COUGAR PREDATION ON BIGHORN SHEEP
IN THE
JUNCTION WILDLIFE MANAGEMENT AREA,
BRITISH COLUMBIA

By
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Seventeen cougars (*Felis concolor*) utilizing the Junction Wildlife Management Area (W.M.A.) in central British Columbia were fitted with radio collars. All collared cougars within the area were relocated using ground-based and aerial radio telemetry. Relocations were made daily during intensive field work (December-August), and a minimum of four per week the remainder of the year. General site reconnaissance and direct sampling work from 1986 to 1988 revealed 132 prey species mortalities of which 50 were confirmed as recent cougar kills. Although bighorn ewes and lambs (*Ovis canadensis californiana*) were not important prey items for the cougars, bighorn rams comprised 77.6% of the total mortality sample and 46.5% of the confirmed cougar kills. Cougars selected rams in greater proportion than would be expected based on the availability of rams in the prey population. Poor post-rut body condition and restricted rear and peripheral vision were factors that increased the rams’ vulnerability to cougar predation.

Cougar predation rates on bighorn sheep and mule deer (*Odocoileus hemionus hemionus*) were determined for two females with kittens. Kill rates varied from 0.7 - 3.0 ungulates/week. Interactions between cougars and coyotes (*Canis latrans*) at kill sites influenced the cougars’ utilization of kills and predation rates. In 200 km² of the 425 km² study area, 130 coyotes were removed over a two-year period. The predation rate of a cougar with three kittens within the coyote removal area averaged 1.1 kills/week while that of a female with two similarly-aged kittens in the non-removal area averaged 2.6 kills/week. Moreover, observations of cougars
abandoning kills following harassment by coyotes, suggested that cougar/coyote interactions were an important part of the system.

Poor lamb recruitment and a decline in the number of mature rams in the Junction herd are a concern for the Ministry of Environment (MOE) Wildlife Branch. I make two recommendations that address these concerns:

1. Maintain the resident cougar population without removing cougars. Cougars were not important predators of the lamb segment, nor were cougars keying on the older, larger rams. Moreover, removal of the resident cougar population will disrupt the intraspecific and territorial dynamics of the cougar population resulting in an influx of transient cougars. This, in turn, will lead to the Junction system stabilizing at cougar numbers equal to or possibly greater than pre-removal levels.

2. Initiate an alternating, two-year on, two-year off, February-April coyote removal program until lamb recruitment remains above 20 lambs/100 ewes throughout a four-year cycle. This program is preferable to cougar removal in that coyote removal can be implemented more effectively on a temporally and spatially scale. Coyote removal will result in an increase in lamb recruitment to the bighorn population, including the ram component. Moreover, fewer rams from this increased population will be killed because of lower cougar predation rates that also will result from the decrease in coyote scavenging/displacement pressures.
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CHAPTER ONE - INTRODUCTION

The cougar epitomizes the popular notion of a predator. The cougar’s morphological and behavioural traits support this. The cougar has musculature and skeletal characteristics specific to pouncing (Gonyea 1976) and primitively prominent canines and blade-like carnassial teeth that shear tendons and bones (Anderson 1983:21-22). The cougar is secretive and solitary. The acquisition of prey relies on stalking and surprise attacks and its physical abilities enable the individual to capture and subdue prey. Although these traits reveal that the cougar is, undoubtedly, a predator, its proficiency as a predator has enabled few insights into its role as a predator.

Knowledge about the cougar has been acquired in three phases. The first phase was undertaken by houndsmen hunting cougar for sport and for bounty. Chronicled in books such as The Lee Brothers (Lee 1947) and Slash Ranch Hounds (Evans 1951) or intact in the memories of retired government predator hunters (J. Lay, pers. comm.), the first insights into the cougar’s ecology were provided by the work of these men and their dogs. During the second phase, researchers accompanied cougar hunters (Hibben 1937) or collected hunter-killed cougar stomach samples for diet analysis (Connolly 1949, Robinette et al. 1959). The final phase began 20 years ago with the use of radio telemetry that allowed researchers to simultaneously follow a number of cougars in a relatively non-intrusive manner.

Studies of cougars have generally examined home range size and utilization...
or intraspecific population dynamics (Seidensticker et al. 1973, Ashman et al. 1983, Pall et al. 1988). Data on prey use by cougars has been gathered primarily from the stomachs of hunter-killed cougars or from cougar kills discovered incidentally during capture efforts (Spalding and Lesowski 1971, Seidensticker et al. 1973, Toweill and Meslow 1977, Pall et al. 1988). Few studies (Hornocker 1970, Shaw 1975) have specifically addressed the predatory aspects of cougar ecology. My study was initiated to examine the specifics of cougar predation within the Junction W.M.A.

The Junction Bighorn Sheep

The Junction supports one of the largest herds of California bighorn sheep on the continent. The herd is provincially renowned for its accessibility to non-consumptive users and its high quality harvest opportunities. In addition, since 1954, the Junction herd has provided seed stock from which California bighorns have been re-established on former sheep ranges throughout the United States (Demarchi and Mitchell 1973).

Numerous studies have been conducted on the Junction bighorns: pregnancy testing (Ramsay and Sadlier 1979); patterns of lambing mortality (Hebert and Harrison 1988; MOE unpubl.); nutritional levels and seasonal food habits (Hebert and Hebert 1986); stress levels using serum cortisol (MOE unpubl.); general population health testing through necropsy (MOE unpubl.); an analysis of group size and sexual segregation (Ashcroft 1986), and an comparative examination of ram horn growth (Hirsch in progress). The Junction rangelands have also been studied
and have remained stable in poor to fair condition (Demarchi and Mitchell 1973, MOE unpubl.). All studies have demonstrated that the Junction herd is relatively disease free; however, high mortality of lambs and of older rams has been of concern since the late 1970’s (MOE unpubl.).

