OBSERVABILITY AND HABITAT CHARACTERISTICS
OF THE MOUNTAIN GOAT (Oreamnos americanus BLAINVILLE, 1816)
IN WEST-CENTRAL BRITISH COLUMBIA

by

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Abstract

Mountain goat spatial distribution, observability and utilization of habitat types was investigated from May, 1976 to August, 1978. Data were collected by systematically viewing mountain goats from the ground along a fixed transect.

Mountain goats were contagiously distributed within the study area, with 99.5 percent of all observed groups occurring on southerly-facing slopes of Maroon Mountain. Areas of monthly range use overlapped extensively. The highest levels of contagion occurred during August and December and were correlated with increases in group size. Kidding and rutting locations were generally clumped in their distributions, but no geographic concentrations occurred.

The population was estimated at 137 animals, comprising 90 females and 47 males. Mountain goats were most observable between February and May, however, only 42 percent of the population was visible, on average. Representative portions of the female component (i.e. >50% of the estimated total) were observed during 13 of 16 months examined, however, male representation was evident in only 6 months for the same period. Females were more observable than males because they occurred in larger groups, utilized less densely-vegetated terrain at most times of the year, and spent more time active.

The observed mountain goats did not utilize biotic or abiotic habitats equally, nor in constant proportions. Direct south-facing, scarcely-vegetated areas were predominantly used year round and consisted primarily of a broken rock substrate on
bluffs or outcrops between 35 and 41° slope. Deciduous shrublands were heavily utilized during spring 'green-up'. Densely vegetated areas were used by mountain goats during periods of extreme (hot or cold) temperature and wind. Many goats were located in the alpine during the summer, but in the subalpine during other seasons. Nearly half of all mountain goat observations were located in the vicinity of treeline. Goats did not appear to prefer habitats warmed by atmospheric thermal inversions during winter.

Group composition affected habitat selection. Male-only groups displayed far less frequent choice of habitat than their female counterparts. This may be attributed to the dominant status and higher production requirements of reproductive females. Male-only groups spent more time resting than feeding or travelling. Proportionately more time was spent resting in preferred habitats. Mixed-female groups were observed to spend more time feeding than resting or travelling. Some preferred habitats were used primarily for feeding, while others were used mainly for resting.

In light of the potential biases involved with observation techniques, it is felt that inter-population comparisons of population structure and range use should be treated with caution, particularly when populations occupy different biotopes and have been subjected to varying levels of hunting or other forms of human disturbance. The fulfilment of current harvest strategies of the species cannot be monitored without more accurate inventory techniques.
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Finally, and equally important, I would like to acknowledge the success of respect which developed between ourselves and the grizzly bears that included portions of the study area as a part of their home. A token investigation of some of our field supplies was the only alarming encounter.
This thesis is dedicated to Paul Otto Shulté, one of the true pioneers of the Terrace region. He became acquainted with the study area during a period when stage coaches traversed Kitsumkalum valley and when trails and cabins were cleared and constructed by hand.

Mr. Shulté often enlightened us with stories of the area, particularly with his acute observations of wildlife - most notably of which were the white Kermode bear (Ursus americanus kermodei) and the mountain goat.

Paul Shulté died of natural causes on the 22nd day of December, 1977, while checking his trapline near Maroon Creek. He never returned, to my sorrow, to receive the Christmas greetings left awaiting him.
Postscript

During the fall of 1978, the goats and the bears were once again permitted to reclaim their valley, as torrential rains and flooding washed away the lingering rememberances of Mr. Jack Garland and Mr. Paul Shulté, who in 1938 erected the miner's cabin (background of Dedication photo) in which we lived. Virtual elimination of the Maroon Creek logging road network ensued, thereby halting (at least temporarily) almost all forms of disrupting human activity within the valley.

Thank you Rain - from all of us in the valley.
I. INTRODUCTION

Approximately 45 percent of the world's free-ranging mountain goats (*Oreamnos americanus*) reside in British Columbia (Johnson 1977, Ministry of Environment 1979). In the last half century, however, many goat populations were exposed to accelerating hunting pressures through increased vehicular access (Quaedvlieg et al. 1973, Phelps et al. 1975). By the late 1960's and the early 1970's, provincial wildlife biologists became aware of the consequences of gross mismanagement of the species through unregulated access (Demarchi pers. comm.). Harvest trends declined (Foster 1977) and some populations were severely reduced or obliterated (Phelps et al. 1975). Stricter regulations were created, but were often unenforced.

Interactions and conflicts between mountain goats and various industries and recreationists are increasing in many areas of the province. The need for more intensive (i.e. watershed) management was recognized for the species (Phelps et al. 1975, Hebert 1978, Jamieson 1978), particularly given that habitat variation was identified as an important determinant of regionally-specific characteristics of mountain goat ecology (Foster 1976, Hebert and Turnbull 1977).

Another effect of access, loss of habitat, is also believed to have contributed to the severe reduction of some mountain goat populations (Quaedvlieg et al. 1973), yet no one in British Columbia has documented range attributes necessary for successful goat production. Published studies of mountain goats in this province prior to 1976 are limited to a taxonomic
examination of subspecies (McCrory 1965, Cowan and McCrory 1970), a study on the use of salt licks (Hebert 1967, Hebert and Cowan 1971a), a natural history study (Holroyd 1967), a behavioural investigation (DeBock 1970), and an account of white muscle disease (Hebert and Cowan 1971b). All field studies were conducted in the Kootenay region of southwestern British Columbia.

The need for local predevelopment studies on mountain goat requirements has been publicized only more recently (Hatler 1978). At present, the state of Alaska is leading research in this area as a result of impending coastal logging activities (Fox 1980, Fox and Taber 1981, Fox and Raedeke 1982, Schoen et al. 1981, Smith 1981). These preliminary studies have confirmed that mountain goats require mature subalpine timber habitat, particularly during winter. Because moist coastal environments enable productive forest growth with high commercial value (Resource Planning Unit 1976), the advent of logging poses a much more likely threat to loss of mountain goat habitat in these regions than it does in the drier interior areas.

The broad purpose of this study was to document both spatial and temporal patterns of habitat use by mountain goats within a densely populated region of coastal west-central British Columbia. The investigation was designed as an observational study primarily due to inadequate funding for the provision of radio telemetry equipment. It was felt that the study area to be selected must offer high viewing capabilities, resulting in two study objectives.
One objective of this investigation was to document observational characteristics of the study population which could assist in determining (a) survey bias, and (b) the subsequent level of analysis and degree of interpretation permissible under the main objective. The hypothesis of the first objective, presented in its Alternate (Ha) form, is:

- Mountain goats occur in non-random patterns of spatial dispersion.

This hypothesis in turn is concerned with the main objective of the study which was to investigate relationships of mountain goat habitat utilization. In this study, 'habitat' is recognized to consist of both biotic and abiotic factors. The hypothesis formulated and tested under this objective, presented in its Alternate (Ha) form, is:

- Mountain goats use some or all of the biotic and abiotic components of their range disproportionate to their availability.

The assumptions required of this analysis, and their concomittant methods of accommodation, are discussed in subsequent portions of this thesis.
II. STUDY AREA

1. SELECTION OF STUDY LOCATION

1.1 Rationale

The semi-coastal Nass Ranges was chosen as the study region due to its abundance of productive mountain goat habitat (Ministry of Environment 1979). High mountain goat densities are attributed to the north-south 'herring-bone' configuration of the ranges, resulting in numerous valleys laying east-to-west and offering numerous steep, south-facing mountain sides with an abundance of alpine habitat (Figure 1).

Five prospective study sites were initially chosen after review of a Fish and Wildlife Branch preliminary report (Sumanik 1970) and subsequent examination of 1:50,000 topographic maps of the area. Aerial reconnaissance of the Nass Ranges (96 km long by 46 km wide) was initially undertaken by the author during late April of 1976. Maroon Mountain was chosen as the study site for the following reasons;

(1) A dense mountain goat population of more than one hundred animals was known to inhabit the mountain (Sumanik 1970).

(2) It was accessible by (a) a logging road network in the valley to the south and to the west, and (b) a well-defined trail to the alpine on the northwest side of the mountain.

(3) The township of Terrace was located less than 40 km to the south, minimizing ferry time for fixed-wing and helicopter surveys, and time for obtaining supplies.
Figure 1 - Regional location of the study area (stippled area depicts alpine mountain goat habitat).
(4) Existing roads along Maroon Creek valley enabled excellent ground observation capability of the entire south slope of Maroon Mountain.

(5) Other secondary roads in the adjacent Kitsumkalum valley enabled ground observation north of the main mountain ridge and west of the main peaks from a distance of 3 to 8 km, therefore eliminating the need to hike to the north-facing alpine during systematic sampling.

(6) Two cabins were available for winter observation; one at treeline on the north aspect and the other near the head of Maroon Creek valley in the valley bottom.

1.2 Study Area Boundaries

The proposed study area was separated by small secondary valleys to the north and to the south, and a large glaciated valley and lake to the west. The eastern boundary was considered to be the divide of the Nass Ranges (Figure 2). Telemetry studies in Alaska (Schoen et al. 1981, Smith 1981, Nichols in press), Idaho (Kuck 1973) and Montana (Chadwick 1973, Rideout 1974) have shown that mountain goat home ranges are less than the outlined region (75 km²) chosen as the study area. Additionally, conversations with local loggers and other residents suggested that goats did not cross the secondary valleys to the north and the south.
Figure 2 - Topographic detail of the study area (delimited by the dashed line).
2. **PHYSIOGRAPHY AND GEOLOGY**

Located 35.4 km north of the township of Terrace (54° 47' north latitude and 128° 39' west longitude), the study area lies within the Skeena River drainage system. Maroon Mountain is typical in landform of the Nass Ranges, consisting of rugged terrain with a high and narrow knife-edge ridge. The region was heavily glaciated, with the higher peaks typically being sculptured by cirque glaciers (Holland 1976). The three main peaks of Maroon Mountain are clustered and range between 2042 and 2066 m in height.

The study area occurs within a southern portion of a metamorphosed volcanic and sedimentary rock batholith comprising the Bowser Group of the upper Jurassic and Cretaceous age. Duffel and Souther (1964) describe regional geology in more detail.

3. **CLIMATE**

The nearest continuously operating government climatological facility is located at the Terrace airport, 50 km to the south. The overall climate varies seasonally from a moist, coastal, mesothermal environment to a drier, more continental-like, pseudo-arctic regime. Total annual precipitation averages 1301 mm, comprising 371.3 cm (29%) of usually wet snow (water equivalent=371 mm). The annual temperature averages 6.0°C, with the hottest months being July and August (mean monthly temperature=16.2°C and 15.6°C, respectively). Temperatures may reach 35°C during the summer.
and -25°C in the winter. Mean annual solar insolation approaches 1375 hours, or 31% of the possible annual sunshine total. The sunniest month is generally August and the cloudiest is most often December. Winds are generally from the south during snow-free months of the year (April to October), however, fall and winter are the windiest times of the year, with cold northerly winds. Monthly meteorological data are summarized in annual government reports (Environment Canada 1976, 1977, 1978).

4. SOILS AND VEGETATION

Maroon Mountain lies within a heavily utilized portion of the newly exploited Skeena Public Sustained Yield Unit (British Columbia Forest Service 1979). Spruce (Picea sp.), hemlock (Tsuga sp.), and fir (Abies sp.) predominate the commercially valuable timber species.

Three biogeoclimatic zones (Krajina 1965) occur in the study area. The Coastal Western Hemlock zone is the wettest zone, occurring below 762 m above sea level. Orthic humo-ferric soils are prevalent in this zone (Valentine et al. 1978). The Mountain Hemlock zone is evident between 762 and 1554 m, retaining similar soil types to the Coastal Western Hemlock zone but having only one-half of its total annual precipitation. The Alpine Tundra zone generally occurs above 914 to 1554 m, depending on aspect, and has only one-third the precipitation of the Coastal Western Hemlock zone. Dystric brunisols and mini podzols predominate.
III. METHODS

1. FIELD RECONNAISSANCE

Preliminary observations were conducted throughout the summer of 1976 (May to August), and for two weeks in each of the months of October and December of that year. Observations recommenced in May 1977 and continued for 16 consecutive months, terminating in early September 1978. In all, mountain goats were observed over three kidding periods and three summers, one rutting period and one entire winter.

2. SURVEY METHODOLOGY

The study area was surveyed by one of two modes of travel: air and ground. Aerial surveys were designed to provide better data on population size, composition, and distribution than were available from previous studies (Sumanik 1970). Ground (vehicular and backpacking) surveys were conducted to obtain less costly data on both population and habitat characteristics.

2.1 Aerial Surveys

Fixed-wing aircraft were used for two reconnaissance surveys. In each case, one transect was flown just below treeline, at approximately 1050 m, covering a belt 300 m wide. A helicopter was used for transport and more intensive aerial survey due to additional maneuverability, speed control and landing capabilities. However, funds were not sufficient to fulfill the intensive survey methodology designed, therefore flight paths did not follow one specific contour, nor were they
maintained at a constant speed. Instead they zig-zagged over the study area sampling mountain goats proportional to density (i.e. from group to group), rather than covering all areas, or areas of no apparent use. Mountain goats were seldom sexed on these surveys, and only kids and yearlings were identified to age class. Additional data were collected on group size and distribution (including elevation) in most cases.

2.2 Ground Surveys

Two types of ground survey methods were used; vehicular counts and backpacking observations. Observations of mountain goats were made with the aid of 8X30 binoculars, a spotting scope with 20X and 40X ocular objectives and a 20-40X zoom terrestrial, binocular telescope. Mountain goats were usually observed from distances greater than 0.25 km, to eliminate human disturbance. A 35 mm camera was utilized to document aspects of mountain goat ecology.

2.2.1 Vehicular Counts

Vehicular surveys were conducted at approximately weekly intervals in 1976, and biweekly in 1977 and 1978. Weather and visibility levels affected timing of surveys with respect to date of choice and time of day. A pickup truck was used during snow-free months and a snowmobile during winter.

Mountain goats were located by systematic scanning of the terrain from fixed viewing locations along a permanent road transect. Surveys were initiated at opposite ends of the transect each time in order to reduce sampling bias. On
average, incomplete surveys covered one-half of the transect, and so were included in the analysis of habitat relationships.

Occasionally a survey had to be completed the following day, due to the onset of inclement weather, or dusk. When possible, observations were terminated late in the day at a major geographic landmark and reinitiated early the subsequent morning. This dusk-dawn continuation often supported the belief that large scale movements by goats did not occur overnight.

2.2.2 Backpacking Observations

Backpacking trips were conducted at least once a month, generally during snow-free periods only. This type of survey was considered to be a general, non-systematic reconnaissance, providing supplemental information on mountain goat distribution and range use. Backpacking survey data were not utilized for statistical analysis of population estimates or habitat-related characteristics of mountain goats, due to disturbance factors.

3. POPULATION CHARACTERISTICS

A complete assessment of habitat selection may require knowledge on the structure of the population under study (Oosenbrug and Theberge 1980). Thus information on population distribution and movements, size, density and composition were collected.
3.1 Distribution And Movements

Patterns of mountain goat distribution and movements were recorded by grid location during aerial and ground surveys. The northeast sector of the study area was sampled once a month during snow-free periods by backpacking or helicopter surveys, and on a monthly basis by helicopter only during snowy conditions (October through May).

