AN ABSTRACT OF THE THESIS OF

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Title: THE EFFECTS OF THREE LEVELS OF RANGE IMPROVEMENTS ON ROOSEVELT ELK NUTRITION

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Three types of bottomland pastures on the Beneke Creek Wildlife Management Area, Jewell, Oregon, were compared during the 1976-77 and 1977-78 winters to determine their relationships to Roosevelt elk (*Cervus canadensis roosevelti*) nutrition and distribution. The three types of pastures were: colonial bentgrass (*Agrostis tenuis*), untreated; colonial bentgrass, hayed and fertilized; perennial ryegrass (*Lolium perenne*), hayed and fertilized.

The first winter of the study was abnormally dry with broad ranging daily temperature extremes, while the second winter was near normal with close to average percipitation and a milder than average daily temperature regime.

The dry winter favored high forage production with low nutritive value, while the normal winter favored low forage production of high quality. Elk density and distribution were not affected by differences between the two winters of the study.

The average amount of herbage removed from the experimental pastures was 22.93 g of forage/kg body weight. Elk showed a strong preference for the treated perennial ryegrass pasture over the treated and untreated colonial bentgrass pastures and no difference in preference between the treated and untreated colonial bentgrass pastures. The nutritive value of the herbage, based on digestible energy, digestible protein, and dry matter digestibility, was highest on the treated perennial ryegrass pasture and lowest in the untreated colonial bentgrass pasture. The herbage in the treated perennial ryegrass pasture most often exceeded minimum nutrient requirements. The treated colonial bentgrass herbage met minimum digestible energy requirements half of the time and digestible protein requirements one-sixth of the time. The herbage in the untreated bentgrass pasture never reached minimum requirement levels for digestible energy and digestible protein. Thus, of the three pasture types, the treated perennial ryegrass pasture was shown to provide the best elk winter range, in terms of attracting animals and providing adequate nutrition.

Linear models were provided for the prediction of: elk density ($r^2 = 0.72$), dry matter digestibility ($r^2 = 0.85$), digestible protein ($r^2 = 0.43$) and digestible energy ($r^2 = 0.60$). The relationship between nutritive characteristics of the herbage and elk density emphasized the importance of forage quality to the free ranging ruminant.

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by

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THE EFFECTS OF THREE LEVELS OF RANGE IMPROVEMENTS ON ROOSEVELT ELK NUTRITION

INTRODUCTION

The Oregon Department of Fish and Wildlife purchased bottomland pastures in the Coast Range Mountains to provide wintering areas for Roosevelt elk (*Cervus canadensis roosevelti*). The increasing demands of the public for more elk to view and harvest, combined with the Oregon Department of Fish and Wildlife's desire to maximize production of elk from these pastures has prompted the Oregon Department of Fish and Wildlife to undertake an intensive vegetation management program on the purchased lands. The intensive management on these areas has resulted in an obvious increase in the wintering elk populations. However, to this point, no data were available on the quality of the winter forage provided by the intensively managed pastures as compared to the undeveloped pastures. Also, the degree to which the intensively managed pastures increased the attractiveness of the area for elk as compared to undeveloped pastures has not been determined. The rising cost of management has prompted the desire to closely evaluate these pasture development programs to determine if, in fact, the apparent gains resulting from certain habitat developments, are significant enough to justify the cost.

The objectives of this research were to:

1. Determine the effects of bottomland pasture development on the nutritive values of forage for wintering Roosevelt elk.
2. Determine the effects of bottomland pasture development on elk preference among the pastures on the Beneke Creek Wildlife Management Area.
3. Provide a biological basis upon which to judge the value of habitat developments on bottomland pastures in the Coast Range Mountains for elk.

METHODS FOR PLANT COMMUNITY DESCRIPTIONS

Homogeneous stands of vegetation on the experimental pastures were delineated using an aerial mosaic and field reconnaissance. All stands with similar vegetation attributes were grouped into the same plant communities.

The composition of herbaceous vegetation in the plant communities on the experimental pastures was sampled by locating thirty, 25 cm^2 plots randomly in each plant community and recording frequency of species. The composition of shrubs was estimated by recording density by species in three 1 x 100 m plots per community and estimating species cover by line-intercept along three 100 m transects per community (Cook *et al.* 1962; Pieper 1973). Plant communities were named according to: dominant shrub/dominant grass/ dominant forb.

DESCRIPTION OF STUDY AREA

This research was conducted on the Beneke Creek Wildlife Management Area (W.M.A.), Jewell, Oregon. This area is situated at 174 m above sea level, in the central Coast Range Mountains of Clatsop County approximately 48 km southeast of Astoria in Townships 5 and 6 North, Range 7 West, of the Willamette Prime Meridian (Figure 1).

The Beneke Creek W.M.A. encompasses 276 ha, most of which is stream bottom and alluvial terraces of unconsolidated stream sediments (Beaulieu 1973). Approximately 48 ha are slopes of the Coast Range Mountains. In this area, the parent material of the hillsides is primarily sedimentary in origin (Beaulieu 1973). The area is 4.4 km long (north-south) and 1.0 km at its widest (east-west) point. Beneke Creek runs south through the area and drains into the Nehalem River.

Climate

The average annual precipitation (1966-1975) at Vernonia (25 km east of Jewell) was 150 cm, 66 percent of which fell from November through March. Most of the precipitation was rainfall. The average yearly temperature was 11°C, with an average daily maximum of 16°C and an average daily minimum of 3°C. The mean frost-free period was 188 days (NOAA 1960-1978).

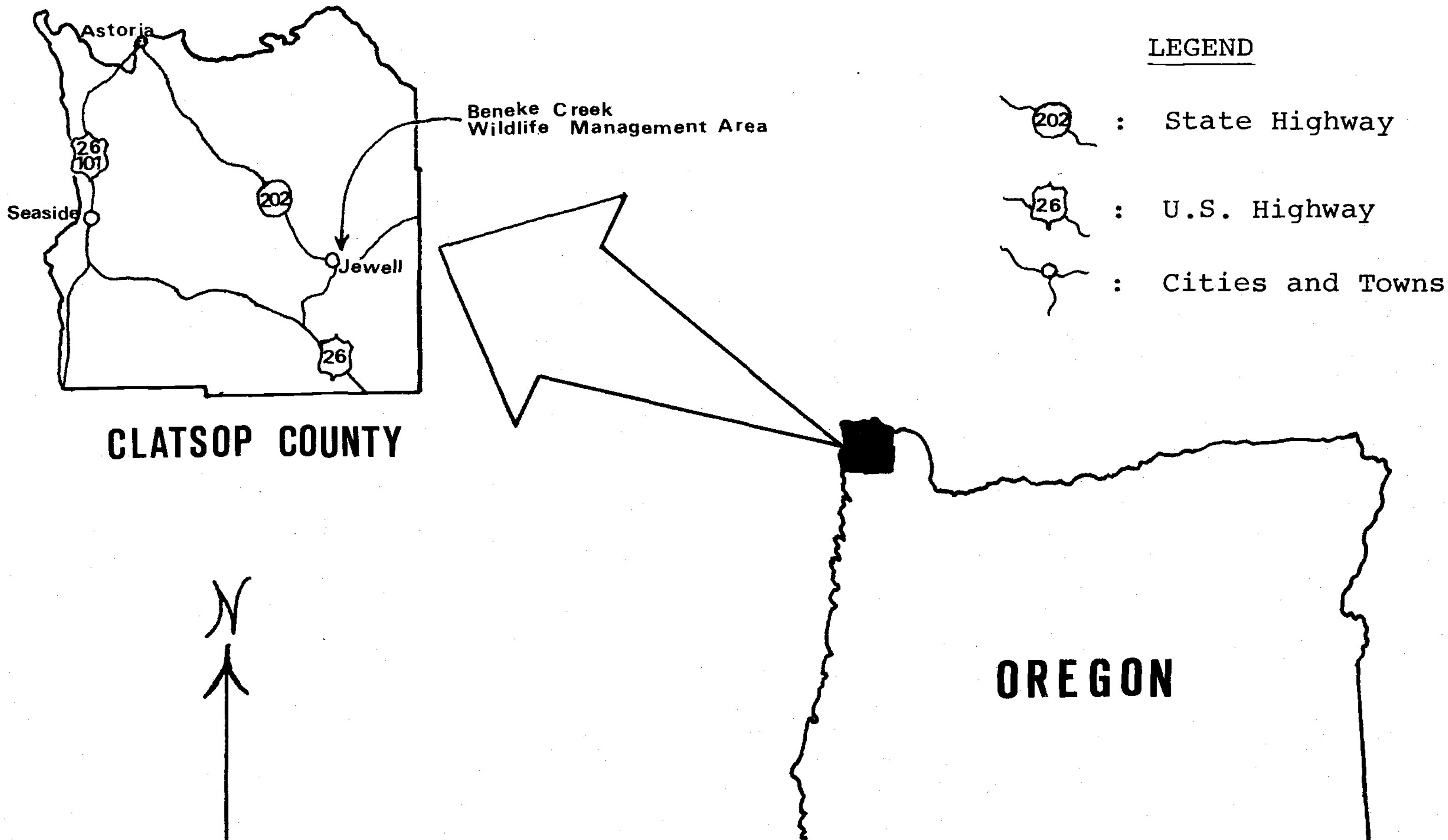

Figure 1. Location of Beneke Creek Wildlife Management Area (study area).

Soils and Vegetation

The soils on the Beneke Creek W.M.A. were described by Leach (1974). Three soil series dominated the experimental pastures, all of which were alluvial in origin: Nehalem Thin Surface Variant Series, Walluski Series and Knappa Series.

The Nehalem Thin Surface Variant is a moderately well drained silt loam (0-69 cm) over a loam (69-152 cm) formed in recent alluvium, occurring on 0-3 percent slopes. This series was classified as a Fluventic Dystrochrepts; coarse-silty, mixed, mesic family (Leach 1974). The Nehalem Thin Surface Variant occupied approximately 30 percent of the experimental pastures.

The Walluski Series is a moderately well drained silt loam (0-33 cm) over silty clay loam soils (31-97 cm) formed in old alluvium, occurring on 0-20 percent slopes. This series was classified as a Typic Haplumbrepts, fine-silty, mixed, mesic family (Leach 1974). The Walluski Series occupied approximately 20 percent of the experimental pastures.

The Knappa Series is a well drained silt loam or silty clay loam (90-173 cm) over a silty clay loam formed in alluvium, occurring on 0-20 percent slopes (Leach 1974). This series has not been classified. The Knappa Series occupied approximately 15 percent of the experimental pastures.

The experimental pastures were comprised of eight plant communities shown in Figure 2. Frequency and species composition of herbaceous plants in these eight plant communities are provided in Appendices A and B respectively. Cover and density of shrubs in each community are given in Appendix C. In Appendix D, are listed the common and scientific names of plant species occurring on the experimental pastures.

Plant communities 1 and 3 (Figure 2) occurred only on soils of the Knappa and Walluski Series. Plant community 4 occurred only on soils of the Nehalem Thin Surface Variant Series. Plant community 5 occurred only on soils of the Walluski Series and plant community 6 occurred on soils of both the Nehalem Thin Surface Variant and the Walluski Series. Plant communities 2, 7 and 8 were found on all of the three main soil series of the experimental pastures.

The timbered areas were dominated by red alder (Alnus rubra) and Douglas-fir (Pseudotsuga menziezii) on the hillsides and sitka spruce (Picea sitchensis), western red cedar (Thuja plicata) and bigleaf maple (Acer macrophyllum) in the bottoms. According to Garrison et al. (1977), this area belongs to the Western hemlock (Tsuga heterophyla) - sitka spruce (Picea sitchensis) ecosystem, extending from British Columbia along the Washington and Oregon Coast Range Mountains and parts of the Western slopes of the Cascades.

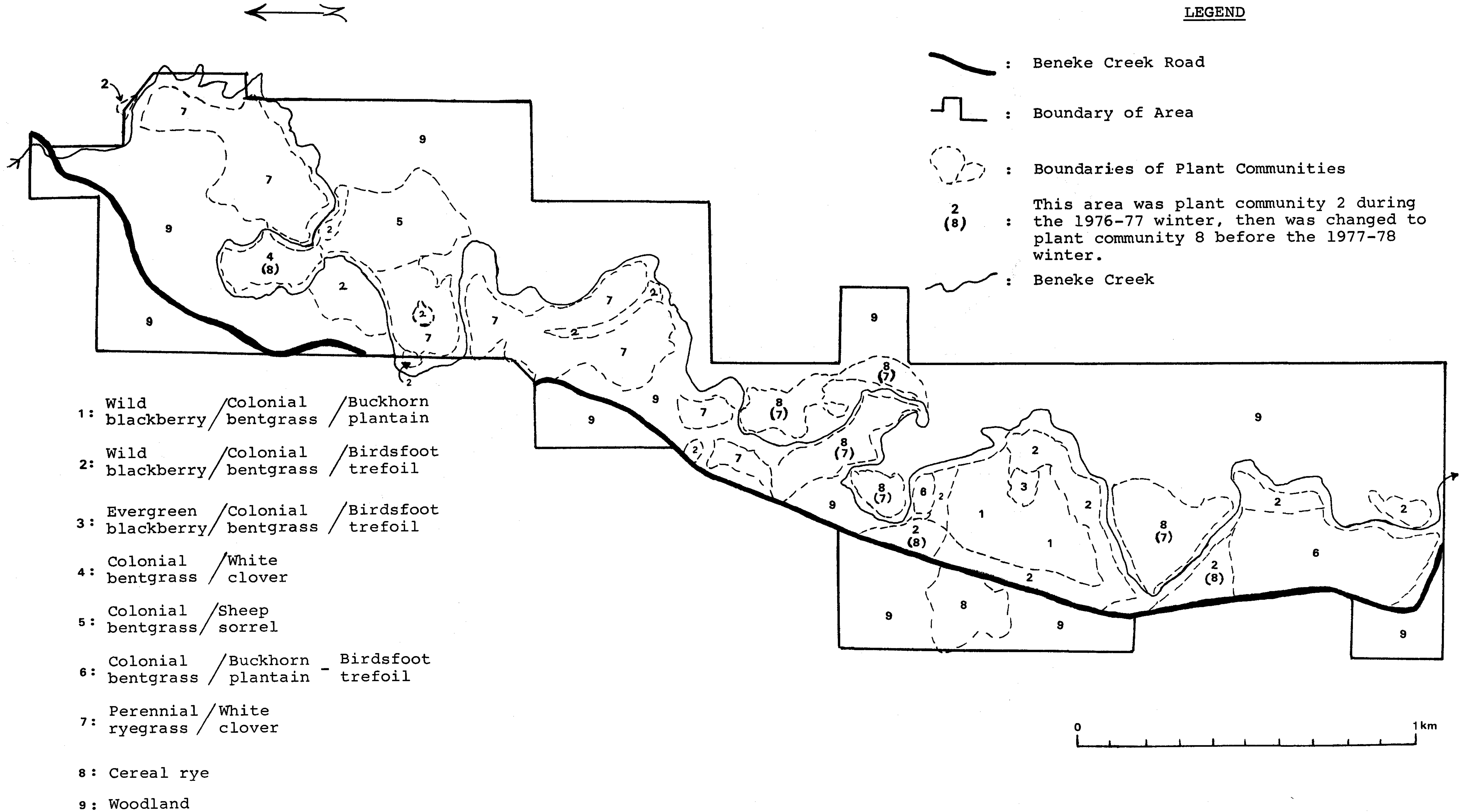

Figure 2. Plant communities on the Beneke Creek Wildlife Management Area (Scale: 1:12,000).

