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The Forage Growth Cycle and Range Communities of the Poplar Lake Range Unit Northcentral British Columbia

by

(C) Michael Willoughby

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(SIGNED) ....

PERMANENT ADDRESS:

.....Bluff...Ave.........

Kamloops....B.C.........

...V2C 1S5..............

DATED ..Oct...15......1986

THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The Forage Growth Cycle and Range Communities of the Poplar Lake Range Unit Northcentral British Columbia submitted by Michael Willoughby in partial fulfilment of the requirements for the degree of Master of Science in Range Management.

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Supervisor

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Date..............................

Abstract

A study was made of the seasonal forage production cycle, and the effect of four harvesting frequencies, on the vascular species in two grassland communities of the Prince Rupert Forest region of Northcentral British Columbia. One site had the native species cow parsnip (*Heracleum sphondylium*) blue wildrye (*Elymus glaucus*) and common brome (*Bromus vulgaris*), whereas, the other was dominated by the introduced herbs Kentucky bluegrass (*Poa pratensis*), creeping red fescue (*Festuca rubra*) and dandelion (*Taraxacum officinale*). Seasonal growth occurred from May to September with most growth occurring in May and June, although atypical spring temperatures or summer drought markedly affected forage production. Higher air temperatures during the spring of 1985 increased forage production 50% compared to 1984; the lack of soil moisture during July and August in 1984 and 1985 caused a reduction in plant growth.

Plots were harvested monthly from June to August in 1984 and 1985. Increased frequency of harvest at the cultivated site tended to increase forb production, whereas, grass production declined. At the native site, forb production was not affected by increased frequency of harvesting and grass production was reduced by more frequent harvesting when soil moisture was limiting. An etiolated growth study (aerial plant growth in the dark) was conducted in the field during 1985 on the dominant forb and grass at each site to evaluate "potential vigor" following the

various defoliation treatments in 1984. The dominant forb and grass at the cultivated site were *Taraxacum officinale* and *Festuca rubra* and the dominant forb and grass at the native site were *Heracleum sphondylium* and *Bromus vulgaris*. The more frequently clipped plots had the lowest amount of etiolated growth.

The two grassland communities studied in the forage growth cycle represented two of the five grassland communities classified in the study area. Native grasslands were dominated by common brome (*Bromus vulgaris*), blue wildrye (*Elymus glaucus*), cow parsnip (*Heracleum sphondylium*), and snowberry (*Symphoricarpos albus*). Plant species composition was affected by soil moisture in the ungrazed situations. On the drier upper slope positions various forbs, *Carex macloviana, Stipa occidentalis, and Symphoricarpos albus* were predominant. Heavy continuous grazing throughout the growing season caused shifts in plant species composition away from native grasses, forbs and shrubs towards introduced species including creeping red fescue (*Festcua rubra*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*) and dandelion (*Taraxacum officinale*).

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1. INTRODUCTION

Management of the rangelands can only be effectively practiced within the limitations of knowledge about the resource. Little is known about the Crown rangelands being grazed by domestic livestock within the Prince Rupert Forest Region of northcentral British Columbia. Although these rangelands have been grazed for several decades limited information is available upon which to make responsible resource management decisions.

The current ecological classification of the Prince Rupert Forest Region (Pojar et al. 1982) selected only climax forest sites for sampling and provided no information on the seral stages of forest succession (Pitt 1984). The majority of forage available for grazing by cattle is within these seral stages.

Most of the range vegetation in the world is in some seral stage of plant succession (Huschle and Hironaka 1982). The primary aim of grazing resource management is to direct this plant succession to a desired seral stage to obtain sustained maximum productivity and stability (Stoddard et al. 1975). In order to attain this maximum level of productivity, it is necessary to have some understanding of the ecosystems to be managed.

In northcentral British Columbia, little is known about vegetation-soil relationships, grassland and shrubland site classification, communities grazed by livestock, succession under grazing, the seasonal forage growth cycle, forage production, forage quality and the response of major forage species to grazing.

Previous work by Willoughby et al. (1982) has shown that grazing by cattle is most extensive in grasslands which appear to be seral to certain forest communities. These communities are grazed from the middle of May to the end of October throughout the Prince Rupert Forest Region. In Part I of this study, an investigation was conducted into the seasonal forage growth cycle and forage production of grassland and aspen forest communities important to livestock. This information is important to determine turnout dates, length of the grazing season, stocking rates, and carrying capacity.

The specific objectives of the forage production study were: (1) to determine the forage growth cycle, (2) to determine the effect of frequency of harvesting on grasses and forbs, (3) to study the relationship of herbage growth to soil moisture , and (4) to study the effect of defoliation on the subsequent etiolated growth of major plant species.

In Part II of the study grassland and aspen forest communities of major importance to domestic livestock were classified and ordinated. A classification of these communities helped to determine succession of the grassland and aspen forest communities in the absence of grazing, succession under grazing, the response of the major forage species to grazing and the development of criteria required for range condition evaluation. The specific objectives were: (1) to describe the grassland forest communities characteristic of the sub-boreal spruce (SBS) biogeoclimatic zone and the sub-alpine fir subzone (e). (2) to study the environmental factors (grazing intensity and soil moisture) which were influencing variation in plant composition in the Poplar Lake study area.

1.1 Hypotheses tested

The following null hypotheses were evaluated.

1.1.1 Part I: Clipping study

1. There was no difference in production of grass or forbs among clipping treatments.
2. There was no difference in production of grass or forbs among years.
3. There was no interaction between defoliation treatment and year on forage production of grasses or forbs.
4. There was no difference in grass and forb production on plots defoliated in May and June compared to those defoliated only in June.
5. There was no interaction between defoliation treatment and year in grass and forb production for those plots defoliated in May and June compared to those harvested only in June.
6. There was no difference in grass and forb production

among plots defoliated in May, June and July; June and July; and July only.

7. There was no interaction between defoliation treatment and year for those plots defoliated in May, June and July; June and July; and July only.

1.1.2 Etiolated growth study

1. There was no difference in total etiolated growth in 1985 among treatments defoliated in 1984.

1.1.3 Part II: Classification and ordination

1. There was no difference in plant species composition among sites caused by gradients of soil moisture, soil nutrients and grazing intensity.

2. SITE DESCRIPTION

The area selected for study was the Poplar Lake Range Unit which is situated north of Tagetochlain lake (commonly referred to as Poplar Lake) and the Nadina River, about 28 km west of Francois Lake at 54°N latitude, 125 ° W longitude (Appendix 1). The area was chosen because it is representative of the livestock grazing resource in the Bulkley, Morice and Lakes Forest Districts. These three districts provide the majority of native range for cattle grazing in the Region.

The range unit is bordered on the north by heights of land, such as the Nadina and Poplar Mountains, in the west by Bittern Lake and in the south by Tagetochlain Lake. The Peter Aleck drainage system which flows into Francois Lake through the Nadina River is the major watershed on the range unit. The study area is part of the Nechako plateau and is within the sub-boreal spruce biogeoclimatic zone. Elevation ranges from 900 m to 1000 m and these grasslands have a south or westerly facing slope.

2.1 Climate

Weather systems generally move into British Columbia from the Pacific Ocean, and as the moist air is lifted over the mountains, it condenses. By the time the air masses reach Poplar Lake they are quite dry, giving rise to a continental climate (Pojar et al. 1982).

Climatic data for Nadina River (elev. 787 m, 10 km south of the study area) indicates that the mean annual precipitation is 437 mm. Mean monthly precipitation from May to September is [illegible] mm. The driest month is April (18.0 mm) and the wettest is December (58.0 mm). Mean annual snowfall is 1770 mm. The average frost free period is 32 days.

Moderating climatic influences are large bodies of water such as Tahtsa Lake to the south, and Nanika and Kidprice Lakes to the west, resulting in longer frost free periods and more growing degree days than other biogeoclimatic zones throughout the Forest region. (Pojar et al 1982).

2.2 Grazing history

The Poplar Lake Range Unit has been grazed since 1961 by most of the existing permittees, Myles Shelford (E. and L. Palmer); Bob and Arnold Peebles; and Gordon McFee. (Ehlert and Smith 1983). The number of beef cattle utilizing the area has varied from 500 to 700 cow-calf pairs per grazing season. There was no hay base within this range unit and livestock were wintered on the home ranches along the North shore of Francois Lake.

Turn out date for livestock varied from May 15 to May 30 and livestock breeding took place in the central grasslands above Poplar Lake (Lot 5385)'.

'Note: Lot 5385 refers to the legal land Description of District Lot 5385 Range 5 Coast District, B.C.

The far eastern portion of the range unit was generally used separately in conjunction with Gordon McFee's herd throughout most of the grazing season. Cattle were removed from the range about October 15 (Ehlert and Smith 1983).

The existing system of management left many areas of the range unit overgrazed. Areas such as the grasslands overlooking Poplar Lake (Lot 5385) and the eastern portion were being grazed throughout most of the growing season. Consequently some areas showed signs of erosion as a result of the heavy grazing. During the early 1970's the whole study area was seeded by airplane with the domesticated grasses *Phleum pratense*, *Festuca rubra* and *Poa pratensis* and the forbs *Trifolium hybridum* and *Trifolium repens*.

2.3 Surficial deposits

Most surficial materials in the Poplar Lake range unit were produced since the last major glaciation, about 10,000 years ago (Pojar et al. 1982). During the height of the glaciation a thick ice sheet covered all of the Nechako plateau and most of Hazelton, Skeena and Omineca Mountains (Armstrong and Tipper 1948). As the ice sheet moved, it picked up and deposited the underlying bedrock and older glacial material to form much of the parent material of the soils in the study area (Pojar et al. 1982). Most of the underlying bedrock was of volcanic origin resulting from eruption of shield volcanoes.

2.4 Vegetation and soils

Presently the British Columbia Ministry of Forests is developing an ecosystem classification of the forests and rangelands of the province. This classification is based on the biogeoclimatic system developed by Krajina (1965). The three primary levels of the classification include the biogeoclimatic zone, subzone and the ecosystematic level (ecosystems, ecosystem associations and their phases) (Pojar et al. 1982).

The Poplar Lake study area falls into the sub-boreal spruce biogeoclimatic zone (SBS) and the sub-alpine fir subzone (e). The sub-alpine fir subzone has the wettest climate of the three SBS subzones in the Prince Rupert Forest Region. Not only does it snow more but the snowpack comes earlier and lasts longer (Pojar et al. 1982). To date no grassland and aspen forest communities have been described for the SBS e sub-alpine fir subzone. These communities closely resemble the grassland and aspen forest ecosystems of the SBS d spruce subzone but no data is currently available to assess the similarities and differences of these subzones.

3. LITERATURE REVIEW

3.1 Vegetation and soils

The plant communities utilized by livestock within the study area are predominantly grasslands and aspen forest communities. The soil orders vary from Brunisols to Luvisols (Pojar et al. 1982).

3.1.1 Grasslands

Grasslands refer to ecosystems in which the dominant vegetation component is comprised of herbaceous species (Coupland 1979).

The grasslands of Poplar Lake are located on south and southwest facing slopes. Usually there is an increase in insolation on south-facing slopes. This tends to raise soil temperature and reduce effective soil moisture (Aayad and Dix 1964, Macyk et al. 1978) thus favoring the formation of grasslands. Little information has been published on the lower elevation grasslands north of 53° latitude. A summary of reconnaissance level information on northern grasslands is outlined by Pojar (1982). He stated that these grasslands are localized to azonal sites. Azonal sites are sites which are dominated by plants and animals not characteristic of the region. These sites develop in response to local variation in topography, soils and microclimate.

The described grasslands most similar to the communities at Poplar Lake are outlined in SBS d biogeoclimatic zone (Pojar et al 1982) as SBS d 05 (grassland) and SBS d 04 (Scrub-Steppe).

The dominant species within the SBS d 05 include *Poa pratensis*[1], *Poa interior*, *Agropyron trachycaulum*, *Stipa occidentalis*, *Elymus glaucus*, and *Bromus carinatus*. *Carex macloviana* is a common sedge. The dominant forbs include *Lathyrus nevadensis*, *Epilobium angustifolium*, *Fragaria virginiana* and *Taraxacum officinale*. These grasslands usually have a submesic to mesic moisture regime and are dominated by Orthic Melanic Brunisols and Dark Gray Luvisols.

The SBS d 04 (Scrub-Steppe) is characterized by xeric to subxeric grasslands on steep upper slopes with shallow rocky soils. Dominant plants include the shrub species *Amelanchier alnifolia*, *Arctostaphylos uva-ursi* and *Symphoricarpos albus*. The forb layer is typified by *Allium cernuum*, *Anemone multifida*, *Penstemon procerus and Vicia americana*. The grass layer is dominanted by *Stipa occidentalis*, *Danthonia intermedia* and *Koeleria macrantha*.

Moss (1952,1955) believed that all the northern grasslands would eventually become forested but this change has long been retarded by fire and edaphic factors. Steep southerly slopes, high soil temperatures and low moisture favor grasslands and inhibit tree growth. Heavy utilization by cattle has also been shown to inhibit tree and shrub encroachment. Moss (1932) hypothesized that cattle could

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[1]Plant nomenclature follows Taylor and MacBryde 1977(see Appendix 2 for species list).

prevent aspen invasion while Johnson et al. (1971) recognized cattle browsing and trampling as inhibitory factors to brush invasion. Arthur (1984) found that heavy grazing by cattle in June resulted in aspen sucker mortality of 58%.

3.1.2 Forested rangelands

Trembling aspen (*Populus tremuloides*) dominated stands are described as SBS e 01 in the sub-boreal classification of B.C. (Pojar et al. 1982). The aspen dominated stands usually represent a seral phase of the dominant climax stands of sub-alpine fir and spruce. The understory vegetation is usually dominated by the shrubs *Amelanchier alnifolia, Rosa acicularis, Spiraea betulifolia, Rubus parviflora, Salix sp.* and *Symphoricarpos albus*. The herb layer is usually well developed, lush and diverse. Common species include *Lathyrus nevadensis, Aster sp., Epilobium angustifolium, Thalictrum occidentale, Heracleum sphondylium* and *Elymus glaucus*.

Aspen is invading grasslands within the Poplar Lake study area. Aspen growth requires good soil moisture (water table at 4 to 6 feet), fine textured soils and a high nutrient level in the soil (Stoeckler 1960 , Scheffler 1976). Most aspen invasion is occurring at the top and bottom of the south-facing, grassy slopes. The dominant soils include Orthic Melanic Brunisols and Gleyed Dark Gray Luvisols. The Ah horizon is well developed and extremely high in organic matter.

Pine and spruce ecosystems dominate much of the area north of Poplar Lake. These ecosystems are represented by the 01 (mesic, bunch-berry, moss), 02 (pine lichen) and 06 (moist thimbleberry) in the sub-boreal spruce classification (SBS e) (Pojar et al. 1982). Generally they consist of an understory of moss, lichens and small forbs such as, *Cornus canadensis*, which are unpalatable to domestic livestock. Consequently, conifer stands usually offer low grazing potentials even though herbage production may vary from 300 to 600 kg/ha. Soils are usually of the Brunisolic or Luvisolic order (Pojar et al. 1982).

The classification of British Columbia's vegetation into biogeoclimatic zones and ecosystem associations is not adequately detailed to distinguish various range types within the Prince Rupert Forest Region. Further classification within the ecosystem association should be undertaken before adequate range management planning can be achieved.

3.2 Forage production cycle

3.2.1 Growth cycle

Plant growth generally follows a bell-shaped growth rate curve (Salisbury and Ross 1978). Initial growth is slow because there are few cells capable of growth. The plant then increases in size at a constant rate until the plant reaches maturity, and begins to senesce. Growth initiation and cessation are affected by the environmental conditions characteristic of the area. These conditions affect the growth cycle of the plant. For example, in their study of Rough fescue in Interior British Columbia, Stout et al. (1981) noted that growth in the spring was initiated by soil temperature and growth cessation in the summer was controlled by soil moisture. Stout et al. (1980) noted that initiation of *Calamagrostis rubescens* growth in British Columbia during the spring depended on favorable temperature conditions and initiation of summer dormancy appeared to depend on soil water depletion since fall regrowth was correlated with fall rains. In British Columbia, Quinton et al. (1982), found that measurable spring growth of *Agropyron spicatum* occurred when the soil temperature reached 6°C at 10 cm depth. They also found that fall regrowth only occurred when there was higher than average September and October precipitation and temperature.

Spilsbury and Tisdale (1944) correlated the development of plant associations in southern British Columbia with variations in soil moisture, temperature and length of frost-free period. Miller et al. (1982) in Ruby Valley, Nevada, noted distinct patterns of vegetation resulting from differences in depth to ground water or from differences in water-retention capacities of soils deriving water only from precipitation.

Obviously, there is a dynamic relationship between plant growth, soil moisture and soil temperature. Growth initiation in the spring when soil moisture is usually non-limiting requires that soil temperature be high enough to release the plant from winter dormancy. As the soil moisture content declines throughout the summer, the plants use increasing amounts of energy to extract water from the soil (Lutwick 1969). The soil moisture supply and amount of energy needed to remove it are useful criteria to interpret plant growth and development (Lutwick 1969).

These conclusions indicate that climatic and edaphic factors will influence the ability of the plant to regrow after defoliation. By measuring soil moisture and nutrients in the study area, their affect on plant growth and regrowth can be determined.

3.2.2 Effects of clipping and grazing on plant growth

Willoughby et al (1982) found that clipping grasslands three times during the summer gave a reasonable indication of the plant growth cycle. Most plant growth occurred in June and July with lesser amounts in May, August and September. On aspen sites, however, there was little regrowth after the first clipping. No statistical analyses could be done on the data in this preliminary study because of a lack of replication.

Aldous (1930) and Albertson et al. (1953) found that plants clipped at 40 day intervals produced more dry matter yield than plants clipped at 10 day intervals. They also found that on a dry matter basis, the plants clipped only once a year gave the highest yields. In a four year study Heinrichs and Clark (1961) showed that plants clipped at three week intervals had a lower biomass production than plants clipped at 6 - 8 week intervals. They also noted that biomass production declined in all clipping treatments over the four years. Moser and Perry (1983), found that top and root yields, new tiller counts and total non-structural carbohydrate levels of *Eragrostis trichodes* were all reduced with multiple harvests within one year. Root growth and root biomass were also reduced by more frequent and severe clipping treatments (Jameson 1963).

Leopold (1949), Willms (1983), and McNaughton (1983) all found an increase in tiller density of grasses that had higher clipping frequencies. Tillering is the process by which the lateral buds that develop in the axils of the leaf nodes continue their development to form new tillers. The removal of the stem apex by defoliation releases the inhibiting effect the apex has on the development of the lateral tillers (Tainton 1981). Leopold (1949) reported that auxin produced in the stem apex inhibited lateral tiller development. Tiller development is most pronounced in plants with high energy reserves, but if defoliation is severe and energy reserves are low, tillering will be inhibited (Tainton 1981).

Energy reserves such as carbohydrates (glucose, fructose, sucrose, and fructosan), starch and protein are important in the growth cycle of the plant. These reserves maybe used as energy to drive the living processes in the plant or they maybe used as structural building blocks (Tainton 1981).

The major reserve constituents are the non-structural carbohydrates (White 1973). Carbohydrate reserves are important for winter survival, early spring growth initiation, and regrowth initiation after defoliation in perennial plants. Generally, carbohydrate reserves are highest in the late fall before winter dormancy and lowest in the spring after leaf initiation (Menke and Trlica 1981).

The accumulation of carbohydrate reserves is affected by a number of environmental factors. These include water, temperature, light intensity and nutrients. Normally the carbohydrate content is highest in plants grown at high light intensities and low temperatures, whereas, it is lowest in plants grown at high temperatures and low light intensities (McIlroy 1967).

If water stress is severe and prolonged and photosynthetic rate, drops below the respiration rate then carbohydrate reserves will be reduced (White 1973). However, carbohydrate reserves can increase if water stress is not severe and photosynthetic rate is not reduced.

Generally, carbohydrate reserves are reduced by more frequent defoliation (Bukey and Weaver 1939, Langille et al.

1965, Tainton 1981, Bahrani et al. 1983, Moser and Perry 1983). Regrowth of the plant after clipping depends upon the leaf area and accumulated carbohydrate reserves (Younger 1972). Plants will utilize carbohydrate reserves for regrowth of leaves after defoliation. If defoliation has not been severe there will be more leaf area for photosynthesis and less carbohydrate reserves will be needed to initiate leaf regrowth (Younger 1972).

Stout et al. (1980) found that *Calamagrostis rubescens* vigor was much more sensitive to clipping during the last half of July and early August when growth was slowing down and summer dormancy was setting in. McLean and Wikeem (1985) found the greatest injury to *Agropyron spicatum* occurred when the plants were defoliated to a height of 5 cm from mid April to the end of May or from early May to mid June. No appreciable damage was incurred by fall clipping to 5 cm or by season long defoliation to 20 cm. For both grasses defoliation had the greatest effect on plant vigor when the carbohydrate reserves were low and the plants were unable to regrow. Menke and Trlica (1981) also found that plants which accumulate carbohydrate reserves quickly after leaf initiation in the spring (or have V-shaped annual carbohydrate reserve cycles) were much better able to withstand defoliation than plants with U-shaped or extended accumulation cycles.

These results indicate that an understanding of the shape of the annual carbohydrate cycle is important to the range manager, enabling him to predict the response of the plant species to defoliation.

3.2.3 Limitations of clipping studies

A number of studies have used clipping to simulate grazing (Stout et al. 1980, Moser and Perry 1983, and Stroud et al 1985). Jameson (1963) indicated that there are a number of limitations in using clipping studies to simulate grazing. These limitations include:

1. Livestock pull vegetation off at random heights instead of at uniform heights.
2. Species preference of animals is not considered.
3. There is no trampling effect.
4. Litter accumulations are different than with grazing.
5. The amount of herbage removed is often much greater than could be achieved through grazing and the effect of clipping is therefore more severe.

Despite these limitations, clipping studies offer the most direct and accurate method of obtaining results which show the actual yield of ran[illegible]s and the relationship of yield to intensity of [illegible] foliage removal (Culley et al 1933).

3.3 Etiolated growth

Etiolated growth is the process whereby plants are grown in the absence of light(Salisbury and Ross 1978). Usually these plants are pale because they lack chlorophyll.

They also have very long stems because the absence of light promotes stem elongation (Salisbury and Ross 1978). The etiolated technique is based on the theory that the weight of aerial regrowth in the dark is related to the level of carbohydrate reserves in the plant (Edwards 1965).

Peterson (1962), in his work on *Stipa comata* found that plants protected from grazing for 16 years grew 2.5 times longer in the dark and had higher yields than plants protected from grazing for one or three years. Klebesadel (1971) found that A-syn.B cultivar of alfalfa had higher etiolated growth yields than Rhizoma, Rambler, and Vernal varieties and this etiolated growth corresponded with better winter hardiness. Langille et al. (1965), McKenzie and McLean (1980) on their work with alfalfa, and Bailey and Mappledoram (1983) on their work with 3 grasses in South Africa, showed a greater reduction in etiolated growth on plants that had a higher frequency of defoliation. Langille et al. (1965), also found that total available carbohydrates were lower in the more frequently clipped plants.

It has been assumed that vigor and regrowth of plants in the dark is related to the level of carbohydrate reserves. Carbohydrates provide both energy and structural units for maintenance and growth of living plant tissue (Edwards 1965). However, Stout (1984) has shown that etiolated growth of alfalfa is not equivalent to chemically measuring total nonstructural carbohydrates. He concluded that total non-structural carbohydrates was a more sensitive indicator of physiological change in the plant than etiolated growth. He postulated that etiolated growth probably reflected stored food reserves which included carbohydrates, fats and proteins,

3.4 Classification and ordination

Classification and ordination are two multivariate analysis techniques which are used to examine a series of variables simultaneously. These analysis techniques in plant ecology are important because plant community data is multivariant (Gauch 1982). Each sample site is described by a number of species and affected by numerous environmental factors. Instead of using statistical methods where only one or several variables at a time can be analyzed multivariant analysis can incorporate all the data to reveal the gradients inherent within the samples (Williams 1976).

There are three methods that plant ecologists use to analyze multivariant data: direct gradient analysis, ordination and classification. Direct gradient analysis portrays species and community variables along known environmental gradients (Whittaker 1978). In contrast ordination and classification organize communities based only on species abundance and do not use environmental data in the analysis (Gauch 1982). The environmental interpretation is left for later steps.

3.4.1 Classification

Classification is the assignment of samples to classes or groups based on the similarity of species. It must be noted that community classification involves an interaction between ecologists and communities (Whittaker 1962). This statement implies that the properties of community classification partly reflect community structure and partly reflect the thought patterns of ecologists. Therefore the emphasis within each community classification may differ from ecologist to ecologist.

There are many methods available for use in community classification as outlined by Mueller-Dombois and Ellenberg (1974), Whittaker (1978), Wishart (1978) and Gauch (1982). There are 3 main groups of classification techniques, table arrangement, non-hierarchial and hierarchial classification.

Table arrangement is the earliest classification technique in community ecology. It was first developed by Braun-Blanquet in 1921 (Braun-Blanquet 1932). The goals in the tablework are to arrange the species in a sequence that brings together samples similar in species composition (Mueller-Dombois and Ellenberg 1974). This method is very informal, time consuming and subjective.

Non-hierarchial classification merely assigns each sample (or species) to a cluster and then places similar clusters together, but the relationships among clusters are not characterized. This technique is excellent for handling redundancy and outliers but is not appropriate for analyzing relationships (Gauch 1982).

Hierarchial classification shows the relationship between classes by grouping similar entities into classes and then arranging these entities into a hierarchy. In addition the hierarchy can be viewed from several levels from detailed to general.

There are three groups of hierarchial classification techniques: monothetic divisive, polythetic divisive, and polythetic agglomerative.

Monothetic divisive classification techniques begin with all samples in a single cluster and then divide them hierarchially into progressively smaller clusters on the basis of presence or absence of a single species (Gauch 1982). There are two problems with this type of classification: 1) Community data is noisy, so classification on the basis of a single species is bound to misclassify many samples as judged by overall species composition. 2) Another problem is that data sets with a small range of community variation may necessitate the analysis of quantitative differences in species abundance and by using only one species this quantitative difference between species cannot be determined (Hill et al. 1975).

Polythetic divisive classification uses information on all species. This technique begins with all samples together in a single cluster and successively divides the samples into a hierarchy of smaller and smaller clusters until each cluster contains only one sample. The polythetic divisive technique is recommended for hierarchial classification because of its effectiveness and robustness. This technique is rarely used because of technical problems in communication and assimilation of results (Gauch 1982).

Polythetic agglomerative techniques use information on all the species and samples. They begin by assigning each sample to a cluster which has a single member. They then agglomerate these clusters into a hierarchy of larger and larger clusters until finally a single cluster contains all the samples (Gauch 1982). This classification technique is used more frequently than any other (Sneath and Sokal 1973) because it overcomes the problems outlined in the monothetic divisive technique.

3.4.2 Ordination

The purpose of ordination is to find relationships among species, communities and environmental variables. The results reduce the dimensionality of the data to 1-3 most important axes to which environmental gradients can be assigned (Gauch 1977).

The latest ordination technique is DECCORANA (Detrended Correspondence Analysis) (Gauch 1982). This is an improved eigenvector ordination technique based on reciprocal averaging. Reciprocal averaging is an ordination technique related to weighted averages but is computationally an eigenanalysis technique related to Principal Component Analysis. Reciprocal averaging (RA) is similar to weighted averages, because the sample scores are calculated from the species scores.