3.1.1 Distribution

The analysis of mountain goat distribution patterns considers neither age nor sex categories, with the exception of kidding and rutting information, which do consider adult males and females.

a. Range Use

Maps representing overall and monthly cumulative range use by mountain goats were constructed for the period May, 1977 through August, 1978. Mountain goat sightings in 1976 were not recorded by grid location but by approximate geographic fixes. Most mountain goat observations were plotted with an accuracy of ±10 m (one half of the length of one grid quadrant), with the exception of some homogenous (e.g. alpine) areas where an accuracy of ±30 m is believed to be more realistic.

Areal determination of monthly range use was measured by dot grid (64 dots/km²), based upon vertical projection of monthly distribution patterns.
The modified minimum area polygon method (Harvey and Barbour 1965) was used to determine monthly range boundaries.

b. Spatial Dispersion

Monthly dispersion patterns of mountain goats, occurring south of the main ridge only, were measured for degree of aggregation. The purpose of this exercise was to determine if range resources were being utilized at random (i.e. poisson distribution) or if certain attributes were responsible for uniform or clumped distributional patterns.

An index of dispersion ($I$) (Elliot 1971, p40) was used to describe monthly dispersion patterns of mountain goats. Myers (1978) stated that this index is easy to compute and readily understandable (in comparison to Green's and standardized Morisita's coefficients). Additionally, 'I' was found by Myers (1978) to be only weakly correlated with density (or quadrat size). The value 'I' is simply the (sample) variance-to-mean ratio. A contiguous grid system comprised of 129 400mx400m quadrats was superimposed over the grid maps of animal locations and each quadrat was tallied by month and in total. The quadrat size used is larger than that recommended by Greig-Smith (1964) for sampling plant communities, because too many cells with zero counts would have resulted. Quadrat size was chosen on the basis of
mean daily movements of mountain goats ($\bar{x}=400$ m) in a nearby study (Foster and Rahs 1981). Monthly values of 'I' in excess of 3.0 were fitted to a general negative binomial model (Petkau and Johnson, in press). The chi-square statistic ($X^2$) was used to determine differences between monthly distributions, at the 0.05 level of significance.

Mountain goat kidding and rutting distributions were similarly calculated, but small sample sizes and the large number of quadrats negated the use of Petkau and Johnson's (in press) model. For these data, a $X^2$ value was calculated (Elliot 1971, p40) and redistributed to the normal variable, 'd'. Agreement with a poisson distribution was not rejected (p≥0.05) if the absolute value of 'd' was less than 1.96. If 'd' was greater than 1.96, with a negative sign, a uniform distribution was suspected. If 'd' was greater than 1.96 and positive, a contagious distribution was implied.

3.1.2 Movements

Mountain goats were identified for observation by a nylon colour-coded neck collar and two black, rubberized 'Ritcey' ear-tags, each painted with a white number, affixed subsequent to free-ranging immobilization with 2.7 mg doses (1.1 cc) of Immobilon (etorphine hydrochloride plus acepromazine – Reckitt and Colman, London, England). Individuals were also identified by morphological characteristics, including broken horns, horn
deformities, scars, molting pattern and pelage colouration. Certain individuals or groups which remained very cohesive, could be monitored for several consecutive days, however, this was not a common trend. Daily movements were obtained by watching several groups of goats from dawn until dusk and recording their locations on a topographic map. Individual goats were monitored over a longer period by resighting tagged and other uniquely marked individuals. A 6 km² portion of the northeast corner of Mt. Garland, to the south, was covered during each survey in order to help document the extent of immigration and emmigration to and from the study area.

3.2 Population Structure

Components of population structure were described in terms of its size, density, and composition.

3.2.1 Population Size

Population size estimates were derived by the 'maximum cohort completion' method (Smith 1976, p35), in which the maximum counts for each sex and age class were added together to obtain a 'maximum observed count'. This figure represents a minimum likely herd estimate. The technique was applied to the vehicular survey data only. Information collected on helicopter surveys was stratified and compared to ground vehicular survey areas, in order to determine survey efficiency of the two techniques. Population estimates were derived from indices of absolute population coverage provided in the literature (McCrorry and Blood 1978, Foster and Rahs 1981). These must be considered
as approximate, for their survey methods were outlined incompletely.

3.2.2 Population Density

Mountain goat densities were calculated based upon corrected map area. Areal determinations were conducted with a dot grid (64 dots/km²) and corrected by the mean hillside slope of the area of mountain goat distribution (for more detail, see 4.2 Habitat Selection). Density was determined by dividing the number of mountain goats observed into the corrected survey area.

3.2.3 Population Composition

Mountain goats were classified by sex and age, on the basis of horn morphology and behaviour, following the first summer of introductory field work. One of fifteen sex-age categories were recorded for each individual, based on three sex and five age classes.

a. Sex

As many of the characteristics presented in Table 1 as possible were used to identify males from females. Most sexing was also estimated independently by a field assistant, and then compared. Where discrepancies occurred between the two observers, or whenever sex could not be otherwise determined, the sex was designated as 'unclassified'.
Table 1 - Summary of sexually dimorphic characteristics used to classify mountain goats in the study area.

<table>
<thead>
<tr>
<th>Sexual Characteristic</th>
<th>Male</th>
<th>Female</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>- symmetric horn curvature</td>
<td>- straighter horns, typically 'kinked' near the tips</td>
<td></td>
<td>Casebeer et al. 1950</td>
</tr>
<tr>
<td>- thick horns with bases nearly touching</td>
<td>- narrow horns with bases well-spaced</td>
<td></td>
<td>Brandborg 1950, 1955</td>
</tr>
<tr>
<td>- 'Roman nose' adult characteristic</td>
<td>- rostrum straight</td>
<td></td>
<td>Brandborg 1955</td>
</tr>
<tr>
<td>- stretch stance urinary posture</td>
<td>- squatting urinary posture</td>
<td></td>
<td>Hibbs 1965</td>
</tr>
<tr>
<td>- large scrotal sac</td>
<td>- vulva and teats</td>
<td></td>
<td>Chadwick 1973</td>
</tr>
<tr>
<td>- black, swollen occipital glands during the rut</td>
<td>- pink or flesh-coloured, swollen occipital glands</td>
<td></td>
<td>DeBock 1970</td>
</tr>
<tr>
<td>- soiled rump, belly and carpal joints during rut</td>
<td>- no 'rutting-pit' activity</td>
<td></td>
<td>Brandborg 1955</td>
</tr>
<tr>
<td>- early spring molt</td>
<td>- barren females same as male</td>
<td></td>
<td>Geist 1964</td>
</tr>
<tr>
<td>- generally solitary</td>
<td>- other females molt during summer</td>
<td></td>
<td>DeBock 1970</td>
</tr>
<tr>
<td></td>
<td>- usually social, frequently accompanied by young of the year</td>
<td></td>
<td>Brandborg 1955</td>
</tr>
</tbody>
</table>
b. Age

Age categories were defined as; kid, yearling, subadult, adult or unclassified. Kids and yearlings were readily differentiated on the basis of body size, horn growth (Foster 1978) and conformation of the face (DeBock 1970; Smith 1976). In this study, young mountain goats are considered kids until their first birthday, and yearlings until their second birthday. A 'birthday' was considered to be the date of the first observed new-born of the year. Identification of two-year olds was not attempted, due to variations in horn growth identified by Foster (1978), despite the fact that other researchers claim to be capable of identifying this cohort (e.g. DeBock 1970, Chadwick 1973, Thompson 1981). In this study, two-year and older animals were classified, based primarily upon the width and the length of the rostrum (see Smith 1976) and to a lesser extent on horn size. Subadults were considered to consist of two and three-year old animals. Mountain goats estimated to be older than three years were considered adults.

4. HABITAT CHARACTERISTICS

Important habitat variables were identified during the first summer's ad lib. observations of the study population. Biotic and abiotic characteristics of the habitat were assessed in terms of vegetative cover, physical structure, and
microthermal variation. Vegetative cover of a point on a grid was recorded as the greatest portion of land lying within that grid's quadrant (400 m$^2$). The terms 'alpine' and 'subalpine' refer to areas above and below treeline, respectively.

4.1 Habitat Use

Investigation of habitat use was conducted throughout the entire study area with the exception of the northeast section (Ridges #1 and #2, see Figure 2). Variables measured were; plant cover, surface expression, substrate, aspect, slope, elevation, and temperature. Variables were categorized a priori and each interval was individually addressed in the analysis.

Data were analyzed using single classification log likelihood ratio (G) goodness-of-fit tests (Sokal and Rohlf 1980, p692) at the 0.05 level of significance. William's correction for continuity was applied to the G-statistic, for two-by-two comparisons only, in order to obtain a better approximation to the chi-square distribution (Sokal and Rohlf 1980, p710). A Fortran program developed by M. Gillingham (Faculty of Forestry, University of British Columbia) and the author was used to calculate the G-statistic.

4.1.1 Biotic Factors

a. Vegetative Cover

Classification of biotic landscapes in the study area were based upon a physiognomic-ecological classification scheme outlined by Mueller-Dombois and Ellenberg (1974, p466). Plant formations were
delineated from 1:15,840 black and white government aerial photographs (Surveys and Mapping Branch 1974). Ground cover was defined as the percentage of points covered by the aerial parts of a plant type under consideration, and was estimated visually. A vegetation map of approximately the same scale was constructed of the area, in 1976, with a Kail plotter, using standard photogrammetric techniques (Slama 1980). Three field reconnaissance missions confirmed the final map draft.

Plant specimens were collected during the summer periods, pressed and air-dried, and later verified for identification at the University of British Columbia herbarium. Scientific names were taken from the nomenclature of Hultén (1968), Schofield (1969), Hitchcock and Cronquist (1974) and Hale (1979).

i. Overstory Assessment

Six plant formations were described on the basis of height and percent ground cover;

**Closed (non-giant) forests** are formed by trees ranging from 5 to 50 m in height, with their crowns usually interlocking. Closed forests are characterized by more than 50% ground cover.

**Open forested woodlands** are formed by trees at least 5 m tall, with most of their crowns **not** interlocking, comprising from 10 to 50% ground cover.
Scrub is defined in terms of shrublands and thickets, with plants ranging up to 4.6 m in height. Shrublands range from 40 to 80% ground cover for deciduous types, and greater than 50% for coniferous types. Deciduous scrub thickets are characterized by ground cover exceeding 80%.

Logging clearcuts are representative of once-forested, low-elevation habitats now cleared of their commercially valuable coniferous timber. Ground cover is variable, depending upon the time since clearing, but is usually greater than 20%. Plants are no higher than 5 m.

Tall-sedge Swamp is frequently flooded with fresh-water and commonly for long periods. As a rule they are natural by creation, however beavers (*Castor canadensis*) created the swamp in this study area. Foliage is frequently taller than 30 cm with sedges dominating throughout.

Scarcely vegetated areas comprise interfluves, vertical rock faces, and litter slopes alike, in both the alpine and subalpine. These areas are generally comprised of ground cover less than or equal to 10%. Plants are no higher than 0.9 m.

Plant formation categories were additionally described on the basis of growth form (e.g. [Description continues...])
deciduous vs. coniferous), species composition, or both. Each formation may not represent either a homogenous stand or a distinct entity, but rather one that may intergrade in variable intensity with adjacent categories.

Plant heights were assigned in relation to the mean shoulder height of an adult goat ($\bar{x}=0.92$ m; Brandborg 1955).

ii. Understory and Strata Characteristics

Several understory characteristics were subjectively described for the major plant formations during field confirmation of the plant cover map. These included herbaceous strata height and percent cover, scrub strata height, and forest woody understory composition.

Herbaceous characteristics were divided into two types of cover ($\leq 50\%$ or $>50\%$), to describe each plant formation in both alpine and subalpine environments. All strata were less than 0.9 m, with the exception of a subalpine herbaceous meadow (i.e. $>50\%$) category, which sometimes exceeded 0.9 m.

Forest woody understory was divided into six types; coniferous, deciduous and mixed coniferous and deciduous tree ($>5.0$ m), and coniferous, deciduous and mixed coniferous and deciduous shrub (2.4 to 5.0 m).
Two krummholz strata were described; a low stratum (upper altitudinal limit of treeline) was described as shrubs less than 1.2 m in height, and the high stratum (lower altitudinal limit of treeline) consisted of trees ranging from 1.2 to 4.6 m. Exposed deciduous shrublands and thickets were also divided into two strata; a high stratum (>1.0 m), and a low stratum (≤1.0 m).

4.1.2 Abiotic Factors

a. Terrain Classification

i. Surface Expression

Surface expression describes surface forms that are not adequately shown (principally by contours) on the 1:50,000 topographic base map (Resource Analysis Branch 1978). Eight categories describe surface expression; rock outcrop, talus, hummocky, shelf, ridge, peak, gully or ravine, and fan. Slope position (e.g. mid-elevation, forested slope, etc.) was not described.

ii. Rock Substrate

This variable describes inorganic substrate textures on which mountain goats were observed (organic mats and snow-covered slopes were excluded). Rock substrate types were described in four categories; broken consolidated (rugged
or crumbly) rock, smooth rock, shale, and gravel-siltstone.

b. Aspect

Aspect was divided into eight classes related to exposure; north, northeast, east, southeast, south, southwest, west and northwest. Aspects were determined by 45° allotments of a compass point, starting at 337.5°. A ninth class ('no aspect') constituted the tops of ridges and peaks and not merely flat areas (such as the 'Tea-Gardens' (see Figure 2) north of the main ridge). Aspect at a point on a grid was recorded as the average aspect of the land lying within a 100 m radius from the point, rather than the immediate aspect of that point.

c. Slope

Slope is described in degrees (rather than percent), and was divided into eleven intervals of unequal size related to steepness; ≤27°, 28-29°, 30-31°, 32-34°, 35-37°, 38-41°, 42-45°, 46-50°, 51-56°, 57-63°, and >63°. Slope was calculated using the trigonometric function described by Thompson 1981, p281). Map measurements were taken to the nearest 0.8 mm on an enlarged 1:50,000 topographic map. Each point of location maintained the mid-point of the vertical distance, which was held constant at 91.4 m.
d. Elevation

The 1928 m vertical gradient from ridge top to lake edge was assessed on two different orders. The first order of selection utilized treeline as a geographic landmark. The upper limit of tree growth (krummholz) was sampled every 500 m from the 1:50,000 base map. Two zones were subsequently defined; alpine and subalpine. The second order of selection classified the altitudinal gradient of the study area into nine 250-m classes; ≤250 m, 251-500 m, 501-750 m, 751-1000 m, 1001-1250 m, 1251-1500 m, 1501-1750 m, 1751-2000 m, and >2000 m.

