--
Western yarrow	1976	2 (0.9)	1 (0.7)	2 (0.8)	2 (0.6)
Achillea millefolium	1977	5 (1.8)	6 (2.5)	7 (1.5)	--
lanulosa	1978	6 (1.5)	2 (0.9)	2 (0.2)	1 (0.7)
Total forbs	1976	47 (1.4)	25 (4.3)	10 (2.1)	5 (1.4)
	1977	52 (6.4)	14 (1.8)	11 (3.1)	2 (1.5)
	1978	49 (6.8)	20 (4.7)	7 (1.2)	5 (1.8)

APPENDIX E. continued

Species	Year	PERIOD 1	2	3	4
Snowberry	1976	4 (1. 1)	12 (0. 8)	7 (1. 7)	4 (1. 7)
Symphoricarpos albus	1977	7 (2. 7)	25 (5. 1)	24 (2. 0)	9 (1. 04)
	1978	6 (2. 5)	21 (1. 8)	18 (1. 1)	19 (1. 8)
Ninebark	1976	1 (0. 6)	2 (1. 4)	16 (1. 9)	2 (0. 7)
Physocarpus	1977	--	12 (4. 0)	8 (3. 1)	6 (5. 9)
malvaceus	1978	T	1 (0. 6)	6 (2. 1)	4 (1. 7)
Total shrubs	1976	6 (1. 6)	20 (2. 9)	25 (3. 1)	10 (1. 4)
	1977	7 (2. 1)	40 (6. 3)	36 (3. 1)	18 (4. 4)
	1978	7 (2. 3)	27 (6. 4)	29 (3. 8)	31 (3. 9)

T = Trace

APPENDIX F. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Season-Long Pasture.

		PERIOD			
Species	Year	1	2	3	4
Idaho fescue	1976	15 (1.6)	15 (1.9)	41 (7.9)	29 (4.8)
Festuca idahoensis	1977	17 (1.9)	9 (0.8)	22 (5.8)	29 (4.2)
	1978	9 (4.2)	28 (2.7)	13 (1.5)	29 (3.3)
Bluebunch wheatgrass	1976	2 (1.2)	14 (1.3)	14 (1.8)	15 (3.2)
Agropyron spicatum	1977	9 (2.0)	3 (2.2)	16 (4.3)	19 (4.2)
	1978	5 (2.1)	8 (0.2)	3 (1.3)	10 (0.2)
Kentucky bluegrass	1976	6 (2.4)	9 (4.2)	4 (1.3)	6 (1.3)
Poa pratensis	1977	9 (2.7)	5 (1.4)	1 (1.2)	T
	1978	15 (0.9)	3 (0.2)	3 (1.3)	1 (0.7)
Sandberg bluegrass	1976	10 (0.6)	3 (2.4)	4 (1.9)	8 (2.1)
Poa sandbergii	1977	5 (1.8)	4 (1.7)	4 (0.4)	7 (1.3)
	1978	6 (1.2)	2 (0.7)	2 (0.9)	2 (0.7)
Elk sedge	1976	T	1 (0.4)	1 (0.9)	4 (0.6)
Carex geyeri	1977	6 (2.2)	4 (1.0)	14 (1.4)	5 (1.0)
	1978	1 (1.0)	9 (2.2)	20 (5.8)	25 (1.8)
Prairie junegrass	1976	T	1 (0.5)	T	2 (0.7)
Koeleria cristata	1977	1 (0.7)	1 (0.5)	1 (0.4)	3 (1.3)
	1978	T	1 (0.5)	T	1 (0.6)
Total grasses	1976	42 (1.0)	53 (2.8)	78 (4.6)	85 (3.5)
	1977	72 (6.7)	32 (5.7)	75 (6.0)	85 (1.6)
	1978	62 (3.4)	63 (5.7)	54 (7.1)	79 (3.6)
Trifolium species	1976	10 (1.2)	1 (0.9)	--	1 (0.7)
Trifolium spp.	1977	2 (1.2)	2 (0.8)	T	1 (0.4)
	1978	5 (1.5)	1 (0.5)	T	2 (0.7)
Western yarrow	1976	8 (2.8)	11 (3.6)	6 (0.8)	1 (0.7)
Achillea millefolium	1977	2 (1.7)	4 (1.1)	1 (0.7)	1 (0.6)
lanulosa	1978	7 (0.2)	11 (2.1)	4 (1.3)	1 (0.7)