Weighted Averages

$$Sj = \frac{\Sigma Aij\ Wi}{\Sigma Aij}$$

where Sj = ordination score for each sample
A = abundance of species
W = weight of each species
i = species
j = sample number

(Gauch 1982)

Only RA goes one step further by calculating new species scores from the sample scores. Then new sample scores are calculated from the new species scores. Iterations continue until the scores stabilize (see Hill 1973 for a sample calculation). The contraction in the range of species scores in one iteration after convergence is reached is the eigenvalue (Hill 1973). The eigenvalue is the variance in the species stand table accounted for by that axis. Other axes can then be extracted after correction for the previously extracted axis (Hill 1973).

RA is similar to Principal Component Analysis (PCA) in that the projection of points in multdimensional space is reduced to fewer dimensions that can be easily understood. PCA uses Euclidean distance to graph points in multidimensional space, equal weights for points and location of origin of the axes at the centroid of the points (Gauch 1982). The first PCA axis is in the direction that captures the most variance along the ordination axes. A second axis is then found perpendicular to the first and accounts for the most of the remaining variation within the species stand table. This continues for as many axes as desired. In contrast RA uses chi-squared distances to locate points in multidimensional space, weights of sample points are proportional to the total for the sample and likewise species points are weighted by species totals. The orgin is also at the centroid (Gauch 1982).

Both RA and PCA ordination have the arch problem, in which the second axis is a quadratic distortion of the first axis (Hill 1973). But in the PCA ordination the arch may be involuted so that the most dissimilar points on the axis appear closer than actually occurs in nature (Gauch et al. 1977).

The second major fault of the RA ordination is that the ends of the axes are compressed relative to the middle (Hill

1973). As a result a distance of separation in the ordination may not be consistent with the actual difference between samples and points.

DECCORANA solves these two problems of RA by detrending and rescaling the axes. In detrending axis 1 is divided into a number of segments and within each segment the axis two scores are adjusted to zero. Detrending is applied to the samples scores at each iteration and when convergence is reached the final sample scores are derived by weighted averages of the species scores (Hill and Gauch 1980).

In rescaling, the small segments along the ordination axis are expanded or contracted so the species turnover occurs at a uniform rate. This is done by averaging the within sample dispersion of the species at all points along the sample ordination axis. This eliminates the compression of the first axis ends relative to the middle. Detrending is applied to the second and higher order ordination axes and rescaling is applied to all axes.

4. PART I: FORAGE GROWTH CYCLE

The specific objectives of the forage production study were: (1) to determine the forage growth cycle, (2) to determine the effect of frequency of harvesting on grasses and forbs, (3) to study the relationship of herbage growth and soil moisture , and (4) to study the effect of defoliation on the subsequent etiolated growth of major plant species.

4.1 METHODS

4.2 Treatments and levels

A single treatment of clipping with four levels was investigated in this study. The four treatment levels for the study are summarized in Figure 1. The levels simulate progressively greater deferrment of grazing ranging from forage harvested monthly from May to August, to a single harvest at the end of August.

The levels of clipping treatments include (1) a clip at the end of May with reclips at the end of June, July and August in the same quadrat (2) a clip at the end of June with the same quadrats being reclipped at the end of July and August (3) a clip at the end of July with a reclip at the end of August, and (4) a single clipping at the end of August.

Treatment	Month			
	May	June	July	August
4	clip-------	reclip------	reclip------	reclip
3		clip--------	reclip------	reclip
2			clip--------	reclip
1				clip

Clipping treatment levels

4. May + June + July + August
3. June + July + August
2. July + August
1. August (control)

FIGURE 1. Clipping treatments

The use of clipping treatments provided forage yields for each month and a relation of plant yield to frequency and degree of harvesting in the easiest and most economical way feasible. A controlled experiment using clipping treatments also offered the opportunity to evaluate alternate grazing management regimes under simulated conditions.

4.3 Clipping Study

Two similar sites were chosen for the clipping study. Both sites had similar aspects (Site 1: 230°, Site 2: 210°) and a range of 8-20% slope. The first site, which has a predominance of cultivated plant species and will be referred to as the cultivated site, was located on a heavily grazed area (88% utilization 1982-83) with predominant plant species being *Poa pratensis* , *Festuca rubra* and *Taraxacum officinale*(Yule 1983). The second site (native site) was moderately grazed (38% utilization 1982-83), and had a higher predominance of native species including *Heracleum sphondylium, Bromus vulgaris, and Elymus glaucus.*

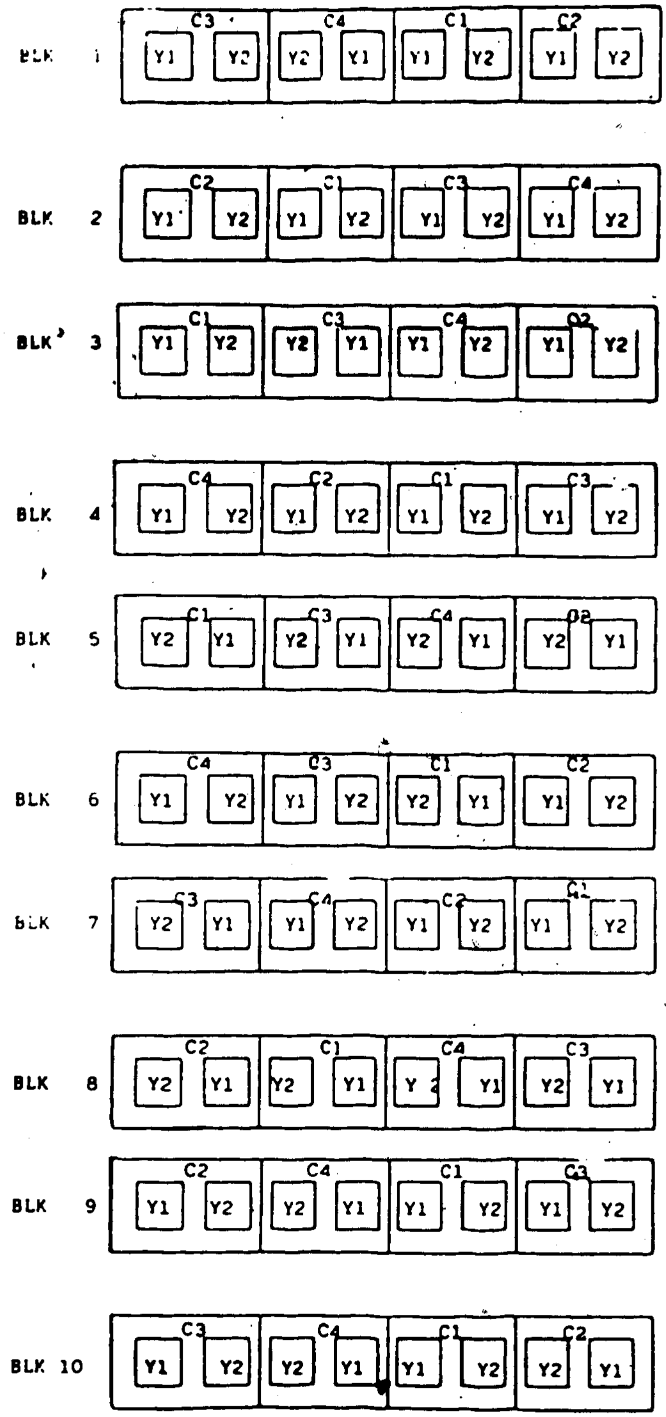

FIGURE 2. Randomizations of years within Blocks for the cultivated site (exclosure one) (BLK=Block, C1=August clip, C2=July+August clip, C3=June+July+ August clip C4=May+June+July+August clip, Y1=year one(1984), Y2=year two (1985))

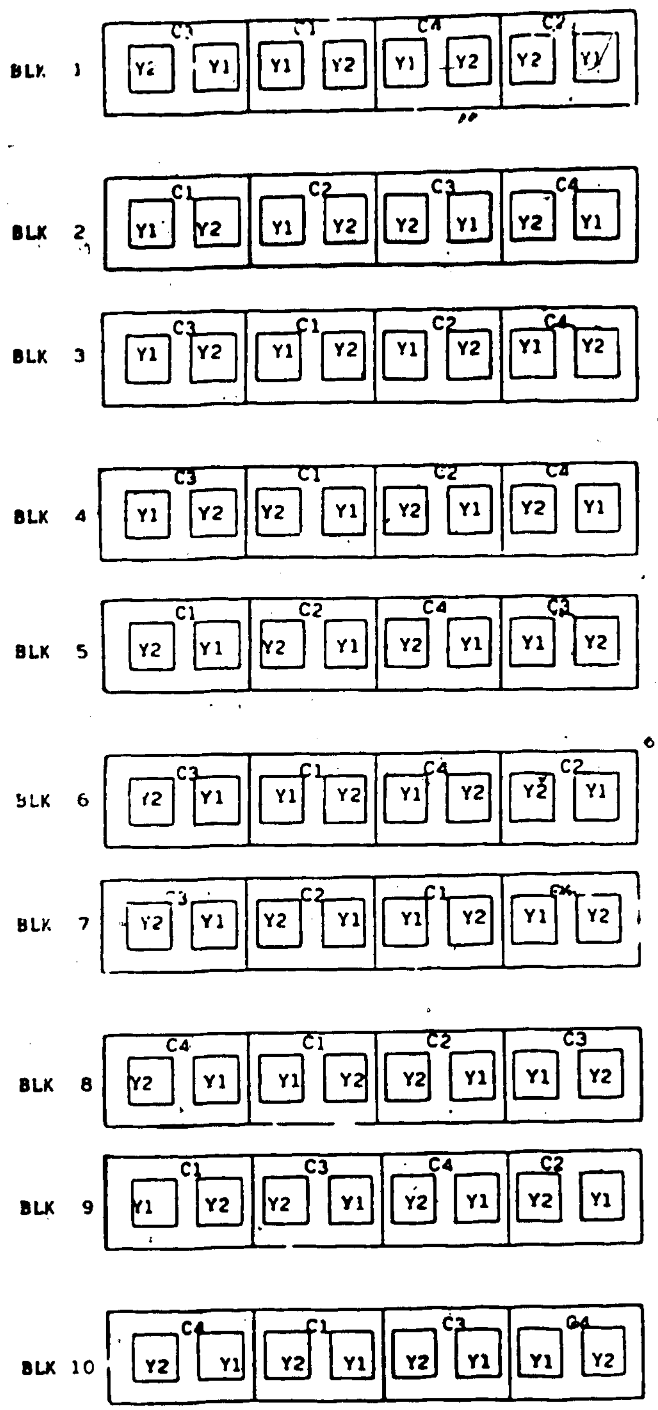

FIGURE 3. Randomizations of years within Blocks for the native site (exclosure two) (codes identical to Figure two).

TABLE 1. Randomizations of treatment level within blocks for the clipping study

	Blocks								
1	2	3	4	5	6	7	8	9	10
cultivated site									
2	1	2	2	1	2	3	2	1	2
4	2	3	3	2	4	2	3	4	4
1	3	1	1	4	1	1	4	2	3
3	4	4	4	3	3	4	1	3	1
native site									
3	2	1	3	1	3	4	2	3	3
4	1	4	2	4	4	3	1	1	4
1	3	2	4	2	2	1	4	4	1
2	4	2	1	3	1	2	3	2	2

Code for clipping treatments
4-May+June+July+August
3- June+July+August
2- July+August
1- August

At each site one 24 m x 40 m exclosure was erected. Each exclosure was divided into ten 12.5 x 1 meter blocks. These blocks were arranged parallel to the contour of the slope. Each block was subdivided into four 3 x 1 meter plots. Each plot was then subdivided into a 1.5 x 1 meter subplot (Figures 2 and 3). The randomization was completed in 2 steps. First, treatment levels (1,2,3,or 4) for clipping (C) were randomly assigned to whole plots within blocks. Secondly, years (Y), representing the year that the clipping treatment would be applied, was randomly assigned to subplots within each whole plot (Table 1, Figures 2 and 3).

4.3.1 Growth cycle

In order to evaluate the growth cycle of the plants it was important to determine how much growth occurred in each month. To obtain this growth rate the difference in total production for each month was determined. For example, the difference between the end of May's production and end of June's production was the growth rate for June. The experimental design was the same as outlined in the clipping study (Figures 2 and 3). A 50 cm x 100 cm quadrat was used to determine monthly forage production within the 10 blocks outlined in each exclosure. The monthly production of both forbs and grasses were separated in each exclosure.

4.3.2 Forage production

Ten 50 cm x 100 cm quadrats were harvested at each date as outlined in Figure 1. Harvesting took place at the end of each month. The quadrats were clipped to a height of 3 cm and the current year's growth of grasses and forbs was separated into paper bags. These samples were then oven dried at 105°C for 24 hours and weighed.

4.3.3 Vegetation

At each site ten vegetative transects were used to describe the foliar cover and frequency of each vascular species. Each vegetative transect was 20 meters long and was located parallel to the contour line of the slope. A transect consisted of 20 one meter square quadrats, situated across the contour line of the hill. Foliar cover was estimated using the procedure outlined by Daubenmire (1968), but foliar cover was estimated to the nearest 1% instead of cover classes. A 20 cm x 50 cm quadrat was nested within a corner of a one meter quadrat. The one meter quadrat was used to estimate the percentage foliar cover for shrubs and the 20 x 50 cm was used to estimate the foliar cover of grasses and forbs.

4.3.4 Soils

Soil pits were dug at each site to determine the following characteristics : order, horizonation, depth to parent material and texture (Dumanski 1978). All soil classification followed the Canadian System of Soil Classification (Canada Soil Survey Committee 1978). Soil samples from each horizon were collected and sent to the Soil Research Lab North Road Victoria B.C. Nitrogen, carbon, pH and exchangeable bases (kg/ha) were determined following the procedures outlined in (McKeague 1978). Bulk densities of each soil profile were determined using the methodology outlined in Klinka et al (1981).

Three soil moisture auger holes were established at each site. At each auger hole gravimetric soil moisture was taken weekly at depths of 10 and 25 cm. All samples were oven dried for 24 hours at 105°C to determine gravimetric moisture content. In addition, a soil moisture characteristic curve was determined for each depth at each site at 0.33, 1, 5, and 15 bars, using the pressure membrane apparatus (McKeague 1978).

Total area (%/month) under the moisture curve above and below wilting point was calculated for each month to determine available water (area above wilting point) and total water (total area under the curve to zero percent gravimetric moisture).

4.4 Etiolated growth study

The etiolated growth study concentrated on the growth of the dominant forb and grass in each exclosure. For the cultivated site, the dominant forb and grass was *Taraxacum officinale* and *Festuca rubra* respectively. At the native site the dominant forb was *Heracleum sphondylium* and dominant grass was *Bromus vulgaris*.

One gallon silver colored tins were used to create a dark environment for etiolated growth in the field. In each site, during May, 1985 one tin was placed over the dominant grass and forb within each one half meter square subplot that had been clipped in 1984. The dominant grass and forb were covered together under one tin where possible. Ten tins were assigned to each of the four treatments (Figures 2 and 3). These ten tins represented replications of each treatment. In addition ten tins were placed on areas where no previous clipping treatment was applied. These tins were placed randomly within a half meter square adjacent to clipping treatment four in year two. The placement of each can followed the procedure outlined by Edwards (1965). The procedure consisted of five steps:

1) The tuft, or tufts, of the plant of which "potential vigour" was to be determined were selected randomly. In this study the tins were subjectively placed over the grass and forb nearest the center of the 50 x 100 cm subplot, because the clipping treatment assigned to each subplot had already been randomly assigned.

2) The number of living tillers were counted on each plant.

3)All leaves and stems were harvested.

4) The basal area of each plant was measured.

5) The tin was then placed on the plants and rotated penetrating the soil to ensure an absence of light.

Etiolated growth was clipped within each subplot at 2 week intervals until no regrowth occurred. Total dry weight/sample and yield/tiller were compared.

The distribution of *Heracleum sphondylium* and *Bromus vulgaris* was not uniform in the native site. *Heracleum* was dominant in the lower half of exclosure two, whereas, *Bromus* was predominant in the upper half of the exclosure. As a result only six replications of *Heracleum* and *Bromus* were possible in this exclosure.

5. DATA ANALYSIS

The following experimental designs test the hypotheses listed in the introduction.

5.1 Clipping study

5.1.1 Experimental design for clipping trials

Hypotheses tested:

1. There is no difference in total production of grass or forbs among clipping treatments.
2. There is no difference in production of grass or forbs among years.
3. There is no interaction between clipping treatment and year on forage production of grasses or forbs.

Experimental Design

Source		df	Test
Block (B)	(r-1)	9	E1
Clipping (C)	(a-1)	3	E1
Error 1 (BxC)	(r-1)(a-1)	27	
Year (Y)	(b-1)	1	E2
Error 2 (CxY)	(a-1)(b-1)	3	E3
Error 3	(YxB + CxYxB)	36	
Total	(abr)-1	79	

Means for total grass and total forbs were separated with a Student-Newman-Keuls' test at the 0.05 level (Steel and Torrie 1980).

5.1.2 Clipping trials May and June vs June only

Hypotheses tested:

1. There is no difference in grass and forb production on plots clipped in May and June compared to those clipped only in June.

2. There is no interaction between clipping treatment and year for those plots clipped in May and June compared to those clipped only in June.

Experimental design

Source		df	test
Blocks (B)	r-1	9	
Clipping (C)	a-1	1	E1
Error 1 (BxC)	(r-1)(a-1)	9	
Year (Y)	(b-1)	1	E2
Error 2 (CxY)	(a-1)(b-1)	1	E3
Error 3	(YxB + YxBxC)	18	
Total		39	

Means for grass and forbs were separated with an F-test as on the previous page.

5.1.3 Trials May, June and July vs June and July vs July only

Hypotheses tested:

1. There is no difference in grass and forb production among plots clipped in May and June and July, June and July, and July only.

2. There is no interaction between clipping treatment and year for those plots clipped in May and June and July, June and July, and July only.

Experimental design

Source		df	test
Blocks (B)	r-1	9	
Clipping (C)	a-1	2	E1
Error 1 (BxC)	(r-1)(a-1)	18	
Year (Y)	(b-1)	1	E2
Error 2 (CxY)	(a-1)(b-1)	1	E3
Error 3	(YxB + YxBxC)	27	
Total		59	

Means for grass and forbs were separated with a Student-Newman-Keuls' test at the .05 level.

5.2 Forage growth cycle

5.2.1 Experimental design for monthly growth of grasses and forbs in cultivated and native sites

Hypothesis tested: 1. There is no difference in grass and forb production between months within a year.

Experimental design

Source		df	test
Blocks(B)	r-1	9	[illegible]
Months(M)	a-1	3	E[illegible]
Error 1 (BxM)	(r-1)(a-1)	27	
Years(Y)	y-1	1	E2
Error 2 (MxY)	(y-1)(a-1)	3	E3
Error 3 (YxB + MxBxY)		36	
Total	bm-1	79	

Monthly means were separated with a Student-Newman-Keuls' test at the 0.05 level

5.3 Etiolated growth study

5.3.1 Data analysis for the cultivated site

Hypothesis tested There was no difference in total etiolated growth in 1985 among treatments defoliated in 1984.

Experimental design

Source	df
Blocks	9
Clipping Freq.(0, 1, 2, 3, 4)	4
Error	36
Total	49

The treatment means were separated using a Student-Newman-Keuls' test at the 0.05 level.

5.3.2 Data analysis for the native site

Experimental design

Source	df
Blocks	5
Clipping Freq.(0, 1, 2, 3, 4)	4
Error	20
Total	29

The treatment means were separated using a Student-Newman-Keuls' test at the 0.05 level.

6. RESULTS

6.1 Soils

The cultivated site (exclosure one) had a Dark Gray Luvisolic soil, whereas, the native site (exclosure two) had a Gleyed Dark Gray Luvisol (Appendix 3). The Ah horizons varied from 11-18 cm thick at the cultivated site to 8-15 cm thick at the native site. The organic matter content of the Ah horizon was 19% at the cultiavated site and 15% at the native site. The base saturation ranged from 57% at the cultivated site to 67% at the native site. The % base saturation was dominated by the cations of calcium and magnesium. The pH varied from 5.6 at the cultivated site to 6.7 at the native site. The majority of roots were found in uppermost 15 cm.

6.2 Vegetation

The dominant forb at the cultivated site was *Taraxacum officinale* with a foliar cover of 25% and a frequency of 100%. *Trifolium repens, Vicia americana, and Plantago major* made up only a small component of the flora of the site with foliar covers varying from 1.3 to 0.09 percent. The dominant grasses included *Festuca rubra and Poa pratensis* with foliar covers of 21 and 17% respectively.

In contrast the native site was dominated by the forbs *Heracleum sphondylium and Thalictrum occidentale* with foliar covers of 20% and 16% respectively. The dominant grasses at the native site were *Bromus vulgaris and Elymus glaucus* with foliar covers of 6 and 5% respectively.

6.3 Forage growth cycle

6.3.1 Climate in the 1984 and 1985 growing seasons

All snow had melted by the end of April in 1984 and by May 10 in 1985.

In general May to August was hotter and drier in 1985 than 1984 (Figure 4, Table 2). The mean weekly maximum temperature was 8-10 degrees warmer during the last two weeks of May 1985 than in 1984. The average mean temperature was two degrees warmer for both May and July (1985) and the temperatures for June and August were only 1.5 degrees colder for the respective months in 1984.

Precipitation in July and August of 1985 was 50% lower than 1984 and the precipitation for July 1984 was half the normal (Table 2). All precipitation for August 1985 fell during one storm about August 8.

The lack of precipitation and high temperatures during the last two weeks of July 1984, the last two weeks in May, first two weeks in June, July and August in 1985 relulted in a soil moisture content below the wilting point for plants in both exclosures (Figures 5, 6 and 7).

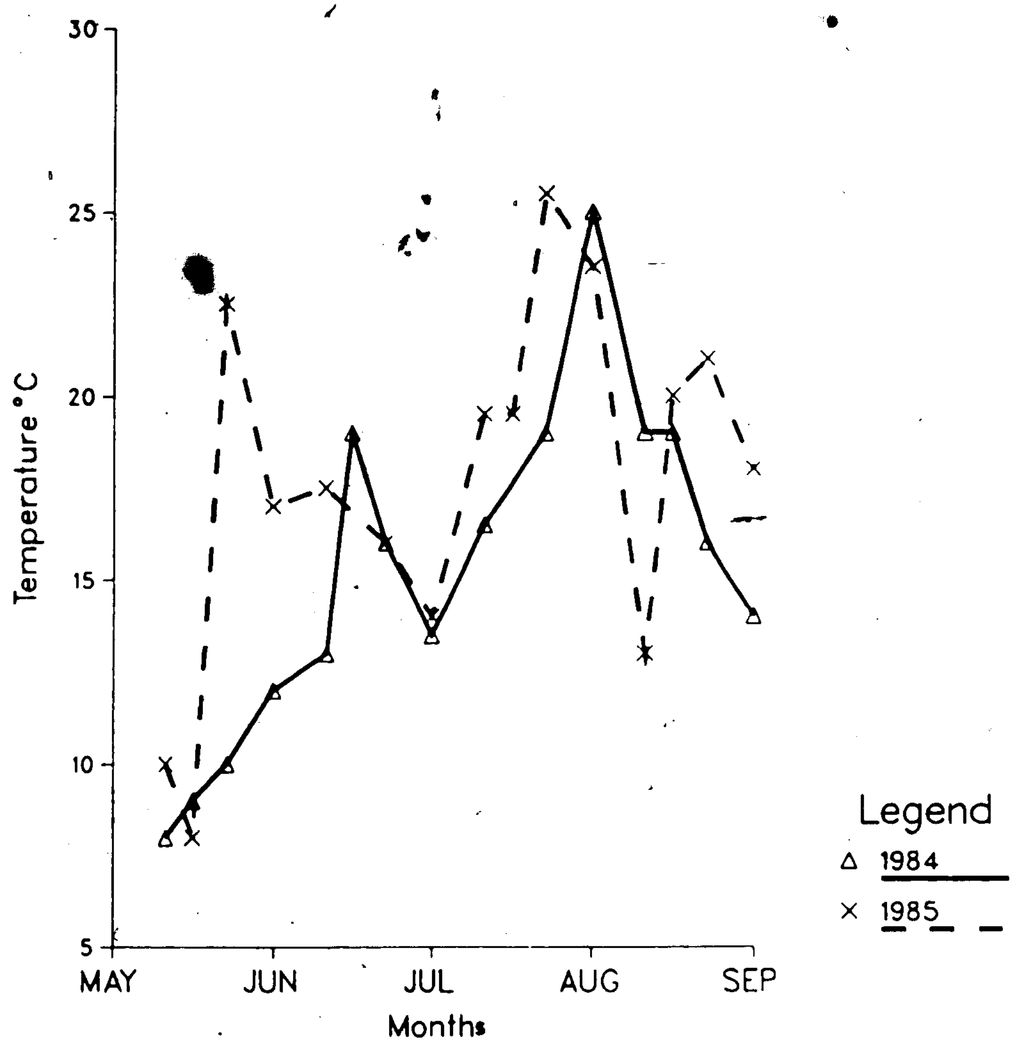

FIGURE 4. Mean weekly maximum temperature(°C) for the growing season in 1984 and 1985 at the cultivated site Poplar Lake B.C.

TABLE 2. Temperature(°C) and Precipitation(mm) data for Poplar Lake in 1984 and 1985 and the 30 year average

	Temperature°C						Precipitation		
	Ave Max		Ave Min		Ave Temp.		(mm)'		
	1984	1985	1984	1985	1984	1985	1984	1985	Norm'
May	9	14	0.5	1	5	8		9	23
June	15	15	4	2	10	9	11*	48	39
July	18	21	7	8	12	14	20	5	41
Aug	19	19	9	7	14	13	60	26	46

* note precipitation recorded was only for last half of June
'Average monthly preciptation
'Nadina river 10 km southwest of the study area.