Elevation was calculated to the nearest 15 m, by superimposing the enlarged 1:50,000 (30.5 m interval) contour map over the vegetation map with an epidiascope, using two government survey reference points in the alpine as controls for scale. Elevation of each control point was confirmed with a Thommen 2000 hand altimeter and also with the altimeter in a Bell 206B 'Jet Ranger' helicopter.

e. Microclimate

To assess annual microthermal variation throughout the study area, six meteorological stations were erected during the summer of 1977 and monitored until the following summer: one was located in the forested valley bottom, below goat ranges, at 725 m (stn #6); two were installed on the lower limit of
goat range - one in a deciduous shrub ravine at 879 m (stn #1); and the other in a coniferous forest at 893 m (stn #2); another was placed in the krummholz, near treeline, at 1433 m (stn #3); one sat on top of a glacial rock interfluve on the exposed, knife-edged, main ridge at 1692 m (stn #4); and the last one was located on a weathered ridge in the hummocky alpine tundra at 1591 m (stn #5). A seventh weather station, monitored by the provincial government, was located in the extreme northwestern corner of the study area (Rosswood, B.C.) at an elevation of 152 m (see Figure 2).

Each recording unit was installed and maintained according to specifications of the provincial government Resource Analysis Branch (Climatology Section 1974). A seven-day thermograph was used in the valley-bottom station (#6) and thirty-day hygrothermographs were located at each of the remaining five sites. Each were installed in a Stevenson screen, situated 1.2 m above the ground on vertically adjustable 3 m stands designed by the author. Two standard (15.2 cm diameter) precipitation barrels, 'topped off' with kerosene (to prevent evaporation), and a totalizing annemometer accompanied each station. Square (5 cm) wire mesh was wrapped around each Stevenson screen to help minimize damage created by porcupines (*Erethizon dorsatum*).
4.2 Habitat Selection

Habitat components were examined only as single independent variables with respect to mountain goat utilization. Analysis of habitat selection is based upon use and availability of biotic and abiotic variables.

4.2.1 Data Considerations

Several aspects of the selection analyses were first considered.

a. Calculation of Habitat Availability

Availability was considered to include a generalized region based upon the cumulative distribution of mountain goats which were plotted on the base map. The entire hillside was considered to be 'available' to a goat (i.e. from valley bottom creek to ridge-top). Lateral boundaries considered included two of the four major geographic barriers discussed earlier as study area boundaries.

Availability of a habitat variable was measured in one of two ways; by direct measurement of area, or by random sampling for estimation of proportions.

i. Direct Areal Measurement

Areal estimates of availability were measured for plant cover types and altitudinal zones by vertical projection, using a dot grid (64 dots/km²). Correction of area for hillside slope was determined by randomly sampling each
plant and elevation category and applying the appropriate correction factor, as described by Thompson (1981, p281). Random sample sizes were determined using the binomial probability function described in Mendenhall (1971, p198). The most conservative values of 'p' and 'q' were used (i.e. 0.5) because no estimate of proportions was available. A 90 percent level of confidence and 10 percent accuracy were selected for the determination of sample size. Random sampling was in some cases terminated prematurely if iteration showed that the desired levels of confidence and accuracy had been achieved.

ii. Estimation of Proportions by Random Sampling

A 'non-mapping' technique (Marcum and Loftsgaarden 1980) was used for estimating the proportions of slope and aspect categories. Estimates of habitat proportions were obtained by superimposing the goat location grid system over an enlarged topographic map of Maroon Mountain and classifying a set of randomly distributed points over the area of availability. Random coordinates were generated using a computer program (Nicol 1981). The procedure for determining random sample size for estimating proportions followed that previously described for determination of sample sizes for mean slope
Mendenhall 1971). The mean slope of these values was then used to adjust the area of availability within each habitat category.

Once corrected for hillside slope, proportions of availability were then reconstructed to equal the number of mountain goat observations for the time period used in the analysis. This design, utilized fixed marginal contingency totals for one criteria (i.e. habitat proportions) and is termed a 'Model II' contingency design (Sokal and Rohlf 1980, p735). The design was intended, in part, to alleviate differing effects of frequency on the distribution of the data. It also facilitates computation of the test statistics involved.

Availability of surface expression, substrate texture, thermal strata and other climatological data could not be accurately assessed from maps or aerial photographs and were therefore excluded from the analysis of selection.

b. Other Considerations

Prior to the analysis of habitat selection, each group of mountain goats was randomly subsampled for one 'representative' individual, in order to eliminate biases involving dependency of the data due to social constraints. Selection of environmental attributes...
are believed to be influenced by other conspecifics (e.g. a nanny leads her kid, the kid does not choose where to be). Without subsampling, such an analysis may be taken to indicate habitat selection by groups rather than by individuals, as presented in the former section on Habitat Use. Analysis using group data violates the requirement of independence in statistical procedures.

Additionally, two group types were defined rather than analyzing by sex alone. Male groups consisted of male goats only, at any age. Mixed-female groups consisted of any composition having at least one female in it. Males occurred in both groups defined, however, because they are subordinate to females, they were considered 'followers' in the sense that it is the dominant animal that selects its own environment (Chadwick 1973). A third group type may also have contained males and females ('unclassified group') but this category was not used in the analysis.

Two limitations were placed on defining a group; visual contact, and proximity to conspecifics. For example, two mountain goats may be visible to each other when several hundred meters apart, or they may be only 20 m apart but on the other side of a ravine, or vegetation strip, or at extreme vertical limits of a bluff (i.e. on top and bottom), such that they are out of sight of each other. Neither condition
constituted a group. In the former case, the goats were aware of each other, and in the latter case, they were not. The former situation was regulated by assigning distance limitations, and for this study, that boundary was arbitrarily set at 100 m. Visual contact was the cue used to determine awareness between conspecifics, and was evidenced by the overt behavioural responses of the goats (e.g. looking up while grazing or turning its head to stare). Consequently, estimation of group size may not always represent point-in-time or 'scan' sampling (see Altmann 1974). Occasionally individual goats had to be watched for several minutes in order to determine if synchrony in activity and direction of movement appeared independent of conspecifics.

c. Statistical Analysis

Use and availability data were analyzed using a two-step technique; multinomial contingency analysis, using the log likelihood ratio (G) goodness-of-fit test (at the 0.05 level of significance), and subsequent analysis of 90 percent simultaneous confidence intervals (SCI), using the conservative Bonferroni approach (Neu et al. 1974, Marcum and Lofstgaarden 1980). The 90 percent SCI's were (arbitrarily) chosen as a reasonable level of significance. By maintaining $\alpha=0.10$, the standard normal deviate ($Z$) changes for each category ($k$). As
a result, individual confidence intervals varied from 0.95 to 0.99 when 'k' equalled 2 and 10, respectively.

4.2.2 Biotic Factors

a. Vegetative Cover

All six plant formations outlined in the previous section on Habitat Use were used in the preference analysis. Understory characteristics were not assessed due to their small scale.

4.2.3 Abiotic Factors

a. Aspect

Six aspect intervals occur on the southern slopes of Maroon Mountain; east, southeast, south, southwest, and west. The ridge and main peaks (i.e. 'no aspect') interval was not included in this assessment because random sampling from a map was not precise enough to delineate knife-edge ridges or peak tops on Maroon Mountain. North, northeast and northwest aspects did not occur in the area of availability, however, other micro-aspect situations probably existed but were not recorded due to the 100 m radius restriction imposed during data collection (see Habitat Use).

b. Slope

Ten slope intervals occur on the southern slopes of Maroon Mountain; ≤27°, 28-29°, 30-31°, 32-34°, 35-37°, 38-41°, 42-45°, 46-50°, 51-56°, and 57-63°.
However, random sampling described only the first seven intervals (0-45°), consequently the eighth, ninth and tenth intervals (used by goats) and the 'eleventh' interval (>63°), unused by goats, were lumped together to create a '>46°' class for this analysis.

c. Elevation

Although eight altitudinal intervals (from 250 to 2250 m) were used by mountain goats, random sampling of available elevation bands documented one additional interval (≤250 m). Therefore, nine elevation intervals were used in the preference analysis. Because no random samples were located in the upper or lowermost categories when sampling for mean slope corrections on the map (due to their small area), the slope correction factor for the adjacent zone was used as a realistic calibration of these areas.

4.2.4 Mountain Goat Activity Within Preferred Habitats

Habitat types were considered to be preferred when an animal selected certain desirable characteristics within that environment. This analysis investigated the biological significance of preferred habitats by assessment of three activity patterns; foraging, resting, and travel. Foraging included browsing and grazing practices. Standing and ruminating animals were considered resting. Travel consisted primarily of animals walking or running. Animals at play were recorded as either walking or running.
4. RESULTS

1. POPULATION CHARACTERISTICS AND OBSERVABILITY

1.1 Distribution And Movements

Maroon Mountain appears to be a geographic 'island' with little or no movement to and from the study area apparently occurring.

1.1.1 Distribution

a. Range Use

Systematic vehicular surveys covered approximately 73% of the study area. These data showed that intensity of mountain goat use north and south of the crest of the main ridge (Figure 3) was significantly different (\(G=1606.6; \text{df}=1\)). Slopes south of the main ridge comprised 29.4% (22.03 km\(^2\)) of the study area, but were used by 99.5% of all groups recorded. Mountain goat observations ranged from ridge tops down to the valley-bottom logging roads. A 9 and 1/2 year old male was found dead in one of the logging clearcuts along Maroon Creek in February, 1978. Helicopter and backpacking surveys over the remaining 27% of the study area indicated that slopes northeast of the main ridge were only occasionally utilized during late summer, and never in winter. Unless in immediate proximity to escape terrain provided by the main ridge, or Hall Creek, mountain
Figure 3 - Distribution of systematically observed mountain goats on Maroon Mountain, B.C., determined by vehicular survey.
goats were observed to utilize hillsides north of the main ridge for periods of a few hours at the most. Travel in these areas was generally at a fast walk, due to the gentle-sloping nature of the area.

Seasonal ranges overlapped with varying intensity. The least overlap in monthly ranges had a coefficient of areal association of 0.18 (see Taylor 1977, p177), between areas used in August and November, 1977. Monthly range sizes were smallest during periods of hot summer temperatures (July, 1977 and 1978) and largest during spring thaw and the associated 'green-up' (April to June). Non-systematic surveys during the summer of 1976 showed range size to be much larger, in the absence of predators.

b. Spatial Dispersion

Mountain goats were determined to be non-randomly distributed over the slopes south of the main ridge, therefore rejecting the Null Hypothesis (G=32.3; df=128). Each analysis by month also rejected the Null Hypothesis, however, mountain goat dispersion patterns during the months of May and November, 1977, did not statistically fit the 'general' negative binomial model used in the analysis (Table 2). Mountain goats tended to be most aggregated in summer (June through August), when food resources were more abundant. However, two months in particular (August and December, 1977) displayed significantly higher
## Table 2 - Monthly distribution statistics of mountain goats inhabiting Maroon Mountain, B.C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Range Use (km²)</th>
<th>Number of Goats per Quadrat</th>
<th>Goodness-of-fit to Negative Binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (X)</td>
<td>Variance (s²)</td>
</tr>
<tr>
<td>1977</td>
<td>May 9.4</td>
<td>1.38</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>Jun 10.8</td>
<td>2.05</td>
<td>18.80</td>
</tr>
<tr>
<td></td>
<td>Jul 4.1</td>
<td>1.03</td>
<td>8.42</td>
</tr>
<tr>
<td></td>
<td>Aug 8.3</td>
<td>1.97</td>
<td>23.98</td>
</tr>
<tr>
<td></td>
<td>Sep 8.6</td>
<td>1.76</td>
<td>15.36</td>
</tr>
<tr>
<td></td>
<td>Oct 5.5</td>
<td>1.06</td>
<td>5.06</td>
</tr>
<tr>
<td></td>
<td>Nov 8.1</td>
<td>1.59</td>
<td>8.42</td>
</tr>
<tr>
<td></td>
<td>Dec 5.4</td>
<td>1.03</td>
<td>17.05</td>
</tr>
<tr>
<td>1978</td>
<td>Jan 6.6</td>
<td>1.17</td>
<td>6.36</td>
</tr>
<tr>
<td></td>
<td>Feb 13.2</td>
<td>1.78</td>
<td>9.80</td>
</tr>
<tr>
<td></td>
<td>Mar 12.3</td>
<td>1.74</td>
<td>7.46</td>
</tr>
<tr>
<td></td>
<td>Apr 14.5</td>
<td>1.46</td>
<td>4.91</td>
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<tr>
<td></td>
<td>May 9.6</td>
<td>1.73</td>
<td>11.54</td>
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<tr>
<td></td>
<td>Jun 9.2</td>
<td>1.48</td>
<td>9.99</td>
</tr>
<tr>
<td></td>
<td>Jul 2.6</td>
<td>0.75</td>
<td>4.88</td>
</tr>
<tr>
<td></td>
<td>Aug 7.8</td>
<td>1.02</td>
<td>10.80</td>
</tr>
</tbody>
</table>

a \[ I = \frac{s^2}{\overline{X}} \]

b \[ k \text{ (clumping variable) is calculated by the Newton-Raphson iteration procedure (Bishop, Fienberg and Holland 1975, p84)} \]

c \[ \theta = \frac{\overline{X}}{k} \]

* significant at \( p<0.05 \)
levels of mountain goat aggregation than all other remaining months (Table 2). August, 1978 showed a similar trend, but was not significant. Low levels of aggregation were noted throughout the winter (January to April), most notably in the month of April, at the onset of spring 'green-up'. There was no apparent relationship between dispersion pattern and range size (Spearman's $t=-3.7; df=14$), however, a positive correlation occurred between clumpedness and group size ($t=3.4; df=14$).

Overall, kidding (and accompanying post-partum isolation) areas were also determined to be contagiously distributed ($d=7.3$). In 1976, however, neonate locations were randomly distributed ($d=0.6$). The existence of annual 'kidding grounds' was dismissed on the basis of a lack in geographical concentration (Figure 4). Certain environmental attributes may be common for each site, however this was not examined.

Similarly, during the rut (November and early December), both tending adult males and adult females were non-randomly distributed (males: $d=2.8$; females: $d=17.2$). Both distributions are believed to be as much a result of areal concentration due to descending snowlines and increasing snowpack at this time of year, as they are of social factors. The existence of annual 'rutting grounds' was dismissed on the basis of
Figure 4 - Distribution of neonate locations in the study area - 1976 to 1978.
a lack in geographical concentration (Figure 5).

1.1.2 Movements

Only one mountain goat, a 3.5 year-old female, was captured and permanently marked (August, 1977). 'Female#2' was resighted 32 times over a 12 month period (Figure 6). Despite numerous attempts, free-ranging immobilization of more mountain goats was found to be logistically too difficult and time consuming. However, permanent identification was possible for seven other mountain goats within the population. Six of these were identifiable by unique (damaged) horn characteristics and one old nanny had a scar across her rostrum.

Each identifiable goat was always resighted south of the main ridge of Maroon Mountain (Figures 6 and 7), confirming the importance of this mountainside in relation to the entire study area. Three of these animals ('female#2', 'unicorn female' and 'left horn-stub female') displayed pronounced lateral shifts in range use of at least 5 to 7 km during late June and early July. No obvious movements of this nature were otherwise recognized, even though these same goats were repeatedly sighted in the more open alpine zone (usually along or near the knife-edge ridge top). No mineral lick was discovered, which could possibly have explained this movement by females.
Figure 5 - Distribution of 1977 rutting locations in the study area.
Figure 6: Observed movements of "female #2" and "bar-nosed female" on Maroon Mountain, B.C. (numbers indicate sequence of sightings).
Figure 7 - Observed movements of "unicorn female" and "left horn-stub female" on Maroon Mountain, B.C. (numbers indicate sequence of sightings).
1.2 Population Structure

1.2.1 Population Size And Density

The minimum Maroon Mountain goat population size was predicted to be 137 mountain goats, based upon the maximum count, which was obtained during a helicopter survey. McCrory and Blood (1978) estimated that helicopters miss 26 to 30% of the actual population during aerial surveys, therefore the Maroon population may range as high as 185 to 196 mountain goats.

