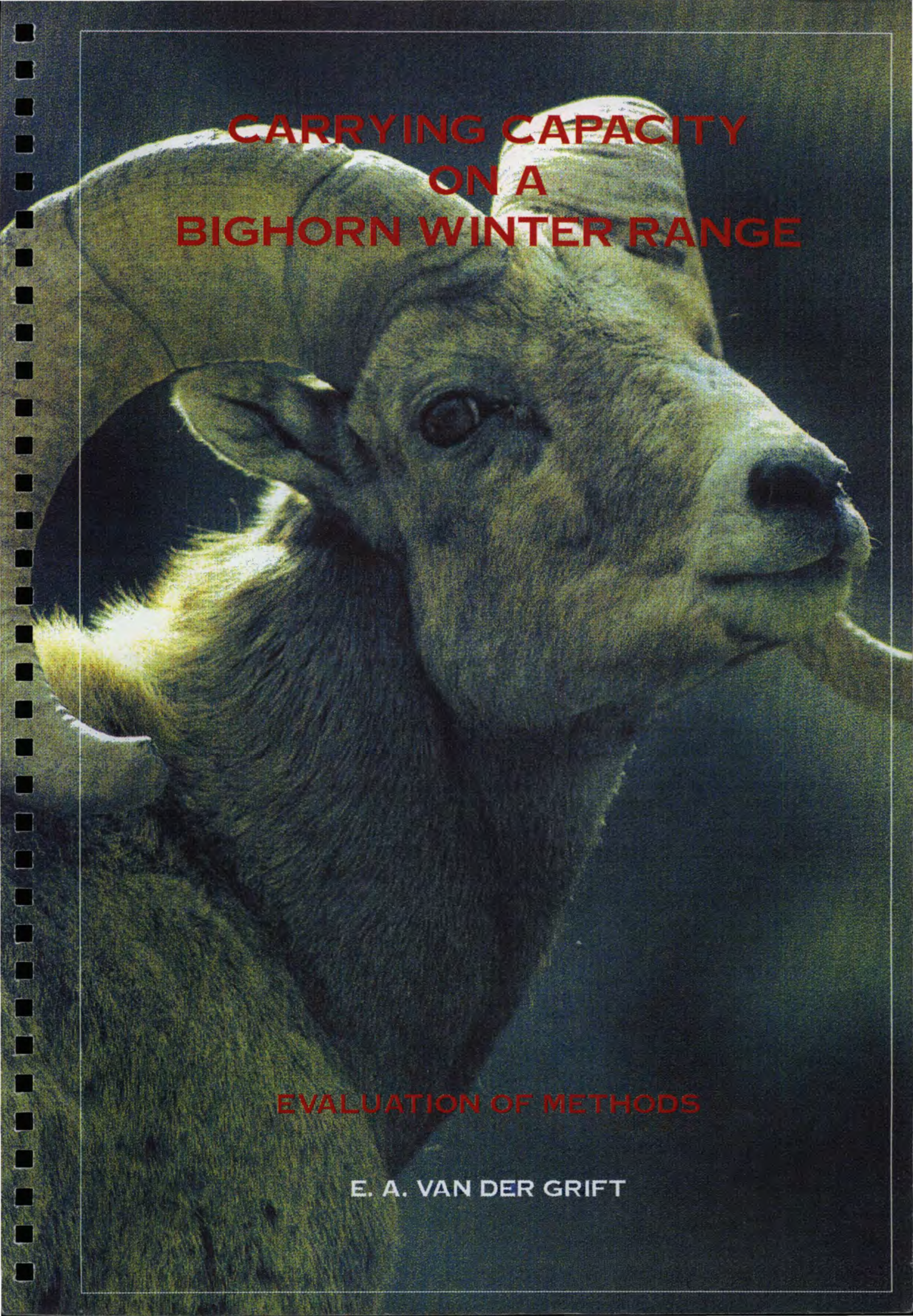
CARRYING CAPACITY ON A BIGHORN WINTER RANGE



EVALUATION OF METHODS

E. A. VAN DER GRIFT

Carrying capacity on a bighorn winter range

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E.A. van der Grift

1999

Wageningen Agricultural University
Department of Terrestrial Ecology
and Nature Management
Wageningen, Netherlands

University of Idaho
Wilderness Research Center
Taylor Ranch Wilderness Field Station
Idaho, USA

PREFACE

This report is the result of a practical experience course in nature management offered by the Department of Terrestrial Ecology and Nature Management of Wageningen Agricultural University (WAU) in the Netherlands. The study was conducted from early April to mid-August 1992 at the Taylor Ranch Wilderness Field Station, a facility of the University of Idaho (UI) Wilderness Research Center. The study area is an important bighorn sheep (*Ovis canadensis canadensis*) winter range along lower Big Creek in the heart of the Frank Church-River of No Return Wilderness in central Idaho.

Financial support was received from the Dutch Ministry of Agriculture, Nature Management and Fisheries and the Management Info, a Dutch foundation for economists. Taylor Ranch Field Station also provided financial support as well as residence and work facilities.

This report is divided into two parts: an introduction to bighorn sheep natural history (for the benefit of the Dutch reader) and an analysis of methodology used to determine forage-based carrying capacity for bighorn sheep on winter range. Preliminary data are evaluated and recommendations made concerning sampling protocols in this long-term research project.

Special thanks are due to Jeff Yeo (UI) and Jan van der Made (WAU) for the opportunity to work at Taylor Ranch Field Station and for supervising the research. Thanks to Marcel Huijser who commented upon an earlier draft of this report. I also thank Ray Guse and Christine Hunter, who collected most of the data, and the other students and scientists working at Taylor Ranch Field Station who made my stay at Taylor Ranch a most interesting and instructive time.

CONTENTS

PART I

INTRODUCTION TO BIGHORN SHEEP

A Classification and distribution

On the American continent three wild sheep species are distinguished: snow sheep (*Ovis nivicola*), thinhorn sheep (*Ovis dalli*) and bighorn sheep (*Ovis canadensis*) (Geist, 1971). The bighorn sheep can be divided into seven living subspecies. Five of them are collectively called desert bighorns (table 1) (Manville, 1990). The Audubon's bighorn (*Ovis canadensis auduboni*) is extinct.

Table 1 Classification of bighorn sheep (*Ovis canadensis*).

SUBSPECIES	
Rocky Mountain bighorn	*Ovis canadensis canadensis*
California bighorn	*Ovis canadensis california*
Desert bighorns	*Ovis canadensis nelsoni*
	Ovis canadensis mexicana
	Ovis canadensis texiana
	Ovis canadensis cremnobates
	Ovis canadensis weemsi
Audubon's bighorn	*Ovis canadensis auduboni*

Bighorn sheep were once abundant throughout western North America. However, since the turn of the century, they have declined in most areas and many populations have been eliminated (Buechner, 1960; Stelfox, 1976). Nowadays they occur in scattered populations in the western states of Canada and the United States south to northern Mexico and east to the Badlands of the Dakotas.

Habiata loss, habitat fragmentation, competition for forage with livestock, hunting, parasites, and diseases introduced by domestic sheep, are the main factors responsible for this decline. Nowadays sheep are found only in the most inaccessible, wildest and highest peaks in the Rocky Mountains and in the deserts of the Southwest (Buechner, 1960). Many populations are small and isolated, often with less than hundred individuals (Krausman et al., 1989).

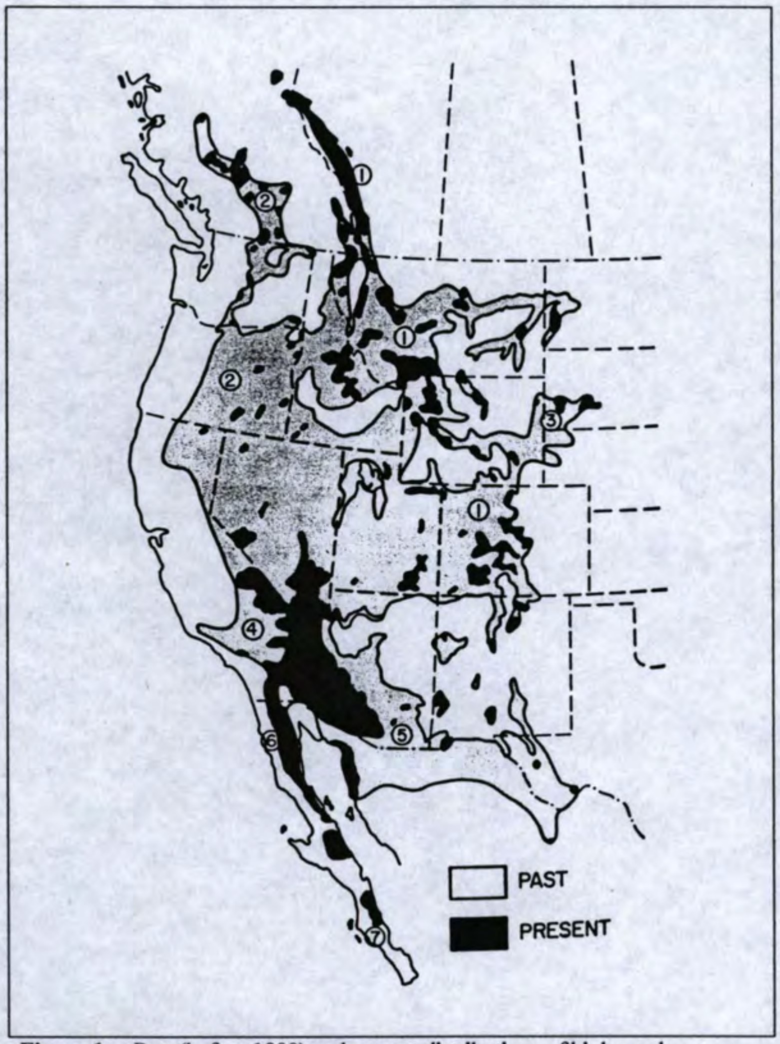

Figure 1 Past (before 1800) and present distributions of bighorn sheep (source: Wishart, 1980): 1. *Ovis canadensis canadensis*; 2. *O. c. californiana*; 3. *O. c. auduboni* (extinct); 4. *O. c. nelsoni*; 5. *O. c. mexicana*; 6. *O. c. cremnobates*; 7. *O. c. weemsi*.

B Habitat and migration

Bighorn sheep generally inhabit remote, rugged terrain with small amounts of precipitation and high evaporation (Van Dyke et al., 1983). The vegetation in habitats selected by bighorn sheep is usually low and has an open structure; sagebrush/grassland and cold desert shrublands are the dominant types. The presence of cliffs or steep slopes is important for escape from predators (Geist, 1971). Cliffs also provide thermal protection (e.g., shade in summer, absorbed heat in winter) and forage, and are particularly utilized during lambing season and in winter (Geist, 1971).

Bighorn sheep show seasonal migration between habitats that differ in elevation and vegetation. Seasonal movements may require migration over great distances, during which streams, forested ranges or other low elevated (and for bighorn sheep less protective) habitats may be crossed. When snow accumulates on higher elevations, the sheep move down to their winter ranges, where breeding occurs during late October to mid-December. In spring the ewes migrate to specific lambing areas which are characterised by rugged, precipitous and remote cliffs. The use of these areas often has a traditional background but it may be altered by environmental conditions like accumulation of snow or lack of forage. The ewe-lamb groups stay in the lambing areas for about a month after which they aggregate on the less rugged summer ranges. Some herds use an area both as summer and winter range (Geist, 1971).

C Sheep biology

Bighorn sheep are generally categorized as grazers. A specialized digestive system with a relatively large rumen enables them to utilize hard, abrasive, dry forage of poor quality (Geist, 1971). Perennial bunchgrasses make up the largest portion of their diet although a variety of browse and forbs are used seasonally in varying amounts (Van Dyke et al., 1983; Rominger et al., 1988). Bighorn sheep can be very selective grazers. One study revealed that over 70% of their diet consisted of forages that contributed less than 10% of available biomass (Hobbs et al., 1983). Annual average daily forage intake of Rocky Mountain bighorn sheep has been estimated at 1.44 kg dry matter per 45.4 kg body weight (Anderson & Denton, 1978).