Currently, the herd consists predominantly of older ewes. This skewed age structure has been compounded annually by poor recruitment into the population. Late winter surveys in the mid 1980’s indicated that recruitment, measured as lambs:100 ewes, was low at 10-18:100 (MOE unpubl.). A typical recruitment ratio for wild *Ovis* spp. at this time of year is 30-40 lambs:100 ewes (Heimer 1978, Harper 1984, Wehausen *et al.* 1987). This predominance of older females combined with poor recruitment could affect the Junction herd’s ability to survive severe winters. Six of the past seven winters have been unusually mild with very little snowfall. When severe winters do occur, they generally have the greatest impact on the old and the young animals (Caughley 1966, Murphy and Whitten 1976). The current age structure at the Junction provides little resilience against such losses.

Conversely, harvest data gathered from 1977 to 1988 through compulsory inspections indicated that the mean ram age and horn length decreased (Hirsch in progress). The harvest throughout this period was restricted and extremely light. The first open hunting season in the W.M.A. was in 1973. From 1973-1983, only 2-4 rams were harvested annually under 5 limited-entry permits from a population of approximately 100 rams (MOE unpubl.). In 1983, the number of permits was
increased to 9 resulting in an annual harvest of 4-7 rams (MOE unpubl.). Illegal shooting of trophy rams, possibly by organized poaching rings, was considered to be a probable cause of the decline (MOE unpubl.). This notion was supported by the belief that few, if any, cougars even resided in the area due to a wild feline distemper epidemic and intensive predator control programs during the 1950's and 60's (MOE unpubl.).

This Study: Hypothesis Testing

Cougars have long been recognized as predators of bighorn sheep (Beuchner 1960, Sugden 1960, Kelly 1980), yet documentation of the occurrence and extent of this predation is poor. Initially, it was necessary to established that there was a cougar presence within the Junction area. Preliminary field reconnaissance during the winter of 1985 confirmed that cougars were using the area and led to my examination of the pattern and extent of cougar predation. The research presented in this thesis addresses three hypotheses regarding the role of cougar predation in the population structure of the Junction bighorns:

\[ H_1: \] Cougars in the Junction select prey on the basis of prey species, sex, or age class.

\[ H_2: \] Poor recruitment of lambs to the Junction is a result of cougar predation;

\[ H_3: \] The decline in mature, full-curl rams in the hunter-killed sample is a direct result of predation by cougars.

During my examination of cougar predation, it became apparent that coyotes were also an integral part of the predator/prey dynamics. Coyotes were found to
be aggressive scavengers of cougar kills, and a fourth hypothesis regarding the role of scavenging by coyotes on cougar predation rates was tested:

\[ H_4: \text{Predation rates for cougars are affected by the presence of coyotes.} \]

**Thesis Structure**

The thesis is presented in six chapters. Each chapter examines further a component of the system presented in the proceeding chapter.

**Chapter 2 -- The Junction: The Area and Use by Cougars** -- describes the study area and the methods used to determine abundance for each of the prominent wildlife species. Area use by the cougars is presented here.

**Chapter 3 -- Selective Predation by Cougars** -- investigates the predator/prey relationships of the Junction by examining the proportions of prey species killed by cougars. The three hypotheses concerning the role of cougar predation are discussed in this chapter.

**Chapter 4 -- Cougar Predation and Kill Utilization Rates** -- addresses the fourth hypothesis of the thesis by examining the predation rates of cougars within coyote removal and non-removal areas.

**Chapter 5 -- Management Considerations** -- outlines the implications of this study’s results for management of the Junction system and predator/prey systems in general.
Chapter 6-- Conclusions -- presents the results for the four hypotheses drawn from the results of this study.
CHAPTER TWO - THE JUNCTION: THE AREA AND USE BY COUGARS

Study Area

Geographic Location and Physiography

The Junction is located between latitudes 51°45’N and 51°54’N and longitudes 122°22’W and 122°35’W in the Chilcotin region of central British Columbia. The area is named for the meeting of the Chilcotin and Fraser Rivers and is characterized by rolling plains and undulating grasslands spotted with coniferous forests. The landscape drops sharply along an edge contiguous with the Chilcotin River to the south and the Fraser River to the east from the 1070 m elevation of the Chilcotin Plateau to the 350 m river level. Sections of this 30-45° gradient sloping to the two rivers are interrupted by a single, 500 m wide terrace at the 530 m elevation.

Pleistocene glacial activity is evident throughout the area, and Miocene lava flows are revealed by the cross-sectional nature of the steep terrain. Below the shallow (1m) layer of dark brown chernozemic top soil, volcanic rock comprises the first 90 m of the surface. Rock and gravel materials form the next 450 m layer. The two rivers cut through the final layer 180 m layer of silty, clay-like sediments left by glacial lakes (Holland 1976).

Climate

Weather patterns vary throughout the Chilcotin region reflecting the local diversity of the terrain. The climate is characterized by hot, dry summers and
cold, relatively wet winters (Daubinmire 1978); seasonal temperatures in the study area range from -40° C to +40° C. The Junction study area is located in the driest part of the region. Mean annual precipitation during the study recorded at the Environment Canada weather station on the Wineglass ranch was 33 cm.