APPENDIX F. continued

Species	Year	PERIOD 1	2	3	4
Total forbs	1976	52 (2.5)	32 (2.9)	10 (1.7)	5 (0.4)
	1977	22 (5.6)	15 (7.03)	10 (2.4)	6 (0.6)
	1978	33 (3.2)	27 (1.6)	8 (1.7)	2 (0.8)
Snowberry	1976	3 (0.7)	6 (2.4)	8 (1.9)	6 (3.6)
Symphoricarpos albus	1977	5 (1.8)	30 (3.1)	9 (2.9)	4 (0.2)
	1978	4 (0.6)	6 (2.8)	19 (4.6)	12 (2.4)
Ninebark	1976	--	2 (1.7)	--	T
Physocarpus	1977	--	4 (1.5)	5 (2.4)	T
malvaceus	1978	--	1 (0.5)	12 (3.8)	2 (0.7)
Total shrubs	1976	6 (0.2)	15 (3.2)	12 (4.7)	10 (3.8)
	1977	6 (2.4)	53 (2.0)	15 (4.9)	9 (0.4)
	1978	5 (0.6)	10 (3.5)	38 (8.1)	19 (3.5)

T = Trace

APPENDIX G. Means and Standard Errors of the Primary Species Occurring in Diet Samples Collected on the Deferred-Rotation Pasture.

Species	Year	PERIOD 1	2	3	4
Idaho fescue	1976	13 (0.6)	10 (3.8)		
Festuca idahoensis	1977			16 (2.0)	16 (3.3)
	1978	10 (5.6)	6 (3.2)		
Bluebunch wheatgrass	1976	4 (0.7)	13 (1.8)		
Agropyron spicatum	1977			10 (0.4)	32 (3.3)
	1978	6 (1.0)	30 (1.1)		
Kentucky bluegrass	1976	9 (1.1)	8 (0.4)		
Poa pratensis	1977			1 (1.4)	7 (1.6)
	1978	13 (4.0)	6 (2.7)		
Sandberg bluegrass	1976	2 (1.7)	3 (0.2)		
Poa sandbergii	1977			5 (1.4)	2 (0.6)
	1978	2 (0.7)	1 (0.2)		
Elk sedge	1976	--	9 (0.4)		
Carex geyeri	1977			25 (4.6)	15 (1.5)
	1978	1 (0.7)	15 (0.9)		
Total grasses	1976	44 (1.5)	53 (1.7)		
	1977			60 (6.3)	81 (1.3)
	1978	48 (3.8)	64 (0.7)		
Trifolium species	1976	10 (1.7)	--		
Trifolium spp.	1977			1 (0.5)	--
	1978	12 (2.0)	2 (0.6)		
Western yarrow	1976	7 (0.4)	1 (0.7)		
Achillea millefolium	1977			3 (1.1)	T
lanulosa	1978	4 (1.3)	2 (0.6)		
Total forbs	1976	48 (1.9)	17 (1.7)		
	1977			25 (2.5)	3 (1.7)
	1978	45 (3.8)	9 (0.5)		

APPENDIX G. continued

		PERIOD			
Species	Year	1	2	3	4
Snowberry	1976	8 (1.5)	28 (1.7)		
Symphoricarpos albus	1977			12 (2.7)	13 (1.7)
	1978	7 (1.2)	24 (2.4)		
Ninebark	1976	--	--		
Physocarpus	1977			--	T
malvaceus	1978	1 (0.5)	1 (0.7)		
Total shrubs	1976	8 (0.6)	29 (2.3)		
	1977			15 (3.7)	16 (1.7)
	1978	7 (1.7)	27 (1.6)		

T = Trace

APPENDIX H. Alpha Code, Scientific Name and Common Name of Plants Occurring in Cattle Diet Samples Collected on the Grassland.