Based upon the minimum known population size of 137 animals, the mountain goat density was 9.59 goats/km$^2$, over the area of observed distribution. The predicted Maroon Mountain population size ($n=185$ to 196 goats) approximated a density of between 12.96 and 13.73 animals/km$^2$. Aerial determinations were significantly different when corrected for hillside slope ($\bar{\text{slope}}=34^\circ$; correction factor=1.20). Therefore, density values were reduced to 10.79 and 11.40 mountain goats/km$^2$.

1.2.2 Population Composition

Neonates were first observed on May 26, 1976, May 24, 1977 and May 19, 1978. Sex-age ratios were not assessed for the 1976 data because adult female classification was biased towards 'goats with kids' and because males could not be distinguished from females with a high degree of certainty. The maximum kid/100 adult female ratio was 73.7, in 1977. The maximum number of yearling/100 adult females was 52.7, in 1978. These data suggest a first-year mortality rate of 28.5%. The maximum
adult sex ratio was 52.6 males/100 adult females.

Actual proportions of the Maroon Mountain population composed of males and females were calculated from the maximum survey count, regardless of age, apportioning the 'unclassified' segment by the classified sex ratio, and adding the two figures for each sex together. In this manner, it was estimated that the maximum number of males and females in the Maroon Mountain population were 47 and 90, respectively. Most of the males were classified as adults (75.6%). Subadults comprised 3.9%, yearlings 13.4% and kids 0.2% of the classified males. Similarly, most females were also classified as adults (86.1%). Subadults comprised 3.9%, yearlings 9.7% and kids 0.3% of the classified females. Kids were the most difficult to sex and, therefore, retained the highest proportion of unclassified animals.

1.3 Mountain Goat Observability

Variations in mountain goat observability were examined by census results, comparison of survey technique and mountain goat sex.

1.3.1 Census Results

Censuses included a 6 km² area on Mt. Garland south of Maroon Mountain, in which on average 8 percent of censused goats were seen. Although not used elsewhere, they have been included in the following discussion of census techniques to maintain complete survey data.
a. Aerial Counts

Four helicopter surveys were conducted in a 'Jet Ranger' during May, August, December, 1976 and July, 1977. Total counts ranged from 70 to 149 mountain goats (Figure 8), producing a mean count of 118.8 animals (SD=35.9). Snow-free months (May to August) provided the highest counts (114 to 142), with the lowest variation (SD=18.5). However mountain goat observability by replication with helicopter was not constant (G=35.1;df=3).

Two fixed wing aircraft surveys were conducted (April, 1976, in a de Havilland 'Beaver'; August, 1977 in a Cessna 180), during which only 14 mountain goats and one lone individual were observed, respectively. Correcting these counts by multiplying with a factor of 5.0, to cover the vertical gradient of the study area, resulted in counts of 70 and 5 animals, or a mean of 37.5 mountain goats, which is far less than the previous aerial survey technique and much more variable (SD=46.0 goats). Mountain goat observability between the two fixed-wing surveys was also significantly different (G=67.2;df=1).

b. Vehicular Counts

Many vehicular surveys were not completed due to changing environmental variables during the course of each survey, which averaged between 6 and 12 hours in duration. However, a total of 63 completed road
Figure 8 - Summary of mountain goat counts on Maroon Mountain and Mount Garland, B.C. (horizontal bar=mean; vertical bar=standard deviation).
surveys were accomplished over 24 months of observation between April, 1976 and August, 1978 (Figure 8). The average number of goats observed by road survey was 63.14 (SD=27.4).

The proportion of the total (estimated) population was not constant throughout the year (G=812.1;df=62), ranging from 12.6% to 85.4% of the total possible number observable. As expected, maximum vehicular counts generally occurred during the period of mountain goat parturition. Late fall-early winter and summer periods generally provided the lowest counts. During the first two years, 59.7 and 57.7 goats were seen on average, but in 1978, a mean of 74.1 goats were seen. Mean counts did not differ significantly between years (Kruskal-Wallis' Hc=8.1;df=2).

c. Comparison of Surveys

Fixed-wing surveys were inadequate for conclusive comparisons. Helicopter surveys were statistically different from ground surveys. A pair-wise comparison of helicopter and follow-up vehicular counts indicates a significant disparity between the two techniques (G=49.8;df=3). Helicopter censuses provided 1.9 times greater accuracy than ground censuses, on average. The level of precision for each of the two methods appeared similar (air SD=20.7; ground SD=18.6), when each of the four helicopter surveys were compared to
their respective follow-up vehicular surveys, however, helicopter surveys were considered more precise because of their proportionately reduced variation in relation to total numbers.

1.3.2 Observability Of Sexes

The average number of males and females were not equally observable throughout the year (Wilcoxon's T=0.0; n=16), nor were they consistently seen throughout the sampling period (males: \( G=405.5, \text{df}=37 \); females: \( G=345.7, \text{df}=37 \)). Representative proportions (i.e. >50%) of the male segment of the population were only observable during 6 of the 16 months sampled (Figure 9). They were seen least during the period of mountain goat parturition (late May-early June), and on into the summer (July-September). Males were most frequently observed during late winter (February and March) and early spring 'green-up' (April and May), and secondarily during the rut (November). Females were considerably more visible than males, being represented in 13 of the 16 months sampled (Figure 9). Similar to males, they were least visible during parts of the summer, and also in late fall, during and after the rutting period.
Figure 9 - Observability of male and female components of the Maroon Mountain goat population (horizontal bar=mean; vertical bar=standard deviation).
2. HABITAT CHARACTERISTICS

2.1 Habitat Use

2.1.1 Biotic Factors

a. Vegetative Cover Description

Six plant formations, comprising fifteen categories of vegetative cover, were described on the south aspect of Maroon Mountain and are depicted in Figure 10. These include:

Closed (non-giant) forests. Five categories are described within the text, three of which are coniferous;

(1) The Tsuga-Abies (Hemlock-Fir) forest is the major cover type on north, east, and west-facing slopes, from as low as 150 m above sea level, on the shores of Kitsumkalum Lake, to the 1252 m (mean) treeline region of Maroon Mountain. *Tsuga* species occur from valley bottom to treeline, whereas *Abies grandis* and moreso *A. lasiocarpa* become increasingly abundant above 610 m. The understory consists primarily of cryptogams such as *Hylocomium splendens*, *Pleurozium schreberi*, *Rhytidiadelphus loreus*, and *Rhytidiopsis robusta*, forming a dense mat. *Menziesia ferruginea* and several *Vaccinium* species occur in the upper subalpine forest understory, where the crown cover is slightly less dense.

(2) The Picea-Abies (Spruce-Fir) forest occurs on
Figure 10 - Vegetative cover of key mountain goat range (south aspect) on Maroon Mountain, B.C.
south-facing slopes and valley-bottoms. *Picea* glauca and *P. sitchensis* are most abundant on slopes less than 762 m, but *Abies amabilis* and *Tsuga heterophylla* are also common. Moss, riparian, *Lysichitum* and *Oplopanax* associations are also common, on the valley-floor. Above 762 m, *Picea* species are quickly replaced by *Tsuga mertensiana*. *Abies amabilis* is replaced by *A. lasiocarpa*, which becomes the dominant tree species above 1067 m. A cryptogamic mat of moss species similar in composition to the *Tsuga-Abies* forest predominates, and a few widely scattered shrubs, mentioned in the previous forest type, are located within the subalpine forest understory. *Ptilium crista-castrensis* and several *Pyrola* species are additions to this understory.

(3) The *Pinus-Populus* (Pine-Aspen) forest occurs only on the drier, rocky slopes of the south-aspect of Maroon Mountain, at the entrance to Maroon Creek valley. *Pinus contorta* is the principal tree species. Secondary trees are *Populus tremuloides* and *Tsuga heterophylla*. *Arctostaphylos uva-ursi*, *Chimaphila umbellata*, *Cornus canadensis*, *Linnaea borealis*, and *Pyrola asarifolia* compose a scant, but more diverse, understory. A heavy cryptogam influence is evident, consisting of *Peltigera apthosa*, *Pleurozium schreberi*, *Polytrichum juniperinum*, and *Ptilium crista-castrensis*. This area was burned sometime during the
1920's or 1930's.

(4) A fourth forest category is a mixed forest of deciduous trees with some coniferous trees. Occurring primarily on the south aspect, on old and undisturbed rock litter slopes, the Populus-Alnus-Thuja (Apsen-Alder-Cedar) forest contains a variety of tree species. *Betula papyrifera*, *Picea glauca*, *Populus tremuloides* and *Thuja plicata* are the dominant trees, with *Alnus rubra* and *A. sinuata* becoming abundant under more riparian influence. *Acer* and *Alnus* shrub forms comprise the taller understory species. *Dryopteris austriaca* and *Gymnocarpium dryopteris* are abundant low-form (fern) species, in addition to a large variety of mosses (mentioned previously) which carpet the rocky floor.

(5) The least abundant forest cover described is the sub-montane deciduous forest, usually found in small patches on gently-sloping hillsides or on alluvial fans. The Populus-Alnus-Acer (Cottonwood-Alder-Maple) forest forms two types. *Populus tremuloides* is the main tree species of the first type, with *Athyrium filix-femina* and *Gymnocarpium dryopteris* common in the understory, in addition to a variety of forbs. The second type is comprised of *Populus trichocarpa* as the major tree species. Characteristically on alluvial fans, *Acer* and *Alnus* shrub forms occur in abundance. The low-form understory species are similarly diverse.
in both types.

**Open forested woodlands.** Three coniferous woodland categories were recognized. Each is merely a diversification of the three coniferous forests described previously. The influence of rocky substrate and increased light filtration is shown by a diverse array of shrubby plants such as *Acer*, *Alnus*, and *Vaccinium* species. Graminoid species of *Agrostis* and *Calamagrostis* are commonly associated with the larger shrub forms, as are cryptogam, *Saxifraga* and *Sedum* species with the more open rocky areas.

**Scrub.** Three scrub categories occur, consisting of two shrublands and one shrub thicket.

(1) The deciduous shrubland is characterized by shrubs which are clumped and divided from each other by a grass stratum (similar to a scrub pasture). Two types occur, determined by rocky influence; one with a tall stratum and the other with a low stratum. The tall stratum, or *Alnus* type grows to 4.6 m in height and is comprised almost solely of clumps of *Alnus sinuata*, interspersed by such graminoid species as *Agropyron caninum*, *Agrostis exarata*, *A. scabra*, *Calamagrostis canadensis*, *Festuca ovina*, *Poa alpina* and *Trisetum spicatum*. *Achillea millefolium*, *Rosa nutkana*, *Carex* and *Luzula*, species and other herbs are also abundant. The low stratum, or *Rubus* type, grows to 1 m in height, comprised of *Heracleum lanatum*, *Rubus*
parviflorus, Smilacina stellata and Veratrum viride. Few graminoid species occur in this sub-type.

(2) A second (coniferous) shrubland, or 'krummholz', is composed mostly of creeping or lodged needle-leaved phanerophytes such as Abies lasiocarpa and some Tsuga mertensiana. Shrub forms are grouped and divided from each other by either exposed rock, cryptogamic or herbaceous layers, or all three strata types in mosaic fashion. The undergrowth may be diverse, consisting of many alpine and subalpine shrub, herb and moss-lichen species requiring a wide range of moisture gradients. Shrubs such as Empetrum nigrum, Rubus pedatus, Phyllodoce, Salix and Vaccinium species all intermix, along with Achillea millefolium, Artemisia norvegica, Carex and Luzula species, Silene acaulis, and Festuca ovina and Poa graminoid species. Broad-leaved forbs are not abundant, however numerous cryptogam species occur, particularly Platismatia glauca, Pleurozium schreberi, and Alectoria species.

(3) The deciduous shrub thicket is more or less dense scrub with or without a significantly reduced herbaceous undergrowth, in contrast to the deciduous shrubland. Deciduous thickets occur primarily on seepage slopes below cliff rock or along ravines. Plant species, when present, are essentially the same as those described of the deciduous shrubland, only in differing proportions; i.e. less herbs and more woody
Logging Clearcut. Logged areas north of Maroon Creek ranged from one to seven years of age, as of the summer of 1978. Each clearcut was slash-burned after logging operations were completed. Succession progressed in order of cryptogam, shrub, and herb strata, respectively. Dense cryptogam cushions of Dicranum, Mnium, Pogonatum and Polytrichum moss species quickly invaded the more recently cleared areas of organic substrate, in addition to a host of other bryophytes. Alnus rubra, A. sinuata and other woody colonizer shrubs such as Aruncus sylvester, Chimaphila umbellata, Ribes laxiflorum, Rosa nutkana, Sambucus racemosa, Sorbus sitchensis, and Cornus, Rubus, Salix and Vaccinium species established themselves soon afterwards, growing in profusion. Agrostis, Arabis, Carex, Cirsium, Epilobium, Mimulus, Phleum and Smilacina species dominate in the older clearcuts (>2 years of age), along with Achillea millefolium, Anaphalis margaritacea, Lupinus latifolius, Montia sibirica, and Tiarella trifoliata. Every clearcut had been replanted with Picea tree seedlings prior to the fall of 1978.

Tall-sedge Swamp. Open bodies of water, created by now-abandoned beaver dams support large homogenous stands of Carex and Equisetum intermixed. Where organic material has filled in more rapidly, a few
small *Picea sitchensis* and *P. glauca* snags stand, less than 5 m in height. A few valley-bottom graminoid species also grow on these higher areas. The beaver dams themselves are covered with young shrub growth, such as *Alnus* and *Salix* species, along with a variety of herbs.

**Scarcely vegetated areas.** Subalpine and alpine categories are recognized. Plants may be scattered or absent.

(1) In the subalpine, chasmophytic vegetation dominated, with permanent plants rooted in fissures of rocks or walls. Many colonizer shrubs occurred, in addition to retarded growth forms of both coniferous and deciduous trees. *Silene acaulis*, *Sedum* and *Senecio* species, in addition to many graminoid species, occurred on well-manured surface rock. *Dicranum*, *Mnium*, *Peltigera*, and *Polytrichum* cryptogam species also abound.

(2) Alpine interfluves, rocks and scree supported permanent herbs or half-woody, prostrate plants with infrequent occurrence. Much of the vegetative cover comprised cryptogam species. Alpine slopes on the south aspect of Maroon Mountain were generally sparsely-vegetated, usually with less than 10% ground cover. No well-defined plant communities dominated an area large enough to map. Therefore, scarcely vegetated rock, small herbaceous meadows, and
cryptogamic mats of lichen and bryophyte species were recognized but not depicted on the vegetation map (see Figure 10).

b. Use of Vegetative Cover
i. Overstory Assessment

Only three 'forest' categories were used to describe mountain goat use (coniferous, deciduous and mixed). References to coniferous forests included all three coniferous forest categories (i.e. Hemlock-Fir, Spruce-Fir, and Pine-Aspen). 'Woodlands' were considered as a single category (i.e. coniferous) only, due to an absence of deciduous and mixed coniferous-deciduous formations in the study area.