Management History

The Beneke Creek W.M.A. was purchased in 1973 by the Oregon Department of Fish and Wildlife to provide a wintering area for Roosevelt elk. Prior to this, the area was used for grain and livestock production and then later for hay and livestock production (Cleary 1976). Approximately 30 to 50 elk used the area during the winter in spite of hazing efforts, prior to 1973. Wheeler (1976) estimated a wintering population of 110 elk in 1976.

At the time of purchase two types of pastures existed on the area: 1. Those which were hayed yearly and grazed by livestock. 2. Those which were too rough to hay but were still grazed by livestock. Prior to purchase, virtually no seeding or fertilization was done on the area (Cleary 1976). After the purchase of the area, the Oregon Department of Fish and Wildlife began to plow and reseed pastures to species that were considered more productive during the winter and more palatable. Fall fertilization and hay removal was implemented on all pastures that were level enough to do so. As a result of this habitat development, four types of pastures, depending on the management level, were present on the area (Figure 3) (Cleary 1976):

Untreated Colonial Bentgrass (*Agrostis tenuis*) (Bentgrass-U):

These pastures have never been tilled. They were cleared of trees more than 50 years ago, possibly broadcast seeded in spots and grazed by livestock.

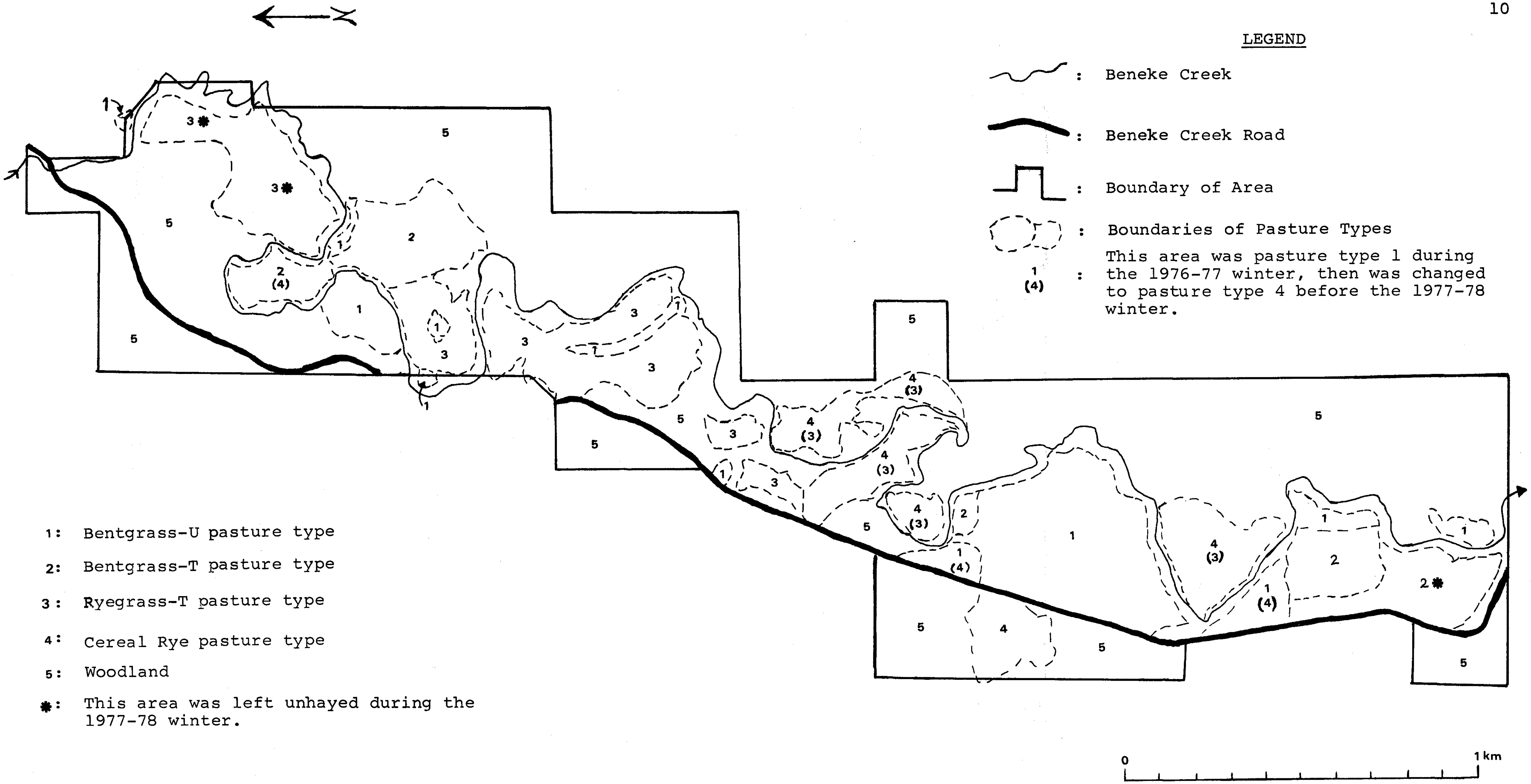

Figure 3. Pasture types on the Beneke Creek Wildlife Management Area (Scale: 1:12,000).

These pastures were neither hayed nor fertilized. They were heavily dominated by colonial bentgrass.

Treated Colonial Bentgrass (Bentgrass-T): These pastures were tilled in the past. They most likely were once grain fields and later used for pasture, but have not been tilled for at least 20 years. Since the purchase of the area, these pastures have been hayed yearly and fall fertilized yearly with 10-20-10 fertilizer at a rate of 393 kg/ha. These pastures were very heavily dominated by colonial bentgrass.

Treated Perennial Ryegrass (Lolium perenne) (Ryegrass-T): These pastures were plowed, limed, fallowed with a cover crop of cereal rye through the winter, then plowed again next spring and seeded to permanent pasture with a mixture of: perennial ryegrass, annual ryegrass (Lolium multiflorum), orchardgrass (Dactylis glomerata), tall fescue (Festuca arundinacea), white clover (Trifolium repends) and subterranean clover (Trifolium subterraneum). They were hayed and fall fertilized yearly with 10-20-10 fertilizer at a rate of 393 kg/ha. Development of these pastures has been the goal of the habitat program on the Beneke Creek W.M.A. They were heavily dominated by perennial ryegrass.

Cereal Rye (Secale cereale): These pastures were the result of plowing one of the first two types of pastures, fallowing them for a summer, applying 6738 kg/ha of lime, then seeding cereal rye and applying 393 kg/ha of 10-20-10 fertilizer in the fall to provide green feed for the winter. The following spring the pasture was plowed and reseeded to the ryegrass pasture type. The cereal rye pastures had no potential as permanent pastures, but rather were an intermediate step between one of the first two and the third type of pasture.

Similarities among plant communities were mainly governed by the four types of vegetation management practices described as pasture types. Table 1 shows the types of pastures and plant communities associated with each other.

Table 1. Plant communities and associated pasture types on the Beneke Creek Wildlife Management Area.

	Plant Community	Pasture Types
1.	Wild blackberry / Colonial bentgrass / Buckhorn plantain	Bentgrass-U
2.	Wild blackberry / Colonial bentgrass / Birdsfoot trefoil	Bentgrass-U
3.	Evergreen blackberry / Colonial bentgrass / Birdsfoot trefoil	Bentgrass-U
4.	Colonial bentgrass / White clover	Bentgrass-T
5.	Colonial bentgrass / Sheep sorrel	Bentgrass-T
6.	Colonial bentgrass / Buckhorn plantain - Birdsfoot trefoil	Bentgrass-T
7.	Perennial ryegrass / White clover	Ryegrass-T
8.	Cereal rye	Cereal rye
9.	Woodland	Not a pasture type

LITERATURE REVIEW

History and Characteristics of Roosevelt Elk

The present range of Roosevelt elk extends from Humboldt and Del Norte Counties, California north to Vancouver Island, British Columbia. They primarily occupy areas in the Coast Range Mountains, although small populations do exist on the west slope of the Cascade Mountains in Oregon and around the Mount Rainier area, Washington, the latter is a herd, which is thought to mix and interbreed with Rocky Mountain elk (Cervus canadensis nelsoni) (Harper et al. 1967). A well established, introduced population occurs in Afognak Island, Alaska (Troyer 1960). Five female calves and three male calves were brought to Afognak Island from the Olympic Peninsula, Washington in 1929 and since have increased to an estimated 800 animals by 1958. Also, successful reintroductions of Roosevelt elk have been made on the west slope of the Cascade Mountains in Oregon by the Oregon Department of Fish and Wildlife (Ives 1978; Harper 1971).

Roosevelt elk are generally found in herds of varying sizes. Franklin et al. (1975) stated that on Gold Bluffs Beach in Northern California, the largest and most stable herds were found on areas where grasslands were the predominant vegetation type. Observations made by the Oregon

Department of Fish and Wildlife staff seemed to indicate the same patterns (Wheeler 1977). Franklin et al. (1975), Graf (1943) and Harper et al. (1967) stated that the herds were generally dominated by older cows. They also pointed out that of all the sex and age classes, adult males spent the least amount of time with the herd, generally forming groups of their own or wandering singly. However, the adult males were said to spend the most time with the herd during the winter season (Franklin et al. 1975; Harper et al. 1967; Harper 1971). Both Franklin et al. (1975) and Harper (1971) agreed that during the winter season, herd size, composition and movements were most stable.

Elk in general seemed to show a preference for grass over other types of forages during the winter (Buechner 1952; Harper 1962; Harper et al. 1967; Kufeld 1973; McBee et al. 1969; Stevens 1966). However, Kufeld (1973) pointed out that this generality may be modified according to the types of grasses and shrubs present on the area, as well as their relative availabilities. Harper et al. (1967) found that 76 percent of the Roosevelt elk diet during the winter on the Prairie Creek, California study area was made up of grasses and sedges, while in his 1971 publication, Harper points out that on the Millicoma tree farm, Oregon, elk utilized trailing blackberry (Rubus spp.) more heavily than grasses. McBee et al. (1969) stated that grasses comprised 91 percent of the Rocky Mountain elk winter diet in Yellowstone National Park, Wyoming. Stevens (1966) in Montana and Hansen and Clark (1977) in Colorado found the percent of grasses and sedges in the diets of elk to be 77 and 55, respectively.

There were certain characteristics of Roosevelt elk that distinguished this subspecies from the Rocky Mountain elk. The Roosevelt elk tended to be larger and darker in color and the males tended to have shorter, straighter and heavier beamed antlers (Graf 1943; Schwartz and Mitchell 1945). Rocky Mountain elk adults tended to average approximately 225 kg, while Roosevelt elk adults averaged approximately 250 kg in weight (Hines 1972; Hines and Lemos 1975; Lemos and Hines 1974; Dean et al. 1976; Thorne and Butler 1976). Also, Roosevelt elk tended to be more sedentary in their habits and less wary of disturbance by man than Rocky Mountain elk (Graf 1943). Trainer (1971) pointed out that in Oregon, Roosevelt elk calf:cow ratios averaged 41:100, while Rocky Mountain elk ratios averaged 51:100. Further investigation showed Roosevelt elk cows that conceived during the fall breeding season had significantly higher fat reserves (Trainer 1969). This was established by measuring the weight of the kidney fat relative to the weight of the kidney (Trainer 1971). During the same period the fat reserves of lactating cows were low and the animals were in generally poor condition. Also, most of the cows that had conceived during the breeding season were found to be dry (did not produce a calf that year) and the few cows that were lactating and had conceived, did so at a later date during the fall breeding season (Trainer 1971). Trainer (1971) stated that under the stress of lactation, most Roosevelt elk cows were unable to maintain energy reserves. This, combined with the fact that little evidence of ovulation was found in such animals, led to the conclusion that the poor condition of the lactating cow at the onset of the breeding season caused her not to ovulate. Thus, during the year in which the cow is barren and dry she was able to restore her energy reserves to a level where she was once again able to ovulate. This resulted in many Roosevelt elk cows producing a calf every other year, rather than yearly (Trainer 1969, 1971). Trainer (1971) suspected that the quality of elk forage was at least in part responsible for this situation. Harper (1962) stated that overpopulation and/or poor forage quality could have contributed to the low nutritional status of Roosevelt elk on Boyes Prairie, California. Schwartz and Mitchell (1945) blamed poor forage quality as the cause of most malnutrition deaths of Roosevelt elk on the Olympic Peninsula, Washington, since most animals examined had their paunch full of "... coarse and unpalatable..." forage.

Factors Affecting Ruminant Production

The relationship between nutrition and animal production is not unique to Roosevelt elk. Cheatum and Severinghaus (1950) found that under poor range conditions, white-tailed deer (Odocoileus virginianus) had lower productivity than those occupying sites in good condition. Similarly, Torell et al. (1974) found a direct relationship between the lamb:ewe (Ovis aries) ratios and the nutritional status of the ewe. By severely restricting the level of protein and energy in the diets of beef heifers (Bos taursus), Bond et al. (1958) found that estrous cycling stopped when the animals reached a 17-20 percent weight loss. Ovulation rates of mule deer (Odocoileus hemoinus hemoinus) on poor range were 67 percent lower than those of mule deer on good range (Julander et al. 1961).

Allden (1970) who worked with sheep and cattle, Verme (1965) who worked with white-tailed deer and Zimerman et al. (1961) who worked with cattle, all found that age and time of breeding of the female was later than average for those animals on diets of low nutritional value. In addition, Zimmerman et al. (1961) reported that beef cows on energy and protein deficient diets cycled less often.

Survival has also been tied to the nutritional quality of the diet. Holter and Hayes (1977) reported that a 40 percent reduction of digestible energy intake during the fall resulted in a 76 percent reduction in body fat deposition of white-tailed deer fawns, although growth rate was not reduced. A direct relationship between poor range condition and poor survival of mule deer in Utah was shown by Robinette *et al*. (1952). Thorne *et al*. (1976) showed that Rocky Mountain elk cows on a higher nutritional plane produced calves that weighed more when compared to cows on a poorer quality feed. Thorne (1973) showed that Rocky Mountain elk calves weighing an average of 15.9 kg at birth had 90 percent survival at 30 days, whereas elk calves weighing less than 11.4 kg at birth had less than 50 percent survival at 30 days. Allden (1970), Bond and Wiltbank (1970), Pinney *et al*. (1962) and Wallace and Raleigh (1964) all found that cattle on poorer diets, nutritionally, produced lighter calves than those on higher quality diets. Bond and Wiltbank (1970) and Wallace and Raleigh (1964) found that levels of diet protein had little or no effect on calf weights, whereas diet energy levels did.