Alpha Code	Scientific Name	Common Name
Grasses		
Agsp	Agropyron spicatum	bearded bluebunch wheatgrass
Brca	Bromus carinatus	California brome
Brmo	Bromus mollis	soft brome
Brte	Bromus tectorum	cheatgrass brome
Caru	Calamagrostis rubescens	pinegrass
Daun	Danthonia unispicata	onespike danthonia
Deda	Deschampsia danthonioides	annual hairgrass
Feid	Festuca idahoensis	Idaho fescue
Kocr	Koeleria cristata	prairie junegrass
Popr	Poa pratensis	Kentucky bluegrass
Posa	Poa sandbergii	Sandberg bluegrass
Sihy	Sitanion hystrix	bottlebrush squirreltail
Stocn	Stipa occidentalis nelsonii	western needlegrass
Grasslikes		
Cage	Carex geyeri	elk sedge
Juco	Juncus confusus	Colorado rush
Forbs		
Acmil	Achillea millefolium lanulosa	western yarrow
Arch	Arnica chamissonis	leafy arnica
Anlu	Antennaria luzuloides	rush pussytoes
Asre	Astragalus reventus	longleaf miser
Basa	Balsamorhiza sagittata	arrowleaf balsamroot

APPENDIX H. continued

Alpha Code	Scientific Name	Common Name
Forbs (continued)		
Erhe	*Eriogonum heracleoides*	Wyeth eriogonum
Erch	*Erigeron chrysopsidis*	dwarf yellow fleabane
Hecya	*Heuchera cylindrica alpina*	roundleaf alumroot
Irmi	*Iris missouriensis*	Rocky Mountain iris
Lole	*Lomatium leptocarpum*	bicolor biscuitroot
	Lupinus spp.	Lupine
Sest	*Sedum stenopetalum*	wormleaf stonecrop
Trdu	*Tragopogon dubius*	yellow salsify
Trre	*Trifolium repens*	white clover
Wyam	*Wyethia amplexicaulis*	mules ear wyethia
Shrubs		
Rogy	*Rosa gymnocarpa*	baldhip rose
Spbel	*Spiraea betulifolia lucida*	Spiraea
Syal	*Symphoricarpos albus*	common snowberry
Trees		
Pipo	*Pinus ponderosa*	ponderosa pine

APPENDIX I. Alpha Code, Scientific Name and Common Name of Plants Occurring in Cattle Diet Samples Collected on Forest.

Alpha Code	Scientific Name	Common Name
Grasses		
Agsp	Agropyron spicatum	bearded bluebunch wheatgrass
Alpr	Alopecurus pratensis	meadow foxtail
Arel	Arrhenatherum elatius	tall oatgrass
Brca	Bromus carinatus	California brome
Brin	Bromus inermis	smooth brome
Brte	Bromus tectorum	Cheatgrass brome
Caru	Calamagrostis rubescens	pinegrass
Daun	Danthonia unispicata	onespike danthonia
Deca	Deschampsia caespitosa	tufted harigrass
Deda	Deschampsia danthonioides	annual hairgrass
Elgl	Elymus glaucus	blue wildrye
Feid	Festuca idahoensis	Idaho fescue
Feoc	Festuca occidentalis	western fescue
Feov	Festuca ovina	sheep fescue
Kocr	Koeleria cristata	prairie junegrass
Phpr	Phleum pratense	timothy
Poco	Poa compressa	Canada bluegrass
Popr	Poa pratensis	Kentucky bluegrass
Posa	Poa sandbergii	Sandberg bluegrass
Stocn	Stipa occidentalis nelsonii	western needlegrass
Grasslikes		
Cage	Carex geyeri	elk sedge
Caro	Carex rossi	Ross sedge
Juco	Juncus confusus	Colorado rush

APPENDIX I. continued

Alpha Code	Scientific Name	Common Name
Forbs		
Acmil	Achillea millefolium lanulosa	western yarrow
Anlu	Antennaria luzuloides	rush pussytoes
Arco	Arnica cordifolia	heartleaf arnica
Asoci	Aster occidentalis intermedius	western aster
Basa	Balsamorhiza sagittata	arrowleaf balsamroot
Erch	Erigeron chrysopsidis	dwarf yellow fleabane
Frvi	Fragaria virginiana	strawberry
Gema	Geum macrophyllum	largeleaf arvens
Hecya	Heuchera cylindrica alpina	roundleaf alumroot
	Hieracium spp.	hawkweed
	Lupinus spp.	Lupine
Osch	Osmorhiza chilensis	sweetroot
Peco	Penstemon confertus	yellow penstemon
Pogl	Potentilla glandulosa	northwest cinquefoil
Thmov	Thermopsis montana venosa	Shasta thermopsis
	Trifolium spp.	clover
Shrubs		
Amal	Amelanchier alnifolia	Saskatoon serviceberry
Arne	Arctostaphylos uva-ursi	bearberry
Phma	Physocarpus malvaceus	Pacific ninebark
Rice	Ribes cereum	wax currant
Rogy	Rosa gymnocarpa	baldhip rose
Spbel	Spiraea betulifolia lucida	spiraea
Syal	Symphoricarpos albus	common snowberry
Vame	Vaccinium membranaceum	big whortleberry
Trees		
Pipo	Pinus ponderosa	ponderosa pine