Mountain goats did not utilize vegetative cover categories in equal proportions (G=7680.4;df=9). They were observed to use twelve of the fifteen plant formation categories on Maroon Mountain previously described. These include two scarcely vegetated areas (alpine and subalpine), krummholz, the three coniferous forest and woodland categories, mixed forests, deciduous shrublands, and deciduous shrub thickets. The scarcely-vegetated rock category, including both alpine and subalpine subtypes, received more use (69.4%), overall, than the remaining categories combined (Figure 11).
Figure 11 - Summary of mountain goat use of vegetative cover on Maroon Mountain, B.C.
Deciduous shrublands were the second-most used plant cover (10.5%). Krummholz, coniferous forests, coniferous woodlands and deciduous shrub thickets were used infrequently (6.3%, 5.9%, 4.0%, and 3.4%, respectively). Mountain goats were only sporadically observed in the mixed forest cover types (0.2%). No mountain goats were observed in the deciduous forest, logging clearcuts, or the tall-sedge swamp.

Utilization of vegetative cover was dependent upon time of year (G=5790.1; df=75). Scarcely vegetated areas were used proportionately more than any other category in every month (n=16). However, in May, 1978, mountain goat use of deciduous shrub areas exceeded that of the scarcely vegetated rock type (Figure 11). Deciduous shrublands and thickets were also used extensively from September through November, and again from February through April. Coniferous timber areas were used primarily during the fall and winter, whereas the krummholz zone received most of its use during the snow-free periods.

ii. Understory Characteristics

Sample sizes for some characteristics were low in certain months. Therefore, one should consider the following interpretation bearing
this in mind.

Herbaceous understory types were not utilized equally by mountain goats (G=2133.5;df=3). Monthly differences accounted for part of this variation (G=608.0;df=45). Averaged over the study period, the most common understory used by mountain goats (68.8%) was comprised of less than 50% herbaceous cover (Figure 12), and was typically associated with rocky substrates. This type was utilized most through all months with the exception of December, when herbaceous meadows (low stratum type) were exclusively used in subalpine areas. This low stratum type was used mostly from September through December, and again from February through May. The alpine (low stratum) and subalpine (high stratum) herbaceous meadows were predominantly utilized during snow-free periods of the year (June through August).

The overall division of use of plant strata within the krummholz zone (Figure 13) was similar (G=0.8;df=1), with 52.5% of the mountain goats observed utilizing the high stratum. Seasonally, however, use of the two strata varied significantly (G=94.6;df=15). The higher stratum was used mostly in the fall, winter and spring, for what appeared to be thermal cover. The lower
Figure 12 - Summary of mountain goat use of herbaceous understory types on Maroon Mountain, B.C.
Figure 13 - Summary of mountain goat use of krummholz strata on Maroon Mountain, B.C.
stratum was utilized the heaviest during late spring and throughout the summer. Although the low woody stratum may hinder travel due to its density, it also assists mountain goats in removal of their shedding hair. Often the stunted trees are clumped and offer a lush herb mat suitable for foraging.

In the deciduous shrub cover category (Figure 14), mountain goats were most frequently observed (71.5%) in areas offering the higher vegetation strata, as this type was characteristic of a diverse array of herbaceous understory material (G=64.4;df=1). The lower stratum generally offered little forage other than the shrubs themselves. Use of each strata was variable throughout the year (G=29.1;df=15), with no apparent trend.

Forest woody shrub understory types were also not used in equal proportions (G=281.1;df=3). Use of each type varied throughout the year (G=80.6;df=45) as well (Figure 15), however, coniferous trees were utilized most, except during parturition (May and June). Coniferous shrub understories were used proportionately more during the kidding period, but were also heavily utilized during winter. Negligible use of the mixed (coniferous-
Figure 14 - Summary of mountain goat use of deciduous shrub strata on Maroon Mountain, B.C.
Figure 15 - Summary of mountain goat use of forest woody shrub understories on Maroon Mountain, B.C.
deciduous) timber and mixed shrub understory types was evident.

2.1.2 Abiotic Factors

a. Terrain Classification

i. Surface Expression

Overall analysis showed that mountain goats utilized landforms in unequal proportions (G=1114.8; df=6). Rock bluffs, outcrops or knolls were used significantly more (42.4%) than any other terrain feature described (Figure 16). They generally offered unrestricted viewing of the immediate surroundings and frequently served as bedding areas. Benches, ledges, and shelves were used less frequently (19.1%) by goats, as were ravines (14.5%), ridges (10.4%), and talus slopes (9.6%). Peaks (2.7%) and hummocky (tundra) areas (1.3%) were utilized to a much lesser extent.

Mountain goat use of topographic features were also dependent upon time of year (G=1080.7; df=90). Rock bluffs, outcrops and knolls were used throughout the year, but with a preponderance of use during the fall and winter periods (November to March) when snow covered most of the ground. A shift to usage of steep ravine rock walls occurred in late winter and
Figure 16 - Summary of mountain goat use of landforms on Maroon Mountain, B.C.
early spring (March to May), subsequent to the peak in use of rock bluffs, outcrops and knolls. Both categories have important snow-shedding features believed to attract mountain goats for feeding. Benches, ledges and shelves were frequently utilized by mountain goats during the period of parturition in 1977, however, steep ravine walls and ridge-tops were used by the goats during the same period in 1978. These differences are thought to result from varying temperature and snow conditions between the two years (i.e. more snow in 1978).

ii. Rock Substrate

Summary of the total mountain goat use of rock substrates shows disproportionately higher use of broken rock (87.7%), throughout the year (G=3579.2; df=3) (Figure 17). Slopes of loose shale were the second most used substrate by goats (only 6.7%), similar in degree to use of gravel slopes (4.6%). Smooth rock surfaces were utilized only 0.9% of the time.

Temporal variation in the use of substrate types also occurred (G=492.9; df=45). The broken rock category was consistently used more than all other categories throughout the entire study period. Shale slopes were utilized primarily during the late spring and early summer (June
Figure 17 - Summary of mountain goat use of rock substrates on Maroon Mountain, B.C.
through August) but to a much lesser extent in 1977, when mountain goats used dirt-gravel slopes proportionately more than for the same period in 1978. The former type is generally used for travel and bedding during hot temperature extremes. The latter category was primarily used for 'dusting' by mountain goats, generally during high summer temperatures.

b. Aspect

Overall assessment of aspect utilization by mountain goats suggests that each category is not used in equal proportion ($G=7566.0;df=8$). Differences in use were accounted for by monthly effects ($G=520.4;df=120$) (Figure 18). Between early May, 1977 and late August, 1978, 96% of all mountain goats systematically observed on Maroon Mountain occurred on southerly-facing slopes between $112^\circ$ and $247^\circ$. Northerly aspects were rarely used by mountain goats and almost exclusively during conditions of high ambient temperatures in the snow-free months of June through September. An incidental mountain goat sighting on a north aspect in late May probably arose from 'exploratory' travel over tundra areas subjected to recent snow-melt conditions.

c. Slope

Mountain goats utilized slopes ranging from $16^\circ$
Figure 18 - Summary of mountain goat use of aspects on Maroon Mountain, B.C.
to 62° disproportionately (G=3546.5; df=10). However, nearly 84% of all mountain goats observed utilized inclines between 30° and 45° (Figure 19). Thirty-eight percent of the goats were observed in the 38-41° interval class.

Temporal variations occurred in the use of slope intervals (G=866.2; df=150). The 38-41° interval was predominantly utilized throughout the year. Steeper slope classes (42-45°, 46-50°, 51-56°, and 57-63°) were used by mountain goats primarily during months when abundant snow cover was present (November and February) or when the ground was exposed by shedding or melting snow (March through June). More gentle grades (≤27°) were used proportionately more during the summer periods (July to September), when snow-free conditions enabled occupancy of alpine ridge and tundra areas.

d. Elevation

Treeline was estimated to occur at 1292 m north of the main ridge, and at 1194 m south of the main ridge, averaging 1252 m throughout the entire study area. The alpine zone ranges vertically over 734 m on the southern slopes of Maroon Mountain. The subalpine zone ranges vertically over nearly half as much again (1057 m).

Overall mountain goat use was significantly different between 250-m interval elevation classes
Figure 19 - Summary of mountain goat use of hillside slope on Maroon Mountain, B.C.
However, more than 60% of the mountain goats observed occurred in alpine habitat (Figure 20). The two 250-m intervals adjacent to treeline (1001-1250 m and 1251-1500 m) accounted for 45% of all mountain goat observations. No mountain goats were observed below 250 m.

Temporal variations in the use of 250-m altitudinal zones were also apparent (G=2281.2; df=120). Use of higher elevations increased during months of snowpack recession and extreme sunny (warm) temperatures (June through September). After this period, altitudinal use dropped steadily, to well below treeline in November, with the onset of stormy weather and strong northerly winds. Most of the mountain goats utilized subalpine habitats from October to May, except in January.

e. Microclimate

Weather stations were monitored for up to twelve months, recording temperature, humidity, wind speed, and precipitation levels whenever possible. Unfortunately only the temperature data were worthy of analysis (excluding the government maintained facility at Rosswood, B.C.), due to instrument failures and other various mishaps. The 'main ridge' weather station (#4) was blown over by strong northerly winds in October and was not recovered until March.

Analysis of the study site temperature data
Figure 20 - Summary of mountain goat altitudinal use by 250-m classes on Maroon Mountain, B.C.
(Figure 21) revealed several important climatological features on mountain goat ranges. Mean monthly temperatures were significantly different between stations ($H_c=13.6; df=6$). Of the seven weather stations assessed, station #1 ('Waterfall': 879 m) was the warmest, during the spring months (April to June). At this time, the coldest locations were the alpine stations (station #4, at 1692 m, and station #5, at 1591 m). Throughout the summer period, Rosswood recorded the highest mean monthly temperature values. During early fall (October), the head of Maroon valley and the valley bottom acted as 'cold-sinks', always being in the shade due to the low angle of the sun. Alpine stations also maintained cold temperatures at this time, with the 'treeline' station being the warmest location. During November, temperatures dropped, becoming indicative of winter, particularly at station #5. However, in December, a pronounced thermal inversion had formed a warm air mass above treeline with alpine stations #3, #4(?) and #5 approaching mean monthly temperatures up to 17°C warmer than lower elevation areas. In winter (January to March), however, the alpine ridges apparently cooled down to temperatures similar to that of the other stations, but the 'treeline' station remained much warmer than the others for the entire three-month period.
Figure 21 - Summary of mean monthly temperature values for six weather stations on Maroon Mountain, B.C. Note thermal inversions as shown by station no.3 in December, January, and February.
Forested areas (station #2) and adjacent non-forested areas (station #1) were not significantly different in their mean monthly temperature regimes \((T=21; n=12)\). However, forested areas were noted to be slightly warmer than neighbouring exposed areas from September to February, with the exclusion of November. From March through August, forested areas were, on average, 4°C cooler than exposed areas.

2.2 Habitat Selection

This analysis is presented to determine if habitats were being used by mountain goats disproportionate to their availability. Selection describes a circumstance, not an act. 'Preferred' habitats are those in which mountain goats were found to use a particular habitat category more than in proportion to its availability. 'Avoidance' refers to the converse (i.e. goat use is significantly less than in proportion to its availability). 'Selection' refers to the circumstances of avoidance and preference; nothing else is implied by the use of these three terms.

2.2.1 Data Considerations

The data were first considered in five different ways before the analysis of selection was undertaken.

a. Area of Availability

Based upon the cumulative distribution of mountain goats presented in Figure 3, and known movements of several individuals (Figures 6 and 7),
the area 'available' to goats was considered to include the entire southerly-facing slope of Maroon Mountain, from ridge-top down to Maroon Creek itself. The summering areas north of the main ridge were not available to the goats in 1977 or 1978 due to the common occurrence of predators (Canis lupus, Gulo gulo and Ursus arctos).

b. Correction For Hillside Slope

Areal calculations and random sample estimation of proportions of availability showed no significant difference in the proportions of plant cover (Wilcoxon's T=16.0;n=10), aspect (T=5.0;n=5), slope (T=17.0;n=8), and 250-m intervals (T=14.5;n=9) after correcting for hillside slope, although in each case the absolute area of each category was obviously larger. The corrected data were included in the preference analysis. Surface expression, substrate texture and plant understory variables were not used.

c. Random Subsampling From Groups

Originally it was planned to subsample groups in order to statistically analyse independent data by reducing biases resulting from social choices rather than habitat choices. However, I did not use the independent (subsampled) data in the final analysis, as it was felt that sex-related attributes (i.e. group types) played a more significant role in goat ecology,
and insufficient data were available to subsample for both group size and group type on a monthly basis.

However, the implications of random subsampling of one animal per group as opposed to using all individuals in the analysis were explored. Significant differences in habitat use occurred for some variables. Use of plant cover \((G=20.3; df=10)\) and elevation at 250-m intervals \((G=70.5; df=8)\) were significantly different between the subsampled and the overall data, but aspect \((G=11.4; df=8)\) and slope \((G=17.8; df=10)\) showed no significant differences.

d. Influence of Social Structure

Group type was also chosen as an important factor in the preference analysis because 33.2% of all males were associated with female goats. It seemed logical, in view of the fact that males are less aggressive than females (Chadwick 1973, Rideout 1974), that male use of habitat attributes was determined by the dominant sex, whom they followed (when in their company). Under this same rationale, when used for group subsampling, only males in 'male-only' groups represented true selection of habitat attributes by each sex.

e. Sample Representation

A further restriction placed on the data prior to analysis was adequate representation of the absolute
numbers of male and female components of the population. From Figure 9, it was apparent that the sampled proportions of males and females did not exceed 50% of each component for 10 and 3 months, respectively, of the 16 months sampled. Because an assessment of selection based upon a non-representative proportion of a sex would be misleading, the analysis was restricted to those months in which each sex was represented by more than 50% of its total estimated number (i.e. November, 1977 and January to May, 1978 for males; May, June, August to November, 1977 and January to July, 1978 for females).

2.2.2 Biotic Factors

a. Vegetative Cover

Mixed-female groups were more selective for vegetative cover than male-only groups (Table 3). Only in May, 1978 was a plant cover type not used equally with respect to its availability by male-only groups, whereas for the same period, mixed-female groups used vegetative cover disproportionately in every month but January. Male-only groups preferred deciduous shrub thickets during May, 1978, but mixed-female groups showed an indifference to their use. Mixed-female groups preferred the scarcely vegetated areas in all months but September and October of 1977,
Table 3 - Mountain goat selection of vegetative cover on Maroon Mountain (south slope) for male-only and mixed-female groups.