Vegetation

The study area represents the northern limit of the *Agropyron spicatum* vegetative Province (Daubinmire 1978). The distribution of vegetation in this semi-arid region is directly linked to terrain aspect. Bluebunch wheatgrass (*A. spicatum*) is the dominant grass on the undulating plains of the upper plateau although re-seeding programs and use by domestic stock have resulted in a variety of grass and forb species in other areas (Demarchi and Mitchell 1973).

Douglas fir (*Pseudotsuga menziesii*) dominates 30-40% of the north-facing slopes with trembling aspen (*Populus tremuloides*) usually clumped in the bottoms of gullies. South-facing slopes are dominated by Bigbrush sage (*Artemisia tridentata*), Pasture sage (*A. frigida*), and Rabbit brush (*Chrysothamnus nauseosus*).

Bounded Study Area

The Junction Cougar Study area encompassed the Junction W.M.A., and two cattle ranches: Riske Creek Ranch (comprised of the Cotton and Deer Park areas) and the Wineglass Ranch. The "Junction" refers to the entire study area while "the Junction Wildlife Management Area (W.M.A.)" refers specifically to that bounded area (Figure 2.1). The Junction study area contains 425 km²; however,
Figure 2.1 - The Junction Cougar Study Area and the Junction Wildlife Management Area. All cougars known to be in the study area were radio collared.
consideration of those areas utilized by cougar, sheep, and mule deer, results in a functional study area of 150 km$^2$. The entire study area and the surrounding 6,000 km$^2$ were closed to the hunting of cougar.

**Wildlife of the Junction**

In contrast to the many wildlife species of the Douglas fir and Lodgepole pine (*Pinus contorta*) forests throughout the Chilcotin, the species composition of the Junction is less diverse reflecting the semi-arid vegetation of the grassland terraces. Few mammalian species share the area with the bighorns. The sheep constitute the area's most prominent wildlife species and have probably inhabited the area for 10,000 - 15,000 years after having migrated northward along the North American west coast as the glacial ice receded (Beuchner 1960).

**METHODS**

**Cougar**

Collaring

Throughout the study, I attempted to radio-collar all cougars within the study area regardless of age or residency status. Intensive tracking for uncollared cougars was aided by, but not limited to, periods of snow cover. Many sections of the study area permitted tracking year-round due to dusty conditions.

During times of snow cover, daily searches for tracks were conducted using trucks, snowmobiles, and on foot. These searches covered 300 km of roads and trails daily and, a minimum of two days per week, employed 5 trucks, 3
snowmobiles, and 10 experienced cougar trackers. A Bell 206 Jet Ranger helicopter was utilized on five occasions for searches of the cliff areas following late spring snows which would have melted prior to reconnaissance by foot. The helicopter was utilized on six other occasions when groups of 7-10 trackers separated by 1000-1200 m would hike down from the "edge" of the plateau to the river level. The helicopter ferried people to the top where the process was repeated.

When a cougar track was located, 5-8 cougar hounds, each equipped with a radio transmitter, were released. The cougar would seek refuge by climbing trees. Frequently, while Dan Lay and myself ran with the dogs, wildlife staff would radio-track the dogs from the helicopter. This method proved invaluable for capturing cougars in the rough terrain where they would frequently jump from the trees before the ground crew could reach the site. One cougar was particularly prone to jumping and did so seven times during one capture.

Cougars were immobilised with a 4:1 ratio of Ketamine (ketamine hydrochloride): Rompun (xylazine hydrochloride) both at concentrations of 100 mg/cc. "Cap-chur" darting equipment was used to inject those cougars judged to weigh >30 kg. A 5 cc dosage of the mixture was administered to all adult cougars to standardize the drugging procedures. Although body weight is an important factor in the determination of the dosage of this drug mixture required to immobilize the cougar quickly (D. Lay pers. comm., personal observation), I found it to be only one of many such factors including age, sex, digestive state, and stress level of the cougar being immobilized.
Injections of 2.5:0.5 cc Ketamine:Rompun were administered by hand to treed cougars weighing from 5-30 kg. Cougars of this size provided a poor darting target when high in a tree. To reduce the potential of injury to the cougar from incorrect dart placement, I would climb the tree to give injections by hand. When cougars were darted from the ground, I climbed the tree before the cougar was completely anaesthetized to secure it with a rope for lowering.

On the ground, the cougar was fitted with a 36-month, mortality-sensing radio collar, and body measurements were taken. Cougars were identified by codes that denoted sex and age class at capture (Adult= >18 months, Juvenile= 6-18 months (judged by tooth eruption), Kitten= 0-6 months), and the numeric ranking of all new captures. For example, KM10 represents the 10th new capture of a cougar: a male (M) kitten (K). All cougars >5 kg were fitted with radio collars; however, kittens were fitted with coyote-sized collars and recaptured one or two more times, depending on age of initial capture, to expand the collar. I attended the cougar until its recovery was complete.

Relocation with Radio Telemetry

Daily radio relocations were attempted during intensive field work (December-August), and a minimum of four relocations/week were attempted from September to December for all radio-collared cougars utilizing the Junction. Ground telemetry was conducted with a single, hand-held H-antenna, and yielded relocation points that were classified under two categories: remote and proximate locations. Remote locations (500-1000 m transmitter-receiver distance) were used for general
confirmation of the cougar's presence in an area. These areas included dens and confirmed kill sites. Proximate locations (10-30 m transmitter-receiver distance) were obtained by hiking into the cougar's location.