Palatability and Preference

Stoddart *et al*. (1975) defined palability as "...the attractiveness of a plant to animals as forage" and preference as "...the selection of plants by animals." Heady (1964), gave similar definitions. It was the general consensus among authors that forage palatability and animal preference were major factors that determined the quality of a free-ranging animal's diet (Dietz 1970; Everist

1972; Heady 1964, 1975; Marten 1970; Voigt 1975; Stoddart et al. 1975). The following quote by Everist (1972) pinpointed the significance of palatability and preference to free-ranging animals: "No matter how abundant or how nutritious a plant may be, it has no value as fodder (forage) unless animals (are willing to) eat it."

It was shown that the species of plants available to an animal were very important, since certain plant species were more palatable than others and thus, were more preferred and readily eaten (Cook and Stoddart 1953; Heady 1975; Stoddart et al. 1975; Voigt 1975). Dairy cattle, forced to eat species of known low palatability, ate less than dairy cattle on forages of higher known palatability (Lassiter et al. 1956). Also, the milk production and body weight of these same cattle was lower on diets of less palatable forage (Seath et al. 1956).

Forage can also be managed to improve palatability. For the most part, palatability and preference for fertilized forage was higher for elk and cattle, than the same forage that was unfertilized (Cook 1965; Geist 1974; Heady 1975; Hooper et al. 1969; Smith and Lang 1958). In contrast, Reid et al. (1966) found that unfertilized orchardgrass was more preferred by sheep than orchardgrass that was fertilized by any of the following forms: $NaNo_3$, NH_4NO_3, NH_4SO_4, NH_4PO_4 and urea.

Anderson and Scherzinger (1975) stated that areas where summer growth of grass was removed and regrowth occurred were preferred by Rocky Mountain elk during the winter over areas on which only mature grasses were available. Regrowth was generally in an early stage of maturity and tended to have a higher proportion of leaves than stems as compared to mature grass. Therefore, the above observation by Anderson and Scherizinger (1975) corresponds to Heady's (1964) statement that grazing animals preferred less mature over more mature forage and to Cook and Stoddart's (1953) statement that leaves were preferred over stems.

Nutritive Value of Forage

Indicators of Nutritive Value

Although the nutritive value of forage for grazing animals is a complex interaction of many factors, there are certain nutrients which tend to be good indicators of nutritive value. Church and Pond (1974), Cook (1970), Crampton and Harris (1969), Moen (1973) and Stoddart *et al.* (1975) all considered energy to be the most important nutrient, quantitatively, in an animal's diet. These same authors further stated that energy metabolism requirements of animals were the basis for determining all other nutrient requirements. Energy (gross energy) levels in forage did not generally vary significantly from one type of forage to another (Crampton and Harris 1969). However, the energy utilized by the ruminant did vary from one type of forage to another depending largely on the digestibility of that forage (Crampton and Harris 1969; Moir 1961; Walmo et al. 1977). Crampton et al. (1960) used the digestibility of energy in feed and intake to formulate a nutritive value index for forages. In most cases, except when plants were high in essential oils or waxes, digestible energy provided a good measure of forage quality (Cook 1970).

Another nutrient commonly used as an overall indicator of forage nutritive value was protein (nitrogen)(Crampton and Harris 1969; Cowan et al. 1970). Church and Pond (1974), Crampton and Harris (1969) and Moen (1973) pointed out that protein was the nutrient in highest concentration in the muscle tissue of animals and was needed for growth, maintenance and repair of body tissues. However, Crampton and Harris (1969) indicated that protein (nitrogen), unlike energy, did not have as much value as a feed component as it did as a measure of forage quality. They stated, along with Cowan et al. (1970), that forages low in nitrogen generally are of a poor quality and resulted in poor animal body condition, but the poor performance was not as much a result of low nitrogen levels as it was of low forage digestibility, which the low nitrogen levels generally indicate. In contrast, Dietz (1970) stated that protein was the most important nutrient to the ruminant, since a deficiency impaired normal body functions such as: reproduction, lactation, growth and digestion in the rumen.

Throughout the discussion of energy and protein as indicators of forage nutritive value, the digestibility of forage was brought out as an important interacting characteristic. This was because the digestible portion of a nutrient or a forage reflected the amount of the nutrient or forage that was used by the animal (Church and Pond 1974; Crampton and Harris 1969; Moen 1973). There are several ways of estimating forage digestibility, of which the *in vivo* macrodigestion method was considered to be the most direct and the standard by which all others were judged (Meyer *et al.* 1971; Scales *et al.* 1974; Troelsen 1970; Van Dyne 1968). Indirect *in vitro* methods have recently become popular in estimating forage digestibility, since they were much easier to use and were shown to give results that correlated highly with *in vivo* methods (Pearson 1970; Troelsen 1970). Meyer *et al.* (1971) and Scales *et al.* (1974) compared three *in vitro* digestion methods to the standard *in vivo* macrodigestion technique. The three *in vitro* methods were ones described by: Baumgardt *et al.* (1962), Tilley and Terry (1963) and Van Soest and Wine (1967). Of these three, the method described by Tilley and Terry (1963) proved to be the most reliable predictor of *in vivo* digestibility. Handl and Rittenhouse (1975) found no difference in crested wheatgrass (*Agropyron* *desertorum*) digestibility using three methods described by Tilley and Terry (1963), Van Soest and Wine (1967), and Van Soest (1963).

Manipulation of Nutritive Value

Reseeding was one way of manipulating the nutritive value of a pasture (Heady 1975). Of the many considerations Heady (1975) and Valentine (1971) listed for reseeding, the types of species chosen were most important from the standpoint of animal nutrition. This was because different species have different nutritive characteristics, which also differ according to the stage of maturity and the area they were growing on (Heady 1975; Laycock and Price 1970). Lassiter *et al*. (1956) found a 30 percent difference in crude protein values between Kentucky bluegrass (*Poa pratensis*) and Lincoln bromegrass (*Bromus inermis*) grown under identical conditions. Cogswell and Kamstra (1976) and Polk *et al*. (1976) also found interspecific differences in nutritive value between grasses grown under similar conditions.

The application of fertilizers was shown to increase nutritive value of forage (Knott 1956). Hedrick (1957) found that crude protein in tall fescue increased as the rate of nitrogen fertilization increased. Foster (1977) and Salih and Burzlaff (1977) reported increases in forage digestibility in addition to increases in crude protein, corresponding to increases in rates of nitrogen fertilization. Reid et al. (1966) however, found no significant increase in orchardgrass hay digestibility even at nitrogen fertilization rates of 448 kg/ha. Ramage et al. (1958) found protein levels in an orchardgrass-reed canarygrass (*Phalaris arundinaceae*) stand to increase from 12 to 20 percent with increases in nitrogen rates from 0 to 449 kg/ha respectively, but they found no significant increase in total digestible nutrients (TDN). Cook (1965) found similar results using a lower nitrogen rate (45 kg/ha) for crested wheatgrass (*Agropyron cristatum*) and pubsecent wheatgrass (*Agropyron trichophorum*).

As most herbaceous plants matured, their nutritive value tended to decrease (Cogswell and Komstra 1976; Cook and Harris 1977; Laycock and Price 1970; Stoddart et al. 1975). Laycock and Price (1970) and Anderson and Scherzinger (1975) stated that clipping a grass before it reached maturity would stop the decline in nutritive value, prolong growth and in some cases initiate regrowth. Blaser et al. (1976) stated that the removal of summer growth on intensively managed pastures was essential to prevent senescence and insure forage quality.

METHODS FOR ELK NUTRITION STUDY

Sampling was conducted during December, January and February of the 1976-77 and 1977-78 winters. Each winter was partitioned into three 30 day (monthly) sampling periods. Comparisons were made between the Bentgrass-U, Bentgrass-T and Ryegrass-T pasture types (Figure 3). The Cereal Rye pasture type was not included in comparisons, since it had no potential as a permanent pasture, rather, it is an intermediate stage in the conversion of either the Bentgrass-U or the Bentgrass-T pasture types to the Ryegrass-T pasture type (see pasture type descriptions, pages 8-11). Also, the areas left unhayed during the 1977-78 winter were not included in comparisons, since they were not originally planned as a management alternative, but were the result of the inability to fully harvest the hay crop during the summer of 1977. The following weather data were acquired from a National Oceanic and Atmospheric Administration weather station in Vernonia, Oregon: Mean daily temperatures (°C), Mean daily Maximum-Minimum temperatures (°C), Average precipitation (cm) and the number of days in which the temperature dropped below 0°C per month (NOAA 1966-1978).

Vegetation Sampling

All data pertaining to vegetation were calculated on a dry matter basis.

Total standing biomass of herbage (the amount of plant material available for elk use in a given month) and herbage removal were estimated by clipping caged, paired, 0.22 m^2 circular plots monthly. Three pastures for each of the pasture types being compared, were selected to represent and replicate the appropriate pasture types (Figure 4).

Fifteen cages were distributed randomly in each of the replications and redistributed every 30 days, immediately after clipping. Herbage samples from the clipped plots were oven-dried at 50°C (± 5°C) for five days, then weighed. Total standing biomass of herbage (kg/ha) was estimated by multiplying the oven dry weight of herbage in each caged plot times 44.92. Herbage removal was estimated by the difference in the estimated kg/ha of caged and uncaged plot pairs. The 15 subsample estimates in each replication for each of the above parameters were averaged to provide a value for each of the three replications in each of the three pasture types.

Laboratory Analyses

All data pertaining to nutritive value of vegetation was calculated on a dry matter basis.

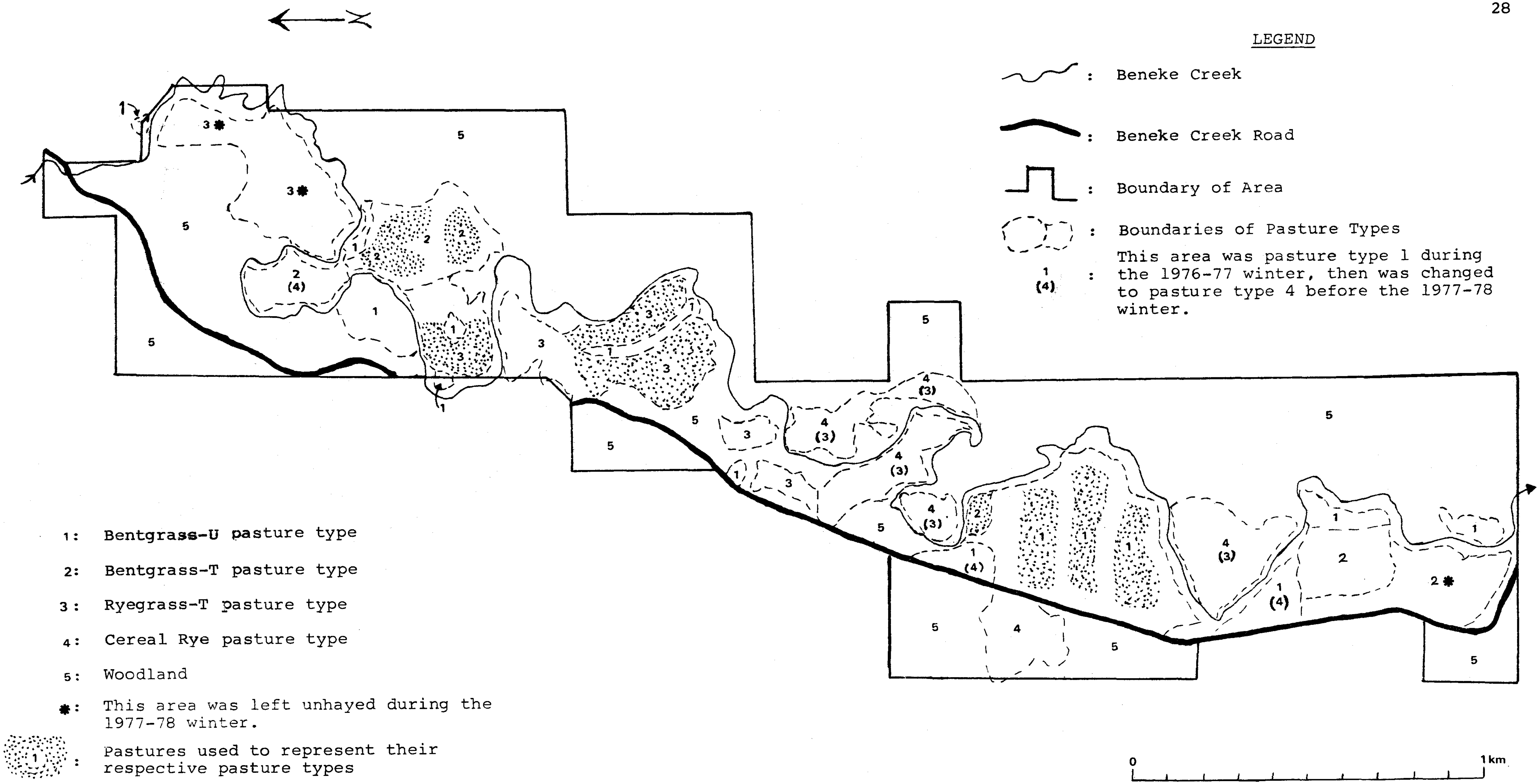

Figure 4. Pasture types and pastures chosen as representative replicates of their respective pasture type (Scale 1:12,000).

After the fifteen caged samples from each replication were weighed, they were composited and a 100 g grab sample per replication was ground through a 40-mesh screen in a Wiley mill. The ground samples were used to determine crude protein, gross energy and in vitro dry matter digestibility.

Five fecal collections were made for each 30 day sampling period in each pasture type replication. During each fecal collection, feces were collected on each replication from observed defecating elk, immediately after defecation. The five fecal collections for each pasture type replication were dried at 50°C (± 5°C), composited and 100 g grab samples for each replication were ground through a 40 mesh screen in a Wiley mill and analyzed for fecal crude protein (FP) and fecal gross energy (FE).

Crude protein (CP) was determined by the micro-Kjeldahl technique (Horowitz _et al._ 1970). Gross energy (GE) was determined by adiabatic bomb calorimetry (Parr 1969). Dry matter digestibility (DMD) of the forage was determined by the two stage _in vitro_ method described by Tilley and Terry (1963). Rumen inoculum was obtained from a fistulated steer that was fed hay from the experimental pastures. The literature indicated that the ability of rumen inoculum to digest feeds among different ruminants (elk, deer and cattle) does not differ markedly, especially for those ruminants fed similar diets (McBee _et al._ 1969; Palmer _et_ al. 1976; Robbins et al. 1975; Ward 1971). Thus cattle, rather than elk rumen fluid was used in the in vitro digestion trials.