APPENDIX J. Alpha Code, Scientific Name and Common Name of Plants Occurring in Cattle Diet Samples Collected on the Meadow.

Alpha Code	Scientific Name	Common Name
Grasses		
Agex	Agrostis exarata	spike bentgrass
Agsp	Agropyron spicatum	bearded bluebunch wheatgrass
Alpr	Alopecurus pratensis	meadow foxtail
Broa	Bromus carinatus	California brome
Brin	Bromus inermis	smooth brome
Brte	Bromus tectorum	cheatgrass brome
Deca	Deschampsia caespitosa	tufted hairgrass
Elgl	Elymus glaucus	blue wildrye
Feid	Festuca idahoensis	Idaho fescue
Feoc	Festuca occidentalis	western fescue
Feov	Festuca ovina	sheep fescue
Feru	Festuca rubra	red fescue
Glst	Glyceria striata	fowl mannagrass
Phpr	Phleum pratense	timothy
Poco	Poa compressa	Canada bluegrass
Popr	Poa pratensis	Kentucky bluegrass
Posa	Poa sandbergii	Sandberg bluegrass
Stocn	Stipa occidentalis nelsonii	western needlegrass
Grasslikes		
Caaq	Carex aquatilis	water sedge
Cage	Carex geyri	elk sedge
Cami	Carex microptera	small winged sedge
Juba	Juncus balticus	baltic rush

APPENDIX J. continued

Alpha Code	Scientific Name	Common Name
Grasslikes (continued)		
Lumu	Luzula multiflora	woodrush
Scmi	Scirpis microcarpus	small fruited bulrush
Forbs		
Acmil	Achillea millefolium lanulosa	western yarrow
Arma	Arenaria macrophylla	sandwort
Epan	Epilobium angustifolium	fireweed
Eqar	Equisetum arvense	common horsetail
Gabo	Galium boreale	northern bedstraw
Podo	Polygonum douglasii	Douglas knotweed
Pogr	Potentilla gracilis	northwest cinquefoil
Ruac	Rumex acetosella	sheep sorrel
	Trifolium spp.	clover
Shrubs		
Rice	Ribes cereum	wax currant
Rogy	Rosa gymnocarpa	baldhip rose
SALIX	Salix spp.	willow
Spbel	Spiraea betulifolia lucida	spiraea
Syal	Symphoricarpus albus	common snowberry

APPENDIX K. Alpha Code, Scientific Name and Common Name of Plants Occurring in Cattle Diet Samples Collected on the Grazing System Pastures.

Alpha Code	Scientific Name	Common Name
Grasses		
Agex	Agrostis exarata	spike bentgrass
Agsp	Agropyron spicatum	bearded bluebunch wheatgrass
Alpr	Alopecurus pratensis	meadow foxtail
Arel	Arrhenatherum elatius	tall oatgrass
Brca	Bromus carinatus	California brome
Brin	Bromus inermis	smooth brome
Brmo	Bromus mollis	soft brome
Brte	Bromus tectorum	cheatgrass brome
Caru	Calamagrostis rubescens	pinegrass
Dagl	Dactylis glomerata	orchardgrass
Daun	Danthonia unispicata	onespike danthonia
Deca	Deschampsia caespitosa	tufted hairgrass
Deda	Deschampsia danthonioides	annual hairgrass
Elgl	Elymus glaucus	blue wildrye
Feid	Festuca idahoensis	Idaho fescue
Feoc	Festuca occidentalis	western fescue
Feov	Festuca ovina	sheep fescue
Kocr	Koeleria cristata	prairie junegrass
Phpr	Phleum pratense	timothy
Poco	Poa compressa	Canada bluegrass
Popr	Poa pratensis	Kentucky bluegrass
Posa	Poa sandbergii	Sandberg bluegrass
Sihy	Sitanion hystrix	bottlebrush squirreltail
Stocn	Stipa occidentalis	western needlegrass