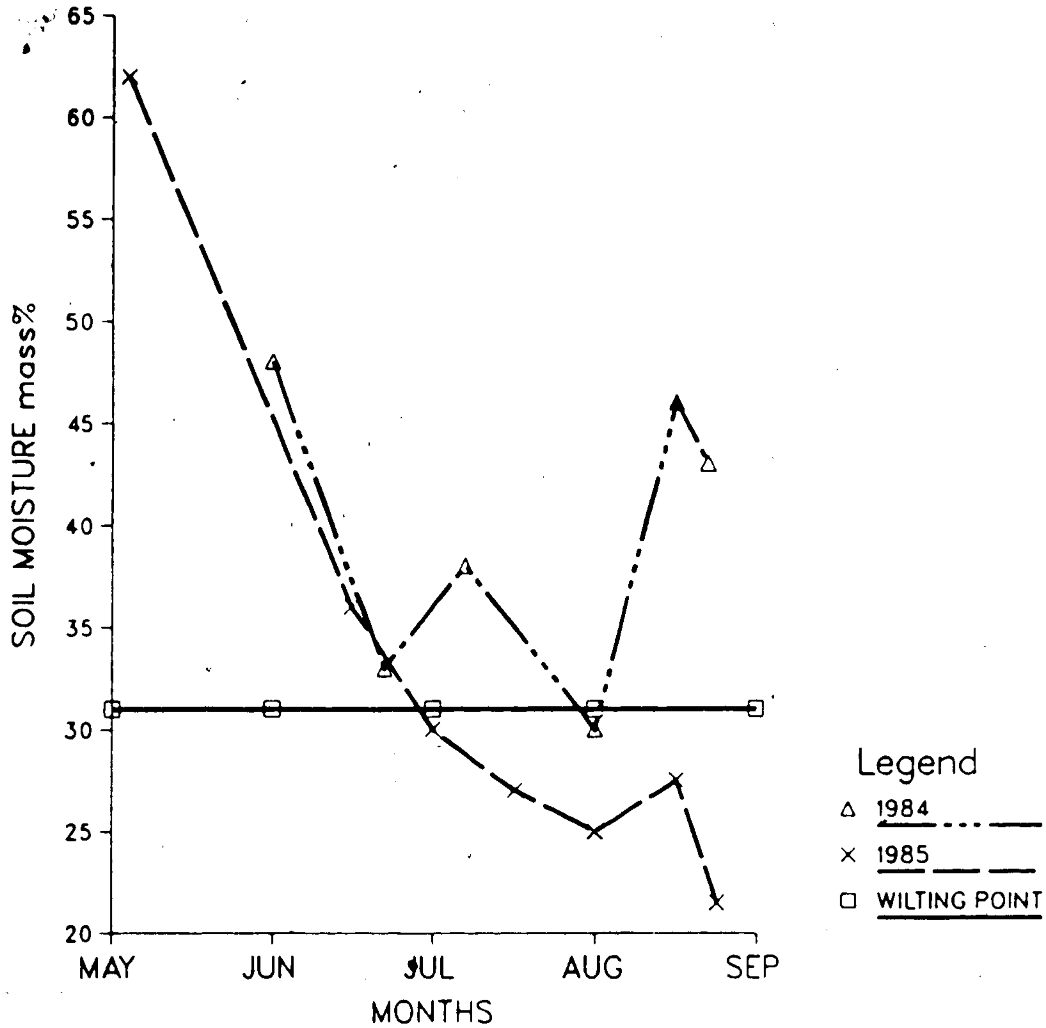

FIGURE 5. Soil moisture at 10 cm depth during 1984 and 1985 in the cultivated site (exclosure one).

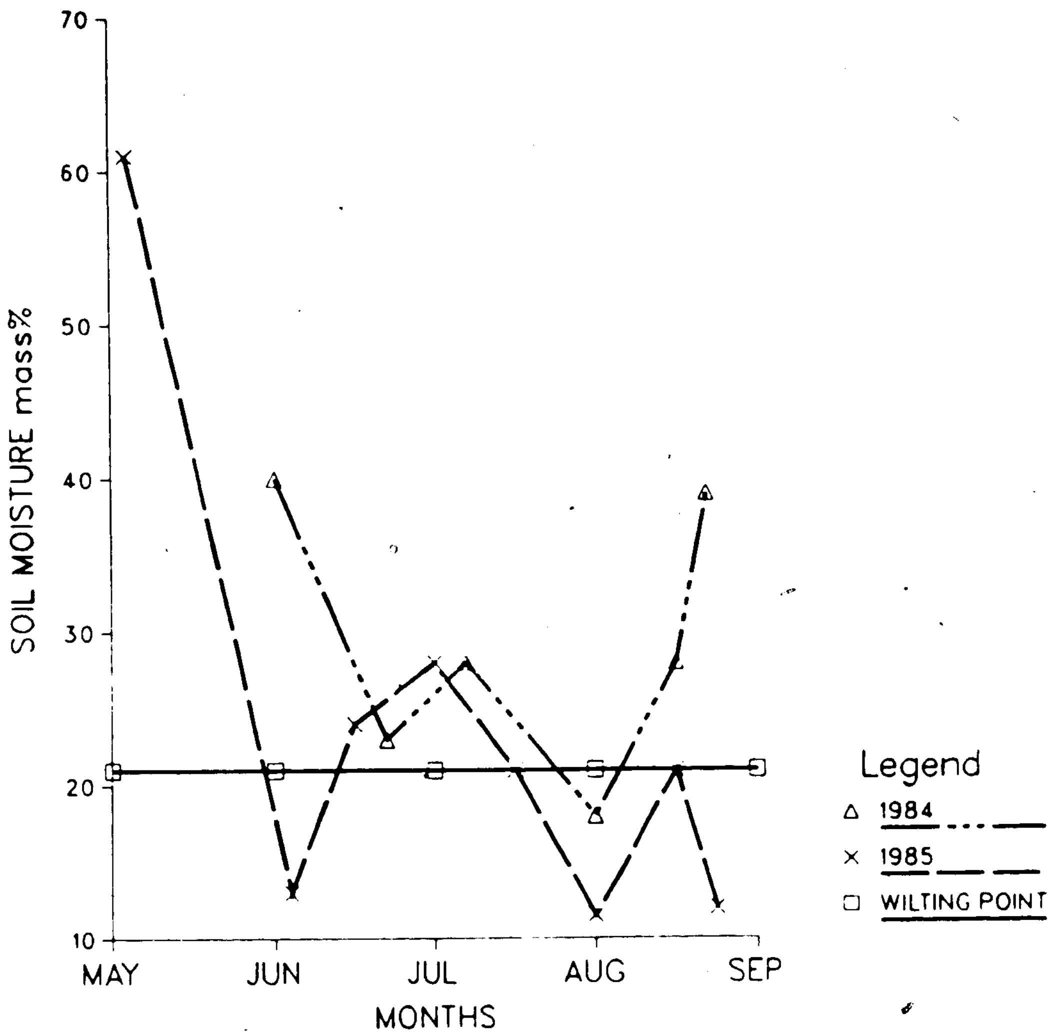

FIGURE 6. Soil moisture at 10 cm depth during 1984 and 1985 in the native site (exclosure two).

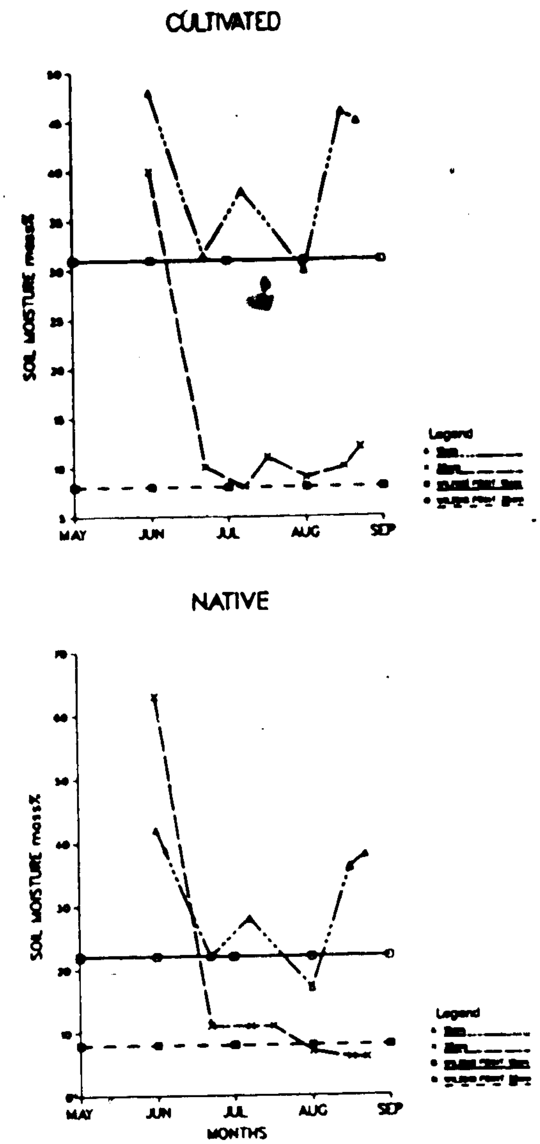

FIGURE 7. Gravimetric soil moisture at the 10 cm and 25 cm depths in the cultivated site and native site for 1984.

There was more water available for plant growth in July and August 1984 in the cultivated site and for all months in 1984 at the native site compared to 1985 (Figure 8). There was also a deficit of available water for plant growth in July and August for both exclosures in 1985. Available soil moisture was generally non-limiting in May and June in exclosures one and two for both years (Figure 8). Available water in June was 100% higher in the cultivated site than the native site in 1985.

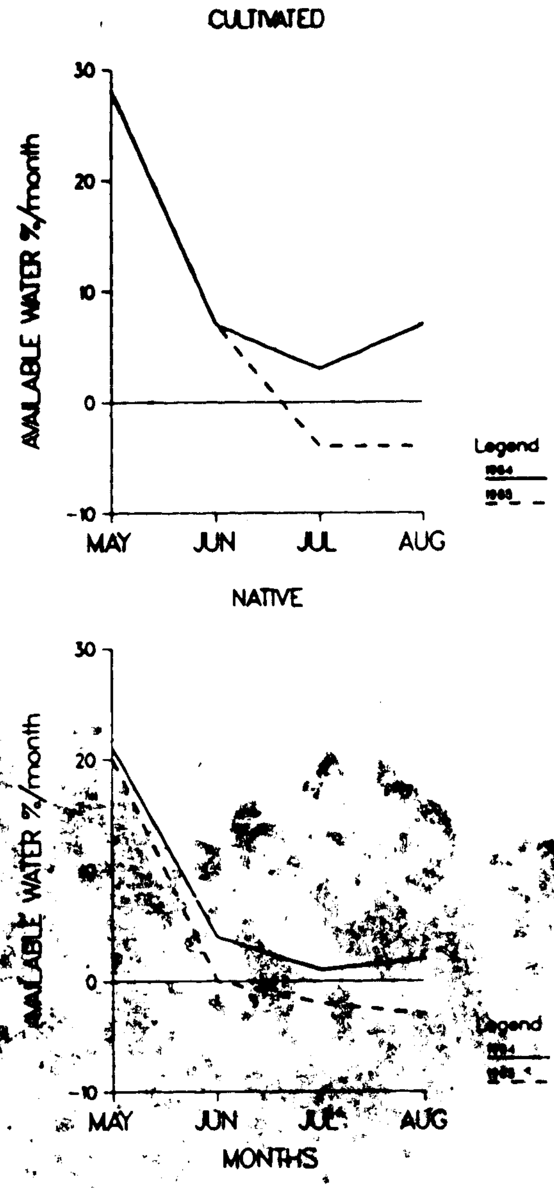

FIGURE 8. Available water for each month in the cultivated site (exclosure one) and native site (exclosure two) for 1984 and 1985 at the 10 cm depth.

6.3.2 Growth cycle

The growing season was primarily from May to September (Figure 9). Total forage production was higher at the cultivated site in 1985, when spring temperatures were warmer, than in 1984 (Table 3). At the native site there was no difference in total forage production between 1984 and 1985. The maximum forage production for forbs in the cultivated site occurred in June in 1984 (Figure 9, Table 3). The maximum production of grasses in the cultivated site occurred in August in 1984 and 1985 (Figure 9, Table 3). In contrast the maximum production of forbs at the native site occurred in June, July and August in 19[illegible] (Figure 9, Table 3). The maximum production of grass[illegible] the native site occurred in July and August 1984 and June and July 1985 (Figure 9, Table 3). The majority of the total forage produced at the native site was forbs (Figure 9). In contrast the majority of total forage at the cultivated site was grasses (Figure 9).

Both forbs and grass have maximum growth rates peaking in May or June and declining thereafter (Figures 10, 11 and Table 4). Forage production and growth rates were higher for forbs and grass in May 1985 compared to May 1984 at both sites (Figures 10,11 and Table 4). Growth of forbs at the cultivated site had largely ceased by the end of July in 1984 and 1985, whereas, grass growth continued through July and August in both years (Figure 10).

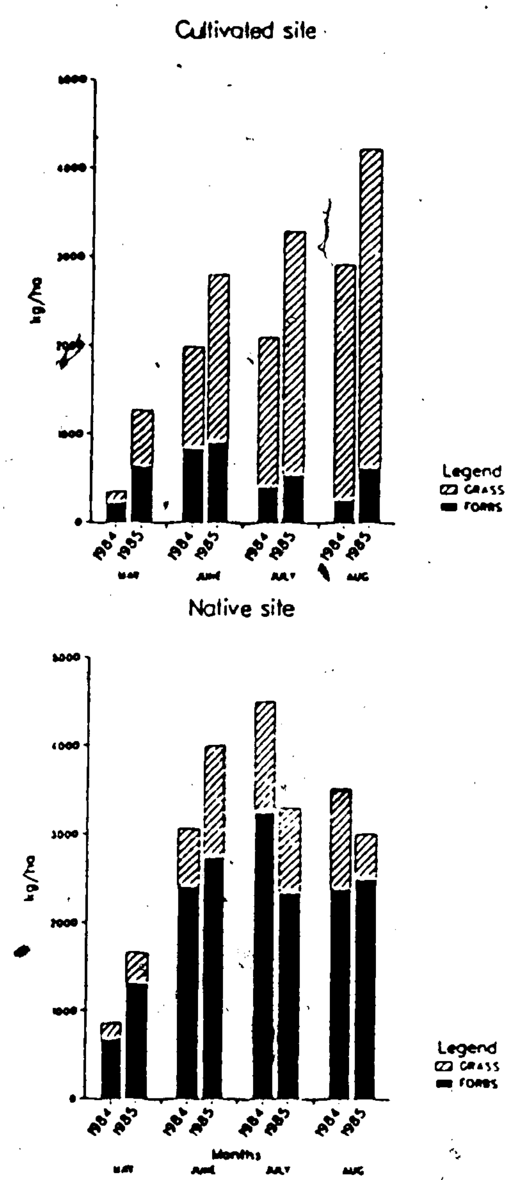

FIGURE 9. Total dry weight kg/ha/month for forbs and grass at the cultivated and native sites in 1984 and 1985.

TABLE 3. The total production of forbs and grass (kg/ha) for each month of the growing season in 1984 and 1985 for the cultivated site and the native site

Months	Forbs 84	Forbs 85	Grass 84	Grass 85
cultivated site				
May	221b[1]	639 a	129c	637 d
June	842a	906 a	1152b	1896 c
July	398b	540 a	1698b	2756 b
Aug	254b	620 a	2664a	3608 a
Grand mean	429	676 *[2]	1411	2215 *
native site				
May	681b	1314 b**	180c	346 b*
June	2402a	2738 a	662b	1270 a*
July	3242a	2340 a	1260a	962 a
Aug	2384a	2498 a	1132a	510 b*
Grand mean	2178	2223	809	773

[1] Means within an exclosure and within a column with the same letter are not significantly different according to a Student-Newman-Keul's test at the 0.05 level.

[2] Means for year separated using a F-test, ** 0.01, * 0.05 level

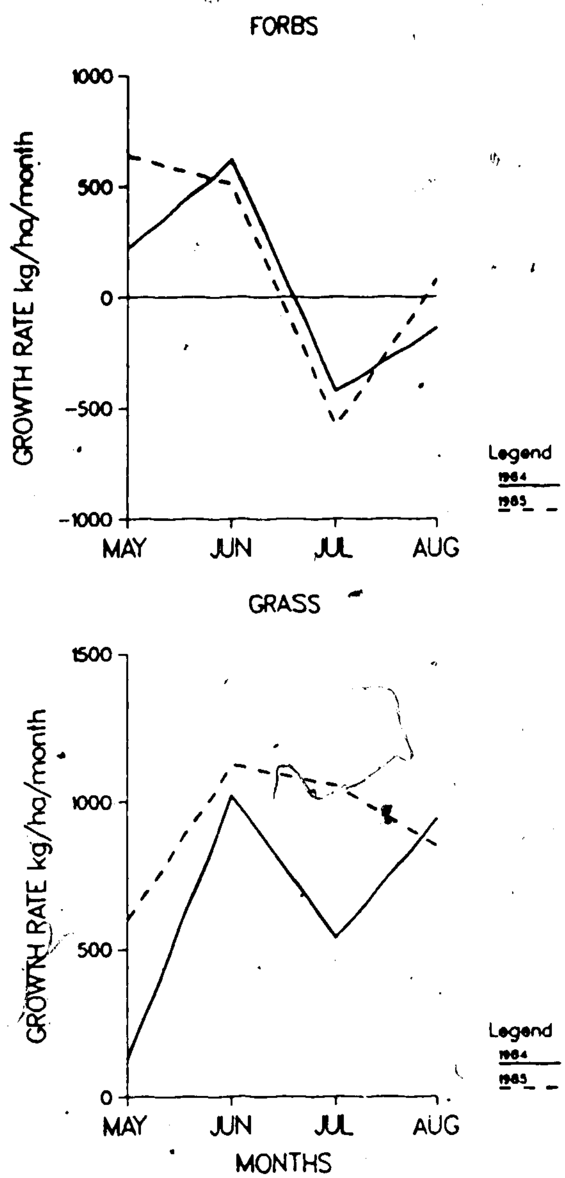

FIGURE 10. Monthly growth rate kg/ha/month for forbs and grass during the growing season at the cultivated site.

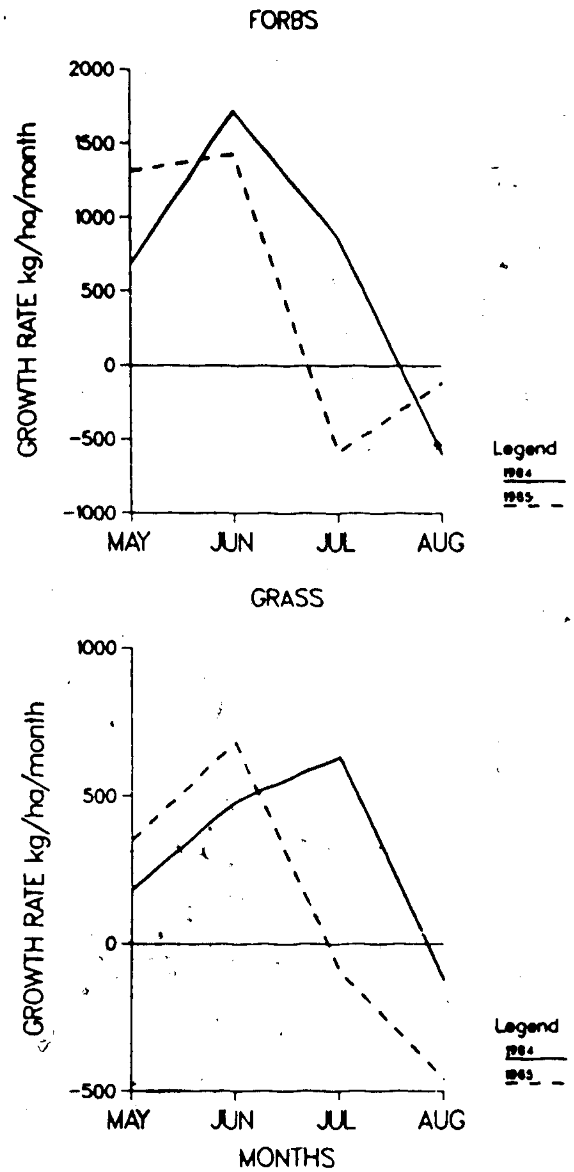

FIGURE 11. Monthly growth rate kg/ha/month for forbs and grass during the growing season at the native site.

TABLE 4. Monthly growth rate[1] of forbs and grass (kg/ha) for each month of the growing season in 1984 and 1985 for the cultivated site and the native site

Months	Forbs 84	Forbs 85	Grass 84	Grass 85
cultivated site				
May	221b[2]	639 a	129b	637 a
June	622a	510 ab	1020a	1124 a
July	-424c	-580 c	538ab	1054 a
Aug	-138c	80 bc	942a	648 a
native site				
May	681ab	1314 a*[3]	180a	346 ab*
June	1720a	1430 a	480a	680 a
July	866ab	-588 b*	632a	-96 c*
Aug	-600b	-116 b	-124a	-460 bc

[1]Monthly growth rate was determined by taking the difference in production from the end of one month to the end of the next month

[2] Means within a exclosure and within a column with the same letter are not significantly different according to a Student-Newman-Keul's test at the 0.05 level

[3]Means for year separated using a F-test, ** 0.01, * 0.05 level

At the native site forb and grass growth had ceased by the end of July in 1985 and the end of August in 1984 (Figure 11).

The regrowth of grasses and forbs after an initial clip for June, July, and August is outlined in Table 5 and Figures 12 and 13. There was a significant month by year interaction for forbs and grass at the native site (Appendix 5) which indicates there were differences in monthly regrowth between years. There was more regrowth of forbs in June and August and grass in June and July of 1984 than in 1985 at the native site (Table 5).

When a comparison of the growth rate in the absence of clipping (Figures 10 and 11) was made with the growth rate after an initial clip (Figures 12 and 13), there is some regrowth of forbs in the cultivated site and forbs and grass at the native site in July and August. This indicates that a single clipping stimulates some regrowth at a time when the plants have normally ceased growth.

When the growth rate is plotted against temperature index (area under the temperature curve above 5°C) the higher air temperatures in May (1985) caused the total growth rate to be 1000 kg/ha greater at the cultivated site and 800 kg/ha greater at the native site compared to May 1984 (Figure 14).

TABLE 5. The regrowth of forbs and grass (kg/ha) after an initial clip for each month of the growing in 1984 and 1985 for the cultivated site and the native site

Months	Forbs 84	Forbs 85	Grass 84	Grass 85
cultivated site				
May	221b[1]	639 a**[2]	129b	637 a**
June	533a	471 b	681a	655 a
July	192b	103 c	253b	224 b
Aug	8c	0 c	244b	234 b
native site				
May[3]	681b	1314 a**	180b	346 a*
June	1168a	604 b**	482a	87 b**
July	323c	426 b	158b	68 b**
Aug	285c	29 c**	120b	99 b

[1] Means within a exclosure and within a column with the same letter are not significantly different according to a Student-Newman-Keul's test at the 0.05 level
[2]Means for year separated using a F-test, ** 0.01, * 0.0 level
[3]At both sites May growth refers to total growth to the end of the month without previous clipping.

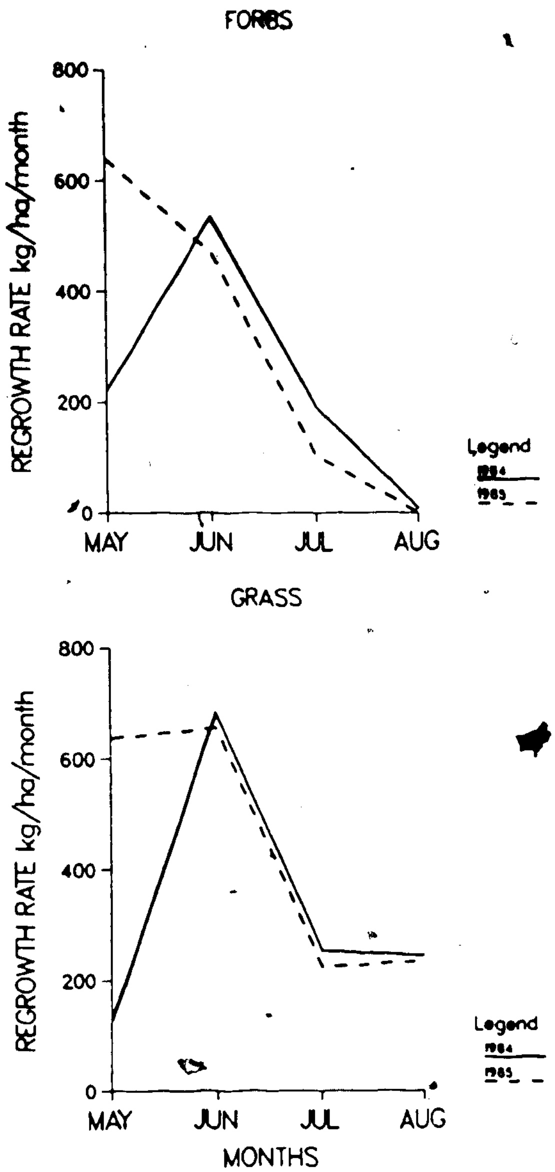

FIGURE 12. The monthly regrowth rate after an initial clip for the cultivated site (May's growth refers to total growth to the end of the month without previous clipping).

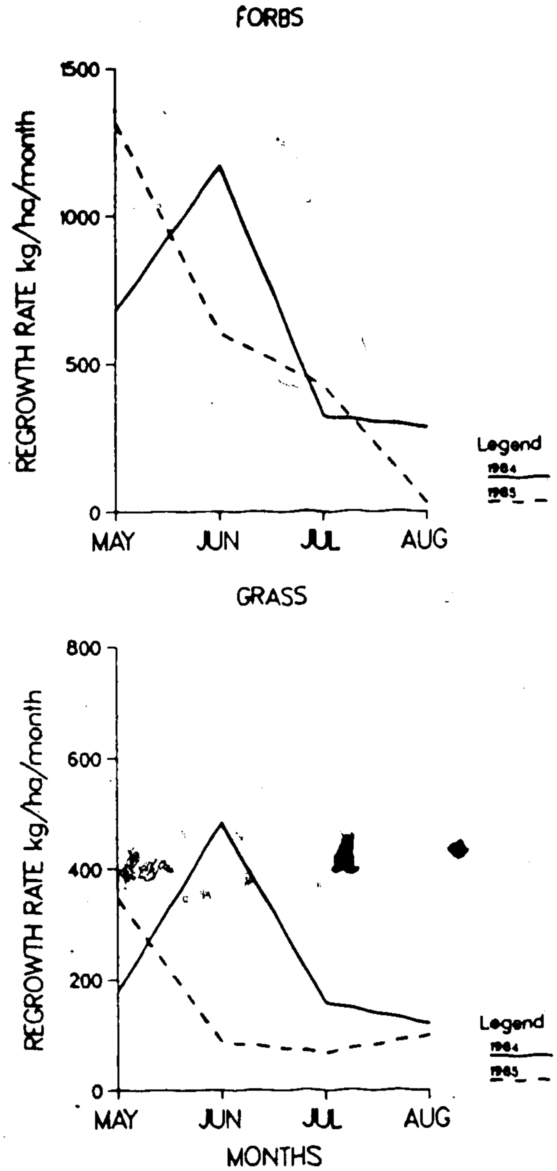

FIGURE 13. The monthly regrowth rate after an initial clip for the native site.