Estimates of DMD were used to calculate total fecal output (TFO):

$$(1 - \%DMD)(\text{Intake kg/ha}) = \text{TFO kg/ha} \qquad \text{(Harris 1968)}$$

The following series of equations were used to calculate digestible protein (DP):

$$(\%FP)(\text{TFO kg/ha}) = \text{FP kg/ha}$$

$$(\%CP)(\text{Intake kg/ha}) = CP_{intake}\ \text{kg/ha}$$

$$100\left(1 - \frac{\text{FP kg/ha}}{CP_{intake}\,\text{kg/ha}}\right) = \text{Digestibility Coefficient}_{protein} \text{ or } DC_{protein}$$

$$(DC_{protein})(\%CP) = \%DP \qquad \text{(Crampton and Harris 1969)}$$

The following series of equations were used to calculate digestible energy (DE):

$$(\text{FE Mcal/kg})(\text{TFO kg/ha}) = \text{FE Mcal/ha}$$

$$(\text{GE Mcal/kg})(\text{Intake kg/ha}) = GE_{intake}\ \text{Mcal/ha}$$

$$100\left(1 - \frac{\text{FE Mcal/ha}}{GE_{intake}\,\text{Mcal/ha}}\right) = \text{Digestibility Coefficient}_{energy} \text{ or } DC_{energy}$$

$$(DC_{energy})(\text{GE Mcal/kg}) = \text{DE Mcal/kg}$$

(Crampton and Harris 1969)

Elk Density and Distribution

Ten total counts of elk on the Beneke Creek W.M.A. were conducted during each monthly sampling period. These counts were stratified according to adults and calves. The number of calves were converted to the number of adult equivalents by the following relationship:

$$\frac{\text{Average calf weight kg}^{0.75}}{\text{Average cow weight kg}^{0.75}} = \frac{79\ \text{kg}^{0.75}}{250\ \text{kg}^{0.75}} = 0.42$$

$$(0.42)(\text{number of calves}) = \text{Adult elk equivalents}_{\text{calves}}$$

$$(\text{Adult elk equivalents}_{\text{calves}}) + (\text{Adult elk}) = \text{Total adult elk equivalents}$$

The weight of an animal to the 0.75 power is considered to be more representative of an animal's actual metabolic requirements than the animal's true weight (Church and Pond 1974; Crampton and Harris 1969; Moen 1973). Average Roosevelt elk weights were acquired from Hines (1972), Hines and Lemos (1975) and Lemos and Hines (1974).

During the 10 counts per month, it was probably that the total elk population using the Beneke Creek W.M.A. was observed. Thus, the "Method of Bounded Counts" described by Overton (1971) was used to estimate the total adult elk equivalents using the Beneke Creek W.M.A. during each sampling period.

The distribution of elk among the plant communities and replications was measured by placing a 1 x 100 m plot in each plant community and replication and counting pellet groups in each plot monthly. The number of old pellet groups (ones that had obviously deteriorated, such that they would not be present during the next count) were recorded and subtracted from the next count for the next sampling period to provide an estimate of total pellets deposited per 100 m^2 during that sampling period. The following relationship was used to estimate the density of adult elk equivalents (Elk) in each plant community (Comm.):

$$\text{Elk/ha in } i^{th} \text{ Comm.} = \left[\text{Total Elk} \left(\frac{\frac{\text{Pellet groups}}{\text{Comm. } i}/\text{plot} \times \frac{\text{ha}}{\text{Comm. } i}}{\sum_{i}^{\text{Comm.}} \left(\frac{\text{Pellet groups}}{\text{Comm. } i} /\text{plot} \times \frac{\text{ha}}{\text{Comm. } i} \right)} \right) \right] \div \frac{\text{ha}}{\text{Comm. } i}$$

$$= \text{Total Elk} \left(\frac{\frac{\text{Pellet groups}}{\text{Comm. } i}/\text{plot}}{\sum_{i}^{\text{Comm.}} \left(\frac{\text{Pellet groups}}{\text{Comm. } i} / \text{plot} \times \frac{\text{ha}}{\text{Comm. } i} \right)} \right)$$

The density of Elk in each replication generally corresponded to the type of plant community which comprised that pasture. However, in some of the replications, more than one plant community existed. In these cases, the density estimates for the plant communities, weighted according to the area they occupied in the replication, were averaged to represent that particular replication.

Although the cereal rye pasture type and the area left unhayed during the 1977-78 winter (Figure 4) were not included in comparisons, measurements were taken in these areas to account for their effects on elk density and distribution.

Estimates of Elk/ha/replication were used to determine the amount of intake by Elk. An average intake value of 22.75 g/kg was estimated to be required daily for free ranging, gestating, adult elk by Thorne et al. (1976). Thus, an Elk, weighing 250 kg, would consume approximately 171 kg/month (30 days). Thorne and Butler (1976) found similar requirements (24.2 g/kg) for free ranging elk fed on alfalfa hay and Raleigh and Lesperance (1972) reported a 21.3 g/kg intake for cattle on Nevada winter range. The intake values calculated from the Elk/ha/replication were used in the calculation of TFO, DP and DE.

Statistical Analyses

Standing biomass of herbage, herbage removal, Elk density, gross energy, crude protein, and dry matter digestibility were tested for differences among pasture types, winters, and months using the following nested factorial analysis of variance (Steel and Torrie 1960):

Source of Variation	Degrees of Freedom
Pasture type (P)	2
Error P	6
Winter (W)	1
Month (M)	2
P X W	2
P X M	4
W X M	2
P X W X M	4
Error PWM	30
Total	53

Since there was no measurable elk use in two of the replications of the Bentgrass-U pasture type during the January and February sampling periods of the first year, intake could not be calculated. Therefore, estimates of DE and DP could not be calculated for those replications and months. The model used for analysis requires equal numbers of observations for each treatment, thus two analyses were used for the DE and DP data. The first analysis of variance tested differences between the Bentgrass-T and Ryegrass-T pasture types, both in winters and months:

Source of Variation	Degrees of Freedom
Pasture type (P)	1
Error P	4
Winter (W)	1
Month (M)	2
P X W	1
P X M	2
W X M	2
P X W X M	2
Error PWM	20
Total	35

The second analysis of variance was performed on data from the second winter only. There were no missing observations for DE and DP in the second winter, thus the split-plot analysis of variance tested differences between all treatments over the three months of the second winter:

Source of Variation	Degrees of Freedom
Pasture type (P)	2
Error P	6
Month (M)	2
P X M	4
Error PM	12
Total	26

The Duncan's New Multiple Range Test was used to test for significance of differences among treatment means where the analysis of variance indicated such differences existed (Steel and Torrie 1960). All results reported as significant will be so at $P < 0.05$ and results reported as highly significant will be so at $P < 0.01$ throughout the text.

The stepwise regression analysis was used to determine the best linear regression models for the following dependent and independent variables (Draper and Smith 1966):

Dependent Variable	Independent Variables
Elk/ha	Standing biomass, GE, CP, DMD, DE, DP
DMD	Standing biomass, GE, CP, Elk/ha
DE	Standing biomass, CP, Elk/ha
DP	Standing biomass, GE, Elk/ha

RESULTS AND DISCUSSION

Weather Patterns

The weather patterns during the two winter sampling periods of this study were different. During the first winter (1976-77), monthly precipitation figures were markedly below those for the 10 year averages (Figure 5) (NOAA 1966-1978). Although mean daily temperatures for the study period were very similar to the 10 year average (Figure 5), daily minimum temperatures were far below and daily maximum temperatures were above those of their respective 10 year averages (NOAA 1966-78)(Figure 6). The interaction of the low levels of precipitation and the broad ranges in daily temperatures, resulted in the following observed weather pattern during the first winter of the study:

During the period from November to the middle of February of the first winter, the general weather pattern was to have two to five consecutive days of relatively clear skies followed by two to three days of cloudy, rainy weather. A cloudy day is considered normal during the winter season in this area and the temperature patterns on the cloudy days of the first winter generally reflected those indicated by the 10 year averages (Figure 6). On the clear nights the temperatures dropped abnormally low,

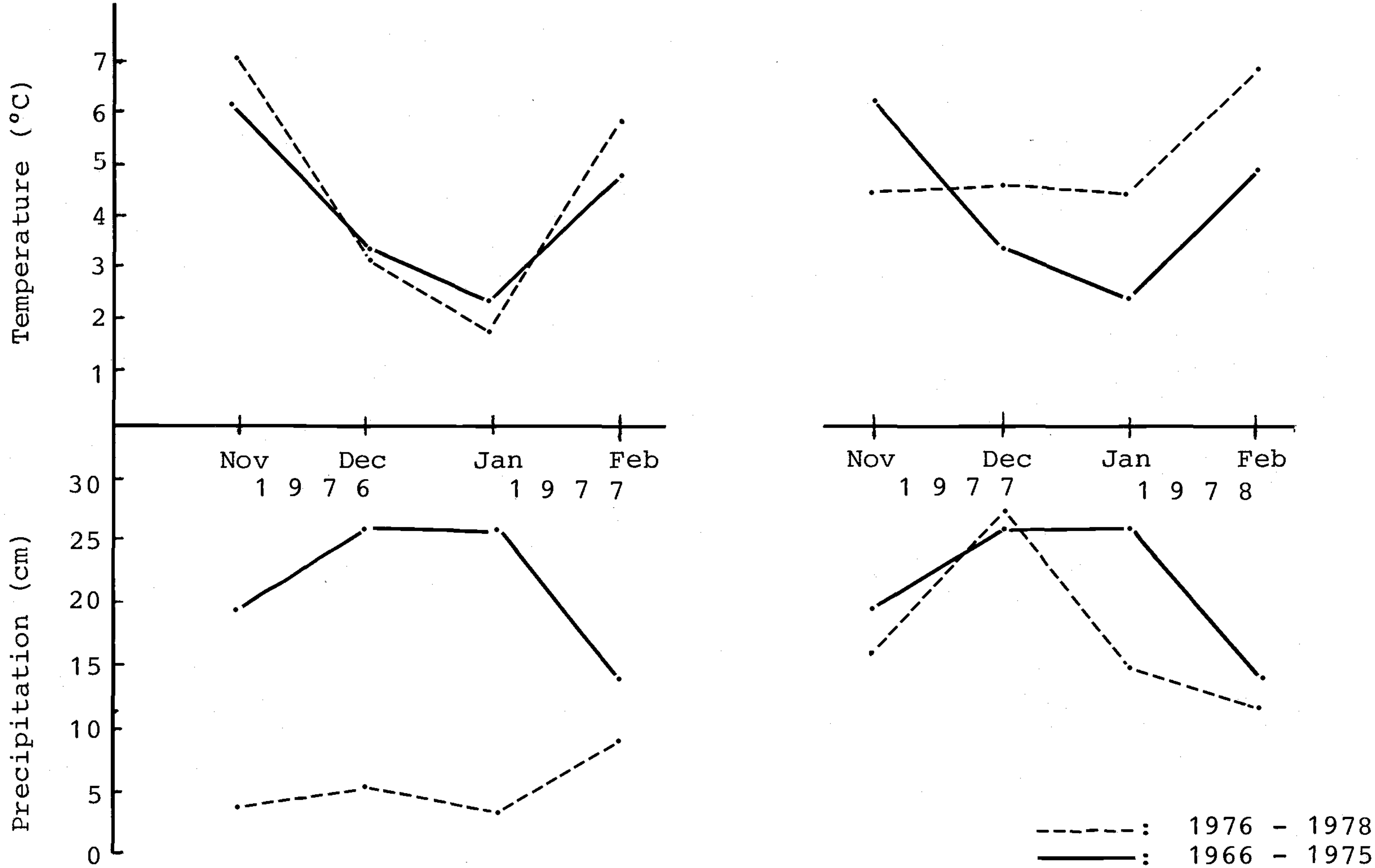

Figure 5. Comparison of precipitation and temperatures for the two winters of the study to a 10 year average (NOAA 1966-1978).

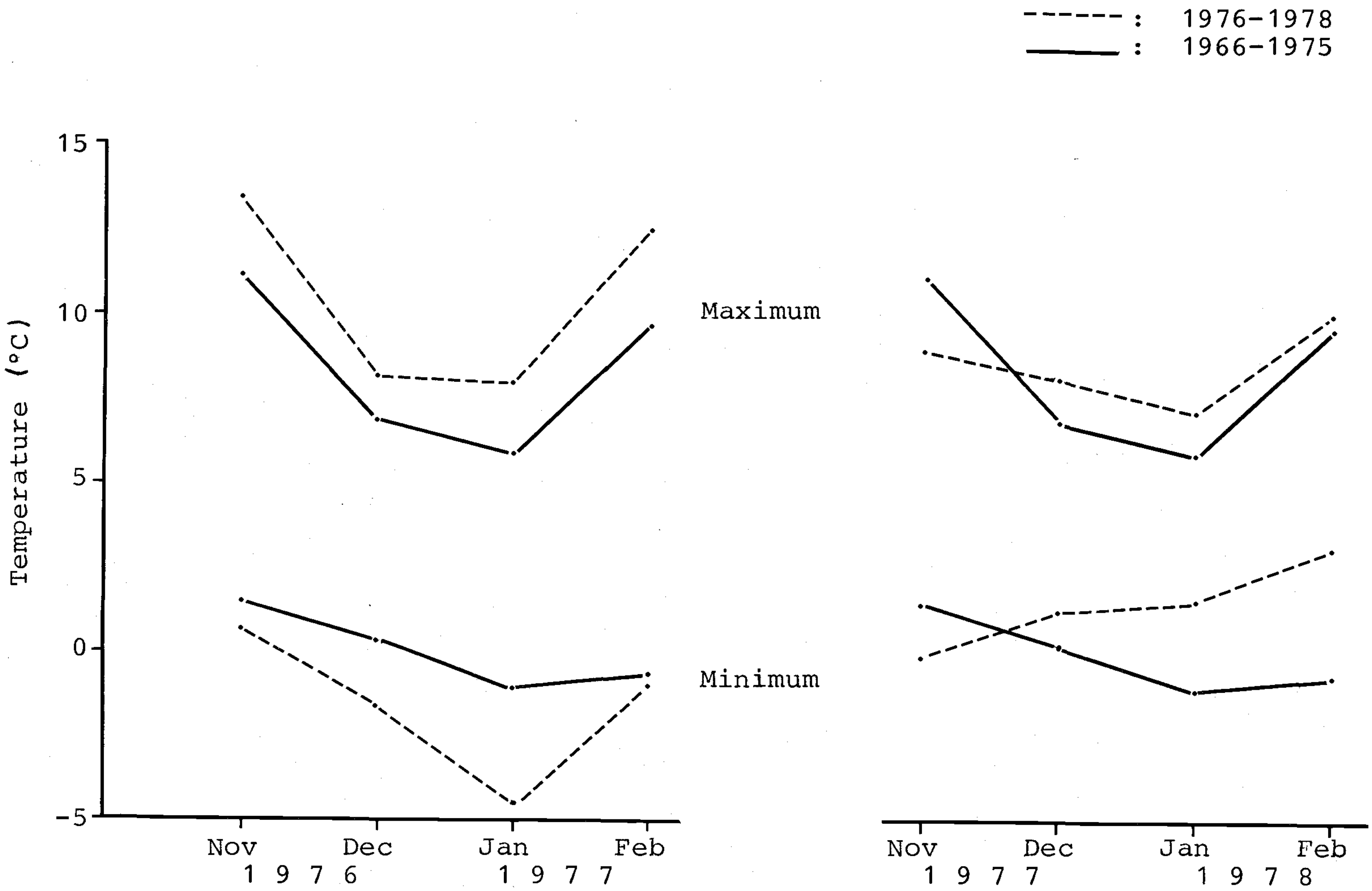

Figure 6. Comparison of daily maximum and minimum temperatures for the two winters of the study to a 10 year average (NOAA 1966-1978).

resulting in frost and during the clear days temperatures rose abnormally high. During this first winter of the study the number of clear days was abnormally high, as was indicated by low levels of precipitation (Figure 5) and the broad ranges in daily maximum and minimum temperatures (Figure 6). The abnormally high number of clear days resulted in an abnormally high number of days per month in which a frost occurred (Figure 7) (NOAA 1966-1978).