Ewes give birth to one lamb, usually in May (Geist, 1971). Mortality of lambs is high, especially in the first two months of life. Lambs from the previous year usually remain with the ewe-lamb groups for several years. After sexual maturation, males associate with male-only bands.
Females usually live longer than males. Males suffer high mortality after reaching full maturaty at 8-9 years of age (Geist, 1971). Sick, old or weakened sheep are often taken by predators with little or no impact on sheep populations (Geist, 1971). Common predators are grey wolf (*Canis lupus*), mountain lion (*Felis concolor*), grizzly bear (*Ursus horribilis*), coyote (*Canis latrans*), wolverine (*Gulo gulo*) and lynx (*Lynx lynx*).

D Management

Habitat management.
Habitat loss is one of the main factors responsible for the reduced numbers and limited range of bighorn sheep. Agricultural and industrial development, an expending road network, urbanization, and increased recreation resulted in serious competition for space with human society. Paradoxically, also nature management in bighorn ranges itself may have degraded suitable habitats. Consistent fire suppression caused a change in vegetation structure and composition. Succession occured from grassland and open shrubland to dense shrubland and forest, which inhibit sheep movements and are less suitable habitat (Risenhoover & Bailey, 1985; Wakelyn, 1987).
To maintain and enhance habitat for bighorn sheep, well considered vegetation management is needed. Management should focus on improving forage availability, expansion of seasonal ranges, establishment of new seasonal ranges and maintaining or re-establishing migration corridors (Wakelyn, 1987).

Reintroduction.
Bighorn sheep are slow to inhabit new habitats (Geist, 1971), which makes the reintroduction of animals an important management tool to stimulate geographic expansion and reoccupation of former ranges. Many transplants have been accomplished throughout the western states of the United States, but not all have been succesful (Risenhoover et al., 1988).

Hunting.
Most bighorn populations are hunted, but small and less viable populations are protected. The hunt is regulated through a system of permits, which limits the total harvest, and sets a minimum (legal) horn size for males (Festa-Bianchet, 1989).

PART II

THE STUDY:

CARRYING CAPACITY ON A BIGHORN WINTER RANGE

1 Introduction

1.1 Background of the study

Since 1986, high lamb mortality has been recorded in the bighorn population that winters along the lower Big Creek (Yeo, 1992). In 1988 research was initiated to assess both the extent of lamb mortality and the potential causes of this problem (Akenson & Akenson, 1991). In 1984 and 1985, winter counts produced an average lamb:ewe ratio of 46:100. Over the period 1986-1990 a ratio of 16:100 was recorded. This pattern continued in 1991. While high lamb:ewe ratios were observed in June, no lambs were observed in July and dead lambs were found without signs of predation or injury.

The immediate cause appeared to be lung infections by *Pasturella haemolitica* (Akenson & Akenson, 1991). A pregnant ewe was removed from lower Big Creek in March 1991. Her lamb was born in captivity and contracted a heavy infection of *Pasturella haemolitica* while in captivity but survived. Selenium levels in this ewe were found to be the lowest measured in bighorn sheep in Idaho (Yeo, 1992). Selenium, while poisonous in forage at high doses, is an important trace element in the immune system as it is part of the enzyme glutathione peroxidase (Flueck, 1991).

There are several factors that may play a role in the susceptibility of sheep for *Pasturella haemolitica*. First, the nutritional quality of the winter range might have been reduced by a persistent drought during the period 1987-1991. This may also have caused an exotic species, cheatgrass (*Bromus tectorum*), to become more abundant on the winter range. At some sites this grass gained dominance over native bluebunch wheatgrass (*Agropyron spicatum*). Both the persistent drought and the expanding cheatgrass has and will influence the quality as well as the availability of forage for wild ungulates. Cheatgrass has a short growing season and flowers early. Bluebunch wheatgrass initiates growth later, but retains nutritious until winter. Persistent drought may also have been the cause of a possible change in availability of certain grasses or forbs that have a high concentration of selenium.

Another factor is the expanding elk (*Cervus elaphus nelsoni*) population at lower Big Creek. Especially in the years 1987-1991 a considerable population growth has been recorded. Population trends of mule deer (*Odocoileus hemionus*) are unknown. The bighorn sheep numbers were the highest on record in 1992, but showed no significant change over the years 1987-1992 (Akenson & Akenson, 1991; Yeo, 1992). The hypothesis is that multiple factors have reduced carrying capacity for sheep and, as a consequence, have increased the susceptibility of lambs to fatal disease (Yeo, 1992).

1.2 Objectives

The Wilderness Research Center of the University of Idaho intended to start a long term study on bighorn sheep to get some answers to the questions mentioned above. Primary objective of this study would be to determine carrying capacity for the Big Creek bighorn population. A preliminary study was initiated to test and evaluate methods for obtaining desirable data. Primary objective of this preliminary study was to determine temporal changes in forage availability for wild ungulates on the bighorn winter range in lower Big Creek (Yeo, 1992).

This was specified into several (sub)objectives:

- To determine changes in biomass of forage during winter, assesing the proportion of biomass taken by the ungulates.
- To determine food intake of bighorn sheep in order to estimate an energy budget.
- To determine habitat utilization of bighorn sheep, elk and mule deer on the winter range and changes in population densities of those ungulates.

1.3 The study area

The Big Creek drainage is located in the heart of the 2.4 million acres large Frank Church - River of No Return Wilderness in central Idaho. The lower Big Creek area encloses the lower 12 miles of the stream, from Cabin Creek to the confluence with the Middle Fork of the Salmon River. This area is characterized by high mountain peaks and sharp ridges up to more than 9,000 feet, separated by deep canyons and basins (figure 2).

The streams and their variety of riparian zones are surrounded by steep slopes which range from nearly bare to heavily timbered. Four major vegetational zones can be distinguished: (1) the ponderosa pine zone (*Pinus ponderosa*), at the lowest elevations and in some places bordering the river, (2) the douglas fir zone (*Pseudotsuga menziesii*), which occurs above the ponderosa pine zone and ranges from streamsides up to ridges, (3) the spruce fir zone, dominated by Engelmann spruce (*Picea engelmannii*) and alpine fir (*Abies lasiocarpa*), and (4) at the highest elevations the alpine zone with a vegetation that primarily consists of dwarfshrubs and mat plants (Hornocker, 1970).

The ungulate winter range is part of the lowest two zones; ponderosa pine and douglas fir (Seidensticker et al., 1973). Grassland slopes and benches, dominated by bluebunch wheatgrass (*Agropyron spicatum*) and accompanied by Idaho fescue (*Festuca idahoensis*), Sandberg's bluegrass (*Poa secunda*), pinegrass (*Calamagrostis rubescens*) and cheatgrass (*Bromus tectorum*), frequently occur on south facing sites. Arrowleaf balsamroot (*Balsamorhiza sagittata*), wild hyacinth (*Brodiaea douglasii*), white flox (*Phlox multiflora*) and bluebell (*Mertensia oblongifolia*) are just a few forbs of these species rich mountain grasslands. Important shrubs that provide winter browse are mountain mahogany (*Cercocarpus ledifolius*), bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*) and spring greasebrush (*Glossopetalon nevadense*) (Hornocker, 1970).

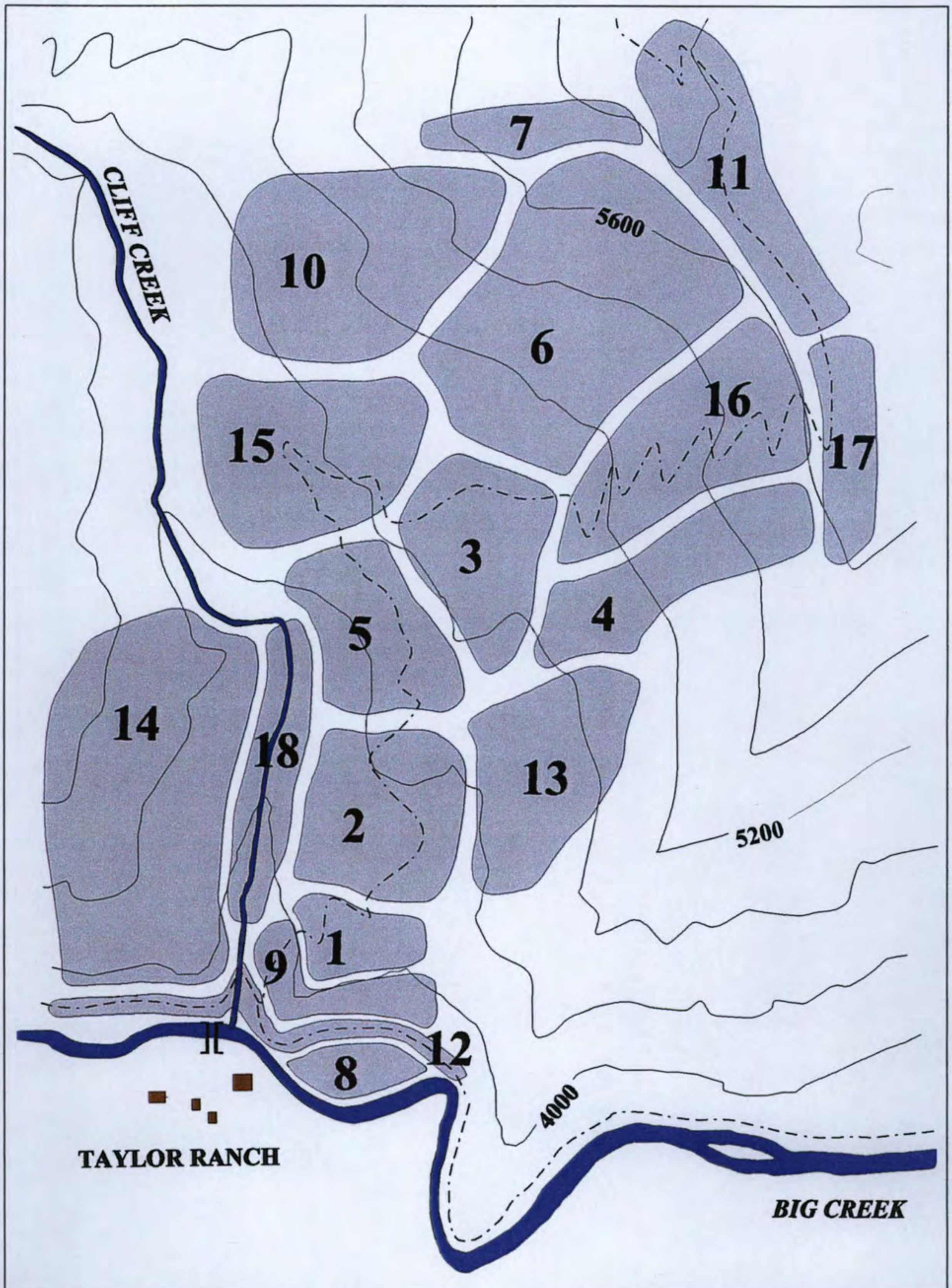

Figure 2 The study area at lower Big Creek and the location of Taylor Ranch Research Station. The winter range is divided into eighteen topographical sites: see also Appendix IV.

1.4 The Big Creek bighorn population

Aerial winter counts, conducted by the Idaho Department of Fish and Game, estimated the bighorn sheep population in the Big Creek drainage at 200 animals in 1989 (Oldenburg & Turner, 1991), 93 sheep in 1991, which is questioned, and again 200-250 animals in 1992 (Michael Schlegel, personal comment).
Since the early 1980s, population numbers steadily increased from a 100 sheep to the previously stated more than 200 sheep in recent years (figure 3). Meanwhile ewe:lamb ratios decreased rapidly after 1986 (figure 3).