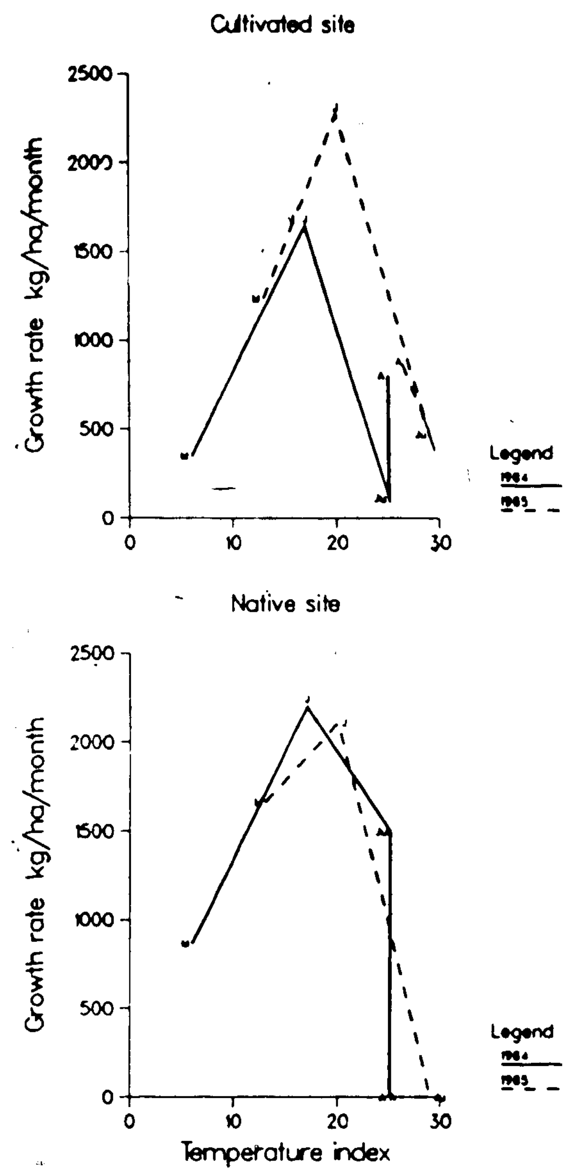

FIGURE 14. Total monthly growth versus temperature index (area under the temperature curve to 5°C) for the cultivated site and the native site in 1984 and 1985 (M=May, J=June, Ju=July and A=August)

As the temperature index increased, the growth rate declined for July and August at the cultivated and native sites.

Generally, as soil moisture decreased, plant growth rate decreased during the months of July and August in 1984 and 1985 (Figure 15). Despite the high available water in May 1984 and 1985, the growth rate in May 1985 was higher.

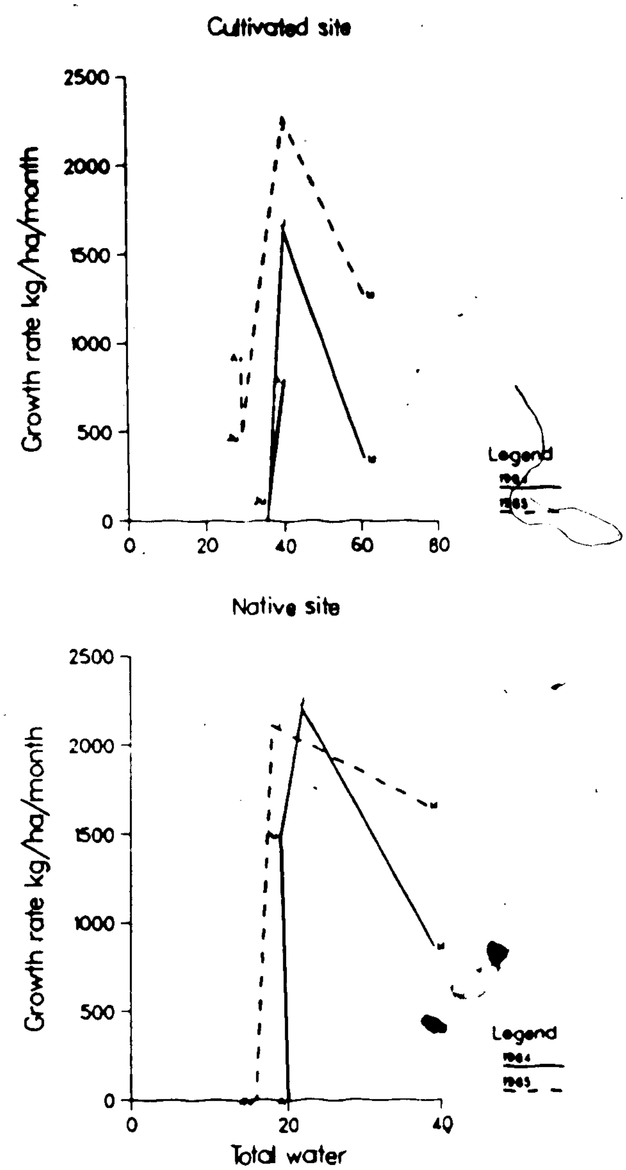

FIGURE 15. Total monthly growth versus total water for the cultivated site and the native site in 1984 and 1985 (M=May, J=June, Ju=July and A=August)

6.3.3 Defoliation and yield at the cultivated site

There was significantly higher cumulative production of forbs and grass in 1985 compared to 1984 for the heavy defoliation treatment (May, June, July and August) (Table 6). Three or four harvests per season yielded higher forb production in 1984 and 1985 than one or two harvests per season (Figure 16). Harvests done at the end of August (one/season) and at the end of July and August (two/season) occur after much of the current years' growth had senesced and disappeared. Consequently, yields in treatments one and two were lower.

An increase in the frequency of defoliation usually resulted in a reduction in the yield of grass within years (Figure 16). In 1985 grass yield was reduced by more frequent defoliation during July, whereas, defoliation had no significant effect on yield during July 1984 (Table 6). By the end of August, however, grass yield was reduced by more frequent defoliation in both 1984 and 1985. Frequency of defoliation had no significant effect on grass or forb yield by the end June.

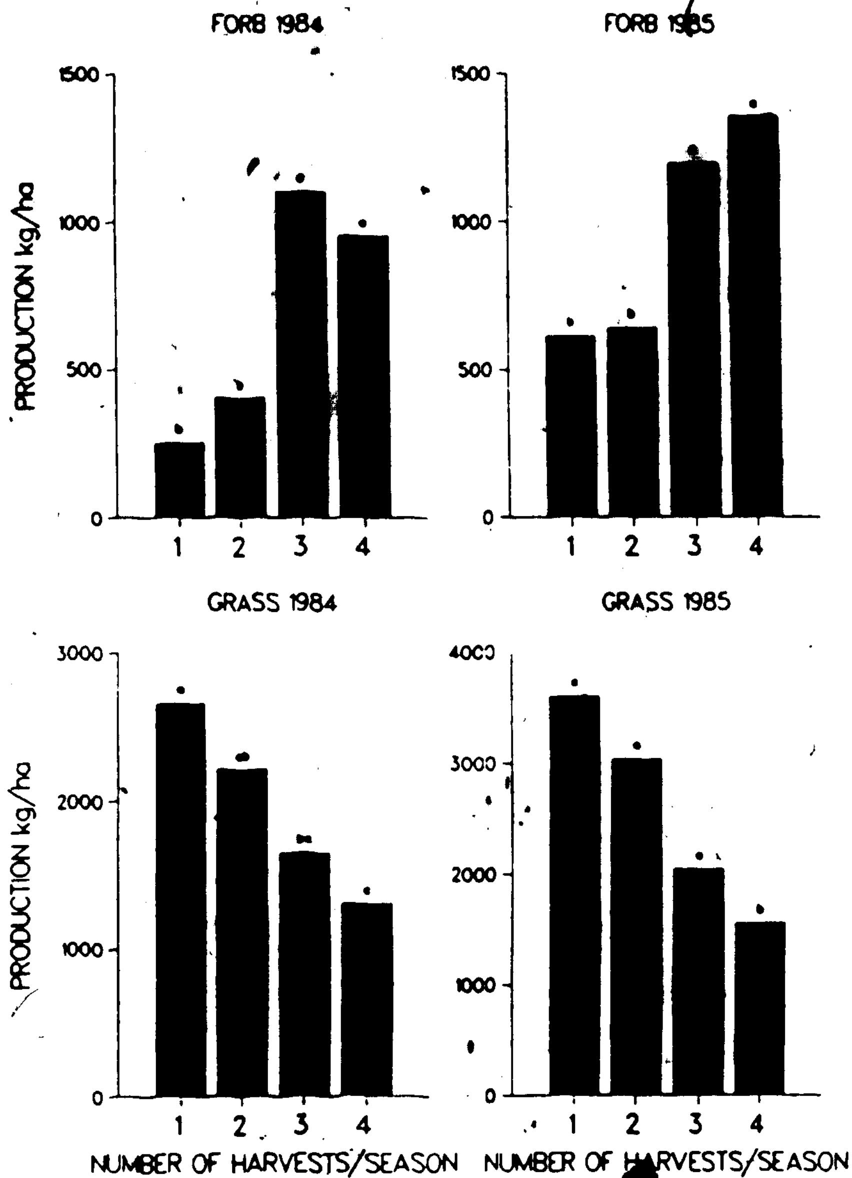

FIGURE 16. The effect of clipping frequency on grass and forb production during 1984 and 1985 in the cultivated site.

TABLE 6. Mean yields for grass and forbs under various clipping treatments for the cultivated site (kg/ha)

Clip freq.	1984 forb	1985 forb	1984 grass	1985 grass
End of August				
4	953a	1357 a	1306c	1559 b
3	1105a	1199 a	1652bc	2050 a
2	403b	642 b	2215ab	3042 a
1	253b	615 b	2663a	3607 a
Grand mean	679	953 *	1959	2565 *
End of July				
3	945a	1357 a	1064a	1464 b
2	1093a	1202 a	1395a	1926 b
1	398b	642 b	1699a	2757 a
Grand mean	609	800	1040	1537 *
End of June				
2	753a	1110 a	810a	1291 a
1	842a	1099 a	1152a	1702 a
Grand mean	798	1105	981	1497 *

Means within a month within a column with the same letter are not significantly different at the 0.05 level according to a Student-Neuman-Keul's test

* Means between years separated using an F-test at the 0.05 level

6.3.4 Defoliation and yield on the native site

An increase in the frequency of defoliation did not significantly affect production of native forb species (Figure 17), although trends varied by year.

It appeared that grass yield was only influenced by frequency of defoliation (Figure 17) if soil moisture was limiting. In 1985, grass yield was already reduced by more frequent defoliation by the end of June, whereas in 1984 there was no difference (Table 7). By the end of July more frequent defoliation reduced grass yield in both 1984 and 1985, but these differences had disappeared by the end of August in 1984. In contrast, in 1985 the more frequently clipped grasses had the greatest reduction in yield by the end of August.

The grand means of the native grasses at the native site were significantly lower in 1985 than 1984. In contrast the domestic grasses in the cultivated site had significantly higher yields in 1985 compared to 1984 (Table 6).

At the native site there was no significant year interaction for forbs (Appendix 8) indicating there was no difference in total forage production for forbs between years. There was also no significant treatment by year interaction for forb at the native site indicating that there was no difference in forage production for forbs between years for each treatment. There also was no treatment by year interaction for forbs and grass at the cultivated site (Appendix 7).

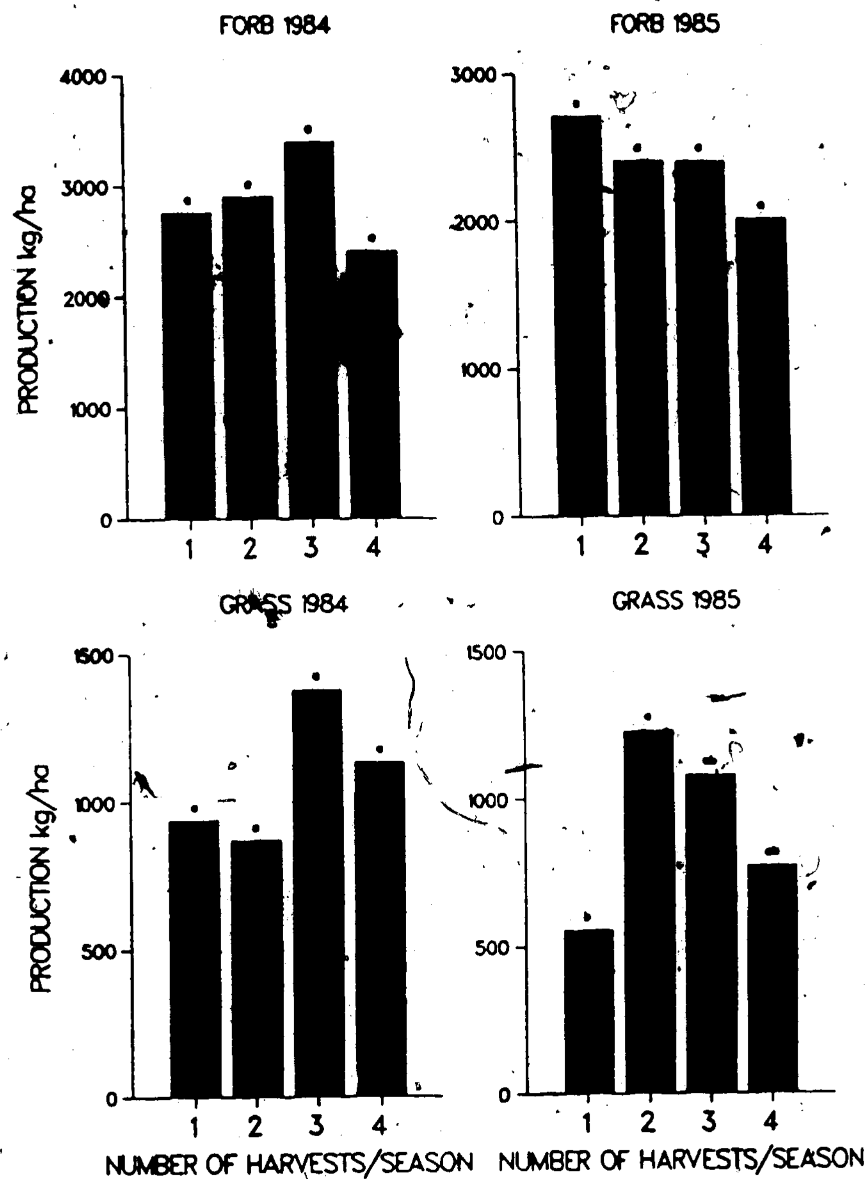

FIGURE 17. The effect of clipping frequency on grass and forb production during 1984 and 1985 at the native site.

TABLE 7. Mean yields (kg/ha) for grass and forbs under various clipping treatments for the native sited

Clip freq.	1984 forb	1985 forb	1984 grass	1985 grass
End of August				
4	2761a	2713 a	939a	556 b
3	2903a	2715 a	870a	1231 a
2	3396a	2407 a	1379a	1082 ab
1	2414a	2016 a	1134a	773 ab
Grand mean	2869	2463	1081	911
End of July				
3	2335a	2635 a	819b	535 b
2	2638a	2281 a	736b	1135 a
1	3243a	2281 a	1260a	966 a
Grand mean	2739	2399	938	878
End of June				
2	1841a	1919 a	667a	435 b
1	2201a	2738 a	662a	1069 a
Grand mean	2021	2329	665	752

Means within a month within a column with the same letter are not significantly different at the 0.05 level according to a Student-Neuman-Keul's test

* means within a year separated with a F-test at the 0.05 level

6.3.5 Etiolated growth

In general plants clipped once or not at all in 1984 tended to grow longer and have higher yields of etiolated growth in 1985 than plants clipped 2, 3 or 4 times (Figure 18 and [illegible] Table 8).

[illegible] three and four harvests during the previous summer had [illegible]st affect on dandelion *Taraxacum officinale* yield (Figure 18). In contrast the *Festuca rubra* plants which were not clipped had higher yields of etiolated growth than plants clipped one, three or four times.

Yields of *Heracleum sphondylium* were greater in the control, one and two clipping frequencies than in clipping frequencies 3 and 4 (Table 8 and Figure 19). The plants in the control and treatment one tended to grow until the end of August, whereas, growth in the dark terminated by the middle of July for treatments 2, 3 and 4.

The most vigorous and highest yielding plants of *Bromus vulgaris* were in the control and treatments one and two (Figure 19, Table 8). The production in these treatments was 2-4 times greater than clipping frequencies 3 and 4. Treatments 1, 2 and the control produced the highest number of tillers per can (Table 9). Tiller number was positively correlated (r=0.76,p=0.0) with total weight per treatment using Pearson's correlation (Steel and Torrie 1980, pg. 272).

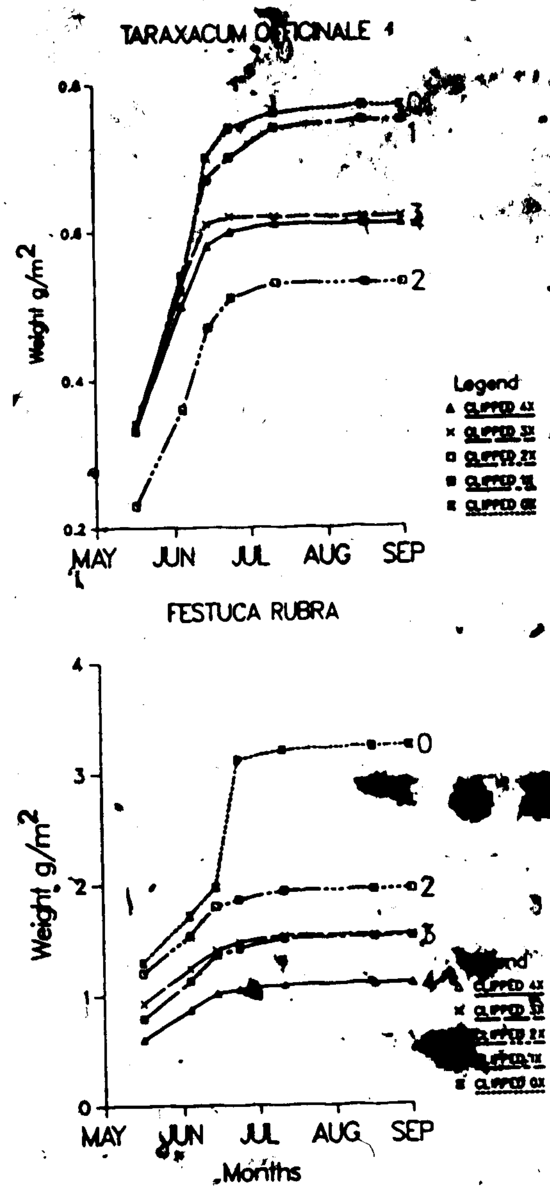

FIGURE 18. Accumulated etiolated growth (g/m^2) for _Taraxacum officinale_ and _Festuca rubra_ in 1985 in relation to frequency of harvesting.

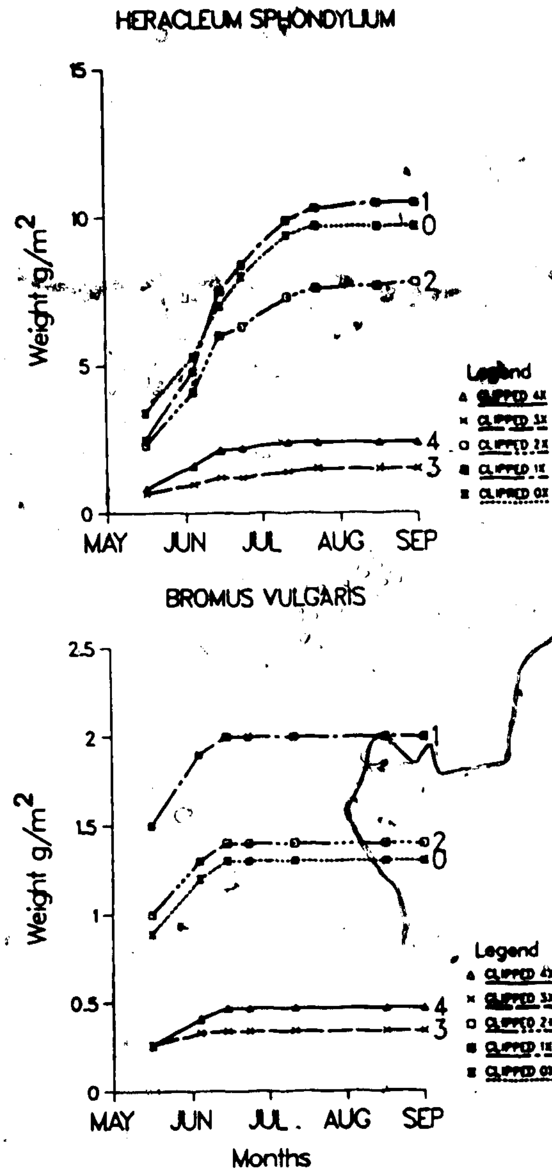

FIGURE 19. Accumulated etiolated growth (g/m_2) for Heracleum sphondylium and Bromus vulgaris in 1985 in relation to frequency of harvesting.

TABLE 8. Total etiolated growth (g/m²) for selected species in relation to frequency of harvesting at the cultivated and native sites.

	Native site		Cultivated site	
clip freq.	Heracleum sphondylium	Bromus vulgaris	Taraxacum officinale	Festuca rubra
4	127b'	38 b	34ab	80 b
3	97b	23 b	32ab	90 b
2	446a	85 a	24b	107 ab
1	524a	111 a	41a	79 b
0	476a	74 a	47a	119 a
	p=0.14	p=0.08	p=0.08	p=0.08

'means within a column with the same letter are not significantly different at the level indicated according to a Student-Newman-Keuls' test

The tiller number/can was also highly correlated with weight for *Heracleum sphondylium* (r=0.83,p=0.0), but there was no significant difference in tiller number among clipping frequency treatments (Table 9).

TABLE 9. Number of tillers/can for *Heracleum sphondylium* and *Bromus vulgaris*

Clipping frequency	Heracleum sphondylium	Bromus vulgaris
4	5.8 a	7.6 b
3	4.2 a	5.6 b
2	8.3 a	12.0 a
1	7.3 a	13.0 a
0	14.6 a	9.1 ab

note means within a column with the same letter are not significantly different at the 0.08 level, according to a Student-Newman-Keul's test

7. DISCUSSION

7.1 Growth cycle

Quinton et al. (1982), noted that bluebunch wheatgrass growth in the Southern interior of British Columbia occurred from mid April until mid August. Stout et al. (1981) found that rough fescue grew from mid April to early July in the southern interior of British Columbia The normal growing season in the study area is approximately May to September but low temperatures in spring and summer drought can markedly affect forage growth. Most plant growth occurred in May and June when soil temperature and soil moisture were favorable. If soil temperature is low and soil moisture declines, plant growth will generally decline.

Non-limiting soil moisture in the spring did not appear to affect plant growth in 1984 and 1985 (Figure 14), but temperature did. Monthly growth was much higher for May 1985 for both the cultivated and native site and can be related to temperature (Table 2, Figure 15). It therefore appears that initiation of plant growth in the spring appears to be more closely related to soil temperature than to soil moisture.

As the growing season [illegible] increase in air temperature, decrease in soil moisture, and a decrease in plant growth (Figures 14 and 15). Generally, higher air temperatures were associated with less precipitation and lower soil moisture (Figure 4, Table 2).

High air temperature[illegible]ave had the effect of increasing transpiration and ev[illegible]on, further lowering soil moisture. This decl[illegible] plant growth appeared to be related to soil mo[illegible]e and to the growth cycle of each plant species. So[illegible]oisture became limiting to the plants during July and August (Figures 5 and 6). It was during these months that there was the greatest reduction in rate of plant growth. Kalu and Fick (1983) have also noted that alfalfa remained in the vegetative state for longer periods of time during extended rainy periods. There was more precipitation during the growing season of 1984 than 1985. The native forage plants in exclosure two therefore remained in the vegetative state for a longer period of time in 1984.

The lack of available soil moisture in 1985 also resulted in lower regrowth rates of forbs in June and August and grass in June and July at the native site (Table 5). Cellular growth is the most sensitive to water stress (Hsaio 1973) and a decrease of external potential by only one bar will decrease cellular growth (Salisbury and Ross 1978).

Growth of plants also appears to be related to soil moisture at the 10 cm depth. During August 1984 rainfall caused the soil moisture at the 10 cm depth to rise but did not change soil moisture at the 25 cm depth (Figure 7). From observations in the field this increase in soil moisture during August 1984 caused previously defoliated plants to regrow, at both sites compared to August 1985 (Table 5).

The majority of forb and grass roots were observed at the 0-15 cm depth. This probably would account for the regrowth of grasses when soil moisture at the 10 cm depth rose above wilting point during August 1984.

During August 1984 there was an increase in soil moisture and a decrease in air temperature. The favorable climatic conditions did not significantly increase plant growth and regrowth when compared to July's growth (Tables 4 and 5). This is likely the result of the annual growth cycle of the plants. Generally, both native and cultivated forbs and grass have flowered and set seed by the end of August. If no defoliation had previously occurred, especially, for the grass species, little new growth would occur under favorable weather conditions at the end of August. Therefore, growth cessation in the summer appears to be mainly controlled by the individual growth cycle of each plant species and as well as soil moisture.

The annual plant growth cycle differed for forbs and grasses at both sites. The dominant forb in the cultivated site was *Taraxacum officinale*. *Taraxacum officinale* grew mostly in May and June with rapid senescence occurring in July. The native forbs (*Heracleum sphondylium*) at the native site, also had the maximum growth rate in May and June. Growth conditions were very favorable in May and June 1985 and by the end of July the plants had set seed and the leaves were withering. In contrast the spring of 1984 was cooler and wetter, delaying plant phenology so the plants were not in flower until the end of July.

The domesticated grasses in the cultivated site (*Poa pratensis, Phleum pratense, Festuca rubra*) have a higher growth rate in favorable weather conditions than the native grasses (*Bromus vulgaris, Elymus glaucus*) at the native site. These domesticated grasses produced an extra 400 kg/ha of forage during May 1985 compared to May 1984 (Table 3). The production for the rest of the growing season was then equivalent to 1984's growth. In contrast growth of the native species reached a maximum and then declined (Table 4). These species do not seem to take advantage of favorable weather conditions to maximize growth. The likely reason for the difference in the plant growth cycle between the two sites was related to the soil moisture regime. If one compares Figure 5 and 6, soil moisture at the native site reached wilting point a month earlier than the cultivated site during 1985. Figure 7 shows soil moisture at the 25 cm depth recovers better in July and August at the cultivated site compared to the native site. The cultivated site may receive extra moisture from ground water throughout the growing season, whereas, the native site may not. The cultivated site was situated at a lower elevation and the area above the site had a shallow slope and a predominant tree cover In contrast the native site was at a higher elevation and the area above it was a steep rocky bluff. It was therefore likely that the cultivated site may have had some groundwater recharge, whereas, water probably flowed quickly through the native site. If there was a lack of groundwater recharge at the native site during the middle of the growing season, rates of plant growth would be affected regardless of whether the plants are native or cultivated species.

It appeared that the forage growth cycle was related to soil and air temperature in the spring, soil moisture during the summer and to the annual growth cycle of the individual plant species.

7.2 Defoliation, yield and etiolated growth

Grass yield decreased and forb yield increased as frequency of defoliation increased at the cultivated site. In contrast at the native site forb yield was not influenced by defoliation and grass yield was only reduced by more frequent defoliation if soil moisture was limiting.

Etiolated growth was used to estimate the potential vigor of the plants following various defoliation treatments. This evaluation of plant vigor provided an indirect measure of the ability of the plant to recover following defoliation.

The plants with clipping frequencies of 3 and 4 times per season in 1984 had the lowest yields of etiolated growth in 1985. Langille et al. (1962), Mckenzie and McLean (1980), and Bailey and Mappledoram (1983) all found similar results. Richards and Caldwell (1985) found that the daily contribution of carbon from stored reserves exceeded photosynthetically fixed carbon for only 2.5 days following defoliation of *Agropyron spp.* when regrowth was maximal. They also found that when the apical meristem was removed, photosynthesis during regrowth immediately outweighed stored reserves as a source of carbon. The plants with the highest clipping frequencies would utilize carbohydrates and other reserves to initate regrowth after defoliation. This reduction in reserves due to defoliation coupled with the reduction of energy reserves due to winter respiration severely reduced the vigor of the plants the next year. Plants clipped 3 and 4 times grew until the middle of June for *Taraxacum officinale and Bromus vulgaris* and the middle of July for *Heracleum sphondylium and Festuca rubra* (Figures 18 and 19). It would appear that defoliations of 3 and 4 times in one growing season would not detrimentally affect the survival of all four species during the following growing season if a sufficient period of recovery was permitted through May and June of the subsquent growing season. This has definite management implications. If a sward was severely overgrazed in one year then recovery would likely occur if grazing is deferred for about 60 days next spring, i.e. until July of the next growing season.