The temperature during the second winter (1977-78) of the study were higher than average (Figures 5 and 6). As a result, the number of days per month in which a frost occurred was abnormally low (Figure 7). Precipitation at the beginning of the second winter was close to the average, then dropped below the 10 year average in January and February (Figures 5 and 6). Both precipitation and temperature averages for the second winter were much higher than those of the first winter.

In general, the weather during the second winter was much closer to average than that of the first winter. Although the second winter had slightly below average precipitation and slightly above average temperatures, the first year's precipitation was comparably very low and average daily temperature extremes had a wide range. Throughout the rest of this text the first winter will be referred to as the dry winter and the second winter will be referred to as the normal winter.

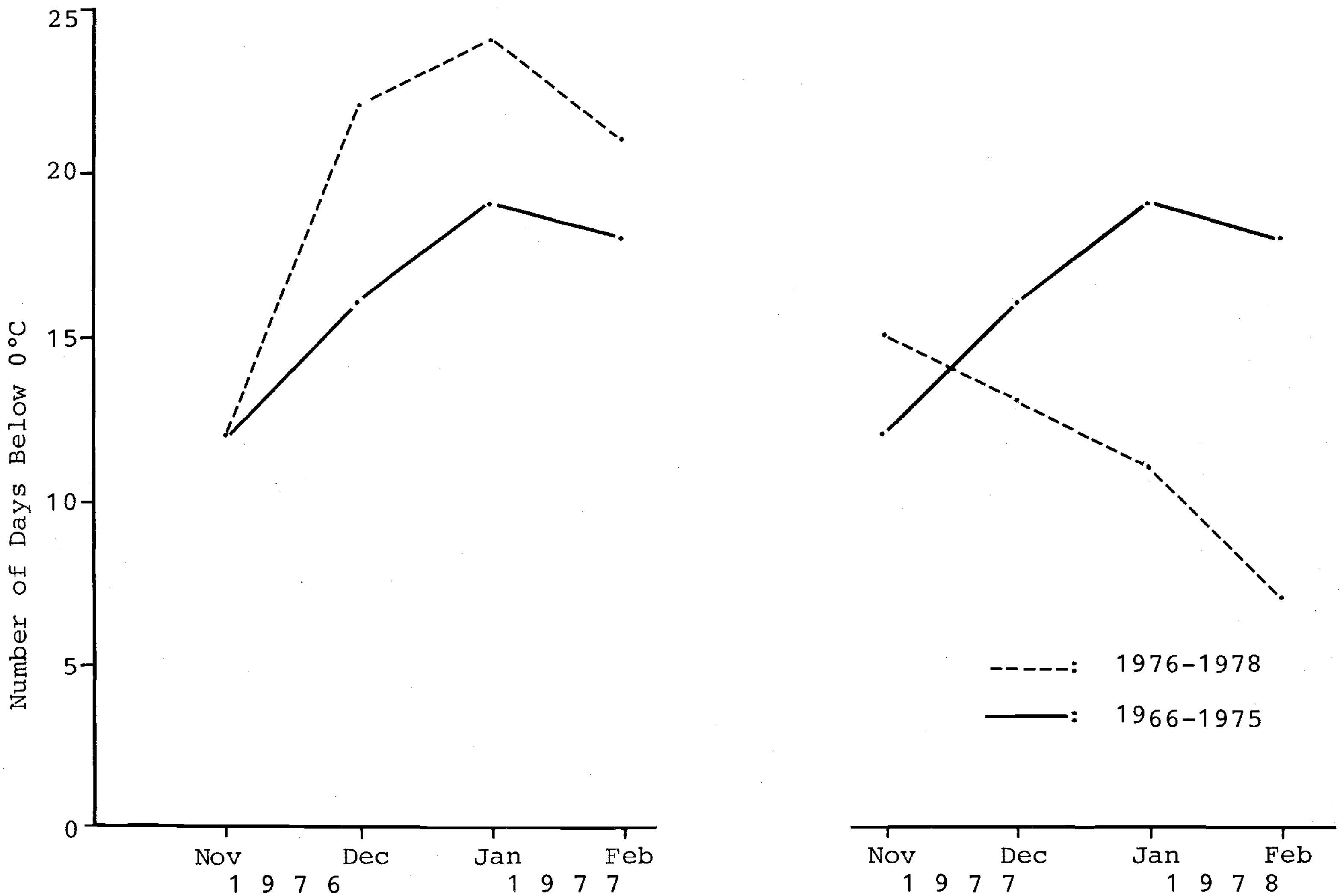

Figure 7. Comparison of the number of days in which the temperature dropped below 0°C for the two winters of the study to a 10 year average (NOAA 1966-1978).

Standing Biomass of Herbage
(kg/ha)

Standing biomass was affected by several inseparable factors, other than pasture types and weather. These factors were: grazing that occurred before the beginning of the study period in each winter, growth of herbage, and deterioration of herbage. Thus, the standing biomass data have little value for evaluation of treatment effects. Rather, their value is descriptive in nature, that is, to provide estimates of the amount of herbage available for elk use in each pasture type during each month and winter.

The analysis of variance (Appendix E) showed highly significant differences among pasture types, winters and months. All pasture types were significantly different within months of the dry winter. The Bentgrass-U pasture type had the most herbage dry matter available for elk use (standing biomass) in each month during this winter, while the Ryegrass-T pasture type had the least (Table 2). During the normal winter, the Bentgrass-U and Bentgrass-T pasture types were not significantly different from each other, but both had significantly greater standing biomass than the Ryegrass-T pasture type in all months (Table 2). There were no significant differences among months within treatments of the dry winter.

During the normal winter, standing biomass in the Bentgrass-U pasture type for December and January was significantly higher than in February. In the Bentgrass-T pasture

Table 2. Standing biomass of herbage (kg/ha).

Month	Pasture Type: Bentgrass-U	Bentgrass-T	Ryegrass-T
	Dry Winter		
December	3830a[1]	3233b	2157c
January	4396a	3666b	2315c
February	3826a	3212b	2224c
	Normal Winter		
December	4358a	3460a	2636b
January	3978a	3580a	1556b
February	3214a	2994a	1213b

[1]Values within rows followed by the same letter were not significantly different.

type standing biomass was significantly higher in January than February and in the Ryegrass-T pasture type December had significantly more standing herbage than January and February. All other comparisons of months within treatments for standing biomass showed no significant differences. These data indicated that regrowth during the normal winter was less rapid than elk use and herbage deterioration. Elk use between the two winters was not significantly different. Thus, the cloudier, rainier and milder weather during the normal winter must have limited regrowth more than the sunnier, drier weather with broad daily ranges in temperature during the dry winter (Figures 5, 6 and 7).

For the months of December and January there was no significant difference between winters, however, for February, the dry winter had significantly higher standing biomass than the normal winter. As a result, there was a highly significant winter x month interaction for standing biomass (Appendix E).

Herbage Removal (kg/ha)

The analysis of variance for herbage removal (Appendix E) showed a highly significant difference among pasture types, a significant difference among months and no significant difference among winters. There was no significant difference in the amount of herbage removed within months from the Bentgrass-U and Bentgrass-T pasture types (Table 3). Herbage removal within months in the Ryegrass-T pasture

Table 3. Herbage removal (kg/ha).[1]

	Pasture Types		
Month	Bentgrass-U	Bentgrass-T	Ryegrass-T
December	0a[2]	267a	708b
January	176a	473ab	779b
February	78a	0a	646b

[1]Values were averaged over winters, since there was no significant difference among winters.

[2]Values within rows followed by the same letter were not significantly different.

type was significantly higher than in both the Bentgrass-U and Bentgrass-T pasture types, except in January, where it was not significantly different from the Bentgrass-T pasture type. Based on personal observations and those of Wheeler (1976), elk use was determined to be the cause of most of the herbage removal on the Beneke Creek W.M.A. during the winter. Thus, these data indicate that in general, elk used forage from the Ryegrass-T pasture type more than from the Bentgrass-U and Bentgrass-T pasture types and showed no differences in herbage use between Bentgrass-U and Bentgrass-T pasture types (Table 3).

Significantly more herbage was removed in January than February from the Bentgrass-T pasture type. No other significant differences occurred between months within pasture types.

There was a significant pasture type X winter interaction for herbage removed (Appendix E), indicating differential patterns of herbage removal in the pasture types between the two years.

The lack of significant differences among herbage removal values that differ considerably numerically shown in Table 3, reflected the high variability of the herbage removal data. Thus, individual observations were not reliable as estimates of elk intake. However, when the sum of herbage removed for the Beneke Creek W.M.A. (54 observations) was divided by a pooled estimate of elk density, the average intake per Elk (adult elk equivalents weighing 250 kg) per month (30 days) was 173 kg (22.93 g forage consumed daily/kg body weight). This was almost identical to Thorne's et al. (1976) estimate of intake for free ranging elk, which was 171 kg/mo for a 250 kg elk (22.75 g forage consumed daily/kg body weight) and is within the range of results of others for free ranging adult ruminants (Table 4).

Table 4. Comparison of Elk intake during the winter estimated from herbage removal data to estimates by other authors.

	Intake[1]	Type of animal
Estimated by herbage removal data	22.9	Roosevelt elk
Thorne et al., 1976	22.8	Rocky Mountain elk
Thorne and Butler, 1976	24.2	Rocky Mountain elk
Raleigh and Lesperance, 1972	21.3	Cattle
Alldredge et al., 1974	20.1	Mule deer

[1]Intake is expressed as g forage consumed daily/kg body weight.

Elk Density and Distribution

Total Elk

There was no significant differences found between the average of 160 Elk using the Beneke Creek W.M.A. during the dry winter and the normal winter average of 175 Elk. The total numbers of Elk using the Beneke Creek W.M.A. during the winter study periods of 1976-77 and 1977-78 averaged

168 Elk. The average elk density on the 78 hectares of pasture was 2.15 Elk/ha of pasture.

Elk Density in Pasture Types
(Elk/ha)

Pasture type differences for Elk density were highly significant, while no significant differences were found for the effects of winters and months on Elk density, according to the analysis of variance in Appendix E. There was no significant difference in Elk density between the Bentgrass-U and Bentgrass-T pasture types but the Ryegrass-T pasture type had a significantly higher Elk density than both the Bentgrass-U and Bentgrass-T pasture types (Table 5).

Table 5. Elk density (Elk/ha).[1]

	Pasture Types	
Bentgrass-U	Bentgrass-T	Ryegrass-T
0.4a[2]	1.3a	4.4b

[1]Values were averaged over winters and months since there was no significant difference among years and months.
[2]Values followed by the same letter were not significantly different.

The Elk density data indicated that elk used the Ryegrass-T pasture type more than the Bentgrass-U and Bentgrass-T pasture types and they used the Bentgrass-U and Bentgrass-T pasture types approximately the same degree, although the higher numerical value for the Bengrass-T than the Bentgrass-U pasture type implied a slightly higher but not significant level of use (Table 5). These results corresponded closely with the results for herbage removal (pages 43-44, Table 3). The elk on the Beneke Creek W.M.A. roamed freely on the area with very little disturbance during the study period. The experimenter was the greatest disturbance, and the elk quickly became accustomed to him. Also, forage availability did not appear to be limiting except possibly during February of the normal winter in the Ryegrass-T pasture type (Table 2), where standing biomass dropped to a low level. As a result, the differences in elk use and herbage removal among pasture types reflected elk preference. Elk preferred the Ryegrass-T pasture type over the Bentgrass-U and Bentgrass-T pasture types but showed no preference between the Bentgrass-U and Bentgrass-T pasture types.

A significant winter x month interaction was found (Appendix E), indicating that elk density varied differently among months of the dry winter as compared to the normal winter. Average Elk densities for December, January and February during the dry winter were: 1.85, 2.65 and 1.67 Elk/ha and for the normal winter: 2.31, 2.06 and 2.35 Elk/ha respectively. The high density (2.65 Elk/ha) during January of the dry winter corresponded to severe weather conditions indicated for this month by Figures 6 and 7. Approximately 0.4-0.6 m of snow in the surrounding hills probably drove elk down to this area that they normally did not use. In fact, four times during this month, a band of approximately 30 elk was observed that was never seen before or after.

Nutritive Value of Available Herbage

Gross Energy (Mcal/kg)

The analysis of variance for gross energy (Appendix E) showed no significant differences among pasture types, winters and months, nor were any significant interactions found. This indicated that the energy in the feed, which ranged from 4.2 to 4.7 Mcal/kg, did not differ between the different types of forages throughout the two winters of the study. Crampton and Harris (1969) stated that, generally, gross energy did not vary significantly among different feeds. Thus, gross energy was not a good measure of forage quality. Estimates of gross energy were summarized in Appendix H.

Digestible Energy (Mcal/kg)

Highly significant differences were found among pasture types and winters, and significant differences were found among months for digestible energy (DE), according to the analysis of variance in Appendix F. This analysis did not include estimates for the Bentgrass-U (see methods page 34). The analysis of variance on the normal winter's data, which included data for all three pasture types, showed highly significant differences among pasture types and months (Appendix G).

During the dry winter, the Ryegrass-T pasture type had a higher DE value than the Bentgrass-U pasture type. There were no significant differences within months between the Bentgrass-T and Ryegrass-T pasture types during January and February of the dry winter (Table 6). Although values for the Bentgrass-U pasture type in the dry winter (Table 6) could not be compared statistically to the Bentgrass-T and Ryegrass-T pasture types they appeared to be very similar to those for the Bentgrass-T and Ryegrass-T pasture types except in December.

Table 6. Digestible energy (Mcal/kg).