APPENDIX K. continued

Alpha Code	Scientific Name	Common Name
Grasslikes		
Cage	Carex geyeri	elk sedge
Cami	Carex microptera	small winged sedge
Caro	Carex rossi	Ross sedge
Juco	Juncus confusus	Colorado rush
Lumu	Luzula multiflora	woodrush
Scmi	Scirpus microcarpus	small fruited bulrush
Forbs		
Acmil	Achillea millefolium lanulosa	western yarrow
Anlu	Antennaria luzuloides	rush pussytoes
Arch	Arnica chamissonis	leafy arnica
Arco	Arnica cordifolia	heartleaf arnica
Arma	Arenaria macrophylla	sandwort
Asoci	Aster occidentalis intermedius	western aster
Asre	Astragalus reventus	longleaf miser
Basa	Balsamorhiza sagittata	arrowleaf balsamroot
Cabu	Capsella bursa-pastoris	shepherd's purse
Eqar	Equisetum arvense	common horsetail
Erch	Erigeron chrysopsidis	dwarf yellow fleabane
Erhe	Eriogonum heracleoides	Wyeth eriogonum
Frvi	Fragaria virginiana	strawberry
Gabo	Galium boreale	northern bedstraw
Gema	Geum macrophyllum	largeleaf arvens
Hecya	Heuchera cylindrica alpina	roundleaf alumroot
	Hieracium spp.	hawkweed

APPENDIX K. continued

Alpha Code	Scientific Name	Common Name
Forbs (continued)		
Lole	Lomatium leptocarpum	bicolor biscuitroot
	Lupinus spp.	Lupine
Osch	Osmorhiza chilensis	sweetroot
	Penstemon spp.	penstemon
Podo	Polygonum douglasii	Douglas knotweed
	Potentilla spp.	cinquefoil
Saorm	Saxifraga oregona montanensis	saxifraze
Sest	Sedum stenopetalum	wormleaf stonecrop
Smst	Smilacina stellata	starry solomon plume
Thmov	Thermopsis montana venosa	Shasta thermopsis
Trdu	Tragopogon dubius	yellow salsify
	Trifolium spp.	clover
Viam	Vicia americana	American vetch
Shrubs		
Amal	Amelanchier alnifolia	Saskatoon serviceberry
Chum	Chimaphila umbellata	common prince's pine
Phyma	Physocarpus malvaceus	Pacific ninebark
Rice	Ribes cereum	wax currant
Rila	Ribes lacustre	prickly currant
Rogy	Rosa gymnocarpa	baldhip rose
Spbel	Spiraea betulifolia lucida	spiraea
Syal	Symphoricarpos albus	common snowberry
Libo	Linnaea borealis	twinflower
Pamy	Pachistima myrsinites	mountain lover
Trees		
Pipo	Pinus ponderosa	ponderosa pine

APPENDIX M. Percent Crude Protein in Diet Samples Collected on the Grazing System Pastures in 1976, 1977 and 1978.

Grazing Period 1/ 2/	Rest Rotation	Season Long	Deferred Rotation 3/
	1976 Grazing Season		
Late spring	12.2	12.3	10.6
Early summer	9.5	9.8	8.0
Late summer	11.0	11.5	
Fall	9.4	9.3	
	1977 Grazing Season		
Late spring	13.3[a]	10.6[b]	
Early summer	7.8[b]	9.4[a]	
Late summer	6.7	6.9	7.0
Fall	7.9	7.0	7.8
	1978 Grazing Season		
Late spring	10.9	10.7	11.2
Early summer	10.2	9.3	9.9
Late summer	7.4	7.2	
Fall	9.2[a]	7.7[b]	

1/ Means with different letters are significantly different (P .05).

2/ Statistical tests apply only across columns.

3/ The deferred rotation pasture was not included in the statistical analysis.

APPENDIX N. Percent Acid Detergent Fiber in Diet Samples Collected on the Grazing Systems Pastures in 1976, 1977, and 1978.