The terrain of the Junction enabled me to use a top-down approach and made much of the ground telemetry work analogous to aerial work. Initial remote relocations were made from a series of high elevation stations that overlooked the descending hogbacks and gullies and enabled scanning of the entire study area. Triangulation from these stations was used to narrow the signal to a single draw or gulley.

Error polygon sizes were determined using calculations in Hupp and Ratti (1983). The suitability of these calculations at the Junction was by blind relocation exercises where an assistant randomly placed radio collars throughout the study area. The radio-relocation points for these collars were compared to their actual location points.

The ground work was supplemented with aerial telemetry to locate animals, particularly males, that had undertaken long movements. Aerial telemetry work was conducted from a Cessna 172 mounted with two out-facing H-antennas. The same pilot was used for all flights. Aerial relocations were only used to obtain general animal locations for subsequent ground work.
Bighorn Sheep

The bighorn sheep of the Junction range are non-migratory and remain in the area year-round. Population calculations were obtained from a number of sources. Biannual aerial surveys were conducted from 1984 through 1989 (MOE unpubl.). The same pilot and observers flew all surveys in a Bell 206 helicopter. A series of intensive, two-month-long ground censuses were conducted in 1984, 1985, and 1986 (MOE unpubl.).

Some aerial surveys were undertaken solely for obtaining lamb:ewe ratios; therefore, a complete population census was not obtained. These specialized counts did, however, provide population data for blocks within the study site. The Wildlife staff who flew the surveys provided estimates of the number of sheep in other specified blocks.

Calculations of sheep numbers for the 1986-88 period within each cougar’s home area were made using data from the 1986-88 surveys. Population growth during the 1986-1988 period also was calculated using annual lamb:ewe ratios (Hebert and Harrison 1988) and an adult mortality rate of 10% (Beuchner 1960, Heimer 1978). The population estimates from the 1986-88 surveys were combined with the population growth calculations for this same period to provide a mean population estimate of the sheep within a cougar’s home area. Sheep removed during this study by the transplant program were taken into account in the population calculations.
Mule deer

Seasonal indices of deer abundance within the study area were obtained by night spotlighting counts. All roads within the study area (Figure 2.2) were travelled during each sampling effort. A buck:doe ratio of 0.45 (MOE unpubl.) was used when computing sex ratios of populations.

Other Predators and Prey Species

Wolves (*Canis lupus*), red foxes (*Vulpes vulpes*), black bear (*Ursus americanus*), bobcats (*Lynx canadensis*), golden eagles (*Aquila chrysaetos*), and bald eagles (*Haliaeetus leucocephalus*) all were present in limited numbers. Coyotes are a prominent species of the area and are discussed in Chapter 4.

Population cycle trends for Snowshoe hare (*Lepus americanus*), Blue grouse (*Dendragapus obscurus*), and Ruffed grouse (*Bonasa umbellus*) and population estimates of Sharp-tailed grouse (*Pedioecetes phasianellus*) were taken from the wildlife office’s regional information (MOE unpubl.).

Both the Wineglass and Riske Creek ranches run Hereford cow-calf operations. Horses are bred at the Riske Creek ranch. All animals range free outside of the W.M.A. boundaries. Numbers and distribution of domestic stocks were obtained from the ranches.
Figure 2.2 - Road network of the Junction Cougar Study Area. Roads were used as transects for mule deer spotlighting counts and coyote track counts.
Data Analysis

Statistical tests of cougar area use and prey selection (Chapter 3) used data collected from the family groups of females AF4 and AF6. These cougars were the main residents of the Junction and warranted the greatest sampling effort. The log-likelihood ratio using the G-statistic was employed for all goodness of fit statistical tests. The monthly distribution of confirmed kills indicated that the cougars were focusing on rams during the late fall and early winter months; therefore, winter deer numbers were used for the analysis of prey selection.

Cougar Home Areas

I calculated home areas (Seidensticker et al. 1973) for all cougars for which the area observation curve (Odum and Kuenzler 1955) levelled—indicating that additional relocation points were not increasing the size of the home area. Home area sizes were calculated by joining perimeter relocation points because computational methods of home range analysis were not required to address the hypotheses tested here.

Cougar Use of Habitat Types

Radio-relocation points were used to assess habitat and prey-range use by cougars. Relocation data for AF4 and AF6 were analyzed to determine if cougars were selecting habitat types; however, consecutive relocations at the site of a known kill were considered as a single point. When the females were relocated apart from their kittens, the location of the female was used to determine habitat use. Analysis of habitat and prey-range use employed Utilization-Availability statistics (Neu et al.)
Five habitat types were recognized:

**Forest** - areas dominated by Douglas fir.

**Broken Sage/Forest** - more open, usually sloping, areas dominated by Bigbrush and Pasture Sage with scattered Douglas fir.

**Sage** - open sage fields usually on flat terraces.

**Grass** - rolling plains dominated by Bluebunch wheatgrass.

**Cliff** - steep areas of rock or clay; generally void of vegetation.

The proportion of each habitat type within the cougar's home area was determined from 1:20,000 air photos using a digitizing tablet.

**Cougar Use of Prey-Ranges**

The relocation data were analyzed to determine if the cougars were selecting areas occupied by different prey species. The specific habitat requirements of the prey species within the Junction results in the spatial segregation of rams, ewes, and deer (Ashcroft 1986, MOE unpubl.). In addition, along some of the boundaries, a fourth area of sheep and deer overlap exists.