Month	Pasture Types		
	Bentgrass-U	Bentgrass-T	Ryegrass-T
	Dry Winter		
December	1.3[1]	1.3a[2]	2.3b
January	1.7[1]	1.8a	1.9a
February	1.3[1]	1.8a	1.8a
	Normal Winter		
December	1.6a	2.0a	3.0b
January	1.2a	1.6a	2.5b
February	1.2a	1.5a	2.4b

[1]There were not enough observations to test these values statistically.

[2]Values within rows followed by the same letter were not significantly different.

During the normal winter, the Ryegrass-T pasture type had significantly higher within month DE values than both the Bentgrass-U and Bentgrass-T pasture types while the Bentgrass-U and Bentgrass-T pasture types were not significantly different within months. Overall, the Ryegrass-T pasture type provided higher concentrations of DE for elk use than the Bentgrass-U and Bentgrass-T pasture types. Also, the Ryegrass-T pasture type consistently equaled or exceeded the minimum winter energy requirement (1.83 Mcal/kg) for free ranging cattle and sheep, as reported by Cook and Harris (1977).

Trainer (1971) reported that the inability of Roosevelt elk cows to maintain energy (fat) reserves was responsible for their relatively low rates of reproduction. He suspected that inadequate nutrients in the forage may have been the cause of the relatively poor body conditions observed. The relatively low DE levels shown for the Bentgrass-U and Bentgrass-T pasture types (Table 6) indicated that Trainer's (1971) suspicions were correct, since most Roosevelt elk winter habitat was similar in characteristics to the Bentgrass-U and Bentgrass-T pasture types, except that very little was ever fertilized as the Bentgrass-T pasture type was. Thus, the higher and adequate levels of DE in the Ryegrass-T pasture type implied that Roosevelt elk with access to these types of pastures should have been able to maintain higher rates of reproduction.

All values for DE in the Ryegrass-T pasture type of the normal winter were significantly higher than their respective values in the dry winter. Only the estimate of DE in December of the normal winter was significantly higher than the respective value in the dry winter. The December estimate of DE in the normal winter for the Ryegrass-T pasture type was significantly higher than those for January and February of the same winter and pasture type.

The differential variation of DE values in pasture types, winters and months was most likely caused by the differing weather patterns between winters and across months and their effects on the plants. The high incidence of consecutive days of freezing and thawing, followed by short periods of rain described earlier (page 36) during the dry winter, could have indirectly caused the relatively low DE levels in the Ryegrass-T pasture type during this winter (Figures 6 and 7). Larcher (1975) and Leopold and Kriedemann (1975) stated that freezing caused cell membrane rupture, disturbed cell metabolism and hindered transport of nutrients. Thus, the plants may have become more susceptible to leaching. Perennial ryegrass, which heavily dominated the Ryegrass-T pasture type, tended to be taller, stand more vertical and was less dense than colonial bentgrass. The colonial bentgrass in the Bentgrass-T pasture type was lowgrowing and matted. Larcher (1975) stated that low-growing and dense populations of plants were less susceptible to frost damage than taller and more sparse plants. The herbage in the Bentgrass-U pasture type was for the most part dormant and not susceptible to frost damage. This would explain the differential responses of DE values in the Bentgrass-T and Ryegrass-T pasture types between the dry and normal winter (Table 6).

Also, elk grazing might have affected differences within winters among months. Crampton (1959) stated that animals generally selected for forages that were high in DE. Plants that were high in digestibility tended to be more succulent and thus more preferred by grazing animals (Heady 1964). It was possible that the elk could have grazed most of the higher quality plants earlier in the winter season because they were more palatable. This pattern was most prominent in the Ryegrass-T pasture type, since it received the highest level of elk use (Tables 3, 5 and 6).

The combination of weather and grazing effects on DE just discussed, probably caused a highly significant pasture type x winter and significant pasture type x month, winter x month and pasture type x winter x month interactions.

Percent Crude Protein

There was a highly significant difference in percent crude protein among pasture types, winters and months

(Appendix E). The range of crude protein values was from 4.0 percent in January of the dry winter in the Bentgrass-U pasture type, to 22.5 percent in February of the normal winter in the Ryegrass-T pasture type. Crude protein data were not used to evaluate differences in pasture types over winters and months since more accurate digestible protein data were computed. Estimates of crude protein were summarized in Appendix I.

Percent Digestible Protein

The analysis of variance in Appendix F showed highly significant differences for percent digestible protein (DP) among pasture types, winters and months. This analysis did not include estimates for the Bentgrass-U pasture type (see methods page 34). The analysis of variance on the normal winter's data, which included data for all three pasture types, showed a highly significant difference in DP among pasture types and no significant differences in DP among months (Appendix G).

During the dry winter there were no significant differences among pasture types within months except in February, where the Ryegrass-T pasture type had significantly higher DP than the Bentgrass-T pasture type (Table 7). During the normal winter the Ryegrass-T pasture type produced the significantly highest within month DP, while the Bentgrass-U pasture type produced the significantly

Table 7. Percent digestible protein.

Month	Pasture Types		
	Bentgrass-U	Bentgrass-T	Ryegrass-T
		Dry Winter	
December	0.0[1]	1.7a[2]	2.4a
January	0.0[1]	0.0a	0.7a
February	0.0[1]	0.5a	4.7b
		Normal Winter	
December	0.0a	4.6b	15.9c
January	0.0a	3.9b	14.7c
February	0.0a	3.5b	17.0c

[1]There were not enough observations to test these values statistically.

[2]Values within rows followed by the same letter were not significantly different.

lowest within month DP in all months (Table 7). In general, the Ryegrass-T pasture type seemed to provide elk with a higher concentration of DP and the Bentgrass-U pasture type provided no measurable digestible protein. Estimates of DP for the Ryegrass-T pasture type exceeded the minimum DP requirement (4.4 percent) suggested by Cook and Harris (1977) for range cattle and sheep during the winter, except during the first two months of the dry winter (Table 7). Estimates of DP for the Bentgrass-U and Bentgrass-T pasture types were below the suggested minimum requirement for DP, except in December of the normal winter for the Bentgrass-T pasture type.

Crampton and Harris (1969) and Church and Pond (1974) considered protein as a good overall indicator of nutritional quality of feed. In general, the herbage in the Ryegrass-T pasture type had higher concentrations of DP and the Bentgrass-U pasture type the lowest. This indicated that elk using the Ryegrass-T pasture type were eating forage that was relatively high in overall nutritional quality and elk using the Bentgrass-U pasture type were eating forage of relatively low overall nutritional quality.

For the Bentgrass-U and Ryegrass-T pasture types all values in the normal winter were significantly higher than the corresponding values in the dry winter. The same weather patterns that were described as affecting DE levels seemed to have similarly affected DP levels, in that the more extreme conditions (freezing and thawing of herbage) during the dry winter damaged plant tissues and made the nutrients more susceptible to leaching. In addition, Leopold and Kriedemann (1975) stated that freezing and thawing can cause denaturation of proteins. This may have happened in this case, since the effects of freezing and thawing seemed to have a more severe effect on DP levels as compared to DE levels (Tables 6 and 7).

There were broader numerical differences in DP between winters in the Ryegrass-T pasture type than the Bentgrass-U pasture type (Table 7). This further supported the theory discussed for DE, that the herbage, primarily perennial ryegrass, in the Ryegrass-T pasture type was more susceptible to frost damage than the herbage, primarily colonial bentgrass, in the Bentgrass-U pasture type, as a result of morphological differences between perennial ryegrass and colonial bentgrass. These differential responses of DP levels in pasture types to weather patterns within winters and within months, most likely were the reasons for the highly significant pasture type x winter and pasture type x month interactions shown in Appendix F.

Percent Dry Matter Digestibility

The analysis of variance (Appendix E) showed highly significant differences in percent dry matter digestibility (DMD) among pasture types, winters and months. In both winters, the Ryegrass-T pasture type had significantly higher within month DMD than the Bentgrass-U and Bentgrass-T pasture types (Table 8). DMD within months in the Bentgrass-T pasture type was significantly higher in December of both winters and January of the dry winter than the Bentgrass-U pasture type (Table 8).

In general, forage digestibility was highest for the Ryegrass-T pasture type and lowest for the Bentgrass-U pasture type. There was not much difference in DMD between the Bentgrass-U and Bentgrass-T pasture types.

The Ryegrass-T pasture type had significantly higher DMD in the normal winter for December and January than DMD

Table 8. Percent dry matter digestibility.

Month	Pasture Types		
	Bentgrass-U	Bentgrass-T	Ryegrass-T
		Dry Winter	
December	30a[1]	37b	52c
January	33a	38a	48b
February	34a	38a	49b
		Normal Winter	
December	35a	42b	62c
January	33a	39b	57c
February	32a	32a	54b

[1]Values within rows followed by the same letter are not statistically different.

for the respective month in the dry winter. This difference was most likely caused by the weather patterns described earlier in the discussions for DE and DP. DMD was significantly higher in February of the dry winter in the Bentgrass-T pasture type than the respective DMD in the normal winter. The only explanation for this difference is that it appeared that the elk, through selective grazing in the normal winter, consumed the more palatable forage, which is frequently of a higher DMD (Heady 1964; Voigt 1975) and herbage of lower DMD was left in February. Another relationship which supported this theory is that in December of the normal winter for the Bentgrass-T and Ryegrass-T pasture types, DMD was significantly higher than respective DMD values for February of the same winter. This may have been caused by selective elk grazing.

The Bentgrass-U pasture type showed no significant differences in DMD among winters and months. The differential responses of DMD in pasture types between winters just discussed caused a highly significant pasture type x winter interaction (Appendix E).

There were no significant differences in DMD averages for months in the dry winter, but in the normal winter the average DMD for December was significantly higher than DMD in February. This caused the highly significant winter x month interaction shown in Appendix E.

Linear Relationships Among Parameters

Linear Model for Percent Dry Matter Digestibility

The stepwise regression analysis on percent dry matter digestibility (DMD) as the dependent variable and gross energy Mcal/kg (GE), Elk density (Elk/ha), percent crude protein (CP) and standing biomass of herbage kg/ha (SB), as independent variables, produced the following regression equation, which was determined to best predict DMD: ($R^2 = 0.85$)

$$DMD = 11.75\ GE + 2.98\ Elk/ha + 0.89\ CP - 25.34$$

The relatively high coefficient of determination (r^2) indicated that GE, CP and Elk/ha were good predictors for DMD.

Linear Model for Digestible Energy

The stepwise regression analysis on digestible energy Mcal/kg (DE) as the dependent variable and Elk density (Elk/ha), standing biomass of herbage kg/ha (SB) and percent crude protein (CP) as independent variables produced the following regression equation, which was determined to best predict DE: ($R^2 = 0.60$)

$$DE = 0.05\ CP + 0.11\ Elk/ha + 1.01$$

The relatively low coefficient of determination indicated that although CP and Elk/ha do predict DE, they did not explain 40 percent of the variability associated with DE.

Linear Model for Percent Digestible Protein

The stepwise regression analysis on percent digestible protein (DP) as the dependent variable and Elk density (Elk/ha), standing biomass of herbage kg/ha (SB) and gross energy Mcal/kg (GE) as independent variables produced the following regression equation, which was determined to best predict DP: ($r^2 = 0.43$)

$$DP = -0.004\ SB + 1.65$$

The low coefficient of variation indicated that SB was not a good predictor of DP, however, the above model was the best of all possible using the three independent variables.

Linear Model for Elk Density

The stepwise regression analysis on Elk density (Elk/ha) as the dependent variable and standing biomass of herbage kg/ha (SB), percent crude protein (CP), gross energy Mcal/kg (GE), percent dry matter digestibility (DMD), percent digestible protein (DP) and digestible energy Mcal/kg (DE) as in independent variables produced the following regression equation, which was determined to best predict DE: (R^2 = 0.72)

$$Elk/ha = 0.21\ DMD - 0.12\ CP - 2.79\ GE + 6.75$$

The above equation showed that the nutritive value of the herbage was related to the level of elk use and can be used to predict levels of elk use.

CONCLUDING DISCUSSION

The weather differences between the dry winter and the normal winter discussed throughout this text, seemed to have a marked influence on both herbage quantity and herbage quality.

Elk use was similar in the two winters of the study, thus the differences among winters in the quantity of available herbage (standing biomass) was largely dependent on environmental influences. Standing biomass did not change from December through February of the dry winter which indicated that the rate of growth was as rapid as herbage removal. However, during the normal winter standing biomass was lower in February than December which indicated that the rate of regrowth was slower than herbage removal. The abnormally cold, frosty and clear nights in the dry winter did not have as much of a detrimental influence on regrowth as the abnormally warm and clear days (more than average sunlight) had a beneficial influence. The perpetually cloudy, rainy but mild weather during the normal winter was not as beneficial to regrowth as the weather in the dry winter.

The freezing and thawing of forage during the dry winter seemed to have a detrimental effect on nutritive values (DMD, DE, DP) of the live, green herbage (Bentgrass-T and Ryegrass-T pasture types), especially on DP levels.

This is somewhat opposite to the response of standing biomass just discussed. The reasons for this are as follows: most regrowth occurs at the base of the plant near the soil surface, while older leaves and stems are higher on the plant (Leopold and Kriedemann 1975). Leopold and Kriedemann (1975) stated that the area at the surface of the soil tended to be warmer than air temperatures at night, especially if day time temperatures were high. Thus, the new regrowth occurring at the base of plants could have been temporarily protected from freezing by radiation from the soil while the older portions of the plant, being higher and more exposed, would freeze and become more susceptible to leaching and protein denaturation. As a result, during the dry winter, a pattern may have developed where the increased temperatures and sunlight during the day stimulated regrowth from the base of the plants. This new regrowth would be protected by the warmth from the soil, until it reached a certain height, where it became susceptible to freezing. At this point, the leaves and shoots would be damaged by frost, which ultimately resulted in a lowered nutritive value. The mild weather during the normal winter did not have this effect on the vegetation, thus nutritive values were relatively higher. The lack of nutritive value differences between winters in the Bentgrass-U pasture type was most likely because most of the herbage was dormant.

Although winter forage production on actively growing Coastal Range bottomlands and pastures may not have been affected during drier winters, the data indicated that the higher incidence of freezing and thawing during these drier winters had a detrimental effect on nutritive value of forage as compared to wetter winters. Also, it appeared that more open and taller stands of grasses, such as a perennial ryegrass stand, were more susceptible to frost damage than the shorter more dense stands, such as a colonial bentgrass stand.

As mentioned earlier, elk use did not differ significantly between winters. However, elk showed a strong preference for the Ryegrass-T pasture type over the Bentgrass-U and Bentgrass-T pasture types and no difference in preference between the Bentgrass-U and Bentgrass-T pasture types. Feeds that were higher in nutritive value tended to be more preferred over plants of lower nutritive quality (Cook 1965; Heady 1964; Voigt 1975). This seems to have been the case on the Beneke Creek W.M.A. The forage in the Ryegrass-T pasture type was generally higher in DE, DP and DMD than the other two pasture types. The Bentgrass-T pasture type was higher in DP, slightly higher in DMD and the same in DE as the Bentgrass-U pasture type. The differences in nutritive value between the Bentgrass-U and Bentgrass-T pasture types either were not great enough to influence elk use or differences in the levels of elk use could not have been detected, or another undetected factor in these two pastures influenced elk use more than nutritive value of forage.