7.2.1 Cultivated site

The increase in production of forbs with an increase in clipping frequency shown in Figure 14 was most likely related to the sampling methodology. *Taraxacum officinale,* grew mostly in May and June with rapid senescence occurring during July (Table 3). Clipping treatments 3 and 4 were harvested at the end of May and June. Consequently, yield of dandelion would be higher in these treatments because two harvests were made during the period of maximum growth. Towards the end of July and August most dandelion leaves have senesced; consequently, yield of clipping treatments 1 and 2 were reduced. The favorable weather conditions for growth during May 1985 would also account for the higher yields of forbs in clipping treatments 3 and 4 in 1985 than in 1984.

Dandelion has about 10% crude protein at the end of June (Appendix 4). This high crude protein content coupled with early spring growth makes it an excellent forage for early spring grazing. Dandelion vigor and etiolated growth appeared to be most severly affected by a defoliation at the end of June, July and again in August.

Work by Stout et al (1980) has shown that the vigor of *Calamagrostis rubescens* was most sensitive to clipping during the last half of July and early August when growth was slowing down and summer dormancy was setting in. Range grasses have also been shown to be susceptible to grazing during the growth period and immediately following growth cessation (Stoddart et al. 1975). Dandelion growth has slowed by the end of July. Energy reserves are likely at their lowest at this time. Defoliation at the end of July may stimulate the plant to regrow during favorable weather conditions in August. This would further reduce the amount of energy reserves and the plant may then have low reserves going into winter dormancy.

An increase in the frequency of defoliation caused a significant reduction in the yield of grasses. These results were consistent with the studies of Aldous (1930), Albertson et al. (1953), Heinrichs and Clark (1961), Jameson (1963) and Moser and Perry (1983). Generally, as defoliation frequency increased, the level of carbohydrate reserves decreased (Bukey and Weaver 1939, Langille et al 1961, Tainton 1981, Bahrani et al 1983, and Moser and Perry 1983). Plants will utilize carbohydrate reserves and photosynthetic carbohydrates to initiate regrowth of leaves after defoliation (Richards and Caldwell 1985). The more frequent the defoliation, the less stored and photosynthetic carbohydrates are available for regrowth.

It appeared that frequency of defoliation had the greatest effect on grass yield when soil moisture was the most limiting. From Figure 5 it is evident that during July and August 1985 and the last two weeks of July 1984 soil moisture at the 10cm depth was the lowest. It was during this time period that the most frequently clipped plants had the greatest reduction in yield (Table 6). If water stress is severe carbohydrate levels will decline because the repiration rate will exceed the photosynthetic rate (White 1973). This reduction in carbohydrate level due to water stress coupled with the reduction of carbohydrate levels due to defoliation will severely affect the ability of the plant to regrow.

The results of the etiolated growth study of *Festuca rubra* are consistent with the clipping study. Defoliations of 3 and 4 times/season had the greatest effect on the vigor of *Festuca rubra* plants.

7.2.2 Native site

There were no significant differences among harvest treatments for native forbs (Table 7) although there were substantial differences amongst the means. This is likely the result of extreme variation of forb production within subplots. The main forb was *Heracleum sphondylium*, a major species in the lower half of the exclosure, but less abundant in the upper half of the exclosure. Therefore, production within one month may vary from 300 kg/ha from subplots in the upper part of the exclosure to 3200 kg/ha at the bottom of the exclosure. This high variability is outlined in Appendix 7.

Despite the lack of significance among defoliation treatments there are some large differences in the means between years. These differences can be related to the growth phenology of the plants. These native forbs tend to have maximum growth rate in May and June. By the end of July they have set seed and are undergoing rapid senescence. Growth conditions were very favorable in May and June 1985 and consequently, treatments 3 and 4 had the highest yields.

Treatments 3 and 4 have harvests during these months. By the end of July 1985 the plants had set seed and the leaves were withering. In contrast the cool temperatures of the spring 1984 delayed growth and the plants were just in flower by the end of July. Consequently, the highest mean yields of forbs in 1984 were in clipping treatments 2, 3 and 4 which had harvests during the maximum growth period.

Crude protein levels in these native forbs tend to vary from 15% at the end of June to only 3% at the end of August (Willoughby et al. 1982)(Appendix 4). Maximum yields of the native forbs are achieved in June 1985 and July 1984 (Table 3). These plants should therefore be grazed in May, June and July to get benefit of forage production and crude protein ingested by cattle.

Heracleum sphondylium, the major forb at the native site, continued to produce etiolated growth until the middle of September in the 0 and 1 defoliation treatments and up to the middle of July in the 3 and 4 defoliation treatments. This growth was longer than any other of the species tested. The forb could be heavily defoliated, allowed to regrow, and then defoliated again thereby maintaining maximum productivity. The large root reserves may allow the plant to recover after defoliation.

In general grass yield was not influenced by frequency of defoliation unless soil moisture became limiting. Soil moisture at the 10cm depth was reduced below wilting point during the last two weeks of July, first week in August

1984, and first two weeks of June, July and August 1985 (Figure 7). It was during these time periods that the more frequently clipped plants had the greatest reduction in yield. For example, note that defoliation had significantly decreased grass production by the end June 1985, but there is no difference by the end of June 1984 (Table 7). Soil moisture [illegible] for plant growth in the first 2 weeks of June 1985 [illegible] not in June 1984. Both defoliation and water stress severely reduce the carbohydrate reserves in the plants (White 1973, Tainton 1981). These low carbohydrate reserves inhibit the ability of the plant to regrow.

Leopold (1949), Willms (1983), and McNaughton (1983), all found an increase in tiller density of grasses that had moderate clipping frequencies. Tiller development has also been shown to be most pronounced in plants with high root reserves, but if defoliation is severe and root reserves are low tillering will be inhibited (Tainton 1981). This increase in tillering following defoliation may account for the greater yields of etiolated growth in treatments 1 and 2 for (moderate defoliation) *Bromus vulgaris*. These treatments had the highest tiller density which was positively correlated with total etiolated growth weight (Table 9). Treatments 3 and 4 had the lowest tiller density indicating that defoliation may have been so severe that the root reserves were depleted and tillering was inhibited. Tiller density was not available for *Festuca rubra*.

8. Part II: RANGE COMMUNITIES

The specific objectives were: (1) To quantify the grassland and aspen forest communities characteristic of the sub-boreal spruce (SBS) biogeoclimatic zone and the sub-alpine fir subzone (e). (2) To study the environmental factors which were accounting for variation in plant composition in the Poplar Lake study area.

8.1 METHODS

8.2 Classification and ordination

Twenty-two sites were described during the summers of 1984 and 1985 to quantify the species composition of the grasslands and aspen forest communities within the Poplar Lake Range Unit.

8.2.1 Critieria for site selection

Site selection was based on a topographic position, moisture drainage and grazing regime gradient. In order to study the moisture drainage gradient site types were chosen in a upper slope position, a midslope position, and a lower slope position. It was thought as one moves up the slope soil moisture would become limiting. The midslope and upper slope positions tended to have no tree cover, whereas, the lower slope positions had a predominant aspen cover.

In order to investigate the effect of a grazing regime on species composition site types were studied in heavily grazed and ungrazed treatments. All sites had an aspect of 180-250 degrees(southerly to westerly facing slopes).

Two sites in a heavily grazed submesic grassland, six sites in a moderately grazed submesic grassland, five sites in a heavily grazed mesic and subhygric grassland, two sites in an ungrazed submesic and seven sites in a mesic and subhygric ungrazed grassland were described. A submesic grassland is defined as water removed readily in relation to supply. A mesic grassland has water removed slowly in relation to supply and a subhygric grassland refers to water removed slowly enough to keep the soil wet for a significant part of the growing season (Pojar et al. 1982).

Four sites (3,6,15 and 20) were used in a regression analysis to determine species response to grazing intensity. The four sites had similar mesic to subhygric moisture regimes and all occupied a lower slope position, with a range in slope from 2-15% and aspects of 200-220°. The soils ranged from Gleyed Dark Gray Luvisol to Orthic Melanic Brunisols with a Btj horizon. The sites varied from ungrazed at site 15, to heavily grazed (86% utilization) (Yule 1982) at site 20. Site 3 and 6 were moderately utilized with grazing intensties of 47% and 66% respectively.

8.2.2 Vegetation description

Each selected site consisted of a 10 x 20 meter macroplot situated in the most homogeneous area of vegetation going up the slope. Each macroplot had 10 transects located within it. Five of these ten transects were randomly selected to describe the vegetation.

A transect consisted of 20 one meter square quadrats, situated across the contour line of the hill. Foliar cover was estimated using the procedure outlined by Daubenmire (1968), but foliar cover was estimated to the nearest 1% instead of cover classes. A 20 x 50 cm quadrat was nested within a corner of a one meter quadrat. The one meter quadrat was used to estimate the percentage foliar cover for shrubs and the 20 x 50 cm quadrat was used to estimate the percentage foliar cover of the vascular forbs and grass. In addition the slope position was determined for each macroplot in the procedure outlined by Pojar et al. (1982). The number 2 indicates an upper slope position, 3 indicates a midslope position and 4 refers to a lower slope position in relation to the topography of the area.

8.2.3 Soils

Soil pits were dug at each site to determine soil characteristics: order, horizonation, depth to parent material and texture (Canadian System of Soil Classification 1978).

Six sites were used to collect soil moisture and soil nutrient data. These six sites exhibited differences in species composition caused by different grazing and drainage regimes. Sites 2 and 5 represented grazed and ungrazed submesic grasslands whereas, sites 3, 4, 6 and 8 represented moderately grazed and ungrazed mesic to subhygric grasslands.

Gravimetric moisture was collected weekly at 10 cm and 25 cm depths and oven dried for 24 hours at 105°C to determine gravimetric moisture content. Area under the soil moisture curve to 0% gravimetric moisture was calculated for each site to determine total water for each month. Monthly differences were then tested going down the slope. Sites 2, 3 and 4 represented one catena and sites 5,6 and 8 represented the other. Each test for sites was done within a catena because there was not enough information to determine if the same slope positions were equivalent within catenas. Sites 2 and 5 represented upper slope positions and had slopes of 31 and 39% repectively. The aspects of the two sites ranged from 194-220°. Soils were Brunisolic Dark Gray Luvisols at site 2 and Orthic Eutric Brunisols at site 5. Sites 3 and 6 represented midslope positions with aspects of 220 and 200° and slopes of 8 and 11%, respectively. The soils varied from a Orthic Melanic Brunisol to a Gleyed Dark Gray Luvisol. Sites 4 and 8 represented lower slope positions with aspects of 220 and 210° and slopes of 14 and 11%, respectively. The soils varied from a Dark Gray Luvisol to a Orthic Melanic Brunisol.

The moisture regime for each macroplot was determined using a 9 point scale ranging from 1 (very xeric) to 9 (hydric) (Pojar et al. 1982). These assesements were found to be quite subjective. Alternative approaches were outlined in Fraser (1954), Rowe (1956), Wali and Krajina (1973:288), and LaRoi and Hnatiuk (1980). Fraser (1954) used a 10 point scale and then plotted number of trees/ basal area/acre versus the moisture regime. Rowe (1956) assigned weights of 1, 2, 4, 8 and 16 to species which occurred in dry, fresh, moist, very moist and wet columns respectively. The geometric increase of the values was a recognition of the greater significance of species on the wetter side of the table. Wali and Krajina (1973) calculated an Available Water Capacity(AWC) by multiplying available water (0.33 to 15 bar) by bulk density and thickness of the horizon. LaRoi and Hnatiuk (1980) used the species indicator concept of Rowe (1956) but did not weight the species moisture indicator value because they found no difference in weighted and unweighted synthetic moisture indices. A synthetic moisture index of each site was then calculated based on the average of the moisture indicator value of each species within a macroplot (LaRoi and Hnatiuk 1980).

The moisture relationships of the species were determined from published vegetation research (Moss 1959, Hitchcock and Cronquist 1969, Pojar et al. 1982, and Looman 1983). The Synthetic Moisture Index (SMI) of each stand was then calculated as the unweighted average of the Moisture Indicator Value (MIV) for each species within a macroplot. The species indicator concept was used because there was not enough information available for all 22 sites to assess moisture regime by the Wali and Krajina approach.

Nine soil cores were taken at depth of (0-15 cm) in June 1984 from the same seven sites that soil moisture data was collected. These cores were taken at 1.5 meter intervals along a transect parallel with the contour line. Each soil was sent to the Soil Research Lab (North Road) in Victoria for determination of soil nitrogen, carbon, pH, and exchangeable bases.

9. DATA ANALYSIS

A regression of species response to grazing intensity, an ANOVA of soil moisture within a catena and classfication and ordination techniques were used in the study of range communities.

9.1 Regression of species response to grazing intensity

The following experimental design tests for a species response to grazing intensity.

Null hypothesis

Ho = There is no relationship between X (grazing intensity) and Y (species foliar cover).

X=grazing intensity

Y=foliar cover

Experimental design

Source		df
X	1	1
Y	y-x-1	18
Total	N-1	19

9.2 Anova of soil moisture within a catena

Hypothesis

Ho = There is no difference in soil moisture within the catena.

Experimental design

Source		df	test
sites	s	2	
Error	s(n-1)	6	E1
Total	sn-1	8	

9.3 Classification and ordination

The classification procedure used in this analysis is a polythetic agglomerative technique. There were two steps involved in this procedure: 1) First a similarity or dissimilarity matrix was determined for all stands. 2) The stands were agglomerated or combined based on species similarity or dissimilarity. The most similar stands were combined to create a hierarchy of increasingly larger clusters (Gauch 1982).

In this analysis Euclidean distance was used to determine a dissimilarity matrix between stands. Euclidean distance (ED) was determined by the following formula

$$ED = \sqrt{\sum^{p} (Xi - Yi)^2}$$

where X = species abundance in sample 1

Y = species abundance in sample 2

i = stand

(Whittaker 1978)

Euclidean distance was a multidimensional system where each axis represented the quantity of a species and each point represented the floristic composition of each vegetation sample (Whittaker 1978). This method used the foliar cover of species to calculate the distance of dissimilarity between two stands.

Samples were then assigned to a cluster using the average linkage agglomerative method (Sokal and Sneath 1973). Samples with the highest similarity to the average of the similarities of samples within each cluster were combined. The resulting was a dendrogram with all sites being combined into larger and larger clusters until all sites were contained within one large cluster.

In addition all stands were ordinated using the ordination technique DECCORANA (Gauch 1982). This indirect ordination technique was used to help determine the environmental variables which accounted for the most variation within the species-stand table.

10. RESULTS

10.1 Vascular species richness and growth form spectra

There were 76 species of vascular plants in 60 genera and 19 families within the areas studied. The major growth forms included 1 tree, 14 shrubs, 46 forbs and 15 graminoid species.

This compares to 130 species Pojar et al. (1982) found in the subhboreal spruce biogeoclimatic zone. The mean number of species per plot was 19 and this varied from 10 to 35. The ungrazed submesic macroplots generally had the highest number of species, whereas, the fewest species were usually found in the heavily grazed treatments.

10.2 Percentage constancy of vascular species

The percentage of stands in which a species was found (constancy) was calculated for all 76 vascular species. There were 32 species found to have a constancy of greater than 20% (Table 10). Twenty percent was chosen because there were a number of species which were diagnostic and only occurred in a few macroplots.

The only tree, *Populus tremuloides* was found in 55% of the stands and *Rosa acicularis* was found in 64%. The forbs with highest constancy were *Vicia americana*, *Taraxacum officinale*, *Lathyrus nevadensis* and *Smilicina stellata* with constancy values of 86, 82, 77 and 72% respectively.

TABLE 10. Plant species with a constancy(%) greater than 20%.

Species	% Constancy
Tree:	
Populus tremuloides	55
Shrubs:	
Rosa acicularis	64
Symphoricarpos albus	27
Salix scouleriana	23
Forbs:	
Vicia americana	86
Taraxacum officinale	82
Lathyrus nevadensis	77
Smilicina stellata	72
Thalictrum occidentale	68
Achillea millefolium	64
Aster modestus	59
Epilobium angustifolium	59
Utrica dioica	59
Arabis hirsuta	55
Heracleum sphondylium	54
Collomia linearis	50
Geum macrophyllum	36
Aster cilolatus	32
Fragaria virginiana	32
Ranunuculus acris	32
Aster conscipuus	27
Castilleja miniata	27
Potentilla arguta	27
Collinisia parviflora	23
Graminoids:	
Poa pratensis	82
Bromus vulgaris	77
Elymus glaucus	77
Carex macloviana	68
Phleum pratense	54
Melica spectibilis	50
Poa interior	41
Calamagrostis canadensis	27

The grasses with the highest constancy were *Poa pratensis*, *Bromus vulgaris* and *Elymus glaucus* with constancy values of 82, 77 and 77% respectively.

10.3 Ordination

10.3.1 Axis one (Grazing intensity)

When the species and stand table were ordinated, two large group were distinguished (Figure 20). Group A had significantly more foliar cover of *Taraxacum officinale* , *Poa pratensis* and *Festuca rubra* (Figures 21 and 22, Table 11). In contrast group B had low foliar cover of these species and significantly higher foliar cover of *Heracleum sphondylium*, *Thalictrum occidentale*, *Lathyrus nevadensis*, *Bromus vulgaris* and *Elymus glaucus* (Figure 21 and 22, Table 11).

When the foliar cover of *Taraxacum officinale*, *Poa pratensis*, *Heracleum sphondylium*, *Bromus vulgaris* and *Elymus glaucus* were regressed against grazing intensity, *Taraxacum* and *Poa* showed a significant positive increase in foliar cover as grazing intensity increased (Figure 21). In contrast *Heracleum*, *Bromus* and *Elymus* showed a significant decrease in foliar cover as grazing intensity increased (Figure 23).

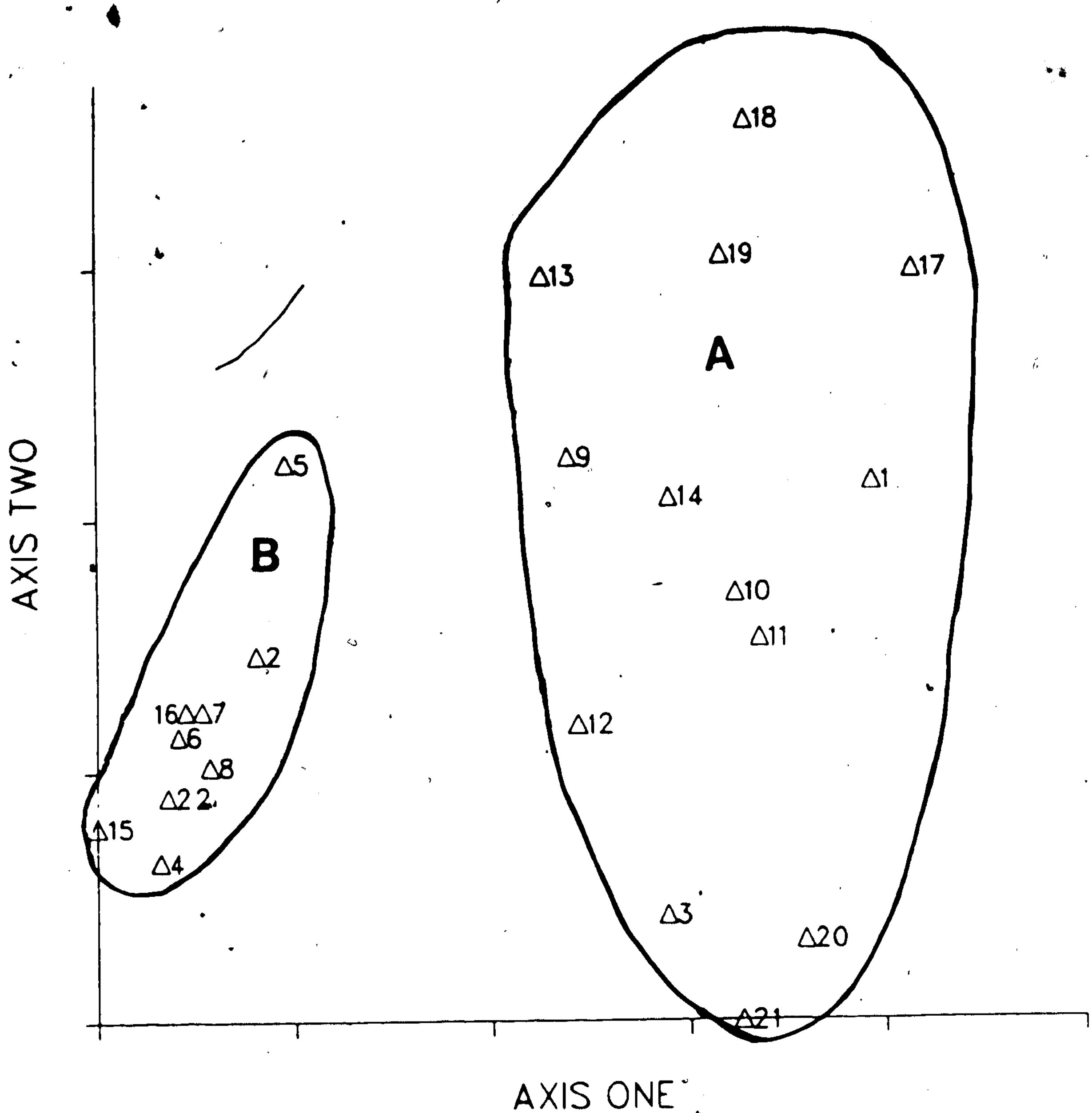

FIGURE 20. Ordination of grazed and ungrazed macroplots.

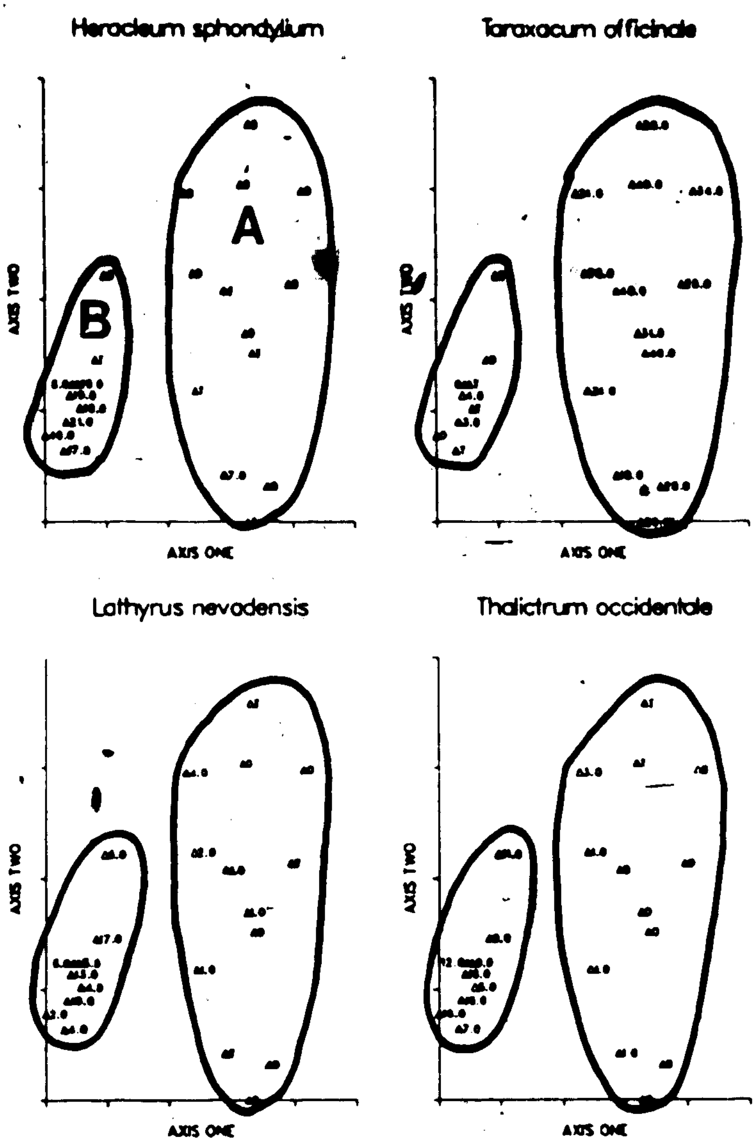

FIGURE 21. Foliar cover(%) of selected forbs plotted on the macroplot ordination(refer to Figure 21 for location of macroplots).

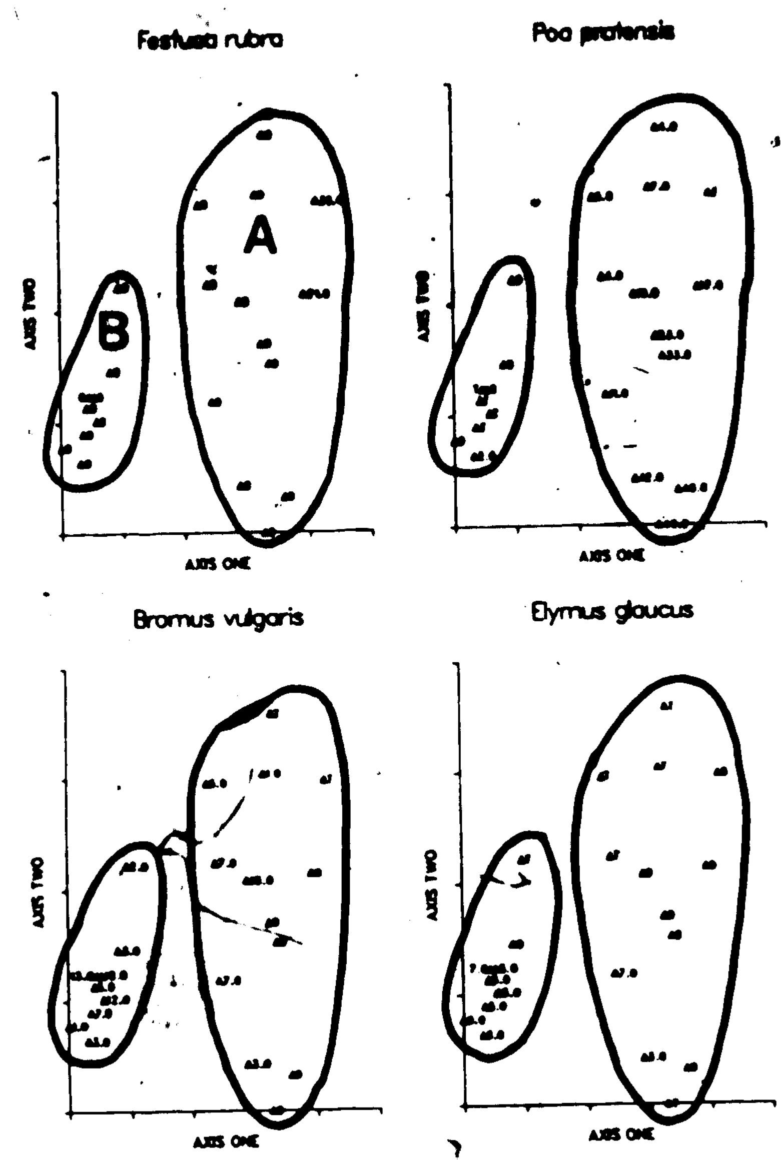

FIGURE 22. Foliar cover(%) of selected grasses plotted on the macroplot ordination(refer to Figure 21 for location of macroplots).