The total number of relocations in each prey-range for AF6 were plotted by month to examine seasonal prey-range use. Relocation points associated with known cougar kills were not plotted. Home area shift by AF4 precluded similar plots for her range use.

The proportion of relocations, in each prey-range each month, were corrected for the availability of that prey-range. The number of relocations in a particular
prey-range for each month were divided by the total number of relocations recorded in that month. This percentage was then multiplied by the probability of those relocations being in any other prey-range. This probability was calculated as (1-the proportion of area in the current prey-range). For example, the 12 relocations in ram range in February (Figure 2.6a) were divided by 30 (the total number of relocations in February over all prey-ranges). This percentage (40%) was multiplied by (1-0.15) to show the use of the ram range (15% of total home area, Table 2.4b) relative to its proportional availability.

RESULTS

Coug

Collaring and Radio Relocation

During this study, 970 man-days of field work were conducted. About half of this time was spent tracking and radio-collaring cougars. A total of 18 cougars were known to utilize the study area during the 1986-88 period (Figure 2.3). Annual population levels ranged from 8-10 animals when all age classes were considered (Table 2.1). Individual radio-relocation points are shown for AF4 and AF6 (Figure 2.4).

The radio-collaring of all age classes of cougars revealed high cougar mortality rates, particularly for kittens: of 11 kittens known to be in the area, 9 died (Figure 2.3). Only one of these deaths was associated with capture efforts. Intraspecific cougar interactions were implicated in the remainder of kitten deaths. A series of such interactions in May 1987 exemplified the impact of these associations. The
Figure 2.3 - Intervals during which individual cougars were known to be in The Junction Cougar Study Area. Numbered animals represent those fitted with radio collars, and heavy lines separate family groups. A cross at the end of a bar indicates that the cougar was known to have died. The fate of one cougar was unknown as indicated by the question mark. One juvenile male cougar, JM1 (not shown), was collared in November 1985 and was relocated for one month before radio contact was lost.
Table 2.1- The number of cougars known to be in the Junction study area from May 1986-June 1988. The number of uncollared cougars (usually siblings) known to be in study area are shown in parentheses.

<table>
<thead>
<tr>
<th>Year</th>
<th>Adult Males</th>
<th>Adult Females</th>
<th>Juveniles</th>
<th>Kittens</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>2+(3)</td>
<td>8</td>
</tr>
<tr>
<td>1987</td>
<td>1</td>
<td>2+(1)</td>
<td>2</td>
<td>2+(2)</td>
<td>10</td>
</tr>
<tr>
<td>1988</td>
<td>1</td>
<td>3</td>
<td>2+(1)</td>
<td>1+(1)</td>
<td>9</td>
</tr>
</tbody>
</table>
Figure 2.4 - Individual relocation points for radio-collared cougars AF4 (n=97) and AF6 (n=325). Data were gathered during The Junction Cougar Study in central British Columbia, 1986-1988. Relocations recorded for AF4 during movements south of the Junction and west of the Fraser river (n=63) are not shown.
presence of an uncollared cougar in the vicinity of both collared family groups (AF4 and AF6 each with two kittens) was initially indicated by tracks. Within the month, the two kittens of AF6 had been killed by a cougar (Provincial Vet Lab necropsy rep.) and AF4 and her family had vacated the study area by swimming the Chilcotin River despite full freshet conditions and a river width of 15 m. The AF4 family returned to the Junction twice for periods of one and two weeks; however, they eventually remained west of the rivers until their deaths. Relocation points recorded for AF4 outside of the Junction were not considered in any analyses.

In addition to radio-relocation work conducted during collaring, 349 man-days were spent relocating collared cougars. Error polygons calculated by Hupp and Ratti (1983) were applicable to the remote locations in this study and ranged from 0.25 Ha to 2.9 Ha for transmitter-receiver distances of 400 and 1000 m respectively. Error polygons for proximate locations were estimated at 0.06 Ha. Cougar tracks, kills, or sightings often confirmed relocation points. I made 26 sightings of cougars, including 8 observations of more than 1.5 hours each. I observed activities ranging from resting to stalking prey. Home areas were measured for two males and three females (Table 2.2) for which the area observation curves (Odum and Kuenzler 1955) had reached a plateau (Figure 2.5).

**Cougar Use of Habitat Types**

The five habitat types were not used in proportion to their availability (AF4: G=18.4, df=4, P<0.001; AF6: G=168, df=4, P<0.001). For AF4, individual habitats
Table 2.2 - Home area sizes for cougars utilizing The Junction Cougar Study Area. Data were collected by telemetry relocation of radio-collared cougars from 1986-1988.

<table>
<thead>
<tr>
<th>Cougar</th>
<th>Home Area Size (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF4</td>
<td>45.8</td>
</tr>
<tr>
<td>AF6</td>
<td>61.3</td>
</tr>
<tr>
<td>AM9</td>
<td>859.2</td>
</tr>
<tr>
<td>AF12</td>
<td>77.4</td>
</tr>
<tr>
<td>AM13</td>
<td>394.6</td>
</tr>
</tbody>
</table>
Figure 2.5 - Home area maps for radio-collared cougars utilizing The Junction Cougar Study Area. Data were collected using ground, fixed-wing, and helicopter radio telemetry.
were used in proportion to their availability with the exception of the broken sage/forest terrain (Table 2.3a). Conversely, only the forest area was used as expected by AF6 (Table 2.3b).