One of the objectives on the Beneke Creek W.M.A. was to attract elk from adjacent private lands to the area during the winter. The Beneke Creek W.M.A. was closed to vehicles. Thus, the limitation on disturbance served as an attractant to elk. The pastures on the surrounding areas varied in characteristics between those like the Bentgrass-U pasture type and those like the Bentgrass-T pasture types, but few were fertilized. As far as pastures contributing to the area's attractiveness to elk, the Ryegrass-T pasture type was the only one most likely to significantly add to the attractiveness of the area over that of the protection from disturbance.

The herbage in the Ryegrass-T pasture type most often exceeded the recommended minimum concentrations of DP and DE by Cook and Harris (1977). The Bentgrass-T pasture type's herbage met minimum DE levels half of the time and DP levels one-sixth of the time. The herbage in the Bentgrass-U pasture type never reached minimum requirement levels for DE and DP. This does not mean that the diets of elk using the Bentgrass-U and Bentgrass-T pasture types were always deficient in energy and protein. Bedell (1966) stated that the diets of sheep and cattle on ryegrass - subterranean clover pastures contained higher concentrations of crude protein than was available in the herbage. This indicated that the sheep and cattle were selecting plants and parts of plants higher in crude protein over those with lower crude protein concentration. It was possible that, through selective grazing, elk diets were of a higher quality than the herbage nutrient data indicated. However, the herbage nutritional quality data did indicate that elk had much more opportunity to acquire adequate levels of DP and DE in the Ryegrass-T pasture type, than in either the Bentgrass-U or Bentgrass-T pasture types and elk had a slightly better chance of consuming a nutritionally adequate diet in the Bentgrass-T pasture type than they did in the Bentgrass-U pasture type. Thus, elk in the Coastal Range Mountains with access to pastures like the Ryegrass-T pasture type should tend to have a higher rate of reproduction and higher winter survival than those which only have access to pastures like the Bentgrass-U and Bentgrass-T pasture types, since protein and energy in ruminant diets have been directly tied to survival and reproduction (Allden 1970; Verme 1965; Zimmerman et al. 1961; Holter and Hayes 1977; Thorne et al. 1976).

The relationship between nutritive characteristics of the herbage and elk density described by the linear model for elk density emphasized the importance of forage quality to the free ranging ruminant. This also indicated that a better understanding of free ranging ruminant movements and distribution and the possible prediction of such parameters could be enhanced by a better understanding of the vegetation upon which the ruminant is dependent.

This research showed that of the three pasture types compared, the herbage in the Bentgrass-T pasture type is generally better in nutritive value than the Bentgrass-U pasture type but that it has no advantage as an elk attractant over the Bentgrass-U pasture type. Also for the pastures studied, the Ryegrass-T pasture type was shown to provide the best elk winter range, in terms of attracting animals and providing adequate nutrition. However, this does not mean that the Ryegrass-T pasture type reflected the best management system for western Oregon elk winter range. Rather, the information provided for the three pasture types should be used as a basis of comparison for future adjustments in elk winter range management. Such adjustments might be in: seeding rates, seeding mixes, time of seeding, fertilizer types, fertilizer rates, time of fertilization, tillage practices, summer herbage production removal, etc. The effects of adjustments or changes in any of these pasture management practices should be compared back to the base data provided herein, to determine whether the adjustment increases or decreases the quality of the winter range for elk.

LITERATURE CITED

Allden, W.G. 1970. The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutr. Abstr. Rev. 40:1167-1184.

Alldredge, W.A., J.F. Lipscomb, F.W. Whicker. 1974. Forage intake rates of mule deer estimated with fall-out cesium-137. J. Wildl. Manage. 38:508-516.

Anderson, E.W., R. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. J. Wildl. Manage. 28:120-125.

Baumgardt, B.R., M.W. Taylor, J.L. Cason. 1962. Evaluation of forages in the laboratory. II. Simplified artificial rumen procedure for obtaining repeatable estimates of forage nutritive value. J. Dairy Sci. 45:62-68.

Beaulieu, J.D. 1973. Environmental geology of inland Tillamook and Clatsop counties, Oregon. Department of Geology and Mineral Industries, State of Oregon Bulletin 79. 65p.

Bedell, T.E. 1966. Seasonal cattle and sheep diets on _Festuca arundinacea-Trifolium subterraneum_ and _Lolium perenne-Trifolium subterraneum_ pastures in western Oregon. Ph.D. Thesis. Oregon State Univ., Corvallis. 283p.

Blaser, R.E., D.D. Wolf, H.T. Bryant. 1976. Systems of grazing management. p. 581-595. _In:_ M.E. Heath, D.S. Metcalfe, R.F. Barnes (Eds.) Forages - the science of grassland agriculture. The Iowa State Univ. Press, Ames, Iowa. 755p.

Bond, J., J.N. Wiltbank. 1970. Effect of energy and protein on estrus, conception rate, growth and milk production of beef females. J. Anim. Sci. 30:438-444.

Bond, J., J.N. Wiltbank, A.C. Cook. 1958. Cessation of estrus and ovarian activity in a group of beef heifers on extremely low levels of energy and protein. J. Anim. Sci. 17:1211.

Buechner, H.K. 1952. Winter range utilization by elk and mule deer in Southeast Washington. J. Range Manage. 5:76-80.

Cheatum, E.L., C.W. Severinghaus. 1950. Variations in fertility of white-tailed deer related to range conditions. N. Amer. Wildl. Conf. Trans. 15:179-190.

Church, D.C., W.G. Pond. 1974. Basic animal nutrition and feeding. D.C. Church, O.S.U. Bookstore, Corvallis, Oregon. 300p.

Cleary, D. 1976. Personal communication. Habitat Biologist, Northwest Region, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Cogswell, C., L.D. Kamstra. 1976. The stage of maturity and its effect upon the chemical composition of four native range species. J. Range Manage. 29:460-463.

Cook, C.W. 1965. Plant and livestock responses to fertilized rangelands. Utah Agr. Exp. Sta. Bull. 455. 35p.

Cook, C. Wayne. 1970. Energy budget of the range and livestock. Colo. State Univ. Exp. Sta. Bull. TB109. 28p.

Cook, C.W., H.H. Biswell, R.T. Clark, E.H. Reid, L.A. Stoddart, M.L. Upchurch. 1962. Basic problems and techniques in Range Research. National Academy of Sciences - National Research Council, Washington, D.C. Publication No. 890. 341p.

Cook, C.W., L.E. Harris. 1977. Nutritive value of seasonal ranges. Utah Agr. Exp. Sta. Bull. 472. 55p.

Cook, C.W., L.A. Stoddart. 1953. The quandry of utilization and preference. J. Range Manage. 6:329-335.

Cowan, R.L., J.S. Jordan, J.L. Grimes, J.D. Gill. 1970. Comparative nutritive values of forage species. p. 48-56. In: Range and wildlife habitat evaluation - A research symposium. USDA Forest Service. Misc. Publication 1147. 220p.

Crampton, E.W. 1959. Interrelation between digestible nutrient and energy content, voluntary dry matter intake, and overall feeding value of forage. J. Anim. Sci. 16:546-552.

Crampton, E.W., E. Donefer, L.E. Lloyd. 1960. A nutritive value index for forages. J. Anim. Sci. 19:538-544.

Crampton, E.W. and L.E. Harris. 1969. Applied animal nutrition. W.H. Freeman and Co., San Francisco. 753p.

Dean, R.E., E.T. Thorne, I.J. Yorgason. 1976. Weights of Rocky Mountain elk. J. Mammal. 57:186-189.

Dietz, D.R. 1970. Definition and components of forage quality. p. 1-9. In: Range and wildlife habitat evaluation - A research symposium. USDA Forest Service Misc. Publication 1147. 220p.

Draper, N.R., H. Smith. 1966. Applied regression analysis. John Wiley and Sons, Inc., New York. 407p.

Everist, S.L. 1972. Australia. p. 16-25. In: C.M. McKell, J.P. Blaisdell, J.R. Goodin (Ed.) Sect. 1. Continental aspects of shrub distribution, utilization and potentials. Wildland shrubs - their biology and utilization. USDA Forest Serv., Gen. Tech. Rep. INT-1.

Foster, M.A. 1977. Effect of fertility on yield and quality of hay produced on subirrigated meadows. Abstract, 30th Annual Meeting, Society for Range Management, Portland, Oregon. p. 26.

Franklin, W.L., A.S. Morsman, M. Dale. 1975. Social organization and home range of Roosevelt elk. J. Mammal. 56:102-118.

Garrison, G.A., A.J. Bjugstad, D.A. Duncan, M.E. Lewis, D.R. Smith. 1977. Vegetation and environmental features of forest and range ecosystems. USDA, Forest Service, Agricultural Handbook No. 475. 68p.

Geist, J.M., P.J. Edgerton, G.S. Strickler. 1974. 'Yukky to yummy' - with fertilizers. Rangeman's Journal 1: 39-41.

Graf, W. 1943. Natural history of the Roosevelt elk. Ph.D. Thesis. Oregon State College, Corvallis. 222p.

Handl, W.P., L.R. Rittenhouse. 1975. A comparison of three methods of estimating digestibility for determining intake of grazing cattle. J. Range Manage. 28:414-416.

Hansen, R.M., R.C. Clark. 1977. Foods of elk and other ungulates at low elevations in northwestern Colorado. J. Wildl. Manage. 41:76-80.

Harper, J.A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. J. Wildl. Manage. 26:97-100.

Harper, J.A. 1971. Ecology of Roosevelt elk. Oregon State Game Commission. 44p.

Harper, J.A., J.H. Harn, W.W. Bently, C.F. Yocum. 1967. The status and ecology of the Roosevelt elk in California. Wildl. Monogr. 16. 49p.

Harris, L.E. 1968. Range nutrition in an arid region. The Faculty Association, Utah State University, Logan. 100p.

Heady, H.F. 1964. Palatability of herbage and animal preference. J. Range Manage. 17:76-82.

Heady, H.F. 1975. Rangeland management. McGraw-Hill Book Company, San Francisco. 460p.

Hedrick, D.W. 1957. Fertilizer treatments on tall fescue. Oregon Atric. Exp. Sta. Misc. Paper 52. 21p.

Hines, W.W. 1972. Ecological study of Roosevelt elk; elk investigations. Oregon State Game Commission. W-70-R-2, Subproject C. 22p.

Hines, W.W., J.C. Lemos. 1975. Ecological study of Roosevelt elk; elk investigations. Oregon Wildlife Commission. W-70-R-5, Subproject C. 18p.

Holter, J.B., H.H. Hayes. 1977. Growth in white-tailed deer fawns fed varying energy and constant protein. J. Wildl. Manage. 41:506-510.

Hooper, J.F., J.P. Workman, J.B. Grumbles, C.W. Cook. 1969. Improved livestock distribution with fertilizer - a preliminary economic evaluation. J. Range Manage. 22:108-110.

Horwitz, W.P., P. Chichilo, H. Reynolds (Eds.). 1970. Official methods of analysis of the association of official analytical chemists. A.O.A.C. Washington, D.C. 1015p.

Ives, F. 1978. Personal communication. Assistant Regional Supervisor, Northwest Region, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Julander, O., W.L. Robinette, D.A. Jones. 1971. Relation of summer range condition to mule deer herd productivity. J. Wildl. Manage. 25:54-60.

Knott, N.P. 1956. Possible effects of fertilization on forage production and game use. Proc. 36th Ann. Conf. W. Assoc. State Game and Fish Commissions. 207-209.

Kufeld, R.C. 1973. Foods eaten by Rocky Mountain elk. J. Range Manage. 26:106-112.

Larcher, W. 1975. Physiological plant ecology. Springer-Verlag. 252p.

Lassiter, C.A., D.M. Seath, J.W. Woodruff, J.A. Taylor, J.W. Rust. 1956. Comparative value of Kentucky blue grass, Kentucky 31 fescue, orchardgrass, and bromegrass as pastures for milk cows. II. Effect of kind of grass on the dry matter and crude protein content and digestibility and intake of dry matter. J. Dairy Sci. 39:581-588.

Laycock, W.A., D.A. Price. 1970. Environmental influences on nutritive value of forage plants. P. 37-47 In: Range and Wildlife habitat evaluation - A research symposium. USDA Forest Service Misc. Publication 1147. 220p.

Leach, D. 1974. Soil and water conservation plan. Beneke Wildl. Meadows. USDA, Soil Conservation Service. 32p.

Lemos, J.C., W.W. Hines. 1974. Ecological study of Roosevelt elk; Enclosure Study. Oregon Wildlife Commission. W-70-R-4, Subproject C. 40p.

Leopold, A.C., P.E. Kriedemann. 1975. Plant growth and development. McGraw-Hill Book Company, New York. 545p.

Marten, G.C. 1970. Measurement and significance of forage palatability. p. D1-D55. In: Proc. Nat. Conf. Forage Quality Evaluation on Utilization. Nebraska Center for Continuing Education, Lincoln, Nebraska.

McBee, R.H., J.L. Johnson, M.P. Bryant. 1969. Ruminal microorganisms from elk. J. Wildl. Manage. 33:181-186.

Meyer, R.M., E.E. Burtley, F. Julius, L.R. Fina. 1971. Comparison of four in vitro methods for predicting in vivo digestibility of forages. J. Anim. Sci. 32:1030-1036.

Moen, A.N. 1973. Wildlife ecology. An analytical approach. W.H. Freeman and Company, San Francisco. 458p.

Moir, R.J. 1961. A note on the relationship between the digestible dry matter and digestible energy content of ruminant diets. Aust. J. Exp. Agric. Anim. Husb. 1: 24-26.

NOAA. 1966-1978. Climatological data. National Oceanic and Atmospheric Administration, Department of Commerce, U.S.A. Vol. 72-84.

Overton, S.W. 1971. Estimating the numbers of animals in wild populations. In: R.H. Giles (Ed.) Wildlife management techniques. The Wildlife Society, Washington, D.C. 633p.

Palmer, W.L., R.L. Cowan, A.P. Ammann. 1976. Effects of inoculum source on the in vitro digestion of deer foods. J. Wildl. Manage. 40:301-307.

Parr Instrument Company. 1969. Instructions for 1241 and 1242 adiabatic calorimeters. Parr Instrument Co., Moline, Ill. Manual No. 142. 23p.

Pearson, H.A. 1970. Digestibility trials: in vitro techniques. p. 85-92. In: Range and wildlife habitat evaluation - A research symposium. USDA Forest Service Misc. Publication 1147. 220p.

Pieper, R.D. 1973. Measurement techniques for herbaceous and shrubby vegetation. New Mexico State Univ., Las Cruces. 187p.