Grazing Period 1/ 2/	Rest Rotation	Season Long	Deferred Rotation 3/
	1976 Grazing Season		
Late spring	41.9	43.2	44.3
Early summer	41.7	44.6	45.7
Late summer	50.8	50.0	
Fall	51.9	51.4	
	1977 Grazing Season		
Late spring	45.5	49.9	
Early summer	51.2	49.0	
Late summer	54.5	54.2	51.4
Fall	53.2	55.9	52.7
	1978 Grazing Season		
Late spring	47.2	46.2	47.1
Early summer	47.3	50.1	48.7
Late summer	51.1	51.9	
Fall	49.5	53.1	

1/ Means with different letters are significantly different (P .05).

2/ Statistical tests apply only across columns.

3/ The deferred rotation pasture was not included in the statistical analysis.

APPENDIX O. Average daily weight gains in kg on the Phase 3 meadow pastures.

Year	Rest rotation	Season-long	Deferred rotation
1976	0.09	0.31	0.28
1977	0.24	0.36	0.14
1978	0.32	0.66	0.38
Avg. daily gain	0.22	0.44	0.27

APPENDIX P. Average daily weight gains in kg on the triangular pasture.

	Year		
	1976	1977	1978
Late spring	--	+1.02	+1.02
Early summer	+0.70	-0.06	-0.06
Late summer	--	--	
Fall	+0.75	--	
Avg. daily gain	+0.73	+0.46	+0.48

APPENDIX Q. The number of samples required to sample cattle diets on the grassland during the four periods.

Plant Species 1/	Late Spring	Early Summer	Late Summer	Fall
Bluebunch wheatgrass	65	29	39	41
Idaho fescue	164	49	80	31
Sandberg bluegrass	171	336	748	300
Total grasses	16	8	6	7
Western yarrow	257	193	285	314
Total forbs	58	92	116	127
Snowberry	294	79	313	584
Total shrubs	182	26	50	73

1/ The number of samples required to be within 10% of the mean at the 90% confidence level is given for each period.

APPENDIX R. The number of samples required to sample cattle diets on forest during the four periods in 1976.

Plant Species 1/	Late Spring	Early Summer	Late Summer	Fall
Idaho fescue	227	105	58	145
Elk sedge	174	967	94	117
Total grasses	13	28	53	19
Heartleaf arnica	116	1256	59	41
Total forbs	76	462	97	135
Snowberry	203	135	301	115
Total shrubs	143	134	149	68

1/ The number of samples required to be within 10% of the mean at the 90% confidence level is given for each period.

APPENDIX S. The number of samples required for crude protein and *in vitro* dry matter digestibility on the forest and grassland during the four periods in 1976.

Periods 1/	Forest		Grassland	
	CP	IVDMD	CP	IVDMD
Late spring	18	12	8	8
Early summer	13	18	21	20
Late summer	32	26	41	12
Fall	9	14	16	13

1/ The number of samples required to be with 5% of the mean at the 95% confidence level is given for each period.

APPENDIX T. The number of collections required to estimate forage intake on the grassland and forest in 1976.

Periods 1/	Grassland	Forest
Late spring	10	8
Early summer	14	15
Late summer	14	13
Fall	12	13

1/ The number of samples required to be with 5% of the mean at the 95% confidence level is given for each period.

APPENDIX U. Crude protein intake in kg and digestible energy intake in Mcal on the grazing systems pastures in 1977 and 1978.

Grazing Period 1/ 2/	Crude Protein RR	Crude Protein SL	Crude Protein DR	Digestible Energy RR	Digestible Energy SL	Digestible Energy DR
	1977 Grazing Season					
Late spring	1.07[a]	0.79[b]		18.1[a]	16.6[b]	
Early summer	0.55[b]	0.69[a]		11.9	11.3	
Late summer	0.49	0.46	0.51	12.9	12.2	13.8
Fall	0.57	0.52	0.52	13.3	13.8	12.5
	1978 Grazing Season					
Late spring	0.90	0.86	0.93	18.4	20.6	
Early summer	0.74	0.71	0.97	15.9	16.5	
Late summer	0.55	0.52		13.6	13.9	18.6
Fall	0.59	0.50		11.2	13.0	17.3

1/ Means followed by different letters are significantly different ($P < .05$).

2/ Statistical tests apply only across columns.