TABLE 11. Mean foliar cover (%) of selected species in the two large ordination groups.

Species	Groups A	Groups B
Poa pratensis	19	7**
Festuca rubra	5	0**
Taraxacum officinale	30	8**
Bromus vulgaris	3	7**
Elymus glaucus	1	5**
Heracleum sphondylium	1	15**
Lathyrus nevadensis	1	7**
Thalictrum occidentale	1	11**

** are significantly different at 0.05 level according to a Mann-Whitney test

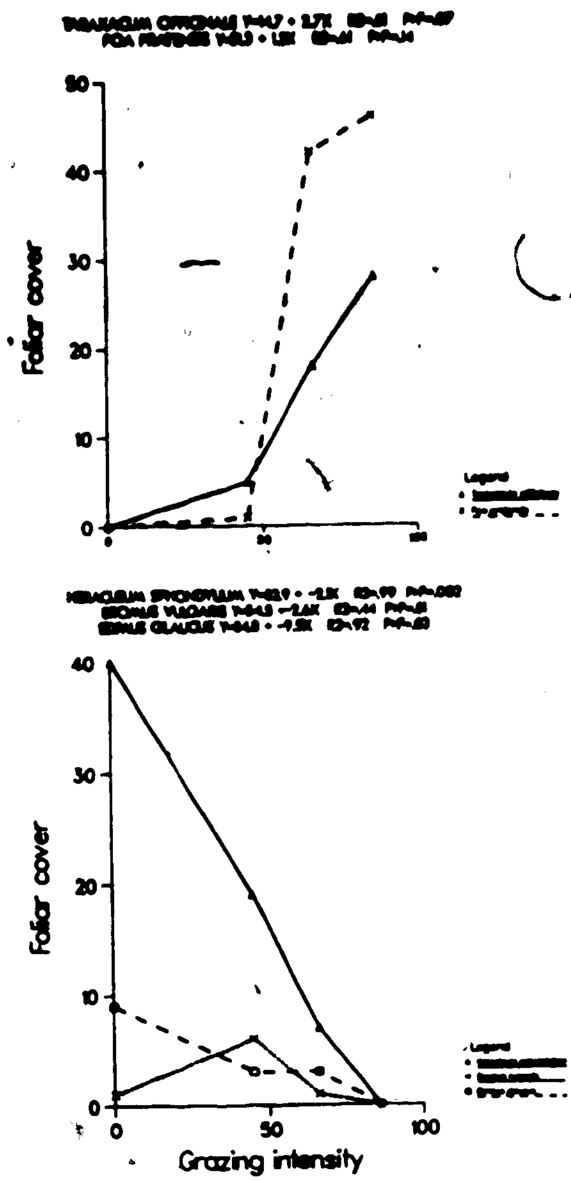

FIGURE 23. Regression equations of species foliar cover (*Poa pratensis*, *Taraxacum officinale*, *Heracleum sphondylium*, *Bromus vulgaris* and *Elymus glaucus*) versus grazing intensity.

Note that despite the highly significantly results in the regression all four sites regressed were assumed to be similar except for differences in grazing intensity.

When the species were ordinated *Taraxacum*, *Poa* and *Festuca* were found on the right side of axis one while species like *Heracleum*, *Thalictrum*, *Bromus* and *Elymus* were found on left side of axis one (Figure 24). The location of plant species, adapted to heavy grazing on the right side of the figure (24) and grazing intolerant plant species located on the left side of figure makes one suspect that axis one in the ordination accounted for a grazing intensity or grazing management gradient. The first axis accounted for 77% of the variation within the species stand table.

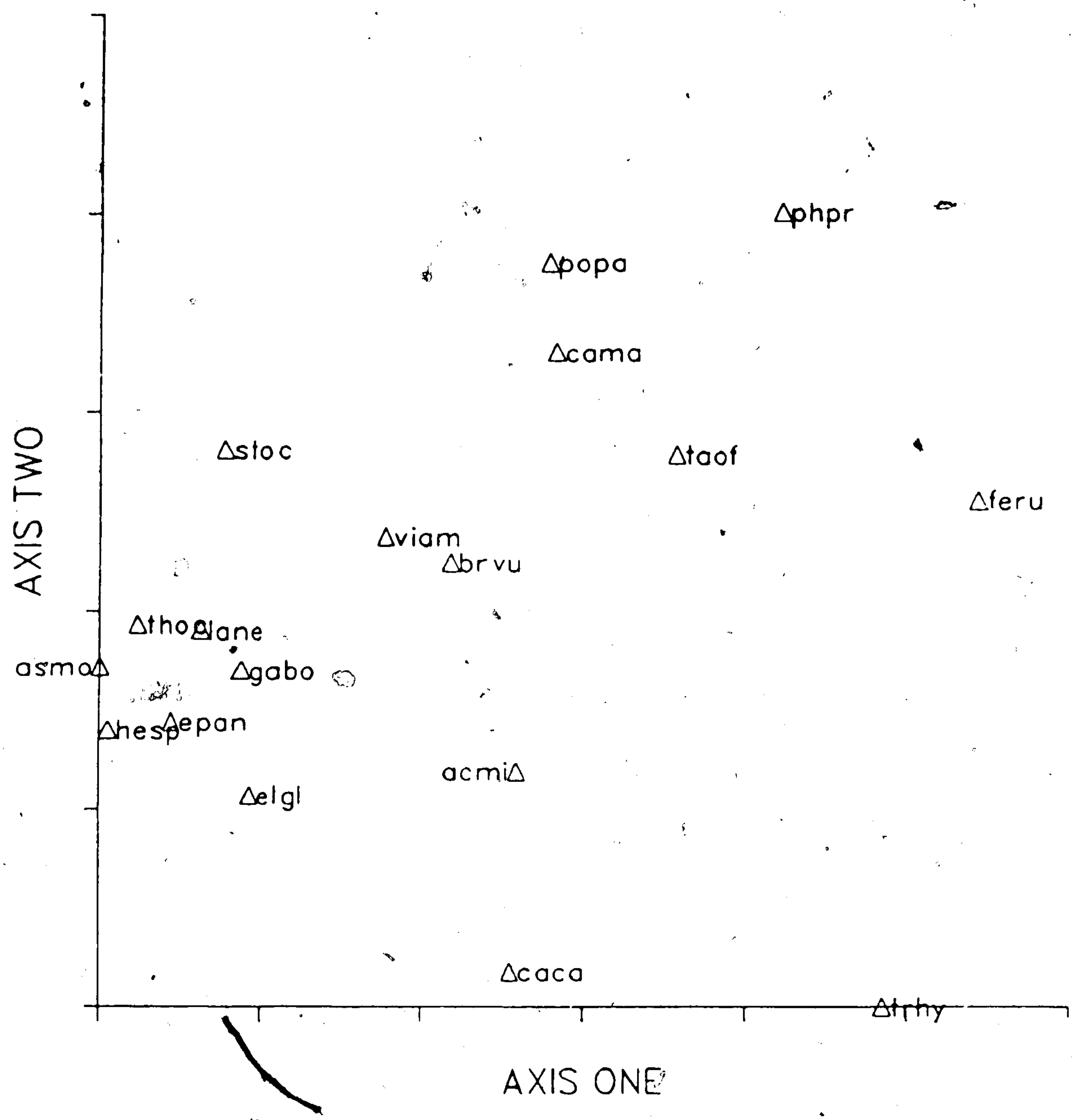

FIGURE 24. Ordination of plant species for ungrazed and grazed macroplots (see Appendix two for species code).

10.3.2 Axis two (Soil moisture)

Generally, the lower slope positions had the highest total water values for catena one in May and for catena two in May, June and August (Table 12, Figure 25). There were no significant differences in water capacity for either catena in July.

As the growing season progressed, the total water value for each site declined (Figure 25). The greatest decline in water capacity and soil moisture occurred during the month of June. It was usually during this month that the slope of the total water curves exhibited the steepest decline (Figure 25).

The calculated Synthetic Moisture Indices (SMI) were all very close to mesic (3.0), ranging from 2.5 to 3.5. In an effort to make the differences in SMIs more visible the differences were rescaled from 0 to 100 (Table 13) with 0 being submesic and 100 being subhygric. It was found that the SMI was positively correlated (r=0.74, p=0.0) with slope position using Pearson's correlation. The higher slope positions had the lower SMI values.

TABLE 12. Total water capacity at 10cm depth for each month (1985) in catena one (sites 2, 3 and 4) and catena 2 (sites 5, 6 and 8)

site	May catena 1	May catena 2	June catena 1	June catena 2	July catena 1	July catena 2	Aug catena 1	Aug catena 2
upper	57 a	42 b	36a	20b	23a	15 a	15 a	11 c
mid	47 b	67 a	32a	25b	25a	22 a	19 a	19 a
lower	62 a	57 a	39a	42a	30a	27 a	24 a	15 b

Pearson's correlation of water capacity with Synthetic Moisture Index (SMI)

	May	June	July	Aug
r	0.5	0.63	0.88	0.81
p	0.16	0.09	0.01	0.02

means within a column with the same letter are not significantly different at the 0.05 level according to Student-Newman-Keul's test

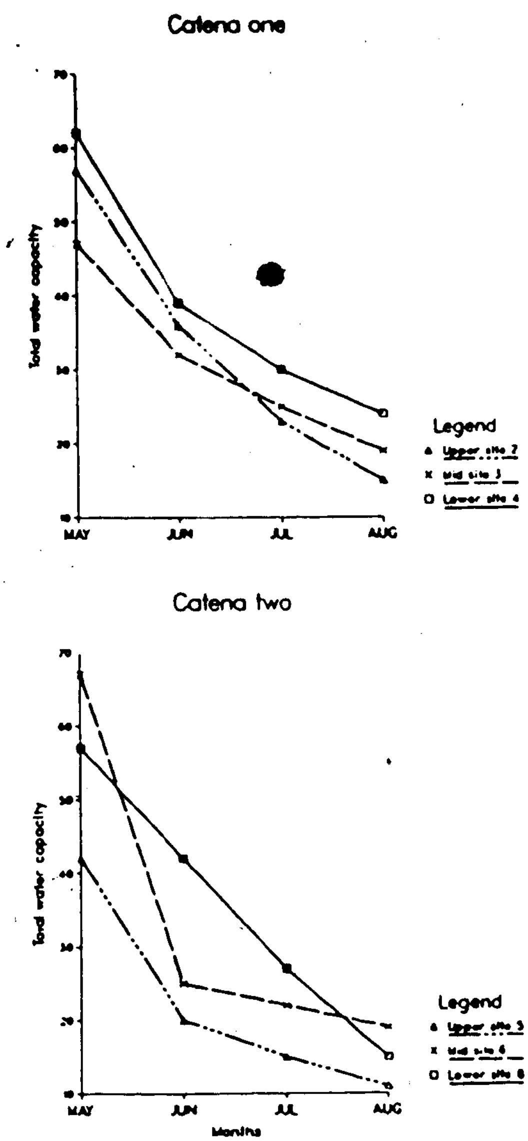

FIGURE 25. Total water capacity for each month for catena one (sites 2, 3 and 4) and catena two (sites 5, 6 and 8) in 1985.

TABLE 13. The utilization of forage (%) by cattle, synthetic moisture index and slope position for all 22 macroplots

Site	utilization (%) 1981-84	85	moisture index	slope position
1	86	87	50	3
2		18	10	2
3		66	60	3
4		68	90	4
5		20	0	2
6	43	50	50	3
7	0	0	90	3
8			70	4
9	67	0	30	2
10			10	2
11			90	3
12			60	4
13			10	2
14	68	0	20	3
15	0	0	99	4
16	0	0	70	3
17	86	88	30	2
18			20	2
19			30	2
20	86	88	40	3
21	86	88	80	4
22	0	0	70	4

moisture regime: 0-30 submesic, 30-70 mesic, 70-100 subhygric
Slope position 2=upperslope 3=midslope 4=lowerslope
note: Percent utilization is determined by taking the difference in forage production between the inside and outside of folding production cages.

Stand synthetic moisture indices based on the mean moisture indicator value for each species confirmed the previous observations that species adapted to dry upper slope positions had the lower moisture indicator values (MIV) and species adapted to lower slope positions had the higher MIV values (see Appendix two for moisture indicator value for each species). A high SMI value indicated a greater concentration of plant species characteristic of moist lower slope positions. A low SMI value indicated plant species characteristic of dry upper slope positions. It was also found that SMIs were positively correlated with total water values in July and August (Table 12). The higher SMI values tended to have the higher total water values.

When the SMIs were plotted on the ordination of grazed and ungrazed macroplots it was observed that the macroplots on the upper part of the figure had lower SMIs than macroplots on the lower part of the figure (Figure 26). This is evidence for axis two, which accounted for approximately 4% of the variation within the species stand table being a moisture regime gradient.

When the foliar cover of the major species was plotted against synthetic moisture index (SMI) species such as *Heracleum sphondylium, Bromus vulgaris and Poa pratensis* were found to occupy mesic to subhygric moisture regimes (Figure 27).

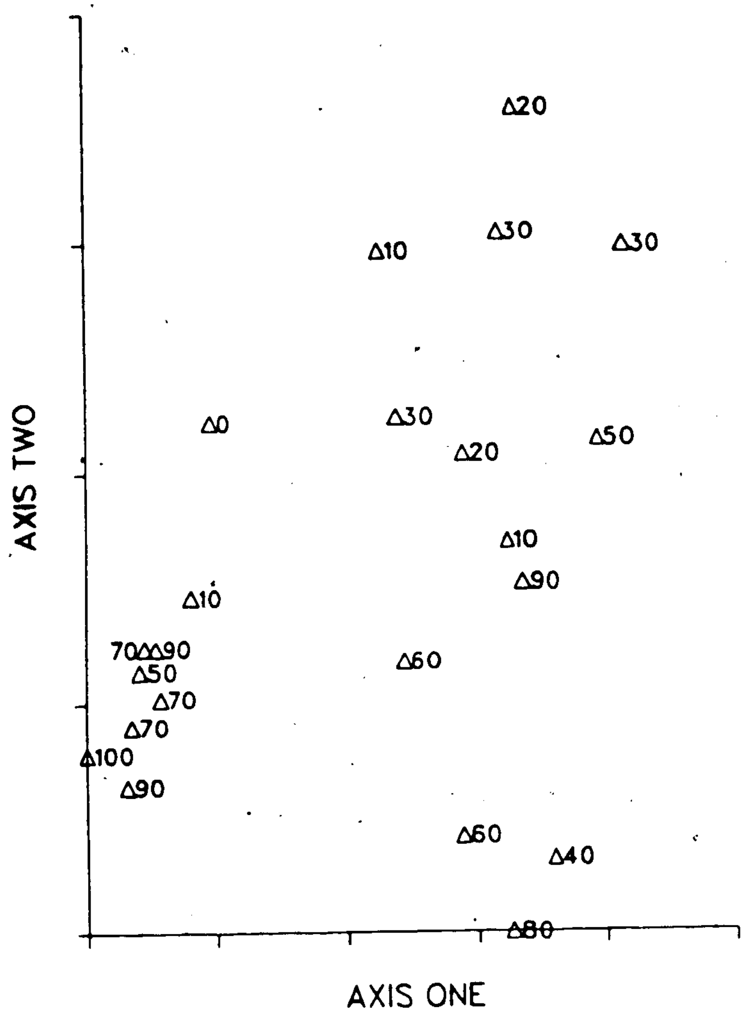

FIGURE 26. Synthetic moisture index (SMI) for the 22 macroplots.

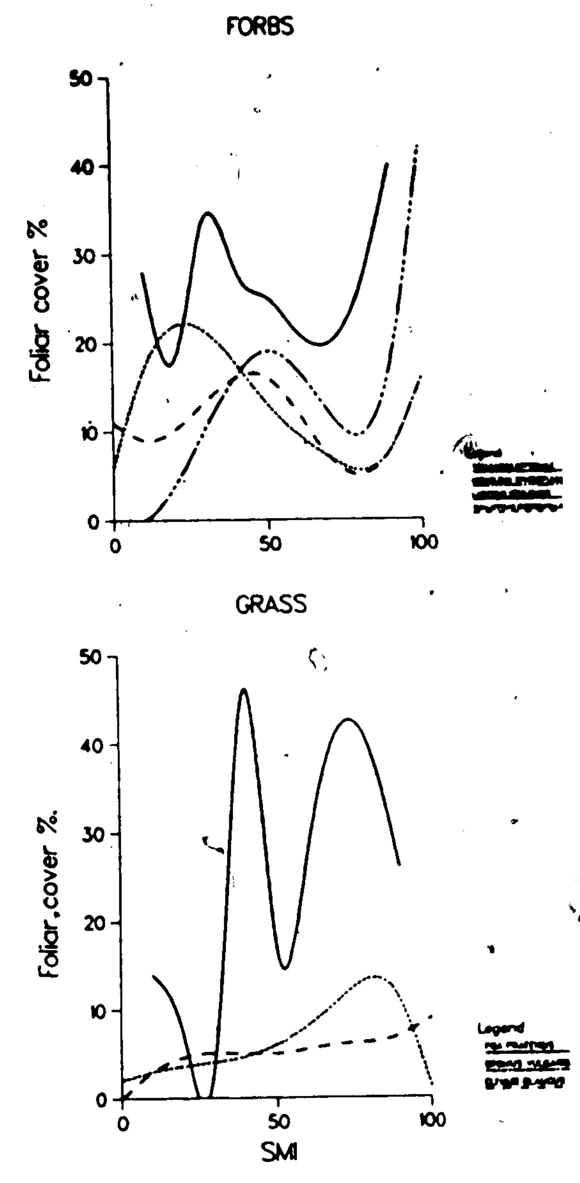

FIGURE 27. Foliar cover of the most common species (*Taraxacum officinale, Heracleum sphondylium. Lathyrus nevadensis, Thalictrum occidentale, Poa pratensis, Bromus vulgaris, and Elymus glaucus*) plotted againest Synthetic moisture index.

In contrast *Thalictrum occidentale* occupied submesic to mesic moisture regimes, while *Taraxacum officinale*, *Lathyrus nevadensis* and *Elymus glaucus* occupied ecological amplitudes from submesic to subhygric.

When the ungrazed or lightly grazed macroplots (Group B) were ordinated separately as a group, two distinct groups could be separated along the x axis (axis one) (Figure 28). Group one was represented by sites 6, 7, 8, 15, 16, and 22. Group two was represented by sites 2 and 5. The macroplots in group two tended to have low SMI values, both occupied upper slope positions (Table 13), and lacked foliar cover of *Heracleum sphondylium* a moisture loving species. In contrast the macroplots in group one had high SMI values, occupied lower slope positions and had high foliar covers of *Heracleum sphondylium*. This is evidence for the first axis, which accounted for 47% of the variation within the species stand table, being a moisture gradient. The y axis was thought to represent a grazing regime gradient. Site 4 was moderately grazed, whereas, site 15 was an ungrazed site at Bill Nye lake (Table 13). The y axis accounted for only 4% of the variation.

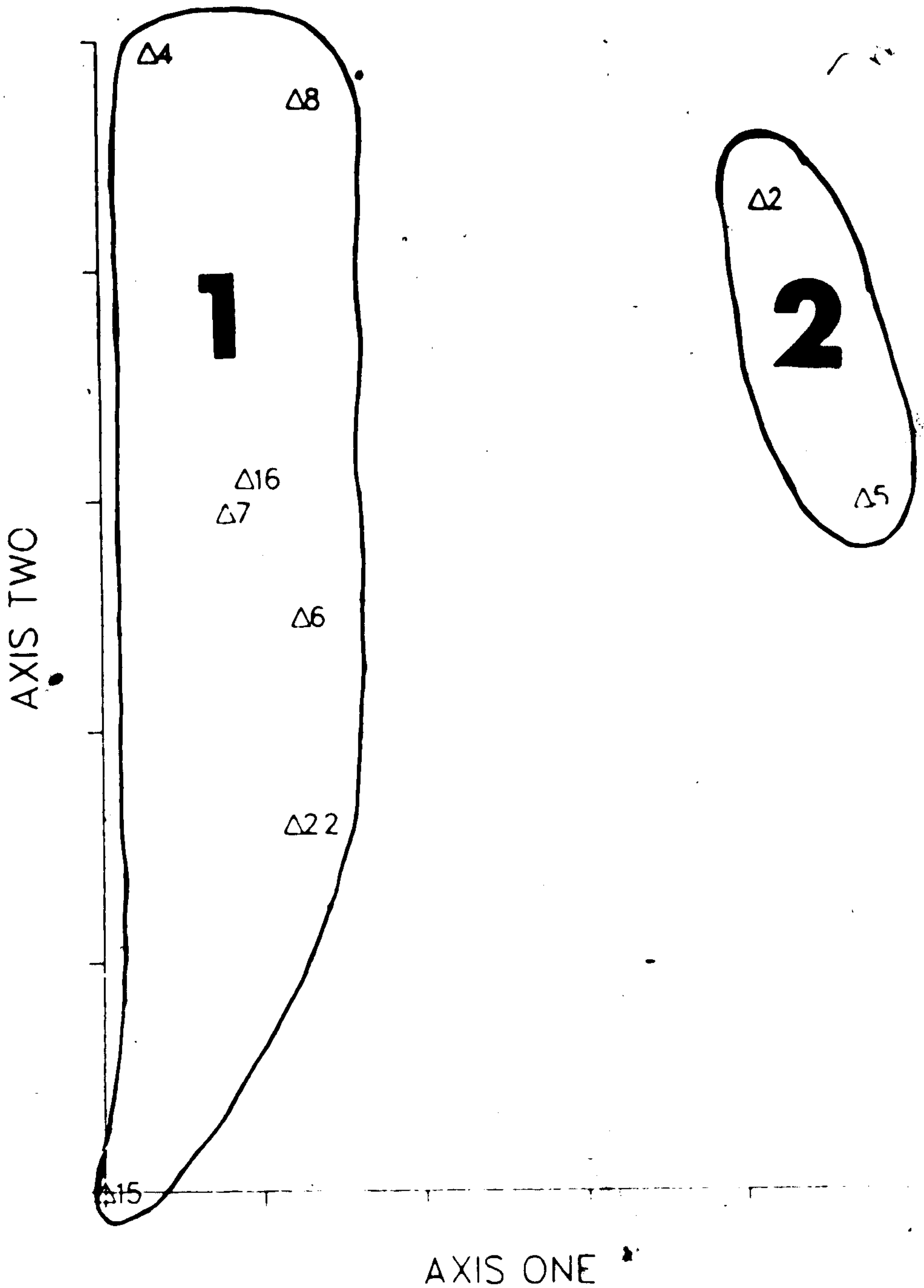

FIGURE 28. Ordination of lightly to ungrazed macroplots

10.4 Classification of stands

The results of the sequential agglomerative nonoverlapping cluster analysis technique are outlined in Figure 29. The five main clusters represent similarities among sites based on the foliar cover of the vascular species. The most similar clusters were clusters 2 and 3 with fusion occurring at a coefficient of (0.7). Cluster one then fuses with clusters 2 and 3 at a coefficient of (0.6) to create group A. Clusters 4 and 5 fuse at a coefficient of (0.3) to create group B.

Group A was composed of sites, 1,3, 9, 10, 11, 12, 13, 17, 18, 19, 20 and 21. All macroplots were grazed as indicated by the high foliar cover of *Taraxacum officinale, Poa pratensis, Festuca rubra, and Phleum pratense* (Figure 29). In contrast, group B was composed of sites 2, 5, 6, 7, 8, 15, 16, and 22. These sites were thought to be generally ungrazed because they contain low foliar covers of introduced species and high foliar covers of the native species *Heracleum sphondylium, Bromus vulgaris, Elymus glaucus, and Thalictrum occidentale.*

The next division in the cluster analysis was based on the foliar cover of the introduced plant species and the moisture indicator value for the site (Table 13). Cluster one was composed of sites 1 and [illegible]. These sites were heavily grazed (86-88%), they had a high coverage of *Festuca rubra and Taraxacum officinale* and they had a mesic to submesic moisture regime (Table 13).

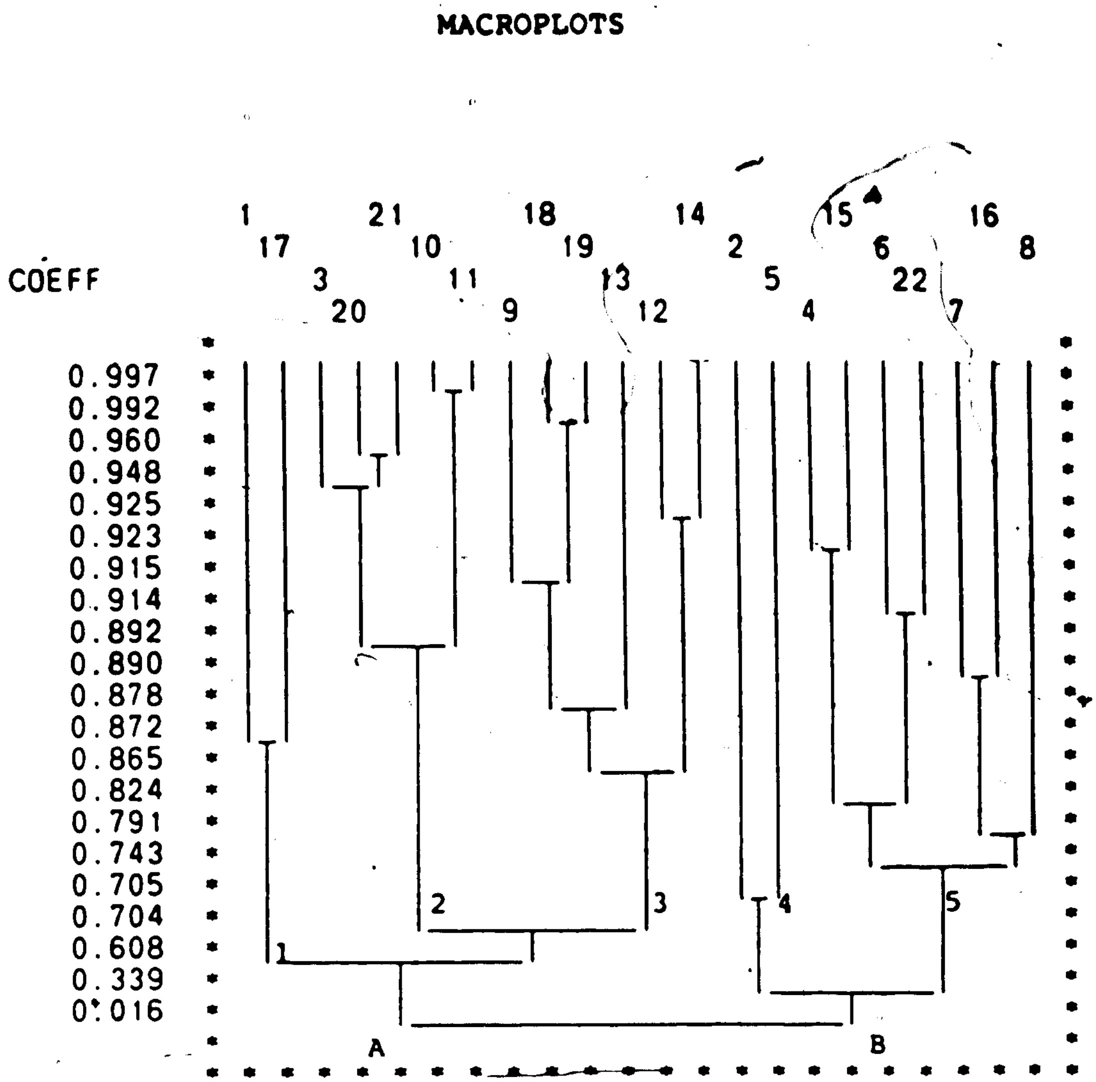

FIGURE 29. Dendrogram for all macroplots described vegetatively in 1984 and 1985 using Cluster analysis

Cluster two was represented by the sites 3, 10, 11, 20 and 21. These sites were heavily grazed (66-88%) having high concentrations of *Poa and Taraxacum* and had a submesic to subhygric moisture regime. Cluster three was composed of sites 9, 12, 13, 14, 18 and 19. These sites were moderately grazed exhibiting plant species characteristic of both heavily grazed and ungrazed sites. The moisture regime was generally submesic. Cluster four was occupied by sites 2 and 5. These sites had low concentrations of the introduced plant species and had a submesic moisture regime (Table 13). Finally, cluster 5 as represented by the sites 4, 6, 7, 8, 15, 16, and 22. These sites were generally ungrazed having low concentrations of the introduced plant species. They had a mesic moisture regime. Further divisions within the dengrogram appeared to separate mesic and subhygric plant communities, but there was not enough information available on the moisture regime within each macroplot to objectively assess differences in the 5 clusters being described. Therefore, no further divisions were made in the dendrogram.