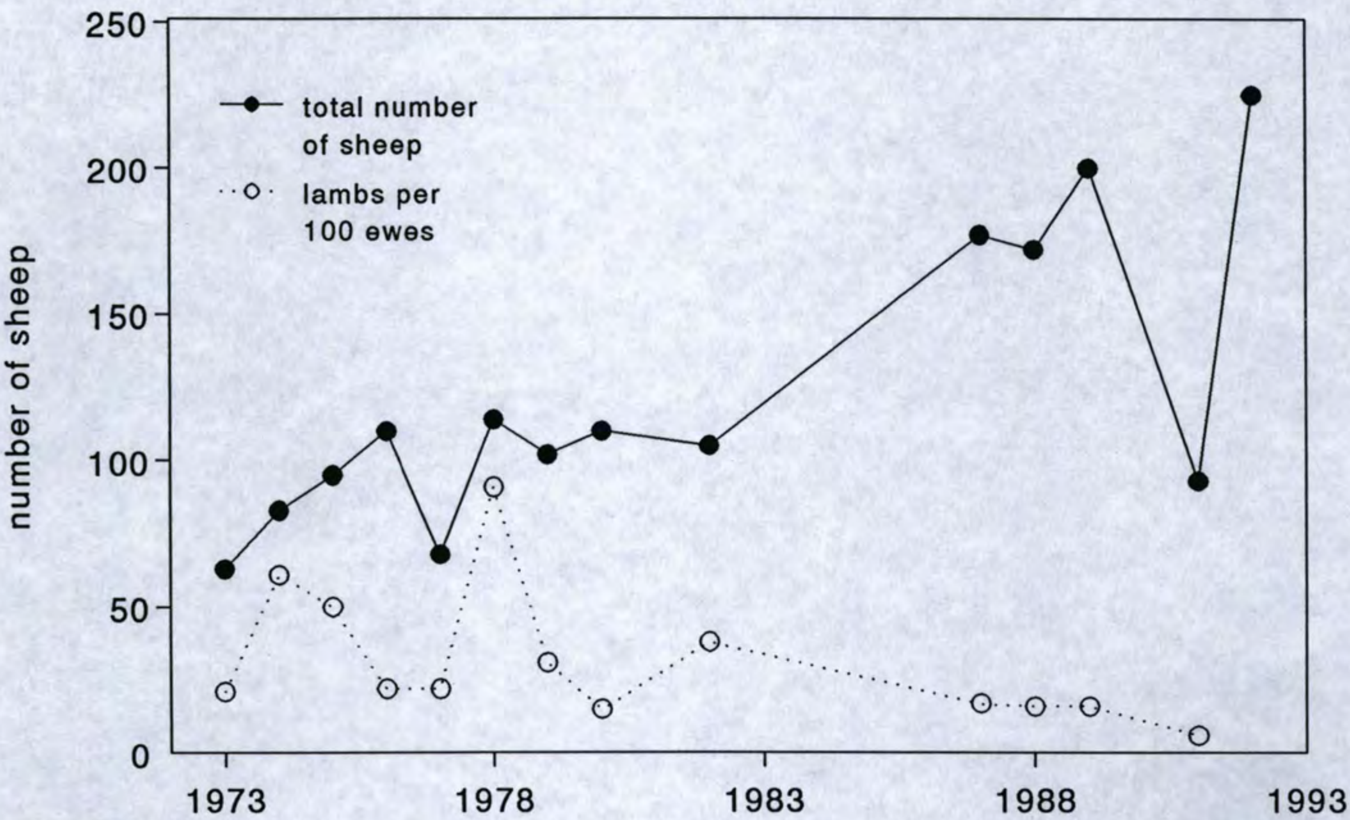

Figure 3 Bighorn population estimates (1973-1992) and the number of lambs per 100 ewes for the Big Creek bighorn population (After: Oldenburg & Turner, 1991).

This study focusses on the Cliff Creek-Big Creek winter range that is used by approximately half of the Big Creek bighorn sheep population (Akenson & Akenson, 1991).
When snow accumulates on high elevations in November and early December, sheep are forced to remain in the lower parts of this area. These are grassy slopes and benches adjacent to Big Creek. While most ewe groups winter in a particular area with little or no movements over great distances, ram bands (so called 'bachelor-groups') display great mobility during winter. Males are only observed for short periods at the Cliff Creek-Big Creek winter range.

In spring (end of April to early May) the ewes move to suitable lambing areas. The physical characteristics of these areas are similar to those of the summer ranges: steep and almost inaccessible cliff complexes which provide protection from predators. In the Big Creek drainage, several areas are used by sheep to give birth. The distance to the winter range of these lambing areas differs. Some lie immediately adjacent to the winter range, like the cliffs east of Cliff Creek, while others are located over 25 miles southwest of the winter range, e.g., the headwaters of Monumental Creek and Marble Creek. The use of those seasonal home ranges seems to be transmitted from older to younger generations.

After lambing the ewe-lamb groups migrate to their summer ranges and groups from different lambing areas aggregate again. The Cliff Creek-Big Creek winter range is also used as a summer range by some ewe-lamb groups, where they reappear in the beginning of June. During the summer the rams are found on very high elevations.

In late fall both ewes and rams gather together on the winter range on which ranks are established previous to and during the rut in November/December. At this time of the year the highest number of bighorns is observed on the Cliff Creek-Big Creek winter range. By January, mature rams separate again from the ewe groups. The latter prefer to remain on the grassland benches, but will utilize rugged bluffs (if snow covers the benches), with mountain mahogany as a primary winter browse.

The Big Creek drainage is part of the Idaho Department of Fish and Game Region 3, Game Management Unit 26, in which 15 permits for the hunt on legal rams are provided. Legal rams are rams having a 3/4-curl or greater horns or exceeding 4 years of age (Idaho Department of Fish and Game, 1991). During the period 1982-1990, an average of 7 legal rams were harvested; about 50% hunter success (Oldenburg & Turner, 1991).

2 Methods

2.1 Forage utilization

The study was limited to the grassland slopes and benches of the Cliff Creek-Big Creek winter range. On the winter range three habitat types were distinguished: (1) grassland vegetation of bluebunch wheatgrass and cheatgrass, in which cover of the latter was over 50%, (2) vegetation dominated by bluebunch wheatgrass and no cheatgrass, and (3) a grassland vegetation of bluebunch wheatgrass and Idaho fescue, which occured on wetter soils. Sandberg's bluegrass was present in all habitat types in small amounts.

In each habitat type, two permanent plots of 25x25 meter were established: plot 1A and 1B in habitat type 1, plot 2A and 2B in habitat type 2, and 3A and 3B in habitat type 3. On a regular basis, about every 10-14 days, basal cover and height was estimated for four grass species in the plots: bluebunch wheatgrass, cheatgrass, Idaho fescue and Sandberg's bluegrass.
Within the six 25x25 meter plots cover and plant height were measured in 30 subplots of 20x50 centimeter. The subplots were placed at 3 meter intervals along 5 transects, oriented upslope, with transect starting points at random distances apart. The minimum distance apart was 2 meter. Basal cover was determined for green growth in Daubenmire cover classes (Daubenmire, 1959): 0-5%, 5-25%, 25-50%, 50-75%, 75-95% and 95-100%. For plant height an average plant was measured.

In early spring green growth of the vegetation was clipped outside those 25x25 meter plots. Cover and plant height were measured simultaneously at these clipping sites in order to be able to correlate basal cover, plant height and biomass. High correlation coefficients would provide an estimate of biomass based on cover and plant height. With this objective thirty plots of 20x50 centimeter were clipped in each habitat type. Plant cover and plant height were determined as described above. The grasses were separated by species, oven-dried at 70° C and weighted to nearest 0.01 gram.

On each site the proportion of grazed plants was obtained by randomly selecting 50 plants and recording whether they were grazed or ungrazed. This was done for each grass species seperately. To estimate grazed portions of plants, plant height was measured of grazed plants from base to bite marks. Grazed plants were compared with ungrazed plants, on which an estimation was made of the proportion of grazed plants that was removed. To estimate the biomass of those removed portions, weight distribution of the four grass species was determined. Herefore ten plants were clipped of each species outside the selected study sites. Each plant was cut into 2 centimeter lengths, oven-dried at 70° C and weighted to nearest 0.01 gram.

The total number of plants of each species were counted in each plot when the plot was established. This to calculate the total biomass that was available at the start of the sampling. This was done by partitioning the plot in strips and counting the number of plants for each species within each segment. If not all plants could be counted, plant numbers were estimated by counting plants in twenty 20x50 centimeter randomly placed plots across the site.

2.2 Estimating food intake

In order to assess carrying capacity of the winter range, biomass data on available forage on the range should be compared with actual food intake by the ungulates. To determine how much forage is taken by a bighorn sheep per day, three parameters should be measured: bite size, number of bites per unit of time and time spend on feeding per day.

Bite size
Estimating bite size can be accomplished by close observation (telescope) of feeding sheep. The location of a plant that is being eaten, and the number of bites taken from that plant should be noticed. After the sheep has left, eaten plants can be examined on number of sprouts that had been taken. Further, the same amount of a nearby plant of the same species can be clipped, oven-dried and weighted to nearest 0.01 gram. If more bites are taken from one plant, the biomass estimate can be divided by the number of bites taken. This should be done for at least 20 plants per eaten grass species. In this study no estimates of bite size were made.

Bite rate
The number of bites per feeding bout were counted by observing individual sheep. Although feeding was classified as "*head down position only*" in the study plan (Yeo, 1992), an alternative, more practical definition of 'feeding' was used: "*the time spend on feeding without standing or moving for more than 20 seconds at a time*". Thus, the latter category included chewing in head up position and movements between plants, for periods shorter than 20 seconds at a time. Each sheep was observed for a 10 minute period or until it quit feeding.

Number of feeding periods per day
One hour periods of study distributed throughout the daylight hours were randomly selected. One individual sheep was observed and activity, divided in feeding, moving, standing and bedded was recorded. Again most observations (n = 46) were classified as feeding included standing or moving for less than 20 seconds at a time. Only 4 observations were conducted on basis of the definition of feeding by *head down position only*.

2.3 Habitat use

To assess habitat use of the wild ungulates at the winter range, a high-elevated location was chosen from which the entire winter range could be observed. Observations were conducted for a one-hour period at a time. The periods were randomly selected within a given day during daylight hours. If visibility was poor due to weather conditions, a random daylight time was selected for the following day. In total 51 observation periods were conducted. This gave an average of 1 observation per 2.25 days. The observations started on January 14 (1992) and continued until the majority of ungulates had left the winter range on May 9 (1992).

The location, number and activity was recorded for each ungulate species. Five types of activity were distinguished: moving, feeding, bedded, standing and salt lick-feeding. If an animal or group of animals was moving, both first and second location were mapped. When the movement continued movement directions were recorded. Aerial photographs were used to pursue accurate mapping of ungulate locations and movement directions.

2.4 Lamb mortality

In order to gain information on lamb mortality in the summer of 1992, the observed bighorn sheep were classified into ewes and lambs and the ewe:lamb ratio was determined. Sheep observations in lower Big Creek are summarized in Appendix I. Ewe:lamb ratios are given after the date the first lambs were seen.

3 Evaluation of methods and recommendations

3.1 Habitat types

No plots were established in the forest and shrub habitats on the winter range since the sheep were believed to prefer the grassland slopes. Furthermore only three main grassland habitat types (see § 2.1) were studied because time was limited. However, a more specific segmentation of the range will be required to increase accuracy of carying capacity estimates, including all habitat types used by sheep.

In 1991 a study was conducted on the grassland benches and slopes of the winter range to define vegetation types based on plant composition and plant cover values (Goldberg, 1992). This classification of habitat types may be helpful to increase accuracy of carrying capacity estimates. Six vegetation types were identified: vegetation dominated by (1) *Agropyron spicatum*, (2) *Bromus tectorum*, (3) both *Agropyron spicatum* and *Bromus tectorum*, (4) *Poa secunda*, (5) both *Agropyron spicatum* and *Poa pratensis* and (6) *Festuca idahoensis*. A species was considered dominant when it had a cover value of ≥25%, and the difference with the second greatest cover value was ≥5%. The vegetation types with two codominant graminoids (*Agropyron spicatum/Bromus tectorum* and *Agropyron spicatum/Poa pratensis*) were distinguished because the difference in cover was less than 5%. Forbs were not included in the classification of the vegetation types, although cover values of ≥25% for *Balsamorhiza sagittata* were noted.

This method of classification can classify samples in a certain vegetation type, while plant composition and/or plant cover values within this type can vary greatly. For example, samples with little similarity like Goldberg-sample 46 (31.5% *Agropyron spicatum* and 16% *Poa secunda*) and Goldberg-sample 20 (42.5% *Agropyron spicatum*, 13% *Bromus tectorum*, 27.3% *Bromus sagittata* and 6.8% *Festuca idahoensis*) are classified in the ***Agropyron spicatum*-type**, while a sample of 29% *Agropyron spicatum*, 36% *Bromus tectorum*, 29% *Bromus sagittata* and 15% *Poa secunda* (Goldberg-sample 28), is classified in the ***Bromus tectorum*-type,** while it shows high similarity with Goldberg-sample 20. This similarity between samples of different vegetation types is in particular the case with samples in the codominant vegetation types.