**Cougar Use of Prey-Ranges**

AF4's use of the four prey-ranges was as expected (G=4.27, df=3; 0.10 < P < 0.25) (Table 2.4a). AF6's use of prey-ranges departed from expected values because of greater use of the ram range and less than expected use of the ewe range (G=44.9, df=3; P < 0.001) (Table 2.4b). Figure 2.6(a-d) shows the seasonal use of prey-ranges corrected for relative availability. During the August-November 1987 period, AF6 spent most of her time in or around the den site. The den was located in a 0.05 km$^2$ open area comprised of large boulders. None of the ungulate species utilized this area, and relocation points at the den site (Figure 2.4) were not included in the analysis. Deer, ewe, and overlap ranges bordered this boulder garden; hence, they were the prey-ranges utilized during this period (Figure 2.6).

**Sheep**

Sheep at the Junction are concentrated in three areas: the Junction W.M.A., the Deer Park, and the Wineglass. Although sheep are not limited to the W.M.A., the Junction Cougar Study area and the home areas of cougars AF4 and AF6 encompass nearly all of the sheep associated with the epicentres. Sheep population calculations for each cougars' home area are presented in Table 2.5.
Table 2.3a- Availability and observed use of habitat types by AF4. Data were collected from November 1987 - June 1988. Relocation points associated with confirmed cougar kills (n=15) were removed from the analysis.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Proportion of Total Area Available</th>
<th>Number of Relocations in Area</th>
<th>Proportion of Total Use (95% CI)</th>
<th>Relative Use of Category¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>0.47</td>
<td>39</td>
<td>0.48 (0.17)</td>
<td>NS</td>
</tr>
<tr>
<td>Broken</td>
<td>0.15</td>
<td>20</td>
<td>0.24 (0.04)</td>
<td>More</td>
</tr>
<tr>
<td>Sage</td>
<td>0.26</td>
<td>13</td>
<td>0.16 (0.12)</td>
<td>NS</td>
</tr>
<tr>
<td>Grass</td>
<td>0.09</td>
<td>3</td>
<td>0.04 (0.06)</td>
<td>NS</td>
</tr>
<tr>
<td>Cliff</td>
<td>0.03</td>
<td>7</td>
<td>0.09 (0.09)</td>
<td>NS</td>
</tr>
<tr>
<td>Totals</td>
<td>1.00</td>
<td>82</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

¹ The relative use of each habitat type compared to its availability. NS = not significant.
Table 2.3b- Availability and observed use of habitat types by AF6. Data were collected from November 1987 - June 1988. Relocation points associated with confirmed cougar kills and denning activities (n=70) were removed from the analysis.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Proportion of Total Area Available</th>
<th>Number of Relocations in Area</th>
<th>Proportion of Total Use (95% CI)</th>
<th>Relative Use of Category¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>0.42</td>
<td>115</td>
<td>0.45 (0.09)</td>
<td>NS</td>
</tr>
<tr>
<td>Broken</td>
<td>0.16</td>
<td>107</td>
<td>0.42 (0.09)</td>
<td>More</td>
</tr>
<tr>
<td>Sage</td>
<td>0.09</td>
<td>12</td>
<td>0.05 (0.03)</td>
<td>Less</td>
</tr>
<tr>
<td>Grass</td>
<td>0.18</td>
<td>3</td>
<td>0.01 (0.01)</td>
<td>Less</td>
</tr>
<tr>
<td>Cliff</td>
<td>0.15</td>
<td>10</td>
<td>0.07 (0.05)</td>
<td>Less</td>
</tr>
</tbody>
</table>

Totals 1.00 255 1.00

¹ The relative use of each habitat type compared to its availability. NS = not significant.
**Table 2.4a** - Availability and observed use of prey-ranges by AF4. Data were collected from November 1987 - June 1988. Relocation points associated with confirmed cougar kills (n=15) were removed from the analysis.

<table>
<thead>
<tr>
<th>Prey Range</th>
<th>Proportion of Total Area Available</th>
<th>Number of Relocations in Area</th>
<th>Proportion of Total Use</th>
<th>Relative Use of Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram</td>
<td>0.12</td>
<td>7</td>
<td>0.09</td>
<td>NS</td>
</tr>
<tr>
<td>Ewe</td>
<td>0.40</td>
<td>28</td>
<td>0.34</td>
<td>NS</td>
</tr>
<tr>
<td>Deer</td>
<td>0.35</td>
<td>32</td>
<td>0.39</td>
<td>NS</td>
</tr>
<tr>
<td>Overlap</td>
<td>0.13</td>
<td>15</td>
<td>0.18</td>
<td>NS</td>
</tr>
</tbody>
</table>

Totals 1.00 82 1.00

1 Observed use was not significantly different from expected use; therefore, the 95% Confidence Intervals were not calculated.
Table 2.4b - Availability and observed use of prey-ranges by AF6. Data were collected from November 1987 - June 1988. Relocation points associated with confirmed cougar kills and denning activities (n=70) were removed from the analysis.