<table>
<thead>
<tr>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Scarcely Vegetated Areas</th>
<th>Coniferous Forest</th>
<th>Coniferous Woodland</th>
<th>Deciduous Shrub Thicket</th>
<th>Deciduous Shrubland</th>
<th>Mixed Forest</th>
<th>Deciduous Forest</th>
<th>Logging Clearcut</th>
<th>Swamp</th>
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<td>1977</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0</td>
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<td>0</td>
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<td>Dec</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</tr>
<tr>
<td>Jun</td>
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<tr>
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<td>66.0977*</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>(0)</td>
</tr>
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<td>Jul</td>
<td>91.8657*</td>
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<td>*</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>*</td>
<td>*</td>
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<td>*</td>
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<td>(0)</td>
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<td>Nov</td>
<td>4.6045</td>
<td>128</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Jan</td>
<td>10.6914</td>
<td>172</td>
<td>*</td>
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<td>0</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Feb</td>
<td>68.2544</td>
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<td>*</td>
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<td>Mar</td>
<td>59.9629</td>
<td>110</td>
<td>*</td>
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<td>*</td>
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<td>0</td>
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</tr>
</tbody>
</table>

1 'x' = preferred, or used in greater proportion than available; '0' = no selection, or used in equal proportion to availability; '-' = avoided, or used in less proportion than available. Bracketed symbols indicate no use.

m = non-representative data (i.e. less than 50% of the estimate sex component in the population)

* significant at p<0.05
and January and May of 1978, followed secondarily by preference for deciduous shrublands in May, October, November, 1977 and May, 1978. Mixed-female groups also avoided more cover categories (e.g. forested areas) than did male-only groups.

Although the analysis frequently showed deciduous forests, logging clearcuts, and the tall-sedge swamp to be used in proportion to their availability, these categories received no use at all by either group type (i.e. they were avoided). This suggests an inability of Marcum and Loftgaarden's (1980) technique to differentiate use and availability where low sample sizes occur or small areas exist (deciduous forests and the tall-sedge swamp comprised 1.41 and 0.67% of the study area, respectively) at the given probability level.

2.2.3 Abiotic Factors

a. Aspect

Contingency tests of independence on mountain goat use and availability of aspect are presented in Table 4. Male-only groups were less selective of aspect categories than were female groups. Male-only groups used aspect categories disproportionate to their availability in February only, preferring south exposures and avoiding southwest exposures. Mixed-female groups displayed similar selection of aspect
Table 4 - Mountain goat selection of aspect on Maroon Mountain (south slope) for male-only and mixed-female groups.

<table>
<thead>
<tr>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Male-only Group Selection¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>South</td>
</tr>
<tr>
<td>1977</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May-Oct</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>4.4728</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Dec</td>
<td></td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>1978</td>
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<td>12</td>
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<tr>
<td>Jan</td>
<td>7.2407</td>
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<td>+</td>
</tr>
<tr>
<td>Feb</td>
<td>17.3677</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Mar</td>
<td>6.3571</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Apr</td>
<td>8.0205</td>
<td>38</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>5.4019</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>Jun-Aug</td>
<td></td>
<td>m</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Mixed-female Group Selection¹</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td>South</td>
</tr>
<tr>
<td>1977</td>
<td></td>
<td>149</td>
<td>+</td>
</tr>
<tr>
<td>Jun</td>
<td>30.3145¹</td>
<td>232</td>
<td>+</td>
</tr>
<tr>
<td>Jul</td>
<td>m</td>
<td>m</td>
<td>n</td>
</tr>
<tr>
<td>Aug</td>
<td>27.0449¹</td>
<td>206</td>
<td>0</td>
</tr>
<tr>
<td>Sep</td>
<td>32.5552¹</td>
<td>165</td>
<td>+</td>
</tr>
<tr>
<td>Oct</td>
<td>13.3237¹</td>
<td>106</td>
<td>+</td>
</tr>
<tr>
<td>Nov</td>
<td>25.1196¹</td>
<td>150</td>
<td>+</td>
</tr>
<tr>
<td>Dec</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>Jan</td>
<td>12.5278¹</td>
<td>128</td>
<td>0</td>
</tr>
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<td>172</td>
<td>+</td>
</tr>
<tr>
<td>Mar</td>
<td>30.2554¹</td>
<td>159</td>
<td>+</td>
</tr>
<tr>
<td>Apr</td>
<td>36.3213¹</td>
<td>118</td>
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</tr>
<tr>
<td>May</td>
<td>19.8711¹</td>
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<td>+</td>
</tr>
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<td>Jun</td>
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<td>+</td>
</tr>
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<td>Jul</td>
<td>32.1929¹</td>
<td>69</td>
<td>+</td>
</tr>
<tr>
<td>Aug</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
</tbody>
</table>

¹ '+' = preferred, or used in greater proportion than available; '0' = no selection, or used in equal proportion to availability; '-' = avoided, or used in less proportion than available. Bracketed symbols indicate no use.

m = non-representative data (i.e. less than 50% of the estimated sex component in the population.

* significant at p<0.05
during February, however they also utilized aspect disproportionate to its availability in all other months as well. In each case, south aspects were generally preferred and southwest aspects generally avoided. Western aspects were also avoided in June, 1977, and southeast facing slopes were avoided in May and August, 1977.

b. Slope

Mixed-female groups were more selective of slope categories than were male-only groups (Table 5). Mixed-female groups selected at least two slope categories in each month of the analysis except for August, 1977. Male-only groups selected only one category in three of the six months analysed. In November and March, male-only groups preferred the 38-41° slope class. Gentle slopes (≤27°) were avoided in May. Although contingency analysis of the February data concluded that selection occurred in this month, none was highlighted by the SCI analysis. Mixed-female groups preferred the 38-41° slope class in almost every month. Additionally, the 35-37° slope class was preferred in June, 1977. Although used primarily during the summer, gentler slopes (≤29°) were avoided for the most part. Female groups also avoided the steeper slopes (≥42°) throughout most of the year.
Table 5 - Mountain goat selection of hillside slope on Maroon Mountain (south slope) by male-only and mixed-female groups.

<table>
<thead>
<tr>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Male-only Group Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤ 27°</td>
</tr>
<tr>
<td>1977 May</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>Nov</td>
<td>15.771*</td>
<td>10</td>
<td>(0)</td>
</tr>
<tr>
<td>Dec</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>1978 Jan</td>
<td>9.0934</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>25.3066</td>
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<td>0</td>
</tr>
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<td>Mar</td>
<td>17.9121</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>Apr</td>
<td>13.5117</td>
<td>38</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>24.6046*</td>
<td>42</td>
<td>(-)</td>
</tr>
<tr>
<td>Jun-Aug</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Mixed-female Group Selection</th>
</tr>
</thead>
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<td></td>
<td></td>
<td>≤ 27°</td>
</tr>
<tr>
<td>1977 May</td>
<td>68.4316*</td>
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<td>Jun</td>
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<td>233</td>
<td>-</td>
</tr>
<tr>
<td>Jul</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>Aug</td>
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<td>86.1726*</td>
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<td>(-)</td>
</tr>
<tr>
<td>Nov</td>
<td>60.5420*</td>
<td>150</td>
<td>(-)</td>
</tr>
<tr>
<td>Dec</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>1978 Jan</td>
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<td>-</td>
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<tr>
<td>Feb</td>
<td>33.7539*</td>
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<td>-</td>
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<tr>
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<td>0</td>
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<tr>
<td>Aug</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
</tbody>
</table>

1 ' + ' = preferred, or used in greater proportion than available; ' 0 ' = no selection, or used in equal proportion to availability; ' - ' = avoided, or used in less proportion than available. Bracketed symbols indicate no use.

m = non-representative data (i.e. less than 50% of the estimate sex component in the population)

* significant at p<0.05
c. Elevation

Male-only groups preferred alpine (above treeline) areas during January and the subalpine (below treeline) zone from March through May. Mixed-female groups exhibited similar preferences during January and May, 1977, however, from February through April, they utilized both zones in equal proportion to their availability. In other months, not represented by male-only groups, mixed-female groups generally preferred the alpine zone.

In a more detailed selection analysis of mountain goat altitudinal use (Table 6), mixed-female groups were more selective for certain 250-m elevation bands than were the male-only groups. Disproportionate use of elevation by the male groups was evident only in May, 1978, when the subalpine (751-1250 m) interval was preferred. Mixed-female groups, however, displayed selection in nine of the thirteen months analysed. In November, when male-only groups did not select for any particular elevation, mixed-female groups preferred elevations about or just below treeline (751-1000 m) and avoided higher elevations. In winter (January and March), female groups displayed a tendency to occupy alpine areas near treeline and avoided subalpine areas in January, whereas the male-only groups showed no preference. Female groups exhibited a high level of selection in May, 1977 but
Table 6 - Mountain goat selection of 250-m altitudinal zones on Maroon Mountain (south slope) by male-only and mixed-female groups.

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
<th>Log Likelihood Ratio</th>
<th>Number of Goats</th>
<th>Male-only Group Selection</th>
<th>Mixed-female Group Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subalpine</td>
<td></td>
<td>Alpine</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>164-250m</td>
<td>251-500m</td>
<td>501-750m</td>
<td>751-1000m</td>
<td>1001-1250m</td>
</tr>
<tr>
<td>1977</td>
<td>May 55.1064*</td>
<td>151</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Jun 9.8340</td>
<td>233</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Jul 261.0226*</td>
<td>227</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Aug 66.3701*</td>
<td>106</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>1978</td>
<td>Sep 51.6216*</td>
<td>154</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Oct 3.5630*</td>
<td>172</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Nov 16.7046*</td>
<td>118</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Dec 5.0440</td>
<td>164</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Jan 3.5630*</td>
<td>164</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>Feb 27.2134*</td>
<td>80</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
</tbody>
</table>

1. '+' = preferred, or used in greater proportion than available; '0' = no selection, or used in equal proportion to availability; '-' = avoided, or used in less proportion than available. Bracketed symbols indicate no use.
2. m = non-representative data (i.e. less than 50% of the estimate sex component in the population).
3. * significant at p<0.05
total indifference during May, 1978. They also showed indifferences to use of elevation zones during other months of the spring (i.e. April and June, 1978), and tended to prefer higher elevations (≥1250 m) during the summer period.

2.2.4 Mountain Goat Activity Within Preferred Habitats

a. Overall Activity Patterns

The most frequently observed mountain goat activities were feeding (48.8%) and resting (43.0%). Travel comprised only 8.3 percent of the observations. Proportions of feeding and resting did not vary significantly by month (G=5.1;df=5). Activity patterns varied, however, by group type. Male-only groups tended to rest (48.4%) and travel (11.8%) more than mixed-female groups (resting=42.1%; travel=8.2%); thus it followed that male-only groups fed (39.9%) less than female groups (49.7%). When the proportions of feeding were assessed by group type over the same period (i.e. November, 1977 and January to May, 1978), no significant differences by month were observed (males: G=8.7;df=5; females: G=1.8;df=5), however, proportions of mixed-female group activities did alter significantly during other times of the year (G=87.0;df=13).
b. Activity Patterns Within Preferred Habitats

Data were insufficient to statistically compare activity patterns of both male-only and mixed-female groups for each habitat category, on a monthly basis, therefore, descriptive statistics (% use) only were used to describe preferred habitats. The proportions of resting, feeding, and travel exhibited by male-only groups were similar in all habitats, however there was a tendency for males to rest more in preferred habitats. Resting predominated (\(\bar{x} = 60.0\%\)), followed by feeding (\(\bar{x} = 31.1\%\)) and travel (\(\bar{x} = 8.9\%\)). For mixed-female groups, however, most preferred habitat categories (54.2\%) were used primarily for feeding (\(\bar{x} = 57.0\%\); resting, \(\bar{x} = 37.5\%\); travel, \(\bar{x} = 5.5\%\)), while others (41.7\%) were used mainly for resting (\(\bar{x} = 52.3\%\); feeding, \(\bar{x} = 36.5\%\); travel, \(\bar{x} = 11.2\%\)). The most preferred habitats were feeding areas occurring mainly in south-facing, deciduous shrublands between 1001 and 1500 m, on slopes of 38 to 41°. Other preferred habitats were scarcely vegetated rock areas, and elevations between 750-1000 and 1501-1750 m (Table 7). The most preferred habitats where resting mainly occurred were scarcely vegetated rock areas with a direct southern exposure. In June, 1977, these habitats occurred on slopes between 35 and 41°, and in July, 1978, these habitats were located within the 1751 to 2000 m elevation interval. Other preferred
Table 7 - Preferred monthly habitats used primarily for feeding and resting by mixed-female groups on Maroon Mountain, B.C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Predominant Activity</th>
<th>Feeding Plant Cover</th>
<th>Aspect</th>
<th>Slope (°)</th>
<th>Elevation (m)</th>
<th>Resting Plant Cover</th>
<th>Aspect</th>
<th>Slope (°)</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977 May</td>
<td></td>
<td>Deciduous Shrubland</td>
<td>South</td>
<td>38-41</td>
<td></td>
<td>Scarcely Veg. Rock</td>
<td>South</td>
<td>35-37</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
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<tr>
<td>1977 Jun</td>
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<td>1977 Aug</td>
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<td>---</td>
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<tr>
<td>1977 Sep</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1501-1750</td>
<td>---</td>
<td>---</td>
<td>38-41</td>
<td>1251-1500</td>
</tr>
<tr>
<td>1977 Oct</td>
<td></td>
<td>Deciduous Shrubland</td>
<td>South</td>
<td>38-41</td>
<td>1001-1250</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1977 Nov</td>
<td>Scarcely Veg. Rock</td>
<td>South</td>
<td>---</td>
<td>750-1000</td>
<td>Deciduous Shrubland</td>
<td>---</td>
<td>---</td>
<td>1001-1250</td>
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</tr>
<tr>
<td>1977 Dec</td>
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<tr>
<td>1978 Jan</td>
<td></td>
<td>---</td>
<td>38-41</td>
<td>1251-1500</td>
<td>1501-1750</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<tr>
<td>1978 Feb</td>
<td></td>
<td>---</td>
<td>South</td>
<td>---</td>
<td>Scarcely Veg. Rock</td>
<td>---</td>
<td>38-41</td>
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</tr>
<tr>
<td>1978 Mar</td>
<td>Scarcely Veg. Rock</td>
<td>---</td>
<td>38-41</td>
<td>1251-1500</td>
<td>---</td>
<td>South</td>
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</tr>
<tr>
<td>1978 Apr</td>
<td></td>
<td>---</td>
<td>South</td>
<td>38-41</td>
<td>Scarcely Veg. Rock</td>
<td>---</td>
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<tr>
<td>1978 May</td>
<td>Deciduous Shrubland</td>
<td>South</td>
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<td>38-41</td>
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<tr>
<td>1978 Jun</td>
<td></td>
<td>---</td>
<td>38-41</td>
<td>---</td>
<td>Scarcely Veg. Rock</td>
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<td></td>
</tr>
</tbody>
</table>
habitats were deciduous shrublands and elevations between 1000 and 1500 m (Table 7).
V. DISCUSSION

1. HABITAT CHARACTERISTICS

Most mountain goat studies, including this one, were based on direct observation of the animals, primarily because this method is cost-effective and causes minimum disturbance to the animals. The implications of observational techniques are considered where possible in the interpretation of the data, and are more specifically addressed in Section 2.