For this reason classification of the 53 Goldberg-samples into vegetation types should be conducted on a base of similarity of samples, rather than the "domination rules", as described above. This can be done by running a clustering analysis, which can be visualized by means of a dendrogram. Figure 4 shows a dendrogram for the data of Goldberg.

Similarity was calculated by the Quantitative Sorenson Index (Schaffers, 1992):

Percentage Similarity = $(2 * \sum \min(a,b)/(\sum A + \sum B)) * 100\%$

with:	$\sum \min(a,b)$	=	sum of each smallest corresponding value for each variable, between sample A and B
	$\sum A$	=	sum values of variables of sample A
	$\sum B$	=	sum values of variables of sample B

Clustering was established by Average Linkage Cluster Analysis. Herefore the cover percentages were translated into 10 cover classes; 1-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90% and 90-100%.

The number of vegetation types distinguished depends on the level of accuracy needed and the objectives of the clustering. For this study six clusters or vegetation types have been distinguished, with a similarity >60% within each cluster (figure 4). For each cluster the average minimum and maximum cover percentages by species was calculated.

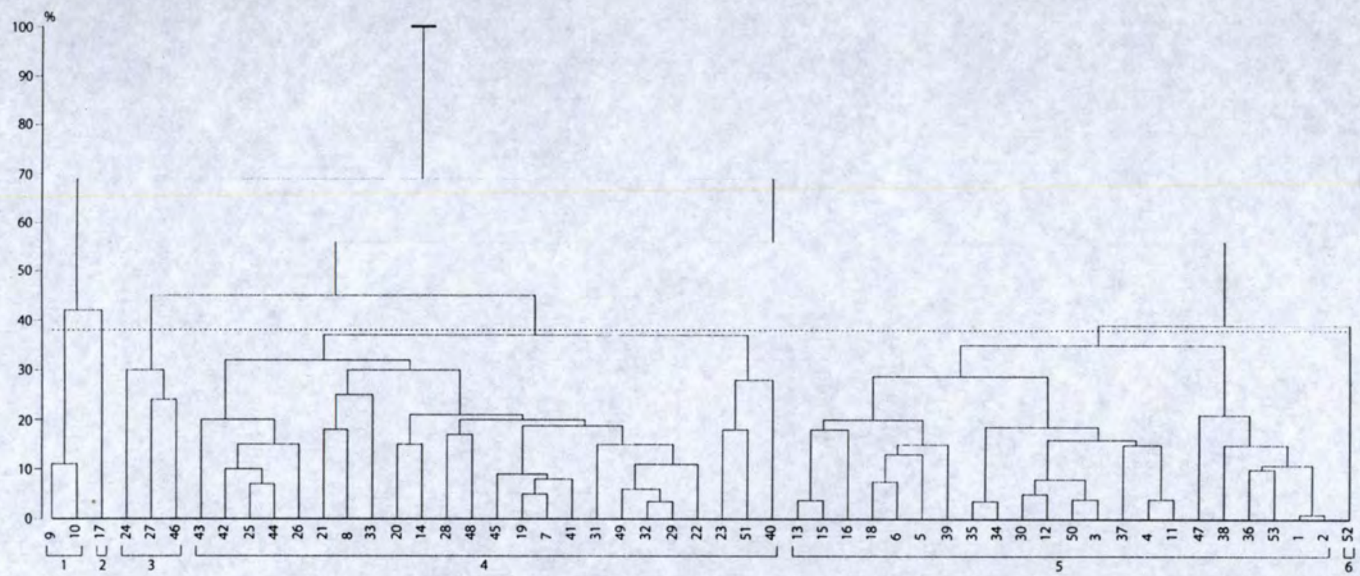

Figure 4 Dendrogram which visualises dissimilarity between the Goldberg vegetation samples, obtained at the grassland slopes and benches of the Big Creek winter range. Percentage of dissimilarity is projected on the y-ax. On the x-ax: sample numbers and distinguished vegetation types (1-6). For further explanation: see text.

A description of species composition of the clusters and geographical location of the samples (see also figure 2):

Cluster 1 (2 samples) represents a vegetation in which both *Festuca idahoensis* and *Bromus sagittata* cover 30-40% of the area, while *Agropyron spicatum*-cover is less than 10%. The samples were taken on the slope, east of and above the third bench, halfway to the ridge.

Cluster 2 (1 sample) is a vegetation type in which *Bromus sagittata* dominates (40-50%), accompanied by *Agropyron spicatum* (10-20%) and *Bromus tectorum* (1-10%). The sample was taken on the west side of the third bench.

Cluster 3 (3 samples) consists of samples in which *Agropyron spicatum* and *Poa secunda* codominate, respectively 23-33% and 20-30%. *Bromus sagittata* occurs with cover percentages less than 10%. The location of the samples is discontinous over the winter range; sample 40 on the slope down from the second bench into Cliff Creek, sample 24 on the slope above the East Knob, close to the ridge, and sample 27 on the slope east of and above the second bench but below East Knob.

Cluster 4 contains most samples (24). It is the vegetation type with highest cover percentages of *Agropyron spicatum* (35-45%). *Bromus tectorum* is present (15-23%) just as *Bromus sagittata* (12-20%). *Poa secunda*, *Poa pratensis,* and *Festuca idahoensis* occur in small amounts; respectively <5%, <8%, and <2% cover. This vegetation type covers most of the winter range. It occurs on the third bench, on the slope from the third bench into Cliff Creek, on the East Knob and on the slope just below the East Knob, on the high parts of the second bench, from the second bench down into Cliff Creek, on the little knob east of the second bench, on the slope between the second and the first bench, and parts of the slope from the first bench into Cliff Creek.

Cluster 5 is a group of 22 samples with very high cover percentages of *Bromus tectorum* (54-64%), occuring on heavily grazed parts of the winter range. Cover by *Agropyron spicatum* is reduced to 15-24%. *Bromus sagittata* covers 8-13%. *Poa secunda*, *Poa pratensis,* and *Festuca idahoensis* can be found in small amounts, respectively <3%, <1%, and <1% cover. Spatial seggregation of this vegetation type is distinct. It occurs on the first, second and third bench. Also on the slope above the third bench, west of vegetation type 1, and on the slopes below the first bench; down to the Lower Pasture and down to the Big Creek Bridge.

Cluster 6 exists of 1 exceptional sample, located on the first bench, and chracterized by high abundance of *Bromus tectorum* and *Poa secunda* (both 40-50%), while *Agropyron spicatum* covers no more than 10-20%.

Some additional remarks:

- The ecological value of distinguishing vegetation types based on just one sample (cluster 2 and 6) is questionable, because of their very limited occurence on the winter range. However, knowledge about those exceptional spots could be importantto understand animal behavior or habitat use. Accurate mapping of even those small but (possibly) important vegetation types is therefore recommendable.

- Goldberg (1992) did not detect the vegetation type in which *Festuca idahoensis* is dominant on the East Knob, although this type covers great parts of that knob. That is why additional sampling on the grassland part of the winter range seems necessary. Especially the slope above the third bench, the third bench itself, the East Knob and the slopes above and below the East Knob.

- Only six dominant species (5 graminoids and 1 forb), were used for the classification of vegetation types, since the Goldberg-data were not fully available. For classification the samples should preferably include all plant species. Not to include pinegrass (*Calamagrostis rubescens*) in the analyses at all seems odd, since it is quite abundant at high elevations on the winter range.

- Classification of vegetation types should be extended to the whole winter range, including forest communities and shrub vegetation, that occur on very steep slopes and rough bluffs.

- The distinguished habitat types should be mapped for the whole winter range. This way positions of observed bighorns can directly be related to habitat types.

3.2 The plots

When more habitat types are distinguished the number of plots will have to increase. For this study sampling was done in one plot of 625 m^2, with one replicate of the same size for each habitat type. For several reasons it is recommendable to decrease plot size and increase plot number:

- With more replicates, the research gains more statistical power.
- With a reduced plot size it will be easier to establish plots in a homogenous vegetation.

Testing for adequate plot size in the study area is usually a prerequisite. The size of the sample plot depends largely on the type of vegetation and the homogeneity of the plant community (Petrak, 1990). A plot size of 40 m^2 should meet the requirements for grasslands, 160 m^2 is suggested for shrub vegetations (Vos & Mosby, 1971). However, all plots should be equal in size in the study for carrying capacity, to ascertain comparability. This way, minimum plot size should be based on the requirements for shrub vegetations. Although plots may be established in forest communities, it is the herb and shrub layer that is of interest. Thus plot size should be based on the undergrowth as described above.

For herbaceous and shrub vegetation with limited plant heigths, a circular plot has distinct advantages (Vos & Mosby, 1971; De Bie & Van de Veen, 1990):

- In a circular plot the edge influence is maximal minimized.
- Circles can be quickly and accurately marked in the field (one stake is sufficient for each plot in contrast to quadrats, no use of compass azimuths in contrast to transects).

The location of the plots was based on representativeness of vegetation types. For statistical analyses, random assessment of plot sites might be considered.
Permanent subplots of 20x50 centimeter within each site are not a premium to obtain the data desired for estimating forage availability. However, it provides information about the development and decay of individual plants, which can be useful in studies on species composition trends and interspecific competition (see § 1.1). That is why established subplots should be maintained. Except cover and plant heigth by species, it is useful to determine the number of rooted plants in each plot. This way the data may point out changes better, or detect differences more accurate between two samplings. For the same reason the subplots could be mapped, however, that will take a lot of time.

3.3 Plant cover

Plant cover measurements can be executed in several ways. Cover can be classified as *canopy cover*, defined as the vertical projection of above ground parts onto the ground (Greig-Smith, 1957), or *basal cover*, defined as the proportion of ground surface occupied by plants (Greig-Smith, 1957). In this study cover percentages were based on basal cover (see appendix II). While basal cover measurements can be obtained with better accuracy, canopy cover reflect fluctuations in vegetation due to environmental factors (i.e., precipitation, grazing, etc.) more exact and thus provides a better parameter to correlate with available biomass.

The estimations of plant cover in 20x50 cm plots, using Daubenmire cover-classes comprises some level of subjectivity by field technicians. That was why another method was tested at the winter range: the Point Quadrat (PQ) method. In this method an estimation of canopy cover is obtained by lowering a certain number of pins vertically in the vegetation. If a plant is touched it will be recorded by species. The total number a plant species is hit, divided by the total number of pins that is lowered within the plot will give the cover percentage for the plot. This method is less subjective and it will provide comparative cover percentages to validate the Daubenmire-estimations. However, as mentioned above, basal cover instead of canopy cover was obtained by means of the 20x50 cm "Daubenmire" plots, so that no comparison of results can be made.

The number of pins used in the PQ-method is dependent on plot size, vegetation type and homogeneity of the vegetation within the plots. In plot 2A, the PQ-method was tested for the number of pins that should be used to obtain representative data (figure 5). In plot 1A and 1B, 3A and 3B, the method was applied to see if changes in canopy cover could be determined. A PQ-frame with 10 pins, 10 cm apart from each other, was systematicly placed across the plots along six transects, 10 frames per transect. In each plot cover percentages were assessed twice, seperated by a two-weeks interval (table 2).