<table>
<thead>
<tr>
<th>Prey Range</th>
<th>Proportion of Total Area Available</th>
<th>Number of Relocations in Area</th>
<th>Proportion of Total Use (95% CI)</th>
<th>Relative Use of Category¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram</td>
<td>0.15</td>
<td>66</td>
<td>0.26 (0.08)</td>
<td>More</td>
</tr>
<tr>
<td>Ewe</td>
<td>0.32</td>
<td>40</td>
<td>0.16 (0.07)</td>
<td>Less</td>
</tr>
<tr>
<td>Deer</td>
<td>0.35</td>
<td>97</td>
<td>0.38 (0.09)</td>
<td>NS</td>
</tr>
<tr>
<td>Overlap</td>
<td>0.18</td>
<td>52</td>
<td>0.20 (0.07)</td>
<td>NS</td>
</tr>
</tbody>
</table>

| Totals     | 1.00                              | 255                          | 1.00                            |

¹ The relative use of each prey-range compared to its availability. NS = not significant.
Figure 2.6 - Seasonal use of ram (a) and mule deer (b) prey-ranges by radio-collared cougar AF6. Number of radio relocations for each month (shown above) were corrected for the relative availability of that prey-range (see text). Ram and deer ranges are shown together for comparison with monthly distribution of actual prey use (Figure 3.2). Dotted lines show a period of concentrated activity around the den site that biased use of nearby deer, ewe, and overlap prey-ranges.
Figure 2.6 (continued) - Seasonal use of ewe (c) and overlap (d) prey-ranges by radio-collared cougar AF6.
Table 2.5 - The number of California bighorn sheep inhabiting the home areas of AF4 and AF6. The Junction sheep are non-migratory and the numbers represent year-round population levels.

<table>
<thead>
<tr>
<th></th>
<th>Cougar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AF4</td>
</tr>
<tr>
<td>Rams ±SE</td>
<td>50 ± 2</td>
</tr>
<tr>
<td>Ewes ±SE</td>
<td>260 ± 8</td>
</tr>
</tbody>
</table>
Mule deer

The mule deer is the only other ungulate common to the area. Forty-three night counts were conducted during the study, and spotlight sightability values of 12% for summer and 25% for winter were chosen to calculate deer abundance on the Junction (Table 2.6). McCullough (1982) estimated that summer spotlight counts revealed 12-13% and winter counts revealed 30-45% of the George Reserve deer population. The percentages of open and forested habitats in the George Reserve are similar to those of the Junction with the exception that the Junction forests are coniferous. This probably resulted in a lower sightability of deer wintering in the Junction than reported by McCullough (1982).

Other Predators and Prey Species

Tracks or sightings of wolves, foxes, bobcats, and bear were recorded 2, 2, 5, and 7 times respectively. Both species of eagles were seen periodically during the spring. Snowshoe hare, Blue, and Ruffed grouse populations were approaching the 1989-90 high in their 10 year cycle (MOE unpubl.). Tracks of the hares were common in the forested habitats, and the two grouse species were seen daily. Sharp-tailed grouse were less prevalent than other small game species with only 30 birds being seen during four years on site.

Other small mammals reported in the diet of the cougar (Anderson 1983), such as beaver (Castor canadensis), porcupine (Erethizon dorsatum), marmots (Marmota spp.), or ground squirrels (Spermophilus spp.), are not present on the Junction. Although the Chilcotin region is renowned for its moose (Alces alces)
Table 2.6 - The number of deer inhabiting the home areas of AF4 and AF6. Deer numbers were calculated from seasonal spotlight indices.

<table>
<thead>
<tr>
<th>Season</th>
<th>AF4</th>
<th>AF6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bucks</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>113 ± 4</td>
<td>135 ± 3</td>
</tr>
<tr>
<td>(± SE)</td>
<td>137 ± 3</td>
<td>165 ± 2</td>
</tr>
<tr>
<td>Winter</td>
<td>171 ± 3</td>
<td>225 ± 3</td>
</tr>
<tr>
<td>(± SE)</td>
<td>209 ± 5</td>
<td>275 ± 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
population, this ungulate is virtually absent from the study area. No other wild ungulates are found in the area.

The entire study area, with the exception of the W.M.A., is used as rangeland for both the Wineglass and Riske Creek cow-calf operations. A combined total of about 3,500 head free-range from April to November. The cattle are corralled during the winter months. The Cotton Ranch runs 30-50 horses in a 5 km² paddock near the ranch house.
DISCUSSION

The constraints of wildlife work often require the researcher to focus on the generalities of large scale systems or on the specifics of smaller ones. The intent of my study was to document cougar distribution and movement within the Junction and to examine the specific dynamics of this predator/prey system. When a specific area is chosen, the researcher must decide whether to include in the analysis cougars that only have portions of their home areas within the study area. This decision and the subsequent analysis will, obviously, depend on the focus of the study.

For studies of intraspecific interactions among cougars (Hornocker 1970, Seidensticker 1973, Ashman et al. 1983, Pall et al. 1988), population estimates generally reflect the number of adult cougars holding home areas. In this study, AF4 and AF6 had home areas completely within the study area while AM9, AF12, and AM13 had portions of their home areas within the study area. My interest was the total number of cougars using a specific area-- the Junction, and a specific prey base-- the bighorns. Each adult female cougar had 2-3 kittens (Harrison 1987). The kittens and juveniles are important when examining cougar predation because these young animals are frequently as large as their mothers and require her to provide a regular supply of meat. Therefore, 8-10 cougars were using the Junction prey base.

This interest in all age classes of cougars within the Junction required the collaring of all animals, including the kittens. With entire family groups radio-
collared, additional insights about the dynamics of the system arose. For example, the simultaneous killing of kittens KF2 and KM3 and drastic movements of AF4 and her two kittens were two events that were my first indication that self-regulatory mechanisms may be important in cougar population dynamics. The continued killing of kittens within the population lent further support to the idea.

Hornocker (1970:17) proposed that territoriality appears to be the primary factor in regulating numbers of [cougars] in the Idaho Primitive Area. Seidensticker et al. (1973:59) in an examination of cougar social organization in the same population Hornocker studied also concluded the land tenure maintains the density of breeding adults below a level set by food. Both authors, however, recognized that high mortality of dispersing juveniles was important for population regulation.