1.1 Habitat Use

Several researchers have described mountain goat habitat use (e.g. Hjeljord 1971, Rideout 1974, McFetridge 1977, Smith 1976, Burleigh 1978, Fox 1978, Thompson 1981, Schoen et al. 1981), however, each view the term 'habitat' to consist of a different set of environmental variables or variable categories. Unfortunately, no standardized guidelines have been followed which allow comparison of habitat variables (including boundaries for their delineation). In an attempt to overcome this major problem, some (e.g. Burleigh 1978, Shea 1980) have recently adopted regionally specific habitat classifications used by the United States Department of Agriculture.

1.1.1 Univariate Analysis

Mountain goat habitat relationships have been investigated mainly by univariate analysis of use information. The most common variables addressed have been plant cover, aspect, slope, and elevation, with distance to escape terrain becoming
increasingly considered. Still other factors, such as interspecific and intraspecific competition and climate are also considered important. These latter factors are addressed incidentally in this section but are discussed more fully in Section 2.)

a. Vegetative Cover

Mountain goats utilize a variety of plant formations throughout the year, due to their annual vertical movements between alpine and subalpine areas (Klein 1953). Heterogeneity of goat ranges was first quantified (subjectively) by Smith (1981) into categories of low, medium and high. Nearly 60% of his observations occurred in areas with high plant variability, and often in association with old-growth forest. Smith (1976) earlier concluded that mountain goat use of vegetative types was most evenly distributed in November, May and June, when snow depths influenced goat movements the most (fall descent and spring ascent). The results from my study are comparable with Smith's (1976) data; October, May and June received the most evenly distributed use of plant cover types.

In many studies, however, mountain goat use of vegetative cover appears to be positively associated with more open habitats. For example, most studies, including this, describe high levels of mountain goat use of alpine tundra, broken rock and boulder fields.
(Hibbs 1965, Chadwick 1973, Rideout 1974, McFetridge 1977, Adams 1981, Thompson 1981). Although mountain goats have been observed to use mature timber and shrubby areas in a number of studies as well (e.g. Hebert 1967, Kuck 1973, Singer 1975, Smith 1976, McFetridge 1977, Burleigh 1978), the authors did not conclude that these cover types were heavily utilized nor essential to mountain goats. Rideout (1974) found significant use of forested areas using telemetry, but only recently have mature coniferous forests been recognized as an important component of mountain goat habitat (Shea 1980, Smith 1981, Fox and Raedeke 1982).

In this study, mountain goats were believed to use forested areas to avoid biting insects and direct sun during the summer, and cold temperatures and driving winds in the winter. Snow depth, hunting, and social behaviour may also result in greater use of timbered areas by mountain goats (see Section 2).

Deciduous shrub areas were considered by Shea (1980) to constitute important foraging areas for mountain goats during the spring. Shrub areas (including shrublands and thickets) constituted the second-most important plant cover type in this study, and were often used for bedding as well as for foraging (see Table 7). Mountain goats were commonly seen to stand on their hind legs to eat alder leaves on high shrubs.
Burned areas were also noted to be favoured by mountain goats (McFetridge 1977, Foster and Rahs 1981), however their use appeared to drop with increasing distance from escape terrain.

b. Aspect

Peck (1972), Rideout (1974), Smith (1976), Stevens (1979) and Thompson (1981) concurred that south-facing aspects were favoured by mountain goats and that increased use of this aspect appeared to be a function of increasing snow depth on other aspects. The conclusions from this study are similar. It should be pointed out, however, that numerous windswept, snow free areas occurred on the tops of alpine knolls and ridges on the north aspect of Maroon Mountain, but intense northerly winds, high snow-drift build up in low-lying areas and lack of cover precluded use of these areas by mountain goats during winter. Southern exposures received more insolation, were warmer, and had a snowline higher in elevation, and less accumulated snow than any other exposure, which allows less restricted travel and enables forage to be more readily available during winter and spring (Schoen et al. 1981). Nichols (pers. comm.), however, stated that typically deep autumn snowfalls in Alaska could isolate mountain goats wherever they happened to occur at the time, for the entire winter.

Northerly aspects were generally considered by
Rideout (1974), Smith (1976) and Thompson (1981) to be used primarily during summer, for thermoregulatory control and accessibility of new plant growth. During high summer temperatures, Stevens (1979) observed 80% of the goats in her study area on north-facing aspects and found that they utilized southern exposures during cooler temperatures in summer. In contrast, Chadwick (1973) and Kuck (1973) found little disproportionate use of exposure by mountain goats during summer, which may have been due to the distribution of suitable habitat.

During this study, a higher incidence of goat use of northern aspects on Maroon Mountain occurred only during the summer of 1976, when unlike subsequent years, large predators were absent. However, on Mount Garland, to the south, mountain goats were frequently observed on north and easterly-facing slopes throughout the year.

c. Slope

Surface inclination is recognized as an important component of mountain goat habitat (Fox 1980, Schoen et al. 1981, Fox and Raedeke 1982). The use of hillside slope by mountain goats varies considerably between studies (see McFetridge 1977, Fox 1978, Stevens 1979). Unfortunately, few researchers utilized standard slope classes, hindering accurate comparisons.
On Maroon Mountain, less than 5% of the goats were observed on slopes greater than 45°, in part because of the limitations in discrimination of the mapping method (<91 vertical meters) for estimating slope. Although other work shows similar slope use, variation does occur. For example, Smith (1976) consistently observed mountain goats on slopes greater than 45° during winter and spring, and on slopes less than 45° in summer and fall. In contrast, Thompson (1981) observed 70% of his summer goat sightings on slopes less than 15°, however, goat use was affected by artificial salt licks.

Recently, Schoen et al. (1981) and Fox and Raedeke (1982) have suggested that distance to the nearest cliff (i.e. escape terrain) was the single-most important attribute defining mountain goat habitat throughout the year. This variable was not examined in this study because the entire south slope of Maroon Mountain was considered to constitute escape terrain. Certainly no animal could have been more than 200 m from the nearest cliff face in this area.

Steep hillsides offer both protection from predators and wintering forage areas. In this study, more than 80% of the observations each month consistently occurred on slopes between 30 and 45°, except during July and August, 1978, when gentler slopes were used proportionately more. Although some
use of more gently-sloping areas was documented in the summer of 1977 and 1978, it was apparent that wolves (*Canis lupus*) inhibited mountain goat use of such areas in these years, in contrast to 1976 when no large predators were observed and the more gently-sloping areas were more commonly used. Similar responses in range utilization by Dall's sheep (*Ovis dalli dalli*) were observed by Murie (1944) in the presence and absence of wolves. Fox (1980) considered predator avoidance to be more influential than even forage availability for mountain goat habitat use.

In this study, use of steep areas on key ranges occurred mainly during late hunting season (October) and may have been a response to gunshots and increased vehicular activity along the valley-bottom. Use of steeper areas was also observed during the rut (November), possibly in response to logging operations also in the valley-bottom. Falling trees sounded remarkably like rifle shots when they crashed onto other fallen trees during the cold weather. Both sounds of gunfire and falling trees were observed to create alarm and distraction in both males and females during their courtship behaviour. Responses to these stimuli were even greater than to late winter and spring avalanches.

Smith (1976) and Kuck (1977) indicated that snow-shedding characteristics of steep slopes were the
primary determinant for utilization of winter ranges by mountain goats. Adams (1981) found that goats utilized steeper areas during winters with greater snowfall. Perla and Martinelli (1978) summarized the occurrence of major slab avalanches and found that 96% occurred on inclinations between 35 and 45°. This corresponds with the observed winter use of slope categories in this study (84% between 30-45°). However, more than 80% of all goats observed occurred on inclines between 30 and 45° slope year-round (spring, summer and fall of 1977, and winter, 1978). Although steep snow-free slopes may be frequently used in winter, there was no evidence from this study to suggest that these areas were used disproportionately more than any other time of the year. It therefore seemed likely, as Schoen et al. (1981) suggested, that the primary function of steep terrain was to serve as an inaccessible retreat from predators.

d. Elevation

Many researchers describe variation in altitudinal use exhibited by mountain goats between summer and winter, but few have quantified these vertical movements. Some (e.g. Rideout 1974, Smith 1976) have observed a positive association between mountain goat distributions and annual snow patterns, while others (e.g. Thompson 1981) inferred that summer use of high elevations was related to plant phenology.
Smith (1978) summarized altitudinal sightings of goats by month and found that from December to May, they used low elevations, and from June to November, they occupied higher altitudes. Similar observations have been made by others (e.g. Anderson 1940, Brandborg 1955, Holroyd 1967, Chadwick 1973, Kuck 1973, Rideout 1974).

However, Casebeer et al. (1950), Lentfer (1955), Chadwick (1973) and Vaughan (1975) frequently observed goats at low elevations and on windblown ridge-tops during winter. Vaughan (1975) noted that most goats in his study area occupied windblown ridge-tops at very high altitudes, due to few, south-facing cliffs at lower elevations, however, Hebert and Turnbull (1977) determined that increased snow density (wetness) determined subalpine wintering locations of goats.

In this study, while mountain goats were widely distributed altitudinally throughout the year, two prominent patterns of vertical ascent and descent were apparent over the twelve month period. A typical summer ascent (May to August) occurred and was believed to be correlated to receding snowline and the pattern of plant growth. A fall descent (late September to November) appeared to be a function of increasing snowfall and strong northerly winds, particularly in November. The location of kidding and
rutting activities also seemed to be a function of snow distribution and concomitant location of adult females. In January, alpine areas were heavily used, due to the availability of wind-blown, snow-free areas on exposed slopes. Subalpine elevations were again used more as snow accumulated over the winter and then during spring 'green-up', prior to the late spring - early summer ascent to alpine areas. Another possible explanation for the descent during late December may have been that the animals were too warm in the alpine thermal inversion zone with their long winter pelage. It is not definitely known if use of lower elevations, such as logging clearcuts and some rocky outcrops along Maroon Creek, would have occurred in the absence of human activity in the valley-bottom.

Assessment of monthly vertical movement allowed documentation of only broad cycles of altitudinal use, and these occurred mainly during the winter. At this time, mountain goats were often observed in the most rugged and barren alpine habitats imaginable. These areas seemed to be unfit for any animal to live out the winter. However, more intensive winter observations showed that cyclical altitudinal patterns were exhibited by many mountain goats every 3 to 10 days. This frequency range appeared correlated with the occurrence of high pressure systems. If suitable windswept areas were available in the alpine, goats
would sometimes stay three or four days, until the onset of the next low pressure disturbance. If the goats, on moving up to the alpine, could not find suitable foraging areas, they usually returned to treeline or subalpine areas the very same or next day as their initial upward movement.

1.1.2 Multivariate Analysis

Four studies of mountain goat habitat use have been conducted to date, in which multivariate analyses have been employed. As will be seen in the discussion below, they vary in their findings, and much of this variation appears due to the fact that they have included different variables in their models, as much as to the fact that they were carried out in quite different study areas.

Schoen et al. (1981) used three interval-level habitat variables (elevation, slope, and distance to escape terrain) to study mountain goat habitat utilization in Alaska, by discriminant function analysis. They identified one variable which could account for 100% of the variation in goat sightings. This was distance to the nearest cliff. In a preliminary test of their model, 100% of the independent observations were accurately predicted.

But, in another Alaskan study, Fox and Raedeke (1982) showed that a greater number of variables were important. In this case, four variables (elevation, timber volume, slope, and distance from cliffs) accounted for 74% of the goat observations and 100% of the areas not inhabited by mountain goats. However,
nominally-scaled variables (e.g. aspect, plant cover, landform, etc.) were not assessed in either study due to restrictions of the statistical analysis. It is believed that inclusion of nominal variables may enhance the model's power, although a different analysis technique is required.

McFetridge (1977) conducted a multivariate analysis of nominally-scaled attribute data on mountain goat habitat relationships in Alberta, between May and October only. This analysis considered plant cover, aspect, slope, elevation and distance to escape terrain. McFetridge (1977) concluded that the most significant relationship of use occurred with all of the variables included in the model, and was applicable mostly to nursery groups, rather than all goat observations. His August data yielded the best relationships, although the 'distance to rock-gravel' variable did not have a significant effect on habitat relationships. This variable consisted of surficial rock, gravel, shale and soil, and was noted to be usually steep and unstable, however, it did not constitute cliff-like escape terrain.

Shea (1980) developed mountain goat habitat suitability index models for spring, summer and winter ranges in Alaska and considered aspect, plant cover and distance to escape terrain as the most important criteria in predicting seasonal range use. However, the models have not been tested.
1.2 Habitat Selection

The use of habitat is affected by numerous social and environmental factors, therefore one would expect temporally disproportionate use of environmental attributes, with respect to habitat availability. However, the implications of such disproportionate use often creates a cloudy issue. This may be due in large part, to several connotations of the terms 'preference' and 'selection' which have been abused and used misleadingly by various authors. For example, McCrory et al. (1977) and Burleigh (1978) discussed 'habitat selection' from a purely subjective assessment. Hjeljord (1971) and others referred to 'habitat preference' based only on the measurement of usage. In each case, the terminologies used misrepresented the comparisons undertaken, even in the quantification of usage.

One of the first mountain goat studies extensively addressing the concepts of use and availability was conducted by Adams (1981). However, his comparisons were for the summer period only, and were based on the forage ratio (Stoddart et al. 1975) which excluded any form of statistical consideration. Thompson (1981), Schoen et al. (1981) and Fox and Raedeke (1982) described mountain goat habitat utilization by contingency analysis of use and availability. However, few authors have shown complete procedural documentation and consideration of sampling requirements. Thompson (1981) and Fox and Raedeke (1982) only partially outlined their methodology for calculating habitat availability, including delineation of their boundaries. Only Thompson (1981) corrected availability data, obtained by
vertical map projection, for hillside slope. None of the authors apparently collected their data in a systematic fashion, thus raising the question of its validity.

1.2.1 Ecological Findings

The level of habitat selection by the two groups being compared was considered to be the sum of their preferences and avoidances. Therefore, the group type with the least number of habitats used in equal proportion to their availability was considered to be 'more selective'. It is left open to discussion whether one group type is more (or less) selective than the other group type, when, for example, group 'A' preferred 6 habitats and avoided 2 of them, while group 'B' preferred 2 habitats and avoided 6 of them.

The analysis used in this study confirmed previous suggestions that: a) sexual differences occurred in the selection of habitat by mountain goat group types, and b) mixed-female groups were more specialized, or selective, than male-only groups.

Fox and Raedeke (1982) did not consider the effect of sex during their investigation, however Schoen et al. (1981) concluded that significant differences in habitat use occurred between sexes for the greater portion of the variables assessed. Unfortunately, nearly half of the seasonal relationships examined in their analysis, violated the chi-square requirements concerning expected frequencies. They concluded, however, that during winter, females were distributed at higher elevations on steeper, more broken and rockier slopes, closer to cliffs than
were males.

In the present study, male-only groups selected for slope and aspect habitat categories similar to those selected by mixed-female groups, but at disimilar elevations and in different vegetative cover categories. Male-only groups selected for more dense vegetative cover in subalpine elevations than did mixed-female groups. Sex differences in habitat selection have also been documented for example in bighorn sheep (Ovis canadensis) (Shank 1979a, Martinelli and Hudson 1981, Tilton and Willard 1982).