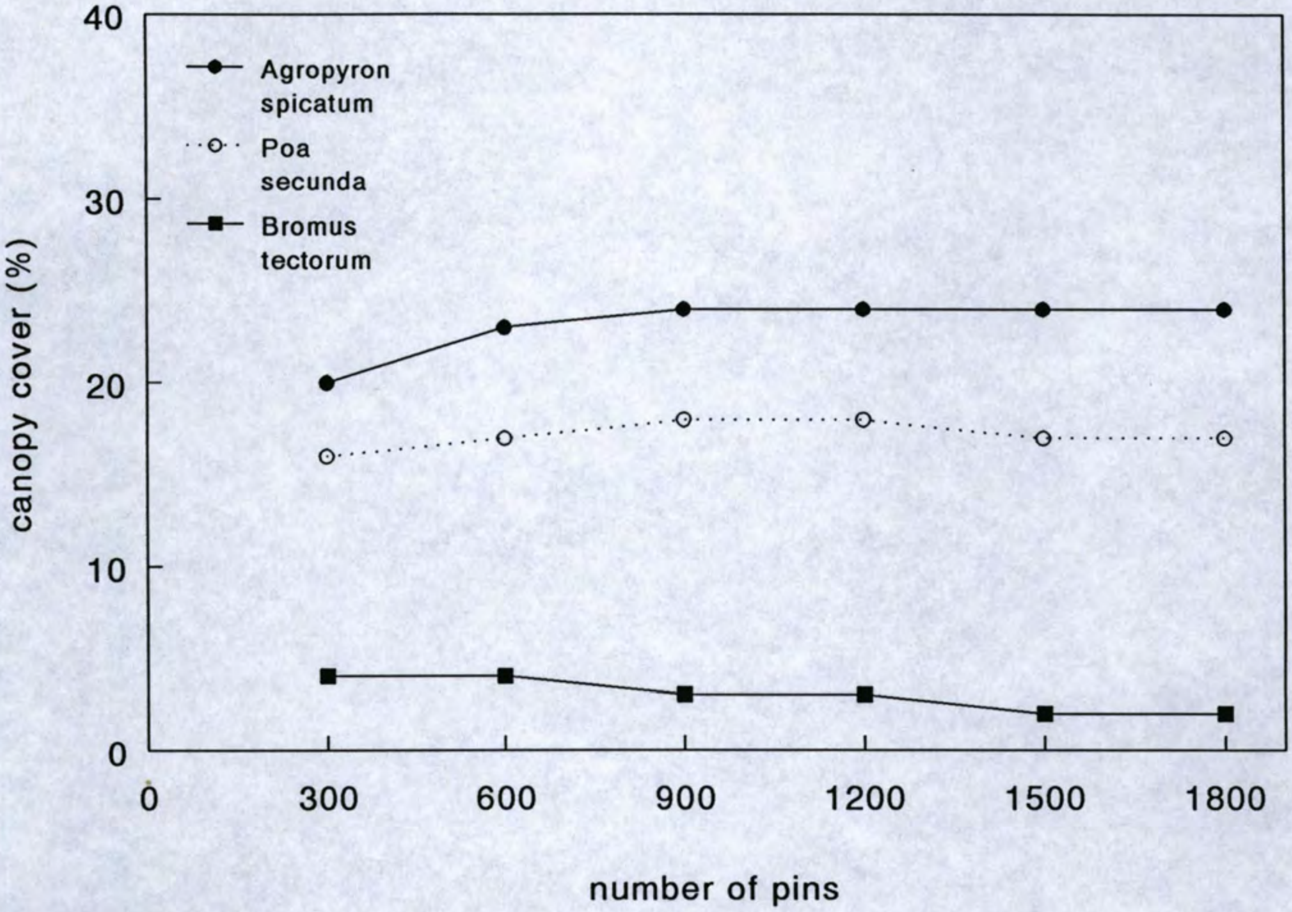

Figure 5 Canopy cover of *Agropyron spicatum, Poa secunda* and *Bromus tectorum* in plot 2B (2 April 1992), in relation to total number of pins used in the Point Quadrat method.

Table 2 Canopy cover of *Agropyron spicatum*, *Poa secunda*, *Festuca idahoensis* and *Bromus tectorum* in plot 1A, 1B, 3A and 3B.

PLOT	SPECIES	DATE			
		4-22	4-23	5-4	5-6
1A	*Agropyron spicatum*		11	10	
	Poa secunda		2	1	
	Bromus tectorum		19	25	
1B	*Agropyron spicatum*		18	26	
	Poa secunda		2	2	
	Bromus tectorum		21	28	
3A	*Agropyron spicatum*	20			25
	Poa secunda	12			4
	Festuca idahoensis	24			24
	Bromus tectorum	<1			2
3B	*Agropyron spicatum*	9			11
	Poa secunda	20			6
	Festuca idahoensis	24			26
	Bromus tectorum	<1			<1

Figure 5 shows a high stability of the measurements already by the use of 600 pins across the plot. Dependent on desired level of accuracy this number may eventually be reduced, since even estimations acquired by 300 pins do not differ too much from the estimations acquired with 1800 pins. Establishing smaller plots, as suggested in paragraph 3.2, will self-evidently require less number of pins.

According to table 2, *Agropyron spicatum* remains about constant in plot 1A and 3B, and increases somewhat in plot 1B and 3A. Cover percentages of *Bromus tectorum* increase both in plot 1A and 1B, while the species occurs in just very low amounts in plot 3A and 3B. Low amounts of *Poa secunda* were found in 1A and 1B, while a substantial decrease in cover is mentioned in plot 3A and 3B. The explanation of this decrease is the confusion of *Poa secunda* with *Calamagrostis rubescens* by identification; not until the second sampling *Calamagrostis rubescens* could be easily distinguished from *Poa secunda*. Cover percentages of the first sampling represent both grassland species. *Festuca idahoensis* shows no change in cover in plot 3A, a little increase in plot 3B.

With exclusion of *Poa secunda* in plot 3A and 3B the overall picture is that of cover percentages which remain constant or slightly increase. The significance of an increased cover percentage within a vegetation type is hard to test, because the differences are small and each plot has just one replicate. Again reason to use more replicates, if small changes in the vegetation should be detected, no matter which method is applied in obtaining cover percentages.

3.4 Biomass

Data of available biomass in relation to plant cover (appendix II) and plant height (appendix III) is summarized in table 3. Plant height was classified into 5 height classes: 1 = 0-5 cm; 2 = 5-10 cm; 3 = 10-25 cm; 4 = 25-50 cm; 5 = >50 cm.

Table 3 Biomass (gram dry matter per 0.1 m^2) and standard deviation (sd) of *Agropyron spicatum, Poa secunda, Festuca idahoensis* and *Bromus tectorum* in relation to basal plant cover (Daubenmire) and plant height. Number of samples between brackets.

SPECIES	COVER (%)	HEIGHT			
		0-5 CM	**5-10 CM**	**10-25 CM**	**25-50 CM**
Agropyron spicatum	0-5	0.18 (2) sd=0.19	0.35 (7) sd=0.13	0.55 (5) sd=0.40	-
	5-25	-	0.91 (5) sd=0.58	1.86 (13) sd=0.73	3.14 (2) sd=0.82
	25-50	-	-	3.91 (2) sd=2.16	9.38 (2) sd=1.78
Poa secunda	0-5	0.21 (13) sd=0.13	0.39 (10) sd=0.26	-	-
	5-25	0.44 (5) sd=0.26	0.44 (4) sd=0.16	-	-
	25-50	-	0.10 (1) -	-	-
Festuca idahoensis	0-5	0.41 (1) -	0.23 (1) -	-	-
	5-25	1.31 (13) sd=0.54	1.16 (9) sd=0.41	1.51 (1) -	-
	25-50	2.16 (1) -	2.08 (4) sd=0.41	-	-
Bromus tectorum	0-5	1.17 (14) sd=1.10	-	-	-
	5-25	1.02 (13) sd=0.58	1.28 (1) -	-	-
	25-50	0.53 (1) -	2.42 (1) -	-	-

Plants of height class 5 were not found. Neither were plants with a cover within Daubenmire cover classes 4, 5 or 6.

Regression analysis were runned for biomass by plant height and species, split by cover class. Variation is high what results in generally low regression coefficients as shown in table 4. Although r^2 has high values for *Agropyron spicatum* in cover class 3, this is based on just four samples. The only regression which results in a high r^2-value and significance of the model ($p<0.01$) with a sufficient number of samples is found for *Agropyron spicatum* in cover class 2 (figure 6).

Table 4 Regression coefficients (r^2) and p-values for regression analysis of biomass by plant height, split by species and cover.

SPECIES	COVER (%)	N	R^2	P
Agropyron spicatum	0-5	14	0.40	<0.01
	5-25	20	0.72	<0.00
	25-50	4	0.99	<0.01
Poa secunda	0-5	23	0.06	0.13
	5-25	9	0.06	0.87
	25-50	1	-	-
Festuca idahoensis	0-5	2	-	-
	5-25	23	0	0.99
	25-50	5	0	0.62
Bromus tectorum	0-5	14	0	0.45
	5-25	14	0.21	0.06
	25-50	2	-	-

It is likely the large range of plant heights for *Agropyron spicatum*, that enables a fitting regression between biomass and plant height. This in contrast with the other graminoids which remain all small in size. Biomass of the small grassland species can only be related to plant cover. With a maximum of just three cover values, however, regression analysis of biomass related to cover is not useful. The following contradiction occurs: a better predictive model needs a large number of cover classes, but a large number of cover classes makes the method of estimating cover by eye in 20x50 cm plots more sensitive to subjectivity and errors by the field technician. Altough more time consuming, use of the PQ-method to determine cover might be preferable, at least in establishing the model. Instead of clipping once, as conducted in this study, regressions should be obtained for each period that data is collected about plant cover and plant height on the sites.

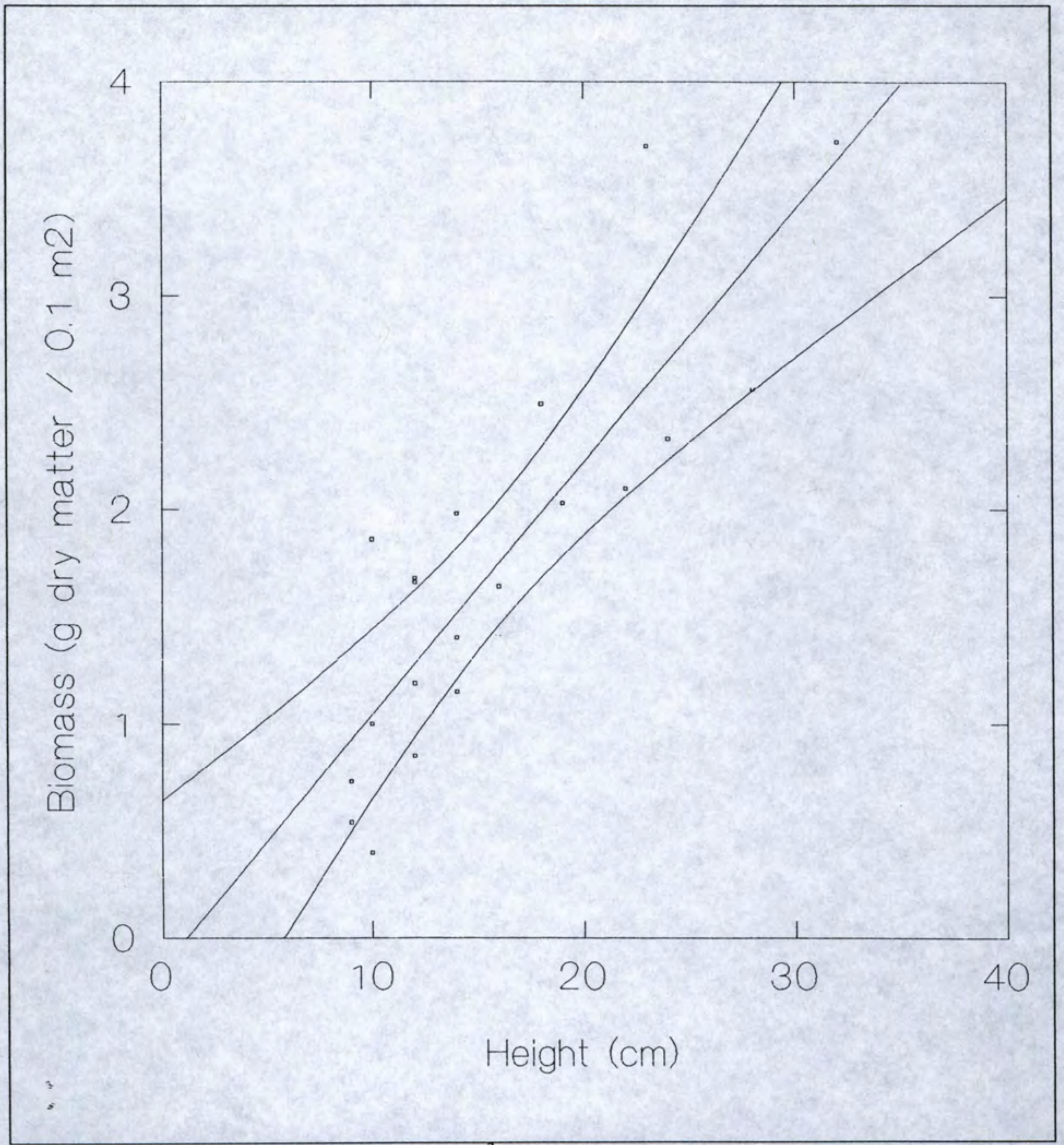

Figure 6 Regression of biomass (gram dry matter/0.1 m^2) by plant height (cm) of *Agropyron spicatum* for cover class 2. 95%-confidence interval is shown. Regression model: $y = 0.12x - 0.13$.