When one compared the cluster analysis with the ordination the two large groups distinguished in the ordination contain the same macroplots as the two large groups distinguished in the cluster analysis (Figures 21 and 30). Using the following key based on the dominant forb and grass species 20 of the 22 macroplots (92%) were correctly identified to the correct cluster. We therefore conclude that the cluster analysis and ordination based on the foliar cover of the dominant forb and grass gave an ecologically meaningful classification of the range communities in the study area.

Key to Plant Communities

1. Community contains high concentrations of Poa pratensis, Taraxacum officinale or Festuca rubra..........2

1. Community contains low concentrations of Taraxacum officinale and Poa pratensis.......... .4

2. The predominant grass is Festuca rubra........... (*Festuca-Taraxacum* community (cluster 1))

2. The predominant grass is Poa pratensis..........3

3. The community is dominated by Poa pratensis and Taraxacum officinale..(*Poa-Taraxacum* community (cluster 2))

3. The community is dominated by Taraxacum officinale but Poa pratensis concentration is low, it has native species present which include Bromus vulgaris, Elymus glaucus, Carex macloviana, Castilleja miniata, and Potentilla arguta.......... (*Taraxacum-Poa-Bromus* community(cluster 3))

4. The community does not contain Heracleum sphondylium it is dominated by the forbs Agoseris aurantica, Penstemon procerus, Castilleja miniata, Potentilla arguta, Rhinathus minor, Fragaria virginana and Collomia linearis and by the shrub Symphoricarpos albus.............(*Symphoricarpos-Lathyrus-Bromus* community(cluster 4))

4. This community contains high foliar cover of the forbs

Heracleum sphondylium, Utrica dioica, Lathyrus nevadensis Epilobium angustifolium..........(*Heracleum-Bromus* community(cluster 5))

The foliar cover of the diagnostic plant species for each community is outlined in Table 14.

10.5 Plant communities and soils

10.5.1 Plant Communities

Table 14 outlines the foliar cover of the diagnostic plant species in the various communities. When one compares grazed and ungrazed communities there is generally an increase in foliar cover of *Taraxacum officinale*, *Festuca rubra*, *Phleum pratense*, and *Poa pratensis* and a decrease in *Heracleum sphondylium*, *Thalictrum occidentale*, *Lathyrus nevadensis*, *Epilobium angustifolium*, *Bromus vulgaris*, and *Elymus glaucus* going from a ungrazed to an grazed community.

Along the moisture gradient from wet to dry there was an increase in the foliar cover of *Penstemon procerus*, *Agoseris aurantica*, *Rhinanthus minor*, *Stipa occidentalis*, *Fragaria virginana*, *Collomia linearis*, *Potentilla arguta*, *Castilleja miniata* and *Carex macloviana* and a decrease in *Heracleum sphondylium*, *Thalictrum occidentale*, *Utrica dioica*, *Epilobium angustifolim*, *Calamagrostis canadensis*, *Bromus vulgaris*, and *Elymus glaucus* going from wet to dry.

TABLE 14. Foliar cover (%) of the diagnostic species in the various plant communities

	Moisture status				
	mesic to subhygric		submesic		
communities	2	5	1	3	4
species					
Taraxacum officinale	27.6		30	31	
Poa pratensis	40.1	T	8.5	8.4	T
Festuca rubra	0.5		30		
Phleum pratense	1.6		2.1	3.1	
Calamagrostis canadensis		.2			
Veratrum viride	0.3				
Heracleum sphondylium	1.8	25.0		T	T
Lathyrus nevadensis	T	4.8		1.1	6.4
Elymus glaucus	0.7	5.9		1.3	0.7
Populus tremuloides	2.5	0.5		1.2	0.8
Thalictrum occidentale		8.3		0.9	4.9
Aster ciliatus	T			0.2	0.2
Aster modestus		3.5		0.2	T
Epilobium angustifolium		9.4		1.3	2.0
Rosa acicularis	T	1.0	0.5	1.0	
Bromus vulgaris	0.4	12.5	T	6.4	2.3
Symphoricarpos albus		T	T	0.9	3.9
Melica spectabilis	T			0.2	1.0
Carex macloviana	0.3		0.2	2.1	1.8
Poa interior		T	T	1.0	0.2
Aster conspicuus				T	4.8
Ranunculus acris				0.3	
Castellija miniata				1.2	2.0
Potentilla arguta				0.8	2.5
Agoseris aurantica					0.2
Penstemon procerus					0.1
Rhinathus minor					0.5
Stipa occidentalis					0.3
Fragaria virginana					3.3
Collomia linearis					2.9

There were five main community types that had developed in response to a grazing management and moisture regime.

Community 1 (Festuca-Taraxacum) was represented by a dominance of the grass *Festuca rubra* and the forb *Taraxacum officinale* (Table 15 and Figure 30). It had a well developed grass layer and a poorly developed shrub layer. The moisture regime was generally submesic. The dominant soil was Orthic Melanic Brunisol with a well developed mull Ah horizon. This community has developed in response to extremely heavy grazing (86%). *Festuca rubra, Poa pratensis, Phleum pratense* and *Taraxacum officinale* increase as grazing intensity increased (Table 15 and Figure 30).

Community 2 (Poa-Taraxacum) was dominated by the grass *Poa pratensis* and the forb *Taraxacum officinale* (Table 16 and Figure 31). It had a well developed tree layer of *Populus tremuloides*. The dominant shrub was *Lonicera involcrata*. This community had a mesic to subhygric moisture regime and was characteristic of extremely heavy grazing (86%). The dominant soil was an Orthic Melanic Brunisol.

Community 3 (Taraxacum-Poa-Bromus) was dominated by the forb *Taraxacum officinale* and the grasses *Poa pratensis* and *Bromus vulgaris* (Table 17, Figure 32).

TABLE 15. Characteristics of the *Festuca-Taraxacum* community (Cluster 1).

		Foliar cover(%)
Shrub:	Rosa acicularis	1 +/- 1
	Symphoricarpos albus	T
Forb:	Taraxacum offinale	30 +/- 7
Grass:	Festuca rubra	30 +/- 13
	Poa pratensis	9 +/- 12
	Phleum pratense	2 +/- 2
	Carex macloviana	T
		n=2

Soil: Orthic Melanic Brunisol
Grazing regime: extremely heavy
Moisture regime: submesic
Slope position: upper

FIGURE 30. *Festuca-Taraxacum* community.

TABLE 16. Characteristics of the *Poa-Taraxacum* community (Cluster 2).

		Foliar Cover (%)
Tree:	Populus tremuloides	3 +/- 5
Shrub:	Lonicera involcrata	T
Forb:	Taraxacum officinale	28 +/- 9
	Ranunculus acris	T
	Trifolium hybridum	3 +/- 5
	Veratrum viride	T
Grass:	Poa pratensis	40 +/- 5
	Phleum pratense	2 +/- 1
	Elymus glaucus	1 +/- 1
rare:	Festuca rubra	1 +/- 1
	Calamagrostis canadensis	T
	Bromus vulgaris	T
		n=5

Soil: Orthic Melanic Brunisol
Grazing intensity: extremely heavy
Moisture regime: mesic to subhygric
Slope position: mid to lower

FIGURE 31. *Poa-Taraxacum* community.

TABLE 17. Characteristics of the *Taraxacum-Poa-Bromus* community (Cluster 3).

		Foliar Cover(%)
Tree:	Populus tremuloides	1 +/- 3
Shrub:	Rosa acicularis	1 +/- 1
	Symphoricarpos albus	1 +/- 2
Forb:	Taraxacum officinale	31 +/- 7
	Castilleja miniata	1 +/- 2
	Epilobium angustifolium	1 +/- 2
	Potentilla arguta	1 +/- 1
	Lathyrus nevadensis	1 +/- 1
	Thalictrum occidentale	1 +/- 1
Rare:	Penstemon procerus	T
	Rhinanthus minor	T
	Fragaria virginana	T
	Collomia linearis	T
Grass:	Poa pratensis	8 +/- 6
	Bromus vulgaris	6 +/- 6
	Phleum pratense	3 +/- 4
	Poa interior	1 +/- 1
	Carex macloviana	2 +/- 2
	Elymus glaucus	1 +/- 3
		n=6

Soil: Brunisolic Dk. Gray Luvisol to Orthic Melanic Brunisol
Grazing intensity: Moderately grazed
Moisture regime: submesic
Slope position: upper

FIGURE 32. *Taraxacum-Poa-Bromus* community.

This community had developed in response to a moderate grazing regime. It contains native species *Castilleja miniata*, *Potentilla arguta*, *Penstemon procerus*, *Bromus vulgaris*, and *Poa interior*, but it also contains species (*Taraxacum officinale and Poa pratensis*) which respond to heavy grazing. It had a poorly developed shrub and tree layer and was associated with a submesic moisture regime. The soils varied from a Dark Gray Luvisol in the moister sites to a Orthic Melanic Brunisols in the drier areas.

Community 4 (Symphoricarpos-Lathyrus-Bromus) was similar to communities 1 and 3, but was not influenced by grazing (Table 18 and Figure 33). This community was dominated by the shrub *Symphoricarpos albus* and the forbs *Lathyrus nevadensis* and *Thalictrum occidentale*. Other forbs characteristic of this site included *Castilleja miniata*, *Penstemon procerus*, *Agoseris aurantica*, *Collomia linearis*, and *Potentilla arguta*. The dominant grasses included *Bromus vulgaris*, and *Elymus glaucus*. Other graminoids characteristic of this type include *Stipa occidentalis*, and *Carex macloviana*.

The moisture regime was submesic and the dominant soils varied from Dark Gray Luvisols to Orthic Melanic Brunisols.

TABLE 18. Characteristic of the *Symphoricarpos-Lathyrus -Bromus* community (Cluster 4).

		Foliar Cover(%)
Tree:	Populus tremuloides	1 +/- 0.1
Shrub:	Rosa acicularis	4 +/- 3
	Symphoricarpos albus	6 +/- 5
Forb:	Lathyrus nevadensis	6 +/- 1
	Thalictrum occidentale	5 +/- 5
	Agoseris aurantica	T
	Castilleja miniata	2 +/- 2
	Penstemon procerus	T
	Rhinanthus minor	T
	Fragaria virginana	3 +/- 2
	Collomia linearis	3 +/- 0.2
	Potentilla arguta	3 +/- 3
	Epilobium angustifolium	2 +/- 2
Grass:	Bromus vulgaris	2 +/- 1
	Elymus glaucus	1 +/- 1
	Stipa occidentalis	T
	Carex macloviana	2 +/- 1
	Melica spectabilis	1 +/- 0.1
	Poa interior	T
		n=2

Soil: Dk. Gray Luvisol (in drainage) to Orthic Melanic Brunisol

Grazing intensity: light to no grazing

Moisture regime: submesic

Slope position: upper

FIGURE 33. *Symphoricarpos-Lathyrus-Bromus* community.

Finally, community 5 (Heracleum-Bromus-Elymus) was characteristic of mesic to subhygric moisture regimes in an ungrazed situation (Table 19 and Figure 34). The dominant grasses were *Bromus vulgaris* and *Elymus glaucus*. Other grasses included *Calamagrostis canadensis* and *Poa palustris*. The dominant forbs included *Heracleum sphondylium* and *Thalictrum occidentale*. The dominant soil was usually a Gleyed Dark Gray Luvisol, but Orthic Melanic Brunisols with a Btj horizon were also present.

TABLE 19. Characteristics of the *Heracleum-Bromus* community (Cluster 5).

		Foliar Cover (%)
Tree:	Populus tremuloides	T +/- 2
Shrub:	Rosa acicularis	T
	Symphoricarpos albus	T
Forb:	Aster modestus	4 +/- 3
	Aster cilatus	1 +/- 1
	Epilobium angustifolium	10 +/- 5
	Heracleum sphondylium	25 +/- 4
	Thalictrum occidentale	14 +/- 2
	Vicia americana	8 +/- 1
	Utrica dioica	1 +/- 1
Grass:	Bromus vulgaris	4 +/- 2
	Elymus glaucus	7 +/- 2
	Melica spectabilis	T
	Poa palustris	T
	Calamagrostis canadensis	T
		n=6

Soil: Gleyed Dk. Gray Luvisol or Orthic Melanic Brunisol with a Btj
Grazing intensity: light to no grazing
Moisture regime: mesic to subhygric
Slope position: mid to lower

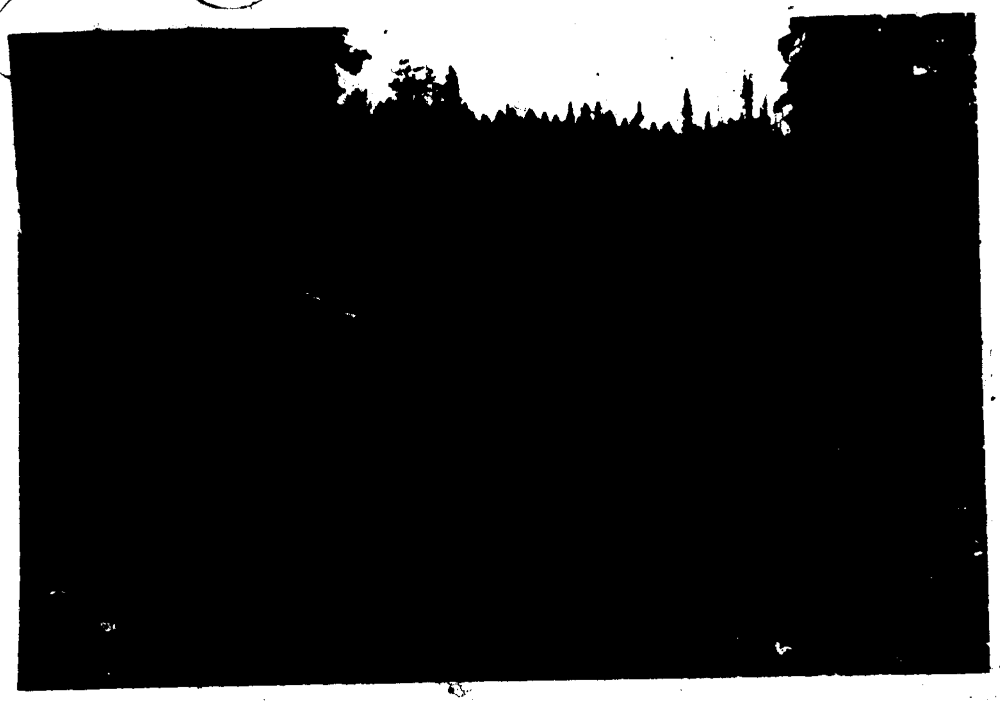

FIGURE 34. *Heracleum-Bromus* community.

10.5.2 Soils

The soils of the study area were within the Brunsolic and Luvisolic Orders. They varied from Eutric to Melanic Brunisols and Dark Gray Luvisols (Table 20). In general the Luvisolic soils were found in sites with moisture regimes of mesic to subhyric. In contrast the Brunisols were found on drier sites where the moisture regime varied from mesic to submesic.

The Ah horizons were generally well developed (>10 cm) and had an average organic matter content of 15% with a maximum of 21% at site one and a minimum of 11% at site 5 (Table 21). The % nitrogen content varied from 1.3 at site 1 to 0.5 at site 5. The average % base saturation was 74 with a predominance of calcium and magnesium. The pH of the soils ranged from 5.6 (site 1) to 6.4 (sites 2 and 5) and the cation exchange capacity averaged 42.

Although not statistically significant, the soil suborders with the greatest profile develoment generally had the highest synthetic moisture indices (Figure 35). The highest mean SMI (59) was associated with Dark Gray Luvisols and the lowest mean SMI (28) was associated with Orthic Eutric Brunisols. It is assumed that a Orthic Melanic Brunisol with a Btj horizon is developing into a Dark Gray Luvisol and therefore has more profile development than an Orthic Melanic Brunisol with a Bm horizon.

TABLE 20. Soil Order, Great Group and Subgroup for each site

Site	Soil type
1	Orthic Melanic Brunisol
2	Brunisolic Dk. Gray Luvisol
3	Orthic Melanic Brunisol
4	Dk. Gray Luvisol
5	Orthic Eutric Brunisol
6	Gleyed Dk. Gray Luvisol
7	Gleyed Dk. Gray Luvisol
8	Orthic Melanic Brunisol
9	Orthic Eutric Brunisol
10	Orthic Melanic Brunisol
11	" " "
12	Orthic Eutric Brunisol
~~13~~	Orthic Melanic Brunisol
14	Orthic Eutric Brunisol
15	Orthic Melanic Brunisol
16	Gleyed Dk. Gray Luv[illegible]
17	Gleyed Eutric Bru[illegible]
18	Brunisolic Dk. Gr[illegible]visol
19	Orthic Melanic [illegible]
20	Gleyed Melani[illegible]sol
21	" "
22	Dk. Gray Luviso[illegible]

TABLE 21. Organic matter, nitrogen, Base saturation, Cation Exchange Capacity and pH for eight selected sites

Site	%OM	%N	%BS	CEC	pH
1	21a	1.3a	57d	61a	5.6e
2	16b	0.9b	83ab	40b	6.4b
3	16b	1.0b	72c	44b	5.9c
4	14bc	0.7b	7c	37b	5.8cd
5	11c	0.5c	90a	27c	6.4a
6	14bc	0.8b	67c	45b	5.7de
8	15b	1.0b	80b	39b	5.8cd
mean	15	0.9	74	42	5.9

means within a column with the same letter are not significantly different at 0.05 level according to a Student-Neuman Keul's test

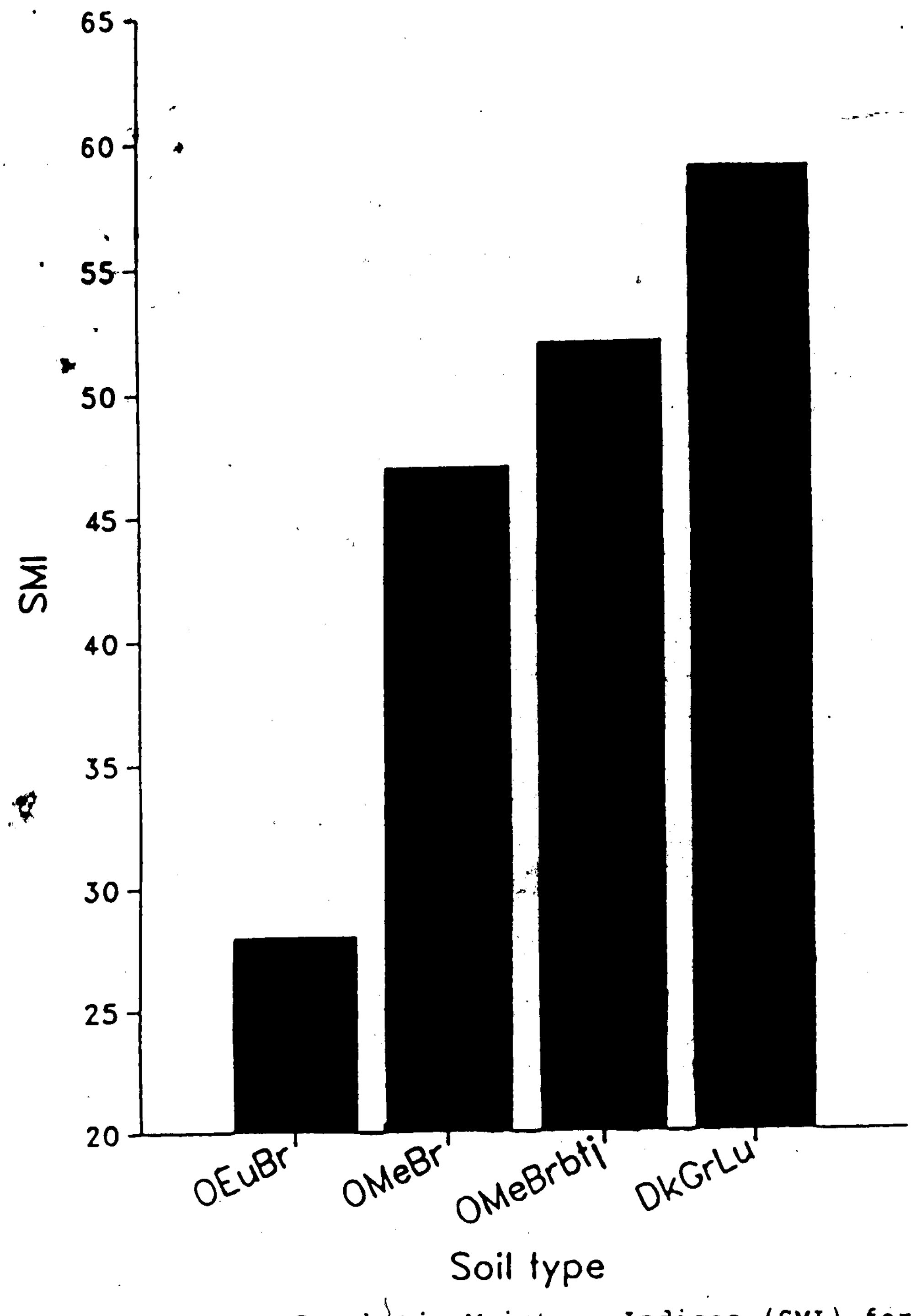

FIGURE 35. Average Synthetic Moisture Indices (SMI) for each soil type Orthic Eutric Brunisol (OEuBr), Orthic Melanic Brunisol (OMeBr), Orthic Melanic Brunisol with a Btj horizon (OMeBrbtj) and Dark Gray Luvisol (DkGrLu).

11. DISCUSSION

11.1 Vascular species

Over 50% of the vascular species found in the sub-boreal spruce biogeoclimatic zone were associated with grass and aspen seral forest communities of the study area. Of the 72 vascular species found approximately 34 were highly palatable to cattle (Looman 1983). The most palatable include exotic species characteristic of heavily grazed areas *Taraxacum officinale, Festuca rubra, Phleum pratense, Trifolium repens and Trifolium hybridum*. The most palatable native species include *Heracleum sphondylium* , *Thalictrum occidentale, Aster modestus, Aster ciliotus, Aster conspicuus, Vicia americana* and all grasses when in the vegetative state.

The species with the highest constancy values included *Taraxacum officinale and Poa pratensis*. These species were well adapted to withstand moderate to heavy grazing (Looman 1983). The majority of the vegetation within the study area was grazed and would account for the high constancy values of these species (Table 10).

LaRoi and Hnatiuk (1982) concluded that their plant community key for *Pinus contorta* stands which gave a 67% success score, represented a meaningful ecological classification. The key developed for these communities had a 92% success scorel The two macroplots which were not correctly identified were from community 3. This plant community exhibits species characteristic of both grazed and ungrazed communities making it difficult to decide at step 3 of the key.

11.2 Environmental relationships of the communities

There are five factor complexes which are important in plant community formation. These include flora, accessibility factor (ability of the species to reach the habitat), ecological plant properties, habitat (sum total of environmental), and time (Mueller-Dombois and Ellenberg 1974). Accessibility factor is only important when plants are invading new substrates and time is only important when the plant communities have not reached equilibrium (Mueller-Dombois and Ellenberg 1974). In general habitat factors and ecological properties of the flora are the core for research activities.

Plant species have distinct ecological responses to different environmental factors. Each species is distributed in its own way, according to its own genetic, physiological, and life cycle characteristics. It also has its own way of interacting with the physical environment and with other species (Whittaker 1970). A change in one environmental factor will affect the the species combination and change the community equilibrium. In plant ecology it is important to recognize the factors that are responsible for the control of species combinations. The vegetation within the study appears to have developed in response to the environmental gradients of grazing management and moisture. The duration and intensity of grazing appears to be a key component in the species composition and production of these rangeland plant communities.

11.2.1 Grazing intensity

It has long been recognized that plant species respond to herbivory in different ways (Dyksterhuis 1949, Parker 1954, and Pitt 1984). For example Ellison (1960), Johnston (1961), McLean and Tisdale (1972) and Willms et al. (1985), have all found that dandelion increased as grazing intensity increased. The rosette growth habit and precocity in flowering and fruiting together with suppression of taller vegetation by grazing allows dandelion to florish (Ellison 1960). *Poa pratensis and Festuca rubra* have creeping rhizomes which allow the plants to withstand heavy grazing treatments and establish thick swards very quickly (Looman 1983).

In contrast the native species of the study area were not adapted to withstand heavy grazing treatments. Ellison (1954), found that *Heracleum sphondylium, Agropyron trachycaulum, Bromus spp. and Castilleja spp.* decreased as grazing intensity increased in the subalpine meadows of Utah. Grime and Lloyd (1973), found that *Heracleum sphondylium* was absent from grazed areas, whereas, species like *Achillea millefolium, Festuca rubra, Poa pratensis, Ranunuculus acris and Rumex acetosa* were associated with these areas. Looman (1983), found that native species of *Rosa spp.*, *Salix spp.*, *Epilobium angustifolium*, *Castilleja miniata*, *Aster conspicuus*, *Lathyrus spp.*, and *Vicia americana* were all palatable and decreased as grazing intensity increased. According to the ranchers the domesticated forages seeded in the early 1970's only established in areas where the cattle had trampled and overgrazed the existing native vegetation. In one area that had been aerial seeded one side of the fence protected from grazing was predominantly native vegetation, whereas, the other side which was grazed had a predominant *Poa pratensis*, *Taraxacum officinale* species composition.

These results indicate that plant species within the study area have distinct responses to herbivory. Areas which were heavily grazed each growing season have high foliar coverage of *Taraxacum officinale*, *Poa pratensis*, *Festuca rubra* and *Phleum pratense*. These species are well adapted to heavy grazing intensities creating stable plant communities well adapted to intense grazing use by cattle. Over 77% of the variation within the species stand table was accounted for by grazing intensity. This environmental gradient has the greatest influence on the species composition within the study area.