Schoen et al. (1981) hypothesized that females may be more selective than males, choosing areas of greater security from predation and areas of greater forage availability. The findings from this study support part of this hypothesis. Mixed-female groups were found more frequently to select steep, rocky, south-facing alpine hillsides during summer and winter and similarly characterized subalpine hillsides in the fall, than were male-only groups. One would expect, a priori that whatever conditions were selected, food resources would be an important component in the selection process, however, Kuck (1977) showed that mountain goat selection for steep, rocky areas in winter was not in response to a better food resource, but to snow-shedding characteristics.
1.2.2 Concepts Of Selection

Selection does not simply imply preference (i.e. greater use than availability), but also includes avoidance responses. Although mixed-female groups selected various habitat attributes throughout the year, they were also much more selective than males in the sense that they avoided nearly twice as many available habitat types than they preferred. The less selective (in both directions) male-only groups, therefore may fit into the strategy of 'generalists' who can optimize their use of habitat conditions by generally using habitat types as they encounter them. Thus they show little avoidance or preference for any particular habitat.

a. Order of Selection

If an analysis of selection is to involve examining the proportions of use relative to availability, then it is essential to determine what is available to the animal. Johnson (1980) described four hypothetical orders of selection relating to an animal's preferences. He refers to first order selection as the physical or geographical range of a species, within which second order selection may determine the home range of an individual. Third order selection pertains to the usage of various habitat components within the home range, and finally, fourth order selection can determine the procurement of food items from those available at that site.

The concept of availability is often quite
arbitrary, based upon components deemed by the investigator to be available to the animal. However, each order is related to a higher order, not by the observer, but by the animal. For example, an animal's home range occurs in a certain location because that animal has already 'decided' to live in that particular part of its range distribution. Consequently, conclusions drawn from such analyses may be inconsistent. Johnson (1980) proposed a method of ranking available home range data, to eliminate classification effects, however no unbiased statistical method is available for comparing usage data to constant proportions of availability, such as attempted in this study.

b. Interpreting Selection
   i. Artefacts of Selection

   If an animal is not observed to occur within certain habitats, then it is generally assumed that these areas are avoided. However, neither Marcum and Loftsgaarden's (1980) SCI technique nor Everitt's (1977) analysis of contingency residuals (used by Schoen at al. 1981) for determining habitat selection were sufficiently sensitive to consider zero use of small areas or proportions to be avoided. Thirty-four percent of the all habitats received no use by mountain goats in this study, and of those, nearly half
(47%) were classified as avoided in the SCI analysis; the remainder were considered to be used in equal proportion to their availability. This problem is not addressed in other studies, but is certainly apparent (e.g. Schoen et al. 1981).

In addition to the problem of zero use, variations in selection between sexes impose further limitations. For example, given an imbalanced sex ratio of two females for every male, such as the Maroon Mountain population, there was proportionately less chance for males to occupy as many habitats as females because there are fewer of them.

When the data were corrected, by identifying zero-use habitats as avoided, before conducting the selection analysis, no change in the relative differences between the sexes resulted. However, different interpretations would have occurred between the two sexes. For example, males could have been mistakenly considered to be more selective than females, because they avoided more habitat types, which was, in actual fact, not the case. There appears to be no immediate solution to this problem. Development of a new preference index based upon proportions should alleviate the problem of disparate sex ratios.
Additionally, biases may have arisen because there were fewer males than females. However, females would be expected to select less habitats because they generally occurred in larger groups, of which there were fewer in number. This confounding effect was not addressed in the analysis, but warrants future consideration.

ii. Preference and Avoidance

Habitats identified by selection analysis as either preferred or avoided should not be taken blindly at face value, nor should habitats used in proportion to their availability be ignored. Animals presumably make decisions to some extent as to the region where they reside, what habitats they use, what plants they eat, etc., but whether these 'decisions' are biologically meaningful remains to be tested. An analysis of selection cannot dictate whether preferred areas are essential and avoided areas unimportant or dangerous. For example, habitat A (e.g. a small grove of trees) may be more preferred than habitat B (e.g. a sparsely vegetated, rocky hillside); but habitat A may be used for comfort only (e.g. shade) and not essential for survival, whereas habitat B is biologically essential for food and escape terrain.

Although mixed-female groups exhibited more
instances of selection than males, this does not necessarily mean that females utilized more 'optimal' areas than male-only groups, for the latter may be able to exploit their environment more efficiently as a generalist. They also have less demands than the females (e.g. pregnancy, lactation) and offspring (e.g. growth, development).

2. MOUNTAIN GOAT OBE SERABILITY

Mountain goat studies have generally been observational in nature (e.g. DeBock 1970, Vaughan 1975, McFetridge 1977, Wright 1977, Stevens 1979, Adams 1981). Additionally, most studies have implemented non-systematic sampling and have been conducted in several biotopes, ranging from northern boreal forest escarpments and subalpine canyons to typical alpine-subalpine mountainous conditions. Consequently, each population studied has the potential to offer unique visibility biases, in addition to specific characteristics of population demography and range utilization.

It is clear from this study that observational biases occurred during systematic sampling of the Maroon Mountain goat population, which limit the comparison and discussion of population and range characteristics of this herd with other mountain goat studies. The large variation in sex and age ratios shown by Driver et al. (1978), between two months of the same year, supports this finding. Non-visible portions of the
population could have been accounted for by one or more of the following reasons: a) mountain goats could have occupied equally visible habitats, similar in proportions to those sampled, but in non-observable areas within the study area (even on the south slope, every square meter of hillside was not visible); b) mountain goats could have been located in more densely vegetated (i.e. non-visible) areas within the study area; or c) mountain goats may have emigrated from the study area, in which case either a) or b) could be true.

The first possibility was substantiated only in 1976, and then by ad lib. observations of mountain goats on Ridges #1 and #2, where both solitary males and nursery groups were periodically observed, during the summer only. However, mountain goats were not observed in these areas during the period of systematic observations. During this period, the presence of wolves appeared to restrict mountain goat range use south of the main ridge.

The third possibility was also rejected; firstly because intensive behavioural observations (>100hrs/month) were conducted on the southern slope of Maroon Mountain, in addition to the time spent during vehicular surveys, and no directional movements of animals going over the main ridge or out along Ridge #3 were observed. However, ad lib. observations in 1976 only, did document limited mountain goat use of Ridge #3 during the summer. Secondly, surveys of adjacent areas (i.e. areas south of the Hanging Valley, Mount Garland and Wesach Mountain) did not show any noticeable influx in numbers of animals during
the study period. Thirdly, ground truthing showed no inter-
mountain movement. The only indications of low elevation use by
mountain goats were one set of tracks on the Maroon Creek
logging road in January, 1977, an adult male wintering across
from the logging road near the mouth of Maroon Creek valley in
1978, and a dead male found in a clearcut along Maroon Creek in
February, 1978. In each case, these animals or their sign, were
observed within the study area and in months in which the
majority of the estimated population was most visible (see
Figure 9).

Consequently, b), utilization of less visible areas within
the study area, is left as the only possible alternative.
Several interspecific and intraspecific factors, in addition to
weather, are believed to affect mountain goat observability.

2.1 Intraspecific Influences

2.1.1 Social Behaviour

Males accounted for much of the variation in mountain goat
observability due to sex-specific differences in habitat
selection, resulting from female aggression. Competitive
exclusion has been the most popular theory governing sexual
differences in mountain goat habitat selection (Chadwick
1973, 1977, Kuck 1977, Smith 1976). It was postulated that sex-
specific differences in habitat selection would become more
apparent with increasing population size, because resources
would become more limiting. Under these conditions, males
should tend to utilize more timbered or brushy habitats of
marginal value than females with young. Conversely, males may be expected to utilize similar habitats as females, if the population was declining due to hunting, for example, in which case resource availability would not be affected.

Other social factors also affect observability, as noted by Bailey and Johnson (1977). For example, males are generally solitary or occur in smaller groups than females (Chadwick 1973, 1977), and therefore may be more easily missed by the observer. Additionally, males are more likely to be placed in the 'unclassified' category than females because fewer characteristics are available to identify males in comparison to females (e.g. maternal behaviour).

2.1.2 Activity Patterns

In this study, males were more lethargic than females (i.e. they rested more than they fed, diurnally). Males were frequently observed to bed for periods of several hours, in contrast to the two-hour cyclical patterns described for females (Chadwick 1973). Resting animals were considered more difficult to see because of their reduced visible surface area and because they were stationary.

Partridge (1979) stated that differences in timing of activity may contribute to ecological segregation. In mountain goats, Rideout (1974) documented that both sexes show activity peaks at dawn, in the late morning, and just before sunrise. However, males displayed less activity in the afternoon, and an earlier peak in the evening. Stevens (1979) observed adult males nocturnally feeding, on at least two occasions.
McFetridge (1977), Fox (1978) and Stevens (1979) noted that mountain goats utilized certain habitat types for different purposes. Inactivity in densely vegetated habitats poses a much more serious observational bias than inactivity in sparsely vegetated areas.

2.2 Interspecific Influences

2.2.1 Biting Insects

Biting insects were frequently observed to disturb molting males and barren females during the spring, and often stimulated their disappearance into heavily timbered areas, which were noted to support much sparser densities of biting insects. Thus, these animals would be less visible at this time of year, whereas females accompanied by young, retaining protective winter coats (Hebert 1967, McFetridge 1977), remained in open habitats. Because females with kids molted later in summer, they were able to obtain relief from biting insects by occupying exposed, breezy sites in the alpine, such as ridge-tops and small peaks. These habitats were readily visible.

2.2.2 Hunting

The observed number of adult males/100 adult females dropped in August, September and October, after a steady increase from May. This was observed to coincide with the hunting season on Maroon Mountain. Although both sexes were open to hunting, males were generally the most sought-after (however there were proportionately less of them shot). It is
believed that most of the males utilized densely vegetated habitats during this period. Swenson (1982) similarly noted that mixed-grass prairie mule deer increased their use of upland timbered cover types during hunting season. In another study, Douglas (1971) monitored the response of chamois (*Rupicapra rupicapra*) and red deer (*Cervus elaphus*) to an intensive eradication campaign. Shortly after the hunting of females ceased, it was apparent that both sexes were exceedingly shy and wary, stayed close to forest cover and fed in the open mainly at night.

2.3 Weather

Fox (1978) concluded that the effects of weather on mountain goat activity and habitat use could significantly influence survey results. During this study, it was noted that hot summer temperatures induced mountain goats to use dense timber and shrub areas for protection from direct sun. Stevens (1979) noted that the coniferous canopy was used almost exclusively during the hottest part of the summer. Stormy, winter weather was also observed to stimulate mountain goat use of densely vegetated areas, for protection from strong winds and driving snow. Hebert and Turnbull (1977) attributed winter use of timbered areas in coastal British Columbia to the characteristic dense snow-pack of the area, in contrast to interior areas, where dry, powder snows are frequently blown free from alpine ridges.

Several climatic conditions create animal inactivity which also reduces observability. Both Fox (1978) and Stevens (1979)
observed that goats were more inactive on sunny days than on cloudy days. In this study, goats were observed to stand for long periods on cold winter days. Malecheck and Smith (1976) noted the same response by cattle. They also considered wind velocity to be inversely related to daily travel, similar to the effect of snow depth (Smith 1976).
VI. CONCLUSIONS AND RECOMMENDATIONS

1. IMPLICATIONS FOR STUDY DESIGN

In observational studies, analysis of open habitats may only yield a partial understanding of mountain goat ecology. A confounding problem, noted also by Rounds (1981), may occur with deciduous shrub and tree cover, in which animal observability for the observer varies seasonally between and within cover types. Systematic sampling methods can help minimize biases, or at least help to keep their departures constant, however, the ultimate goal is not solely precision but also accuracy. The use of a more efficient technique is recommended. For example, helicopter surveys generally result in higher counts than ground or fixed-wing surveys (Ballard 1975, 1977), but they may also affect an animal's activity and possibly even habitat use (Foster and Rahs, in press).

An alternative solution to the problem of visibility would be to use remote-sensing devices affixed to individual animals. Using this technique, Schoen et al. (1981) discovered that certain mountain goat individuals are 'alpine dwellers', while others spend most of their life in the forest. However, it may be necessary to obtain representative samples from all sex and age classes if differential levels of selection commonly occurs for mountain goats as has been documented for mountain sheep (Shank 1979a, Martinelli and Hudson 1981, Tilton and Willard 1982). A few telemetry studies have been conducted with mountain goats (e.g. Chadwick 1973, Rideout 1974, Schoen et al.)
1981, Nichols, in press), but these have concentrated on only a small fraction of the actual population, which precludes documentation of population demography and sex-age differences in mountain goat ecology.

Radio-telemetry studies are not without other disadvantages either. In addition to excessive costs involved with trapping, tagging and equipment for monitoring mountain goat movements, the problem of signal bounce may become excessive in rugged and rocky mountain goat habitat. Furthermore, the accuracy of triangulation fixes may also leave something to be desired, particularly when assessing small-scale habitat relationships in patchy environments. For example, Denton (1973) reported a mean error polygon of 4.3 ha in a western Montana elk study using aerial tracking, with only 88 percent of the approximation areas actually including the elk or the test transmitter.

Although aerial tracking has the advantages of speed and accessibility of even the largest, most remote and rugged study areas, it may be relatively inaccurate if visual contact is not made (Denton 1973). However, some species, such as mountain goats and mountain sheep, seem more alarmed by aircraft at long distances (Shank 1979b).

Biggins and Pitcher (1978) compared the efficiency of visual (flight grid) and telemetric techniques for mule deer (*Odocoileus hemionus*) and concluded that the two methods produced significantly different patterns of diurnal habitat use. Additionally, nocturnal habitat use was impossible to assess objectively by visual techniques and was significantly
different than diurnal use for instrumented deer. Mountain goats are known to be active nocturnally (Chadwick 1973, Rideout 1974, Stevens 1979).

2. MANAGEMENT IMPLICATIONS

The effects of harvest or habitat manipulation on mountain goat population demography cannot be determined until population parameters are first accurately documented. For example, at the recommended 5 percent adult mountain goat harvest level outlined by the British Columbia Ministry of Environment (1979), one would have to be more than 95% confident of the accuracy of survey information collected, in order to document the effects of this harvest strategy. At this time, there is no technique available with the precision and accuracy required for such intensive management of the species. For example, the seven systematic helicopter transect surveys in Van Drimmelin's (1982) mountain goat study contained total counts averaging 31% from the estimated population mean at the 95% probability level. Using this information as test data, it was estimated that more than 250 surveys, at a total cost exceeding $66,000.00 (1/2 hour of helicopter time per survey, at $500.00/hour) would have been required to be 95% confident that the total count obtained was within 5% of the population mean.

Satisfying statistical sampling requirements would be increasingly more difficult to achieve for smaller-sized populations (i.e. <100 animals) due to the large variation associated with missing several animals. Similarly, less dense
populations (i.e. <10 goats/km²) may also increase survey variation. The Ministry of Environment (1979) recognized the need for development of new and standardized inventory techniques for mountain goats, however it is the recommendation of this study to consider the subject a priority issue. Management guidelines should not be implemented without the ability to monitor their effect.
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