3.5 Weight distribution in plants

Figure 7 shows the cumulative weight for the four grassland species as determined by clipping of 10 plants for each species. Because of high variation in height and biomass between plants of the same species, the number of plants for this model should be increased considerably. This is in particular the case for *Agropyron spicatum*, which basal size varies considerably, but might be equal in average height. To divide the plant species into several size classes, variation will be reduced.

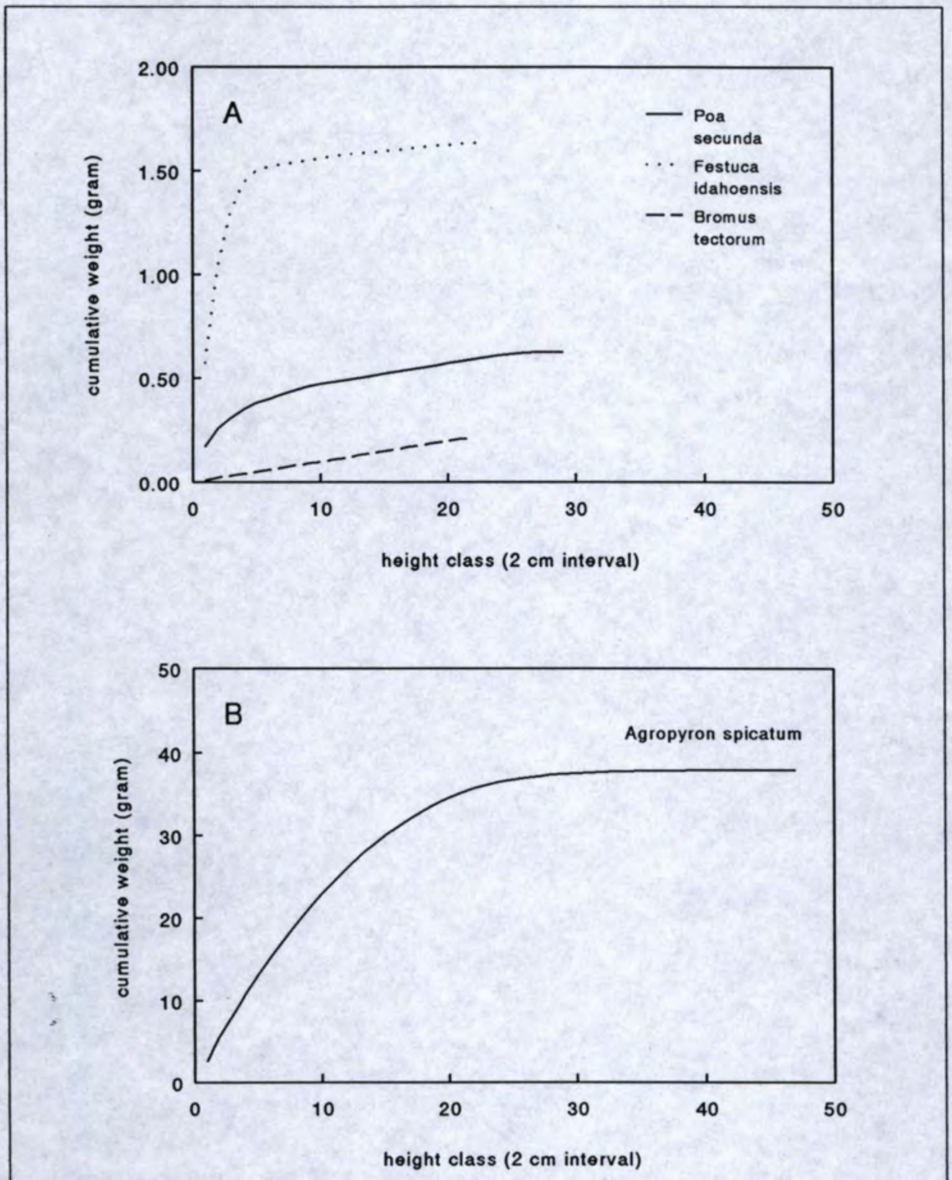

Figure 7 Weight distribution for *Agropyron spicatum, Poa secunda, Festuca idahoensis* and *Bromus tectorum* of plants clipped in winter (respectively 8 February, 8 February, 13 March and 29 January 1992).

3.6 Grazing ratio

Percentage grazed plants is shown in table 5. Figure 8 shows the percentage of plant material that was taken above the average bite mark hight. A few remarks can be made:

- To assess the amount of biomass that is taken between each time interval, one parameter is missing: no average hight was determined for *un*grazed plants.
- Another method of selecting plants to inspect on grazing should be used, since large plants and ungrazed plants will be in favor when plants are randomly selected by eye. Randomly throwing a 20x50 cm frame in the vegetation and inspecting all plants within the frame might be an alternative.
- Except for *Agropyron spicatum* on plots 2A and 2B, no significant changes in the proportion of grazed plants was measured. This may be partly caused by high initial levels of grazing at the beginning of the study in January. A better insight in biomass removal will be achieved if measurements are started at the end of summer when standing crop is high, and just before the animals return to the range in fall.

Table 5 Percentage grazed plants of *Agropyron spicatum, Poa secunda, Festuca idahoensis* and *Bromus tectorum* by plot by date (1 = 13 January and 15 January; 2 = 27 January and 28 January; 3 = 10 February; 4 = 24 February and 27 February; 5 = 9 March 1992).

PLOT	SPECIES	%-GRAZED				
		1	**2**	**3**	**4**	**5**
1A	*Agropyron spicatum*	98	100	100	100	98
	Poa secunda	40	46	44	38	66
	Bromus tectorum	8	8	8	8	8
1B	*Agropyron spicatum*	100	100	96	100	100
	Poa secunda	-	42	48	48	48
	Bromus tectorum	10	12	6	6	16
2A	*Agropyron spicatum*	78	84	90	98	96
	Poa secunda	34	60	52	36	44
	Bromus tectorum	14	8	8	8	4
2B	*Agropyron spicatum*	78	86	92	96	96
	Poa secunda	20	50	32	38	40
	Bromus tectorum	-	12	-	8	4
3A	*Agropyron spicatum*	-	-	-	100	100
	Poa secunda	-	-	-	36	42
	Festuca idahoensis	-	-	-	62	48
	Bromus tectorum	-	-	-	-	8

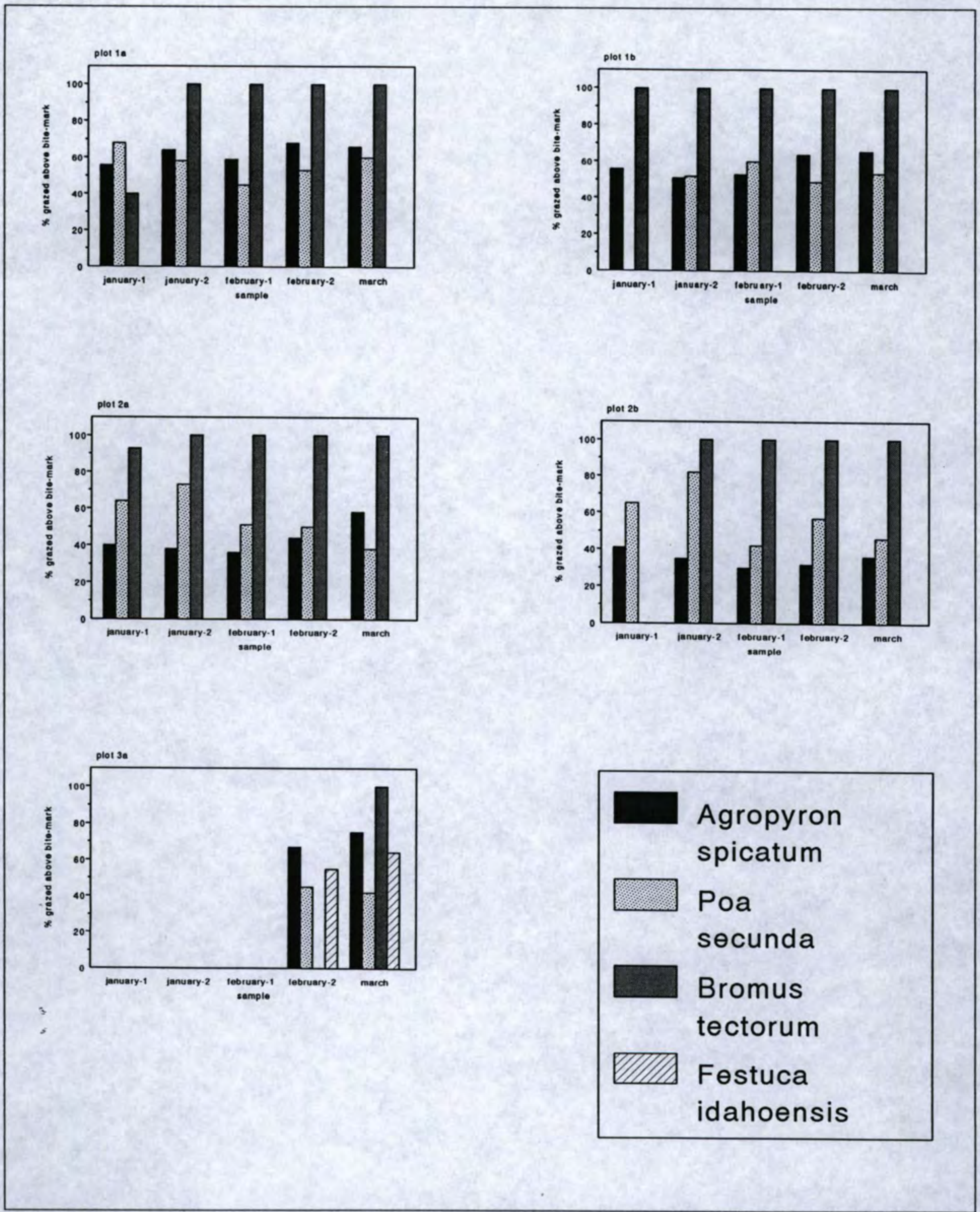

Figure 8 Percentage of sprouts grazed for *Agropyron spicatum, Poa secunda, Festuca idahoensis* and *Bromus tectorum* by plot and date (January-1 = 13 January and 15 January; January-2 = 27 January and 28 January; February-1 = 10 February; February-2 = 24 February and 27 February; March = 9 March 1992).

3.7 Food intake

In literature the method of simulating bites by clipping nearby vegetation is often encountered, e.g., bite size estimates for free ranging cattle (Vulink & Drost, 1991a and 1991b), mule deer (Yeo, 1981; Hobbs et al., 1983), elk (Hobbs, 1979; Hobbs et al., 1983) and bighorn sheep (Goodson et al., 1991a and 1991b; Cook, 1990; Hobbs et al., 1983).
However, this method is hard to apply on the Big Creek winter range. One deals with wild, free ranging animals, which implies that observations can only be done from a distance, supported by binocular and spotting scope to avoid disturbance. A second disadvantage is the high grazing intensity on the winter range, which makes it difficult to distinguish between what was taken at a certain time and what had previously been grazed from the plant, even if a plant could have been identified and the number of bites taken is known. However, alternatives are hard to find since the study area is located in designated a Wilderness Area, in which use of enclosures, exclosures or any permanent structure or installation is prohibited (Hendee et al., 1990). It is questionable if free ranging, tame bighorn sheep (possibly fistulated) should be defined as "livestock", mentioned in the Wilderness Act of 1964.