Three plant communities that developed under grazing *Taraxacum-Poa-Bromus*, *Taraxacum -Festuca* and *Taraxacum-Poa* tended to have less soil profile development (no Bt horizon) than the ungrazed communities. These soils tended to be

Brunisols, whereas, the soils in the ungrazed situations tended to be Luvisols (Table 13 and 20). This lack of profile development might be the result of less moisture movement within the soils. Rauzi and Hanson (1966), found that water intake rates were lowest on the heavily grazed areas and highest on lightly grazed areas. Hanson et al. (1970) found the mean seasonal runoff was 0.79, 0.56 and 0.42 inches for the heavily, moderately and lightly grazed watersheds respectively. Heavy grazing reduced the foliar and litter cover of the area. This lack of vegetative cover would tend to cause an increase in evaporation and water runoff and consequently, less water movement through the soil profile. Heavy grazing by cattle also tended to cause compaction of the soil, reduced pore space and thus lowered infiltration rate (Rauzi and Hanson 1966).

Percent organic matter and percent nitrogen were higher at sites 1 and 3 (Table 21) two grazed macroplots. both sites had high foliar cover of *Taraxacum officinale*, *Poa pratensis* and *Festuca rubra*. Heavy defoliation will cause rapid root turnover in the grazed species, thereby increasing organic matter within the soil (Jameson 1963).

Grazing also seems to inhibit forest succession. Johnston et al (1971) and Arthur (1984) found heavy grazing by cattle inhibited tree and shrub invasion. In the Poplar lake study area heavily grazed areas (86% utilization) had very little aspen sucker or shrub cover present. In one area protected from grazing for the last four years cover of *Rosa* *acicularis* increased.

11.2.2 Soil moisture

Moisture is a major factor limiting the distribution of plants (Krebs 1978). Dix and Smeins (1967) found the gradient in soil moisture to correlate most strongly and consistently with the gradient in community composition. Loucks (1962) found that depth to prevailing water table had a major influence on the vegetation. He also found that areas of high runoff accumulation had high concentrations of black spruce.

When grazing intensity was eliminated as a source of environmental variation, soil moisture appeared to account for most of the variation within the species stand table (Table 13 and Figure 27). There was a definite species response to a moisture regime gradient. Species characteristic of dry upper slope positions included *Castilleja miniata*, *Agoseris aurantica*, *Potentilla arguta*, *Penstemon procerus*, and *Stipa occidentalis* (Table 14). These species were indicative of the *Symphoricarpos* -*Lathyrus*-*Bromus* community an ungrazed submesic grassland. In contrast species characteristic of moister lower slope positions included *Heracleum sphondylium*, *Utriça dioica*, *Delphinium glaucum*, *Elymus glaucus* and *Bromus vulgaris*. The presence of these species was indicative of the *Heracleum*-*Bromus* community an ungrazed mesic to subhygric grassland.

There was extreme variation in total water between the various sites within catenas. Site 2, an upper slope position in catena one tended to have higher total water and soil moisture in May than site 3, a lower midslope position. Site 2 was located in an area of natural drainage and interflow passed through the middle of the plot. Spring runoff occurred in May and therefore total water was high at site 2 during that month. The natural drainage in site 2 may also explain why there was no difference in total water capacity for site within catena one in June, July and August.

There was no difference in total water capacity for each site within either catena for the month of July. July was extremely hot and dry in 1985 (Figure 4, Table 2).

Synthetic moisture index was significantly correlated with total water in July and August. This would indicate that soil moisture in July and August may be most important in determining species response to a moisture regime.

Synthetic moisture index tended to have a more mesic value than was actually the case. There were more mesophytic species than either xerophytic or hydrophytic species in the sample flora and these species tended to pull the SMIs towards a middle position along the moisture gradient (Appendix 2). Rowe (1956), found that the ecological amplitude of the plant species adapted to moist and wet conditions was very narrow compared to those adapted to drier conditions.

The plants characteristic of heavily grazed communities *Taraxacum officinale* and *Poa pratensis*, had wide ecological amplitudes and ranged from submesic to subhygric moisture regimes (Figure 23). These species being very common in the study area tended to pull the SMIs closer to a mesic (3) moisture regime. Species with wide ecological amplitudes tended to distort SMI values because they were usually primarily responding to environmental factors other than soil moisture (ie grazing).

The high constancy values of these mesophytic plant species (*Taraxacum* and *Poa*) in the grazed macroplots would account for the higher SMI values of the submesic macroplots in the grazed situation (Group A) compared to the submesic macroplots in the ungrazed situation (Group B) (Figure 26).

The lack of significant difference between SMIs for the various soil profiles (Figure 25) may be the result of the small sample size. Only 6, 5, 8 and 6 plots were described in the Orthic Melanic Brunisol, Orthic Eutric Brunisol, Orthic Melanic Brunisol with a Btj horizon, and Dark Gray Luvisol, respectively.

11.2.3 Forest succession

In the absence of grazing, forest succession appears to start with *Populus tremuloides* and then succeed to *Picea glauca* and *Abies lasiocarpa* (Pojar et al. 1982). Aspen invasion was very prevalent on all ungrazed sites. Spruce invasion was quite prevalent at Bill Nye Lake (site 7, 15 and 16) and spruce was present in the aspen understory of site 4. In the past tree invasion may have been retarded by fire and moose browsing in these ungrazed situations. Pojar et al. (1982), have pointed out that burning by Indians was quite prevalent throughout the sub-boreal spruce biogeoclimatic zone. Nelson and England (1971) stated that Indians employed fire to control wildlife movements in the northern grasslands of Canada. Fitzgerald and Bailey (1984), found that burning an aspen forest followed by heavy cattle grazing controlled aspen sucker regrowth and converted the forest to a grassland. The cessation of fire in the fescue prairie has also resulted in tree and shrub invasion onto the grasslands. With the advent of modern fire suppression fire has been nearly eliminated from the natural forest ecosystem. It is believed that in the absence of grazing and fire, tree encroachment will occur on these ungrazed grasslands. This will eventually reduce forage productivity as the grasses and forbs are shaded by shrubs and trees.

12. SUMMARY AND CONCLUSIONS

There are predominantly two native grassland plant communities utilized by livestock within the study area. In the drier upper slope positions the native grassland was dominated by the grasses *Carex maclovIana, Stipa occidentalis, Elymus glaucus and Bromus vulgaris*. The dominant forbs included *Potentilla arguta, Castilleja miniata, Rhinanthus minor, and Penstemon procerus* and the dominant shub was *Symphoricarpos albus*. In the moist lower slope positions there was a shift in species composition to moisture loving species *Heracleum sphondylium and Utrica dioica* and the grasses *Bromus vulgaris and Elymus glaucus* became dominant. As grazing intensity and management; increases over a number of years there is a shift in species composition away from the native forbs and grasses to the introduced cultivated species of *Taraxacum officinale, Poa pratensis, Festuca rubra and Phleum pratense*. The heavy grazing regime has acted like an environmental gradient creating stable plant communities which are adapted to high defoliation intensities.

Heavy grazing by cattle also appears to inhibit shrub and tree encroachment. The continuous grazing system may inhibit forest succession and maintain the grassland vegetation.

The soils of the various plant communities were predominantly Orthic Melanic Brunisols and Dark Gray Luvisols. They had relatively thick Ah horizons (0-15cm) with organic matter contents of 12-21%. The percent base saturation was approximately 68 and the pH varied from 5.8 to 6.4. These soils are extremely rich and readily support the growth of grasses and forbs.

The normal growing season of the various grassland and aspen forest communities was about May to September but atypical spring weather and summer drought can markedly affect forage availability. In 1984 there was insufficient growth for cattle until the first week in June whereas, sufficient forage for cattle was available three weeks earlier in 1985. Turnout date should be flexible and dependent upon forage availability. The primary factor influencing the initiation of forage growth and thus range readiness appears to be temperature in May.

Plant growth is reduced by drought and defoliation. When these two factors are combined the ability of the plant to regrow is severely affected. Drought conditions occurred at the end of July in both years. If cattle are to have sufficient forage available to them during drought then the lack of growth during July must be taken into account in range management planning. This would require either that selected areas be ungrazed until July or that light grazing be practiced in May and June permitting the grassland to regrow prior to the onset of drought during July.

Periodic grazing of cultivated grasses (*Poa pratensis, Festuca rubra, Phleum pratense*) with sufficient rest periods between grazings does not cause a decline in production

(Figure 17, two harvests/season) but continuous heavy grazing or grazing at too short an interval between grazings substanially reduces production (Figure 7, 3 and 4 harvests/season).

Both *Taraxacum officinale* and *Heracleum sphondylium*, the two most common forbs, grow early in the season. If optimum use is to be made of dandelion, then it should be grazed soon after cattle turn out in spring. Cow parsnip does not senesce as rapidly as dandelion but it too could be grazed in June and July.

Cow parsnip is an extremely important forage plant within the study area. This plant has a large root mass. It continued to produce etiolated growth until the middle of September in the 0 and 1 defoliation treatments and up to the middle of July in the 3 and 4 defoliation treatments. This growth period was longer than any other species tested. The forb could be heavily defoliated, allowed to regrow, and then defoliated again thereby maintaining maximum productivity. This species was observed to be highly palatable to cattle, particularly during flowering.

It would appear that continuous grazing of cow parsnip over one year does influence its productivity , but continuous grazing over 20 years appears to eradicate it from the plant community.

From observations in the field it would appear that blue wild rye and Columbia brome are palatable in the spring when the plants are in the leaf stage but they became relatively unpalatable as they matured.

The native plant species can withstand two defoliations throughout the growing season without severely affecting forage production (Figure 18). However, it was observed in the field that very little regrowth occurred and this was attributed to limited soil moisture in July and August.

The maximum production of native forbs and grasses in exclosure two occurred by the end of June (Tables 3 and 7). These plants should therefore be grazed between May and July to take advantage of maximum productivity and nutrient content. For practical reasons this is not always possible since a forage supply must be maintained from July to October.

12.1 Grazing systems

The leasees practice a continuous grazing system. This system leaves many areas of the range unit overgrazed and generally eradicates cow parsnip. There is insufficient forage growth for cattle during the drought period in July and August as well as during the fall. Cows are probably either only maintaining weight or losing weight from September onwards under the present management system.

If maximum productivity and stability of the forage resource is to be realized periods of rest during the growing season are required. A number of grazing system alternatives could be applied to the area. A few are presented below:

1. Reduce the stocking rate to moderate. Moderate continuous grazing would make more forage available to cattle in the fall although some areas would remain overutilized. Calf weight gain would probably increase slightly, but cow weight would be considerably greater because of the greater availability of forage from July to October.

2. Rotational grazing system. This would ensure a sufficient rest between grazings enabling recovery of cultivated and native plants. It would also likely result in the maintenance of cow parsnip as a major forage species, an expansion of the grasses, a reduction in dandelion and overall increased forage production if managed appropriately.

Areas currently having extensive growth of dandelion could be grazed as soon as cattle are turned out in spring to take advantage of its maximum growth and nutrient content. Cattle should then be moved elsewhere to permit regrowth and allow the development of an adequate supply of grass growth for August to October fall grazing. Mid-June to mid-July is a good time to graze native grasslands where cow parsnip is abundant.

The rotational grazing scheme must take into account the growth patterns of the forages. Dandelion and cow parsnip both grow early. Grasses provide most mid-summer and fall regrowth so they must be grazed prior to seed set, in order to stimulate tillering and promote continued growth.

A rotational grazing scheme can be adjusted to take advantage of the growth cycles of the various forage species. The scheme is also flexible enough to be adjusted to the varying types of terrain and vegetation on each range community.

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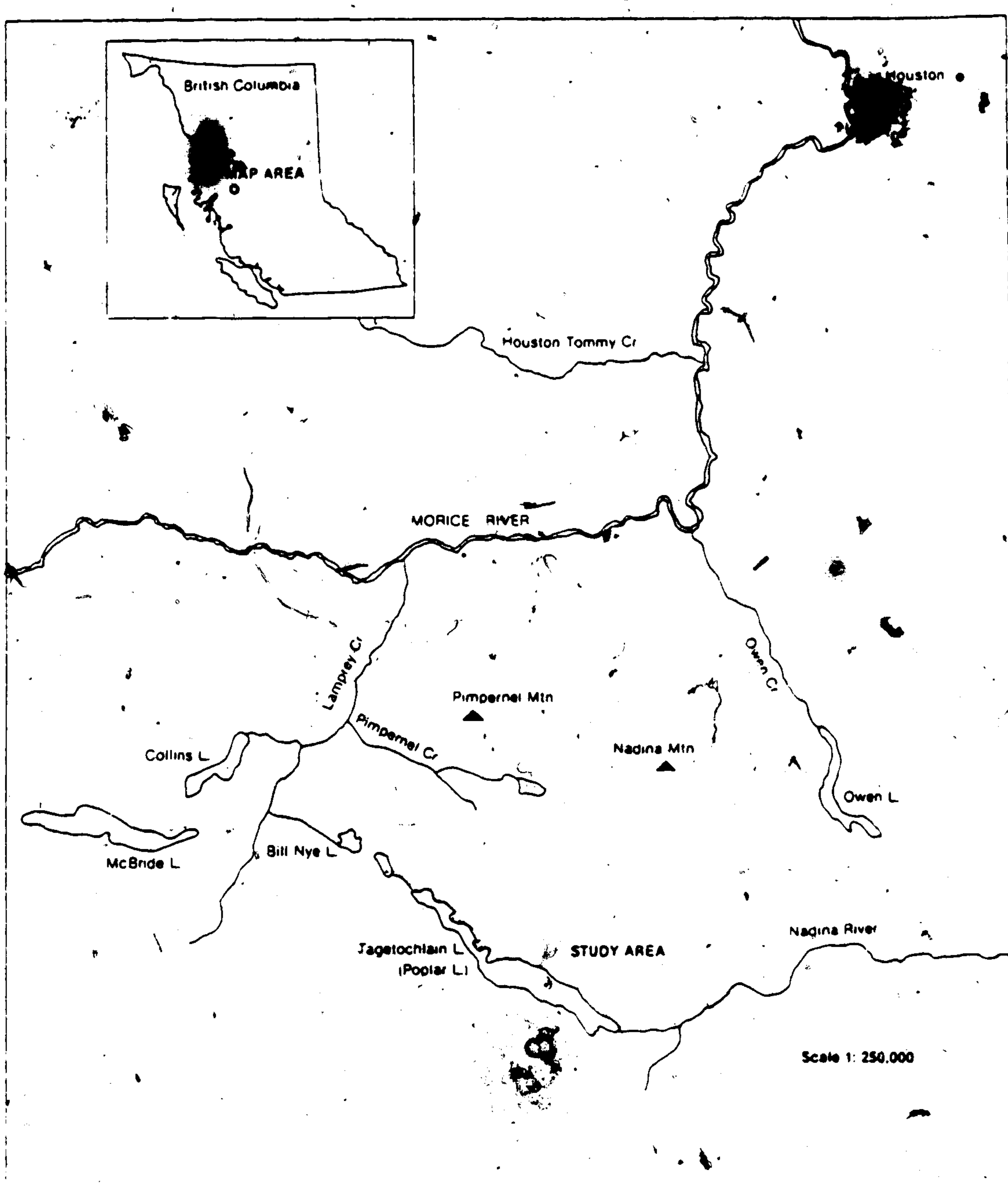
14. APPENDICES

14.1 APPENDIX 1: Map of the study area



Appendix 2: Species four letter code, associated scientific name, and moisture indicator value (MIV)

Species code	Scientific name	Moisture Value
potr	Populus tremuloides	3-4
amal	Amelanchier alnifolia	2
loin	Lonicera involcrata	4
prvi	Prunus virginiana	4
rila	Ribes lacustre	4
roac	Rosa acicularis	2-4
ruid	Rubus idaeus	3
rupa	Rubus parviflora	3-4
sasc	Salix scouleriana	3
spbe	Spiraea betulifolia	2-3
syal	Symphoricarpos albus	2-3
acmi	Achillea millefolium	2
acru	Actea rubra	4
agau	Agoseris aurantiaca	2
alce	Allium cernuum	1
arhi	Arabis hirsuta	2
asci	Aster ciliolatus	3
asco	Aster conspicuus	3
asmo	Aster modestus	3.5
cami	Castilleja miniata	2
cear	Cerastium arvense	2
civu	Cirsium vulgare	4
coli	Collomia linearis	2-3
copa	Collinsia parviflora	2
degl	Delphinium glaucum	4
epah	Epilobium angustifolium	3
epgl	Epilobium glandulosum	4
frvi	Fragaria virginiana	2
frca	Fritillaria camchatshensis	4
gabo	Galium boreale	2-4
gema	Geum macrophyllum	3
hesp	Heracleum sphondylium	4
lane	Lathyrus nevadensis	3
maia	Maianathemum canadense	4
pepr	Penstemon procerus	2
plma	Plantago major	2
poar	Potentilla arguta	2
pogr	Potentilla gracilis	3-4
raac	Ranunculus acris	4
rave	Ranunculus verecundus	4
rhmi	Rhinanthus minor	2
ruac	Rumex acetosa	3
rucr	Rumex crispus	3
setr	Senecio triangularis	5
smra	Smilacina racemosa	3-4
smst	Smilacina stellata	3

stlo	Stellaria longipes	2
taof	Taraxacum officinale	3
thoc	Thalictrum occidentale	3-4
trhy	Trifolium hybridum	3
trre	Trifolium repens	3
utdi	Utrica dioica	4
[illegible]i	Veratrum viride	5
[illegible]	Veronica serpyllifolia	5
[illegible]	Vicia americana	3
[illegible]	Viola adunca	3
[illegible]a	Viola canadensis	4
[illegible]	Agropyron trachycaulum	3
brvu	Bromus vulgaris	3
caca	Calamagrostis canadensis	4
cama	Carex macloviana	2-3
cape	Carex pensylvanica	2
elgl	Elymus glaucus	3
feru	Festuca rubra	3
mesp	Melica spectabilis	2-3
phpr	Phleum pratense	3
popa	Poa palustris	4
popr	Poa pratensis	3
poin	Poa interior	2
scpu	Schizachne purpurascens	2-3
stoc	Stipa occidentalis	2-3
trsp	Trisetum spicatum	2-3

1=xeric, 2=submesic, 3=mesic, 4=subhygric, 5=hygric

14.3 APPENDIX 3: A list of soil characteristics for the cultivated and native site

Horiz	depth (cm)	text	struc	color	roots	%OM	%N*	%BS	pH
Cultivated site									
Ah	0-16	L	Gr	10YR2/1	A	19	3	67	5.6
Bm	16-38	L	FSuBl	10YR4/4	P	2	0.1	65	5.6
AB	38-59	SCL	MSuBl	10YR5/3.5	VF	1	.06	64	5.6
Btg	59+	CL	Ma	10YR4/4	N	1	.04	80	5.2
Native site									
LFH	6-0				A	52	3	108	5.8
Ah	0-9	L	Gr	10YR2/1	A	17	1	81	5.8
Bm	-9-33	SL	FSuBl	10YR3/4	A	1	.09	81	5.9
Btg	33-54+	CL	Ma	10YR4/3.5	VF	1	.07	68	5.8

Texture: L=Loam, CL=Clay Loam, SCL=Sandy Clay Loam, SL=Sandy Loam
Structure: Gr=Granular, FSuBl=Fine subangular blocky, MSuBl=Medium subangular blocky, Ma=Massive
Roots: A=abundant, P=plentiful, VF=very few, N=none
%OM=Organic matter, %N=% Nitrogen, %BS=% Base saturation

14.4 APPENDIX 4. Crude protein (%) of forbs and grass for the months of June, July and August at the cultivated site and the native site

	Exclosure 1		Exclosure 2	
	Forb	Grass	Forb	Grass
June	10[1]	9	15	11
July	10	6	14	6
Aug	8	4	4	6

1. Sites were unreplicated and no statistical test was performed

APPENDIX 5.

Appendix 5.1. Anova table for forbs and grass growth cycle in the cultivated site

Source	df	MS	F-Ratio	p
Forb				
Treat(T)	3	2315	7.9	0.0
Block(B)	9	422	1.0	0.43
Year(Y)	1	3038	5.4	0.04
(TB)	27	289	0.7	
(BY)	9	558	1.4	
(TY)	3	360	0.9	0.8
(TBY)	27	404		
Grass				
Treat(T)	3	68414	75	0.0
Block(B)	9	2240	1.9	0.09
Year(Y)	1	32361	37	0.0
(TB)	27	916	0.8	
(BY)	9	886	0.8	
(TY)	3	824	0.7	0.55
(TBY)	27	1169		

APPENDIX 5.2. Anova table for forbs and grass growth cycle in the native enclosure

Source	df	MS	F-Ratio	p
<u>Forb</u>				
Treat(T)	3	2663	12	0.0
Block(B)	9	4526	2.0	0.05
Year(Y)	1	109	0.05	0.82
(TB)	27	2663	1.2	
(BY)	9	2050	0.99	
(TY)	3	5261	2.5	0.08
(TBY)	27	2081		
<u>Grass</u>				
Treat(T)	3	6395	14	0.0
Block(B)	9	2083	4.0	0.0
Year(Y)	1	378	0.2	0.62
(TB)	27	459	0.59	
(BY)	9	1475	2.9	
(TY)	3	2669	5.3	0.0
(TBY)	27	502		

APPENDIX 6

Appendix 6.1. Anova table for forbs and grass regrowth after an initial clip in the cultivated

Source	df	MS	F-Ratio	p
Forb				
Treat(T)	3	2749	53	0.0
Block(B)	9	126	3.0	0.01
Year(Y)	1	209	2.9	0.11
(TB)	27	52	1.2	
(BY)	9	71	1.7	
(TY)	3	708	17	0.0
(TBY)	27	1107		
Grass				
Treat(T)	3	2049	16	0.0
Block(B)	9	244	2.1	0.06
Year(Y)	1	610	3.0	0.11
(TB)	27	127	1.1	
(BY)	9	204	1.8	
(TY)	3	876	7.8	0.0
(TBY)	27	791		

APPENDIX 6.2. Anova table for forbs and grass regrowth after an initial clip in the native site

Source	df	MS	F-Ratio	p
Forb				
Treat(T)	3	8911	26	0.0
Block(B)	9	429	3.0	0.01
Year(Y)	1	2.6	0.01	0.92
(TB)	27	343	2.4	
(BY)	9	268	1.9	
(TY)	3	3102	22	0.0
(TBY)	27	141		
Grass				
Treat(T)	3	599	10	0.0
Block(B)	9	48	1.0	0.45
Year(Y)	1	161	2.4	0.15
(TB)	27	63	1.4	
(BY)	9	66	1.4	
(TY)	3	710	15	0.0
(TBY)	27	141		

APPENDIX 7 Anova table for forbs and grass in the cultivated exclosure

Source	df	MS	F-Ratio	
Forb				
Treat(T)	3	7672	15	0.0
Block(B)	9	1077	3.7	0.05
Year(Y)	1	3771	16	0.05
(TB)	27	520	1.8	
(BY)	9	719	2.4	
(TY)	3	242	0.8	0.5
(TBY)	27	295		
Grass				
Treat(T)	3	29200	27	0.0
Block(B)	9	4189	2.7	0.05
Year(Y)	1	18311	32	0.02
(TB)	27	1096	0.9	
(BY)	9	568	0.4	
(TY)	3	1380	0.9	0.75
(TBY)	79	1516		

APPENDIX 8. Anova table for forbs and grass in the native site

Source	df	MS	F-Ratio
Forbs			
Treat(T)	3	4884	1.5
Block(B)	9	10183	2.9
Year(Y)	1	485	0.5
(TB)	27	3315	0.9
(BY)	9	943	0.3
(TY)	3	1945	0.6
(TBY)	27	3499	
Grass			
Treat(T)	3	3089	4.6
Block(B)	9	5110	6.5
Year(Y)	1	8548	7.4
(TB)	27	674	0.8
(BY)	9	1148	1.1
(TY)	3	888	1.1
(TBY)	27	791	

14.9 APPENDIX 9: Species foliar cover (%) for each macroplot

Species code	Macroplots 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Tree:																						
potr		1		10	1	T	T	1	T				T								10	5
Shrub:																						
amal		T			1																	
prvi												T										
rila				T															T		T	
roac	T	14	T		8	T	T	2	3	T	T	T	3	T					1			
rupa																			T			
ruid				T																		3
sasc			T	T	T	T							1						T			
spbe									5													
syal	T	8			T		T	T	5													
Forb:																						
acmi		1	2	1	2				2		1	2	T	T		1	1	T				T
acru				1																	T	
agau		T								T			T									
alce																	T					
arhi		T	T	T		T	T		T		T	T				T	T	T	T			
asci				2	T	T		1	T				T									T
asco		2			8	T	1		T													2
asmo		T	T	5		T	3	1	T				1		6	4	T				T	8
cami		T			3				T				5				2	T				
cear									T	T			1									
civu	T																					
coli		3			3	T	3		T			T	T		1		T		T			T
copa				T						T							T	T			T	
degl				T		T																
[illegible]pan		10		6	4	10	4	15	5	T		1	1		4	5						20
[illegible]rvi		2			5								2	T			T	T			T	
[illegible]rca				T		T									T	T						
gabo		1	T	T	1	T	2	T	T			1	T	T	1	T	T	T			T	3
hesp		T	7	17		19	19	10			T	T		T	8	40						21
lane	T	17	T	4	6	13	5	4	2	1		1	4	1	6	2	T					10
pepr		T																				
plma	T																			T		
poar		T			5				T				4	2				T				
raac	T										T					2	1	1		T	1	
rave	T	T	1	2		T																
rhmi		1			T								2									
ruac		1											1									
rucr	T																T			T		
smra				1												T						
smst		1	T	2	1	T	T	1	T	T		1	1		T	1	T				T	T
stlo															T	T	1	2				

taof	25		18	T		4	T	T	28	31	40	24	24	40			40	28	34	28	25	3
thoc		9	1	7	1		9	5	1			1	3		2	6	[illegible]	[illegible]		T		16
trhy	T																			10	1	
trre	1																					
utdi			T	3		2	2	1	T	T	T	1			1	3					T	T
vevi			T								1											
vese				T													T	T				
viam	T	T	T	T	T	1	2	1	1	1		1		T	2	1	1	T	T			2
vica																						
Graminoids:																						
agtr									1			T	1									
brvu		3	1	3	2	6	18	12	7			6	6	18	12	1	1		T			7
caca				T			1									3			T			T
cama	T	1	T		2	T			T	2	1	1	5	3			1	1	T	T		
ca2									2				T									
elgl		1	3	9	T	5	5	5	1			7	T		7	9	T				T	5
feru	21																		34	2	T	
mesp		1	T	T	1	1	T		T				1	TTT								
phpr	4		2						2	2	3	T		T			8	8	1	1	T	
popr	17		42	2	T	T		1	4	23	33	11	5	19			7	4	T	45	40	
poin			T	T	T		T		1			T	4				T	1				
scpu				T																		
stoc					1								T									
trsp													1				T	T				
viad													T					T			T	
loin																					1	
popa																1						1
maca																T						
setr																T						
epgl																1						
pogr													4	T								
gema												T			T	1	1	T	T		4	T

*T = A FOLIAR COVER OF LESS THAN 1%

**SEE APPENDIX FOR SPECIES FOUR LETTER CODE