Pinney, D.O., L.S. Pope, D.F. Stephens. 1962. Winter nutrition and age at calving on lifetime performance of beef cows. J. Anim. Sci. 21:1009.

Polk, D.B., C.J. Scifres, J.L. Mutz. 1976. Establishment, production and protein content of four grasses in south Texas. J. Range Manage. 29:240-243.

Raleigh, R.J., A.L. Lesperance. 1972. Range cattle nutrition. p. 185-199d. In: D.C. Church (Ed.). Digestive physiology and nutrition of ruminants; Vol. 3 - Practical nutrition. D.C. Church, Corvallis, Oregon. 351 p.

Ramage, C.H., C. Eby, R.E. Mather, E.R. Purvis. 1958. Yield and chemical composition of grasses fertilized heavily with nitrogen. Agron. J. 50:59-62.

Reid, R.L., G.A. Jung, S.J. Murray. 1966. Nitrogen fertilization in relation to the palatability on nutritive value of orchardgrass. J. Animal Sci. 25:636-645.

Robbins, C.T., P.J. VanSoest, W.W. Mautz, A.N. Moen. 1975. Feed analyses and digestion with reference to white-tailed deer. J. Wildl. Manage. 39:67-79.

Robinnette, W.L., O. Julander, J.S. Gashwiler, J.G. Smith. 1952. Winter mortality of deer in Utah in relation to range condition. J. Wildl. Manage. 16:289-299.

Salih, M.S., D.F. Burzlaff. 1977. Improvement of crude protein content and in vitro digestibility of range grasses with nitrogen fertilization. Abstract, 30th Annual Meeting, Society for Range Management, Portland, Oregon. p. 26.

Scales, G.H., C.L. Streeter, A.H. Denham, G.M. Ward. 1974. A comparison of indirect methods of predicting in vivo digestibility of grazed forage. J. Anim. Sci. 38:192-199.

Schwartz, J.E., G.E. Mitchell. 1945. The Roosevelt elk on the Olympic Peninsula, Washington. J. Wildl. Manage. 9:295-319.

Seath, D.M., C.A. Lassiter, J.W. Rust, M. Cole, G.M. Bustin, 1956. Comparative value of Kentucky bluegrass, Kentucky-31 fescue, orchardgrass, and bromegrass as pasture for milk cows. I. How kind of grass affected persistence of milk production, TDM yield and body weight. J. Dairy Sci. 39:574-580.

Smith, D.R., R.L. Lang. 1958. The effect of nitrogenous fertilizers on cattle distribution on mountain range. J. Range Manage. 11:248-249.

Steel, R.G.D., J.G. Torrie. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill Book Company Inc., New York. 481p.

Stevens, D.R. 1966. Range relationships of elk and livestock, Crow Creek drainage, Montana. J. Wildl. Manage. 30:349-363.

Stoddart, L.A., A.D. Smith, T.W. Box. 1975. Range Management. McGraw-Hill Book Company, San Francisco. 532p.

Thorne, E.T. 1973. Nutritional requirements of elk for reproduction. Job Progress Report. Wyoming Game and Fish Department. FW-3-R-20. p. 22-32.

Thorne, T., G. Butler. 1976. Comparison of pelleted, cubed and baled alfalfa hay as winter feed for elk. Wildlife Technical Report No. 6. Wyoming Game and Fish Department. 38p.

Thorne, E.T., R.E. Dean, W.G. Hepworth. 1976. Nutrition during gestation in relation to successful reproduction in elk. J. Wildl. Manage. 40:330-335.

Tilley, J.M.A., R.A. Terry. 1963. A two stage technique for the *in vitro* digestion of forage crops. Brit. Grassland Soc. J. 18:104-111.

Torell, D.T., I.D. Hume, W.C. Weir. 1974. Factors affecting blood urea nitrogen and its use as an index of the nutritional status of sheep. J. Anim. Sci. 39: 435-440.

Trainer, C.E. 1969. Roosevelt elk fertility study. Oregon State Game Commission. W-59-R-6. 25p.

Trainer, C.E. 1971. The relationship of physical condition and fertility of female Roosevelt elk (*Cervus canadensis roosevelti*). M.S. Thesis. Oregon State Univ., Corvallis. 95p.

Troelsen, J.E. 1970. Digestible energy in forages by *in vivo* and *in vitro* assays. Can. J. Anim. Sci. 50:557-562.

Troyer, W.A. 1960. The Roosevelt elk on Afognak Island, Alaska. J. Wildl. Manage. 24:15-21.

Vallentine, J.F. 1971. Range developments and improvements. Brigham Young Univ. Press, Provo, Utah. 516p.

Van Dyne, G.M. 1968. Measuring quantity and quality of the diet of large herbivores. p. 54-95. *In*: F.B. Golley, H.K. Beuchner (Eds.). IBP Handbook No. 7. Blackwell Sci. Publ. 308p.

Van Soest, P.J. 1963. The use of detergents in the analysis of fiborous feeds. II. A rapid method for determination of fiber and lignin. J. Ass. Offic. Agr. Chem. 46:829-835.

Van Soest, P.J., R.H. Wine. 1967. Use of detergents in the analysis of fiborous feeds. IV. Determination of plant cell wall constituents. J. Ass. Official Anal. Chem. 50:50-55.

Verme, L.J. 1965. Reproduction studies on penned white-tailed deer. J. Wildl. Manage. 29:74-79.

Voigt, P.W. 1975. Improving palatability of range plants. p. 23-49. In: Campbell, R.S., C.H. Herbel. Improved range plants. Society for Range Management, Denver, Colorado. Range Symposium Series No. 1. 90p.

Wallace, J.D., R.J. Raleigh. 1964. Calf production from Hereford cows wintered at different nutritional levels. Proc. West. Sec. Amer. Soc. Anim. Sci. 15:57.

Wallmo, O.C., L.H. Carpenter,W.L. Regelin, R.B. Bill, D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.

Ward, A.L. 1971. In vitro digestibility of elk winter forage in southern Wyoming. J. Wildl. Manage. 35:681-688.

Wheeler, D. 1976. Personal communication. Area Manager, Jewell Wildlife Meadows, Oregon Department of Fish and Wildlife, Jewell, Oregon.

Wheeler, D. 1977. Personal communication. Area Manager, Jewell Wildlife Meadows, Oregon Department of Fish and Wildlife, Jewell, Oregon.

Zimmerman, D.R., D.C. Clanton, J.K. Matsushina. 1961. Postpartum reproductive performance in beef heifers as affected by protein and energy intake during gestation. J. Anim. Sci. 20:957.

APPENDICES

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APPENDIX A

Percent frequency of herbaceous plants in communities on experimental pastures.

Species	Plant Communities							
	1	2	3	4	5	6	7	8[a]
Grasses								
Perennial ryegrass							90	
Colonial bentgrass	77	70	67	78	97	90	26	
Redtop							5	
Orchardgrass		10	3	53	13	13	50	
Tall fescue	3	60	3	25		63	20	
Sweet vernalgrass	60	10		15	33	7		
Velvetgrass	7	13	10		20	20	30	
Red fescue	17		3	25				
Kentucky bluegrass		3		13		10		
Quackgrass						7		
Soft chess						4		
Timothy					10		4	
Cereal Rye								a
Forbs								
White clover	23	3	37	28	13	20	74	
Subterranean clover							18	
Crimson clover				20	10	7	5	
Birdsfoot trefoil	23	47	40			27		
Sheep sorrel	7	3	7	3	60	20	9	
Curly dock			7		13		10	
Buckhorn plantain	47	17	33	3	47	27	29	
Smooth hawksbeard	23	3	3		17	3	10	
Spotted catsear	7	3		3	10	7	9	
Oxeydaisy	3		27		7			
Bull thistle			17				6	
Creeping buttercup	3	7					3	
Foxglove			17					
Bracken fern	3		10					
Common selfheal	13				3	3		
Tansy ragwort			3					
Little mallow		3						

[a]Community 8 was an annual rye planting. It was fallow during the vegetation sampling period, however, annual rye almost solely dominated this community.

APPENDIX B

Percent species composition of herbaceous plants in communities on experimental pastures based on relative frequency.

Species	Plant Communities							
	1	2	3	4	5	6	7	8[a]
Grasses								
Perennial ryegrass							24	
Colonial bentgrass	24	28	23	30	27	38	6	
Redtop							1	
Orchardgrass		4	2	20	4	4	13	
Tall fescue	1	24	1	10		20	5	
Sweet vernalgrass	19	4		6	9	2		
Velvetgrass	2	5	3		6	6	7	
Red fescue	5		1	10				
Kentucky bluegrass		1		5		3		
Quackgrass						2		
Soft chess							1	
Timothy					2		1	
Cereal rye								a
Forbs								
White clover	7	1	13	11	4	6	19	
Subterranean clover							6	
Crimson clover				8	3	2	1	
Birdsfoot trefoil	7	18	14			8		
Sheep sorrel	2	1	2	1	17	6	2	
Curly dock			2		4		3	
Buckhorn plantain	15	7	12	1	13	8	7	
Smooth hawksbeard	7	1	1		5	1	3	
Spotted catsear	2	1		1	3	2	2	
Oxeyedaisy	1		9		2			
Bull thistle			6				1	
Creeping buttercup	1	3					1	
Foxglove			6					
Bracken fern	1		3					
Common selfheal	4				1	1		
Tansy ragwort			1					
Little mallow		1						

[a] Community 8 was an annual rye planting. It was fallow during the vegetation sampling period, however, annual rye almost solely dominated this community.

APPENDIX C

Cover and density of shrubs in plant communities on experimental pastures.

Percent Cover

Species	Plant Communities 1	2	3	4	5	6	7	8[a]
Wild blackberry	2.8		1.4					
Evergreen blkberry.	1.0	0.8	0.6					
Wood rose	0.2							
Snowberry	p[b]	p	p					
Grouse huckleberry	p							

Density (plants/100 m^2)

Species	Plant Communities 1	2	3	4	5	6	7	8
Wild blackberry	68	1	19					
Evergreen blkberry.	17	16	9					
Wood rose	15							
Snowberry	p	p	p					
Grouse huckleberry	p							

[a] Community 8 was an annual rye planting. It was fallow during the vegetation sampling period, however, annual rye almost solely dominated this community

[b] p = present at very low levels in community, but not present in plots.

APPENDIX D

Common and scientific names of plant species occurring on experimental pastures.

Common Name	Scientific Name
	Grasses
Cereal rye	*Secale cereale*
Colonial bentgrass	*Agrostis tenuis*
Kentucky bluegrass	*Poa pratensis*
Orchardgrass	*Dactylis glomerata*
Perennial ryegrass	*Lolium perenne*
Quackgrass	*Agropyron repens*
Red fescue	*Festuca rubra*
Redtop	*Agrostis alba*
Soft chess	*Bromus mollis*
Sweet vernalgrass	*Anthoxanthum odoratum*
Tall fescue	*Festuca arundinacea*
Timothy	*Phleum pratense*
Velvetgrass	*Holcus lanatus*
	Forbs
Birdsfoot trefoil	*Lotus corniculatus*
Bracken fern	*Pteridium aquilinum*
Buckhorn plantain	*Plantago lanceolata*
Bull thistle	*Cirsium vulgare*
Common selfheal	*Prunella vulgaris*
Creeping buttercup	*Ranunculus repens*
Crimson clover	*Trifolium incarnatum*
Curly dock	*Rumex crispus*
Foxglove	*Digitalis purpurea*
Little mallow	*Malva parviflora*
Oxeyedaisy	*Chrysanthemum leucanthemum*
Sheep sorrel	*Rumex acetocella*
Smooth hawksbeard	*Crepis capillaris*

(continued on next page)

Appendix D (continued)

Common Name	Scientific Name
Spotted catsear	*Hypochaeris radicata*
Subterranean clover	*Trifolium subterraneum*
Tansy ragwort	*Senecio jacobaea*
White clover	*Trifolium repens*
	Shrubs
Evergreen blackberry	*Rubus lacinatus*
Grouse huckleberry	*Vaccinium scoparium*
Snowberry	*Symphricarpos albus*
Wild blackberry	*Rubus ursinus*
Wood rose	*Rosa woodsii*

APPENDIX E

Summary of analyses of variance results for: Standing Biomass kg/ha (SB); Herbage Removal kg/ha (HR); Elk/ha (E/ha); Gross Energy Mcal/kg (GE); % Crude Protein (CP); % Dry Matter Digestibility (DMD).

Source of Variation	Degrees of Freedom	SB	HR	E/ha	GE	CD	DMD
Pasture Type (P)	2	.01[1]	.01	.01	NS	.01	.01
Error P	6						
Winter (W)	1	.01	NS	NS	NS	.01	.01
Month (M)	2	.01	.05	NS	NS	.01	.01
P x W	2	NS	.05[2]	NS	NS	.01	.01
P x M	4	NS	NS	NS	NS	.01	NS
W x M	2	.01	NS	.05	NS	NS	.01
P x W x M	4	NS	NS	NS	NS	NS	NS
Error PWM	30						

[1]Significant at $P < 0.01$.

[2]Significant at $P < 0.05$.

APPENDIX F

Summary of analyses of variance on the Bentgrass-T and Ryegrass-T pasture types in all winters and months for: Digestible Energy Mcal/kg (DE) and % Digestible Protein (DP).

Source of Variation	Degrees of Freedom	DE	DP
Pasture Type (P)	1	.01[1]	.01
Error P	4		
Winter (W)	1	.01	.01
Month (M)	2	.05[2]	.01
P x W	1	.01	.01
P x M	2	.05	.01
W x M	2	.05	NS
P x W x M	2	.05	NS
Error PWM	20		

[1]Significant at $P < 0.01$.

[2]Significant at $P < 0.05$.

APPENDIX G

Summary of analyses of variance on all pasture types in the normal winter in all months for: Digestible Energy Mcal/kg (DE) and % Digestible Protein (DP).

Source of Variation	Degrees of Freedom	DE	DP
Pasture Type (P)	2	.01[1]	.01
Error P	6		
Month (M)	2	.01	NS
P x M	4	NS	NS
Error PM	12		

[1]Significant at $P < 0.01$.

APPENDIX H

Average gross energy (Mcal/kg) content of herbage in pasture types, winters and months.

Month	Pasture types		
	Bentgrass-U	Bentgrass-T	Ryegrass-T
		Dry Winter	
December	4.5	4.4	4.5
January	4.6	4.5	4.3
February	4.5	4.4	4.2
		Normal Winter	
December	4.4	4.6	4.7
January	4.2	4.2	4.2
February	4.3	4.3	4.3

APPENDIX I

Average % Crude Protein content of herbage in pasture types, winters and months.

Month	Pasture types		
	Bentgrass-U	Bentgrass-T	Ryegrass-T
		Dry Winter	
December	4.9	9.6	7.7
January	4.0	6.6	7.1
February	4.6	7.3	11.6
		Normal Winter	
December	7.9	12.5	20.7
January	7.5	11.9	19.1
February	7.8	10.9	22.5