An incompatibility of data is achieved by using two classifications of "feeding"; *head down position only* and *no behavior change within 20 seconds*. The reason for changing the definition to the latter was the difficulty of remaining accurate in recording feeding bouts since *head down positions* were diverted into numerous 2 to 5 second breaks.
Instead of recording number of feeding bouts per hour and the duration of each feeding bout, it may be much better to measure just the total time the observed sheep spend on actual feeding per observation hour, with the more clear and well-defined *head down position only* as definition. This can easily be achieved by using a stopwatch that is started by first feeding behavior of the sheep, interrupted when the animal moves his head up, and restarted if feeding is continued.

When an individual sheep within a group is observed, tracking the animal for an hour is not always easy. Especially if the group is temporarily disturbed or alarmed by something in their surroundings, it is hard to keep an eye on "your" sheep. That is why sheep with a radio-collar were selected for the observation if present in the group. It would be recommendable to mark more sheep for individual identification, for instance by collars of different colors, even if no radio-transmitter is attached. This will provide the opportunity to get better knowledge about size and dynamics of the population, differences in feeding behavior of individual sheep and will result in less errors by observers in obtaining data about food intake (Prins & Bokdam, 1990).
An alternative: don't focus on individual sheep, but scan e.g. every ten minutes the whole group for number of heads down and number of heads up.

Table 6 Number of bites per minute, number of feeding bouts per hour, and mean duration of a feeding bout for feeding classified as *head down position only* and classified as *including head up position or moving for less than 20 seconds*. For each parameter standard deviations are given; N = number of observations.

feeding definition	**feeding bouts per hour**		**duration feeding bout (min:sec)**		**bites per minute**	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**
head down position only	20.0 (N=4)	±14.3	1:27 (N=80)	±1:47	37.8 (N=7)	±3.2
no change in behavior within 20 seconds	2.7 (N=46)	±2.3	14:34 (N=82)	±15:35	28.3 (N=30)	±9.0

Table 6 summarizes the number of bites per minute, number of feeding bouts per hour, and mean duration of a feeding bout. If a sheep was not observed for the full hour, the observation is not used in determining the number of feeding bouts per hour and mean duration of a feeding bout. Standard deviations for number of feeding bouts per hour and duration of feeding bout are high. Less variation can probably be obtained by dividing the data in phenological periods (Petrak, 1990; Van de Veen, 1979). Changes in feeding behavior due to changes in the phenological phases of the forage plants, and thus a quantitative and/or qualitative change in forage, will be detected and if analysed seperately variation may be reduced. Data of this study period (January-May) should be divided in a late-winter period, when only dead plant parts are available, and a early-spring period, starting when the first green growth of grasses occurs. By recognizing phenological periods throughout the year, a better understanding of seasonal variation in habitat use, food preference and food intake rate can be achieved (Goodson et al., 1991b).

In an efford to reduce variation, collected data can also be related to factors that impact feeding behavior, like habitat type, including vegetation type, aspect, steepness, visibility, etc. (Risenhoover & Bailey, 1985), group size (Warrick & Krausman, 1987), and wheather conditions (Goodson et al., 1991a).

3.8 Habitat use

Not every part of the winter range is equally used by bighorn sheep. That is why carrying capacity should be related to the habitat use of the sheep, including their preference for specific habitat types used for feeding. Observations should provide us the following information:

1. Which sites on the winter range are used by the sheep.
2. What is their preference for each site, based on percentage of time spend on a particular site.
3. What is their activity pattern for each site.
4. Is there a temporal change in this preference and/or activity pattern.
5. Is there an overlap in range use with elk or mule deer, and to what extent.

Some remarks about the effectiveness of the used observation method in gaining this information:

Add 1: The observation look-out point is well located in obtaining habitat use data of ungulates over the whole winter range. However, it has to be considered that vegetation has great influence on the visibility and thus the ability to detect the animals (Putman, 1990). Visibility in the forested parts of the winter range is almost zero. Despite the fact that those vegetation types are less important in assessing carrying capacity for bighorn sheep, since sheep prefer and spend most time in habitats with high visibility (Geist, 1971; Risenhoover & Bailey, 1985; Cook, 1990), use of a radio-telemetry system will be a necessity. This in particular when the study will be expanded to the whole lower Big Creek drainage. The number of sheep equiped with radio-transmitter collars, should be as high as possible to gain a sample size that is representative for the whole population.

Add 2: When animals moved during the observation, only the first and second location were recorded, or if the movement continued, the direction of the movement. To get more accurate insight in preference for each site, the exact times the animals spend at different locations should be recorded, as well as the duration of the movement.

Add 3: Activity patterns should be quantified for the observation hour. This can be done by determining activity of all animals in the group at regular time intervals. Additional information about sheep ecology can be obtained if this is done by sexe and age; rams, ewes, yearlings and lambs.

Add 4: Observations to assess habitat use should comprise several years in order to distinguish significant preference patterns from yearly fluctuations due to environmental factors, e.g., weather conditions and amount of accumulated snow.

Add 5: All above described remarks apply to both habitat use of sheep and habitat use of elk and mule deer, so that proper analysis of habitat overlap can be made.

Suggestions for data analysis.

Based on data about plant communities and vegetation structure, the winter range should be divided into a certain number of vegetation types (see § 3.1).
For the whole winter range, all vegetation types together, the average number of individuals that are present at the range during an average hour (U) will be calculated for each species:

$$U = \sum N_i/n$$

where N_i = number of individuals observed during observation hour i
n = total number of observation hours

Also for each single vegetation type this parameter will be calculated, resulting in an U_1, U_2......U_x, for vegetation type 1 to x. If animals do not select their habitat (in other words: show no habitat preference), it is expected habitat use is related to the cover percentages of each specific vegetation type. This results in an availability value (A) for each vegetation type by:

$$A_x = U * (PC_x/100)$$

where PC_x = percentage of area covered by vegetationtype x

An index for habitat preference (I) will be obtained by:

$$I_x = (U_x - A_x)/(U_x + A_x)$$

which result in an index between -1 and 1, whereby habitat preference occur if $I_x>0$, habitat avoidance occur if $I_x<0$, and no preference or avoidance is determined if $I_x=0$.
While habitat *preference* could be equal for different ungulates (when $I_{x1} = I_{x2}$), the *intensity* of habitat use may be different because of a difference in absolute numbers of individuals that use the winter range. This will be expressed by the parameter Percentage Overlap (PO). In literature several formulaes for calculating percentage overlap can be found. This parameter can be useful to reveal answers to specific ecological questions when activity patterns of the animals are taken into account. Multiplying the PO by the fraction of time an animal showed a specific activity pattern (e.g., feeding, bedded) will acquire more insight in the ecological consequences of the overlap.

To visualize temporal changes in habitat use, graphics should be made of observed animal densities by date for each vegetation type. Because no accurate mapping of vegetationtypes on the winter range is yet accomplished, the observation data is tabulated by topographical sites (Appendix IV; see also figure 2). Total number of individuals per ungulate species observed at each site, and demonstrated activity (in percentages) are shown. In case two locations are recorded for an animal or animal group due to movement during the observation hour, the assumption is made that half an hour was spend on each location, which implies that the recorded number of individuals devided by two will offer the actual number of individuals for the observation hour at those locations.

Noteworthy is that about 75% of the sheep observations were within the topographical sites where the permanent plots were established (1st bench, 2nd bench, above 3rd bench, East Knob and below 1st bench). In total 1003 bighorn sheep, 223 mule deer and 285 elk observations were recorded at the winter range during the study period. Highest number of sheep, observed during one hour was 55 (3/8 1992). Figure 9 shows the presence of the three ungulates at the whole winter range during the study period.

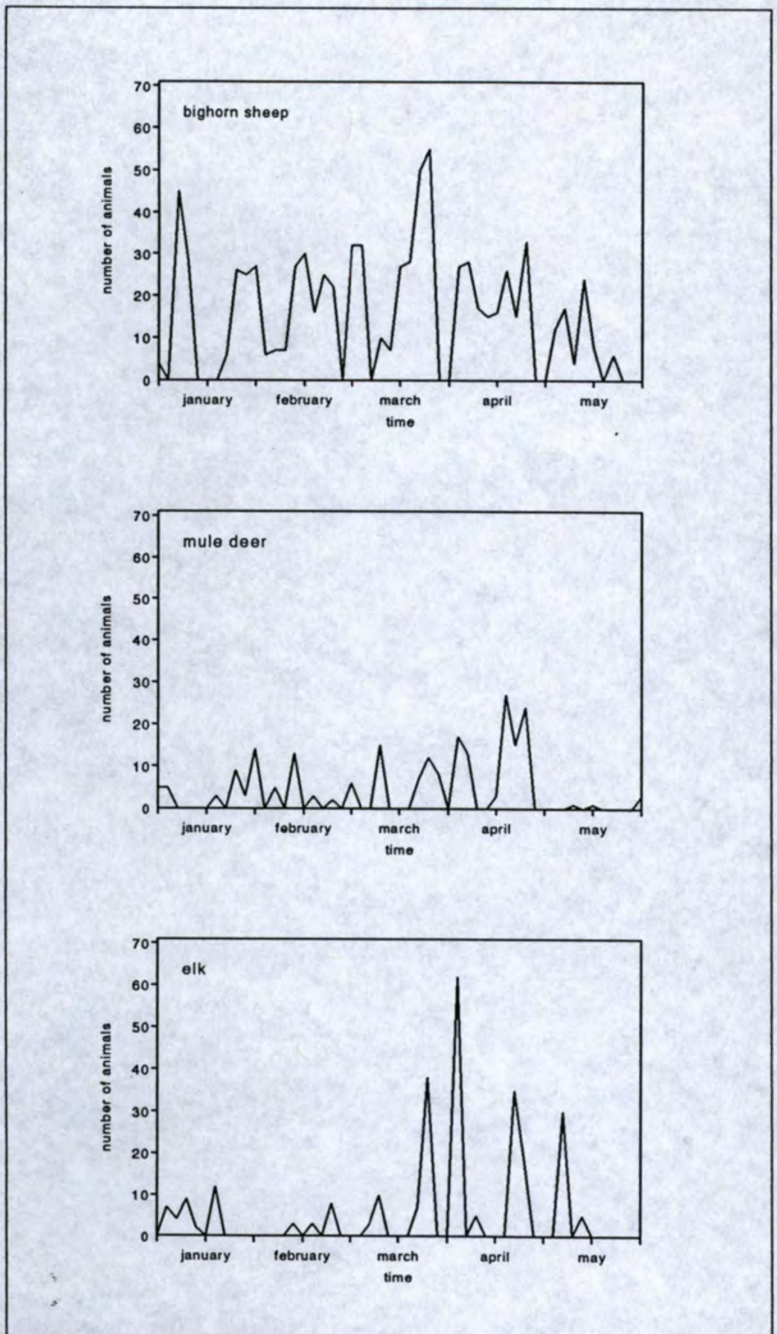

Figure 9 Temporal changes in observed number of bighorn sheep, elk and mule deer at the winter range, January-May 1992.

LITERATURE

Akenson, J. and H. Akenson, 1991. Herd composition and movements in lambing areas and summer ranges of Big Creek sheep in central Idaho. Idaho Department of Fish and Game. Internal Report, 1-28.

Anderson, L.D. and J.W. Denton, 1978. Determining forage consumption rates for big game. Bureau of Land Management, Salmon, Idaho, 1-5.

Bie, S. de, and H.E. van de Veen, 1990. Assessment of browse supply and browse consumption: Discussion: 64-72. In: Groot-Bruinderink, G.W.T.A. and S.E. van Wieren (eds), 1990. Methods for the study of large mammals in forest ecosystems. Proceedings of a workshop organized by the Research Institute for Nature Management, Arnhem, Netherlands.

Buechner, H.K., 1960. The bighorn sheep in the United States, its past, present and future. Wildlife Monograph 4: 1-174.

Cook, J.G., 1990. Habitat, nutrition, and population ecology of two transplanted bighorn sheep populations in southcentral Wyoming. University of Wyoming, Laramie, 1-310.

Daubenmire, R.F., 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43-64.

Dyke, W.A. van, A. Sands, J. Yoakum, A. Polenz and J. Blaisdell, 1983. Wildlife habitats in managed rangelands - The Great Basin of southeastern Oregon; Bighorn sheep. General Technical Report PNW-159: 1-37.

Festa-Bianchet, M., 1989. Survival of male bighorn sheep in southwestern Alberta. Journal of Wildlife Management 53 (1): 259-263.

Flueck, W.T., 1991. Whole blood selenium levels and glutathione peroxidase activity in erythrocytes of black-tailed deer. Journal of Wildlife Management 55 (1): 26-31.

Geist, V., 1971. Mountain sheep: A study in behavior and evolution. The University of Chicago Press, Chicago, 1-383.

Goldberg, G., 1992. Plant community delineation on a bighorn winter range. Wilderness Research Center. University of Idaho.

Goodson, N.J., D.R. Stevens and J.A. Bailey, 1991(a). Effects of snow on foraging ecology and nutrition of bighorn sheep. Journal of Wildlife Management 55 (2): 214-222.

Goodson, N.J., D.R. Stevens and J.A. Bailey, 1991(b). Winter-spring foraging ecology and nutrition of bighorn sheep on montane ranges. Journal of Wildlife Management 55 (3): 422-433.

Greig-Smith, P., 1957. Quantitative plant ecology. Academic Press, New York, 1-198.

Hendee, J.C., G.H. Stankey and R.C. Lucas, 1990. Wilderness Management. Second edition. 1-546.

Hobbs, N.T., 1979. Winter diet quality and nutritional status of elk in the upper montane zone, Colorado. Ph.D.Thesis, Colorado State University, Fort Collins, 1-131.

Hobbs, N.T., D.L. Baker and R.B. Gill, 1983. Comparative nutritional ecology of montane ungulates during winter. Journal of Wildlife Management 47 (1): 1-16.

Hornocker, M.G., 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildlife Monograph 21: 1-39.

Idaho Department of Fish and Game, 1991. Controlled hunt regulations - For moose, bighorn sheep and mountain goat. 1-31.

Krausman, P.R., B.D. Leopold, R.F. Seegmiller and S.G. Torres, 1989. Relationships between desert bighorn sheep and habitat in western Arizona. Wildlife Monograph 102: 1-66.

Manville, R.H., 1990. The origin and relationships of American Wild Sheep: 1-6. In: Monson, G. and L. Sumner (eds), 1990. The desert bighorn – It's life history, ecology and management. The University of Arizona Press, Tucson, Arizona.

Oldenburg, L.E. and J. Turner, 1991. Statewide surveys and inventory - Bighorn sheep. Idaho Department of Fish and Game, 1-83.

Petrak, M., 1990. Habitat use as assessed by vegetation survey: 10-19. In: Groot-Bruinderink, G.W.T.A. and S.E. van Wieren (eds), 1990. Methods for the study of large mammals in forest ecosystems. Proceedings of a workshop organized by the Research Institute for Nature Management, Arnhem, Netherlands.

Prins, H.H.T. and J. Bokdam, 1990. Habitat use of wild ungulates - Discussion: 36-43. In: Groot-Bruinderink, G.W.T.A. and S.E. van Wieren (eds), 1990. Methods for the study of large mammals in forest ecosystems. Proceedings of a workshop organized by the Research Institute for Nature Management, Arnhem, Netherlands.

Putman, R.J., 1990. Patterns of habitat use: an analysis of the available methods: 22-31. In: Groot-Bruinderink, G.W.T.A. and S.E. van Wieren (eds), 1990. Methods for the study of large mammals in forest ecosystems. Proceedings of a workshop organized by the Research Institute for Nature Management, Arnhem, Netherlands.

Risenhoover, K.L. and J.A. Bailey, 1985. Foraging ecology of mountain sheep: Implications for habitat management. Journal of Wildlife Management 49 (3): 797-804.

Risenhoover, K.L., J.A. Bailey and L.A. Wakelyn, 1988. Assessing the Rocky Mountain bighorn sheep management problem. Wildlife Society Bulletin 16: 346-352.

Rominger, E.M., A.R. Dale and J.A. Bailey, 1988. Shrubs in the summer diet of Rocky Mountain bighorn sheep. Journal of Wildlife Management 52 (1): 47-50.

Schaffers, A., 1992. Handleiding en documentatie bij het programma DENDRO. IKC Natuurbeheer, Adviesgroep Vegetatiebeheer, 1-20.

Seidensticker, J.C., M.G. Hornocker, W.V. Wiles and J.P. Messick, 1973. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monograph 35: 1-60.

Stelfox, J.G., 1976. Range ecology of Rocky Mountain bighorn sheep. Canadian Wildlife Service, Report Series 39; 1-50.

Veen, H.E. van de, 1979. Food selection and habitat use in the red deer (Cervus elaphus L.). Dissertation. Groningen, 1-263.

Vos, A. de, and H.S. Mosby, 1971. Habitat analysis and evaluation: 135-172. In: Giles (ed), R.H., 1971. Wildlife management techniques. Third edition. The Wildlife Society.

Vulink, J.T. and H.J. Drost, 1991(a). Nutritional characteristics of cattle forage plants in the eutrophic nature reserve Oostvaardersplassen, Netherlands. Netherlands Journal of Agricultural Sciences 39: 263-272.

Vulink, J.T. and H.J. Drost, 1991(b). A causal analysis of diet composition in free ranging cattle in reed dominated vegetation. Oecologia 88: 167-172.

Wakelyn, L.A., 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51 (4): 904-912.

Warrick, G.D. and P.R. Krausman, 1987. Foraging behavior of female mountain sheep in western Arizona. Journal of Wildlife Management 51 (1): 99-104.

Wishart, W., 1980. Bighorn Sheep: 161-171. In: Schmidt, J.L. and D.L. Gilbert (eds), 1980. Big game of North America – Ecology and management. Wildlife Management Institute.

Yeo, J.J., 1981. The effects of rest-rotation grazing on mule deer and elk populations inhabiting the Herd Creek allotment, East Fork Salmon River, Idaho. M.S.Thesis, University of Idaho, Moscow, 1-119.

Yeo, J.J., 1992. Study Plan: Temporal changes of ungulate forage availability on winter range in lower Big Creek. University of Idaho, Wilderness Research center.

APPENDIX I

LAMB MORTALITY

Number of observed sheep and ewe:lamb ratios on the Big Creek winter range for the period end of May until mid-August 1992.

DATE	LOCATION	NUMBER OF SHEEP			EWE:LAMB RATIO
		TOTAL	EWE	LAMB	
5-25	1st bench	3	3	-	-
6-1	1st bench	1	1	-	-
6-9	1st bench	5	3	2	100:66
6-12	1st bench	1	1	-	100:0
6-19	Horse Mtn.	1	1	-	100:0
6-20	Horse Mtn.	4	4	-	100:0
6-21	1st bench	33	17	16	100:94
6-22	1st bench	34	17	17	100:100
7-5	1st bench	27	14	13	100:93
7-9	1st/2nd bench	2	2	-	100:0
7-11	between Lobauer and Browns Basin	28	17	11	100:65
7-13	1st bench	1	1	-	100:0

APPENDIX II

PLANT COVER

Mean basal cover (M) with standard deviation (sd) of *Agropyron spicatum* (AGSP), *Poa secunda* (POSA), *Festuca idahoensis* (FEID) and *Bromus tectorum* (BRTE) by plot and date (1 = 23 March and 24 March; 2 = 6 April and 10 April; 3 = 20 April; 4 = 4 May 1992).

PLOT	SPECIES	BASAL COVER (%)							
		1		2		3		4	
		M	± sd	M	± sd	M	± sd	M	± sd
1A	AGSP	1	3	1	4	2	4	3	8
	POSE	1	3	<1	1	<1	1	0	0
	BRTE	4	5	5	5	13	7	14	8
1B	AGSP	6	10	6	10	10	14	14	18
	POSE	2	4	2	4	3	8	1	4
	BRTE	4	4	5	5	15	12	20	19
2A	AGSP	6	10	6	9	9	13	-	-
	POSE	11	6	9	6	14	8	-	-
	BRTE	1	1	1	1	2	1	-	-
2B	AGSP	8	9	14	16	18	21	-	-
	POSE	6	6	6	6	8	7	-	-
	BRTE	1	1	2	3	3	3	-	-
3A	AGSP	4	5	5	7	6	7	-	-
	POSE	3	4	5	6	6	8	-	-
	FEID	13	7	10	6	12	9	-	-
	BRTE	0	0	0	0	<1	1	-	-
3B	AGSP	-	-	3	6	4	8	-	-
	POSE	-	-	4	5	9	7	-	-
	FEID	-	-	12	8	16	10	-	-
	BRTE	-	-	0	0	0	0	-	-

APPENDIX III

PLANT HEIGHT

Mean plant height (M) with standard deviation (sd) and number of samples (N) of *Agropyron spicatum* (AGSP), *Poa secunda* (POSE), *Festuca idahoensis* (FEID) and *Bromus tectorum* (BRTE) by plot and date (1 = 23 March and 24 March; 2 = 6 April and 10 April; 3 = 20 April; 4 = 4 May 1992).

PLOT	SPECIES	PLANT HEIGHT (CM)											
		1			2			3			4		
		M	± sd	N	M	± sd	N	M	± sd	N	M	± sd	N
1A	AGSP	8	2	5	9	4	7	11	4	4	17	3	6
	POSE	5	1	5	8	2	5	8	2	5	8	0	1
	BRTE	3	1	28	4	1	29	4	1	30	8	2	30
1B	AGSP	11	4	15	17	7	13	20	8	14	24	8	15
	POSE	4	2	12	5	1	13	5	2	12	4	1	6
	BRTE	2	1	30	2	1	30	3	1	30	4	1	30
2A	AGSP	13	4	18	17	6	12	20	6	14	-	-	-
	POSE	7	2	30	6	2	24	6	2	30	-	-	-
	BRTE	3	1	12	3	1	10	4	1	21	-	-	-
2B	AGSP	12	4	21	16	5	22	20	5	22	-	-	-
	POSE	5	2	28	6	2	25	7	3	26	-	-	-
	BRTE	2	1	11	3	1	16	4	1	27	-	-	-
3A	AGSP	9	2	18	14	4	17	16	5	18	-	-	-
	POSE	6	1	22	6	2	26	6	2	23	-	-	-
	FEID	6	2	27	7	2	27	7	2	26	-	-	-
	BRTE	2	0	1	1	0	1	3	1	3	-	-	-
3B	AGSP	-	-	-	14	4	7	15	5	7	-	-	-
	POSE	-	-	-	5	2	27	4	1	26	-	-	-
	FEID	-	-	-	4	1	30	5	2	29	-	-	-
	BRTE	-	-	-	5	0	1	4	0	1	-	-	-

APPENDIX IV

HABITAT USE

Habitat use and activity pattern of bighorn sheep, mule deer and elk on the Cliff Creek-Big Creek winter range, January-May 1992; M = moving; F = feeding; B = bedded; S = standing; SL = saltlick-feeding.

TOPOGRAPHICAL SITE		NUMBER OF ANIMALS			ACTIVITY (%)				
		sheep	deer	elk	M	F	B	S	SL
1	1st bench	127			0.5	38	22	0.5	39
			5.5			31			69
				2.5		100			
2	2nd bench	177				76	24		
			62			68	32		
				66.5		43	57		
3	3rd bench	27				47	47	6	
			39.5			100			
				55		66	34		
4	east knob	192.5			8	50	42		
			12.5			84	16		
				10	18	41	41		
5	west facing slope below 3rd bench	9.5				100			
			16			100			
				-					
6	above 3rd bench	233			5	63	31	1	
			51		50	100			
				2		50			
7	west ridge above 3rd bench	10				83		17	
			9			100			
				3		100			
8	lower pasture	-							
			-						
				63		72	28		
9	below 1st bench	29				100			
			-						
				-					
10	above timber bench	-							
			-						
				10		100			
11	ridge	49.5				46	54		
			8			100			
				34	14	86			
12	Big Creek trail	10							100
			1						
				-	100				
13	slope east of 2nd bench	78.5				42	58		
			4			100			

TOPOGRAPHICAL SITE	NUMBER OF ANIMALS			ACTIVITY (%)				
	sheep	**deer**	**elk**	**M**	**F**	**B**	**S**	**SL**
			-					
14 east side Horse Mountain	33.5			50	50			
		-						
			-					
15 timbered bench	7				100			
		11			36	64		
			28		25	75		
16 forest east knob	29.5				44	56		
		-						
			-					
17 ridge above east knob	-							
		2			100			
			11		100			
18 Cliff Creek	6			50	50			
		1.5		100				
			-					
TOTAL	**1003**	**223**	**285**					