Seidensticker et al. (1973) also found that females with small kittens, more than any other reproductive class of cougar, were the least tolerant of another cougar's presence. Any links, however, between this behaviour and evidence of male regulation may have been masked by the fact that cougars were harvested during both studies. Although this harvest was light (Hornocker 1970), the removal of even a few animals, particularly males, may have been sufficient to suppress the higher kitten mortality rate observed in the Junction's un-hunted population.

Use of The Junction Area by Cougars

The home areas of AF4 and AF6 were contiguous with the range of the bighorns and were of particular interest. Analysis of home area use revealed that,
of the five habitat types (Table 2.3 a,b), only the broken sage/forest was used in
greater proportion than it was available. This habitat type was not used exclusively
by either of the two ungulate species in the Junction.

The broken sage/forest habitat type may have been favoured by the cougars
because they could hunt this area more effectively. Cougars stalk their prey to
within some critical distance from which they launch a final attack (Hornocker
1970). Cover is a key element of the initial stalk, but the exact form of this cover
is highly variable including bushes, rocks, and tall grass (personal observation).
These substrates share the important characteristic that they provide good cover from
the ground to about 50 cm. This depth allows the cougar to remain concealed
during the approach while maintaining visual contact with the taller ungulate
species. Sage brush is ideal for providing this type of cover year-round; however,
the sage habitat alone differs from the broken sage/forest habitat in two other ways.
The trees in the broken habitat provide cover and attract the ungulates, and much
of the broken habitat types are located on sloping aspects. The slope gives the
cougar a hunting advantage by enabling the cougar to get above its prey thereby
increasing the swiftness and duration of the attack (personal observation).

The seasonal use of prey-ranges within the home area was also important in
explaining the pattern of cougar predation documented at the Junction. The spatial
segregation of the prey species of the Junction was key to this examination. The
fragmented habitat types combined with the specific habitat requirements of sheep
and deer result in a separation of species along often abrupt boundaries. This
segregation is augmented by seasonal movements of the deer and behavioural characteristics of the sheep that result in the rams and ewes utilizing different parts of the sheep range (Ashcroft 1986).

Figure 2.6b shows the use of deer range by AF6 was constant at relatively high levels. The March peak and the December lull in the use of this range correspond to the opposite trends in the use of the ram range. More importantly, these trends in prey-range use reflect the seasonal trends observed in the confirmed cougar kill data (Figure 3.2). Relocations associated with killing and consumption of confirmed cougar kills were removed from the analysis of prey-range use; the prey-range analysis, therefore, represents an independent verification of seasonal prey utilization.

The use of the ewe range was (Figure 2.6c) was lower than that of any of the prey-ranges indicating that ewes and lambs were not utilized to any great extent as a prey species. From the initially low utilization levels, cougar use of the ewe range declined sharply during the spring corresponding to the lambing period. The ewes become secretive during this period (Geist 1971, Ashcroft 1986) and concentrate their activities on the precipitous cliffs used as lambing grounds (Ashcroft 1986). Although cougars are capable of killing prey on the lambing grounds (personal observation), more accessible hunting grounds are available.

The use of the overlap range (Figure 2.6d) exemplified the transitional area between sheep and deer range that this range represents. The seasonal use of this
range paralleled the patterns of all the other three ranges during different periods of the year: Ewe range—January-March; Ram range—April-May; Deer range—June-August; Ewe range—September-December. When the lines were distant, this indicated that the specific prey-range had been chosen distinctly from areas where alternative prey species were available.
CHAPTER SUMMARY

The Junction area and the bighorn sheep range was used by 8-10 cougars when all age classes were considered. Two females had home areas that were contiguous with the sheep range and a third female and two males had home areas that incorporated parts of the range. The broken sage/forest habitat type was used more frequently than expected from its availability. Use of prey-ranges by AF6 showed a seasonal trend in her use of ram and mule deer ranges that corresponded to the seasonal distribution of confirmed cougar-kills.

High kitten mortality was noted in the area as 9 of 11 kittens were killed during the study. Documentation of kittens being killed by other cougars suggests that intraspecific interactions may be important in the regulation of cougar populations.
CHAPTER THREE - SELECTIVE PREDATION BY COUGARS

Selection of mule deer bucks by cougars has been reported in a number of studies (Robinette *et al.* 1959, Hornocker 1970, Shaw 1975, Russell 1978). However, after analyzing prey species composition in these cougar studies, Anderson (1983:68) concluded the assertion of [cougar] selectively killing certain sex and age classes of mule deer remains an untested hypothesis.

Determining the availability of prey is required to demonstrate prey selection by predators (Chesson 1978). Sites for cougar studies are usually chosen on the basis of their cougar densities and distributions. Although this is appropriate for an examination of cougar ecology, if this area cannot be effectively surveyed for all prey species, questions of prey selection by cougars cannot be addressed.

A more subtle, but equally important, consideration affects a study's ability to address cougar predation. Finding cougar kills requires a specialized effort that is unique from any other form of data collection. Simply tracking radio-collared cougars is not sufficient. Cougars conceal their prey very effectively (Chapter 4); the researcher must travel the gullies and thickets and look specifically for dead prey.

METHODS

I collected telemetry relocations under two sampling regimes to determine cougar prey species composition:
1. Direct Sampling-- When cougars were relocated in the same area for two consecutive days or were suspected to have made a kill, the area was subject to a ground sweep. The canyon nature of the Junction made it possible to search the individual draws for kill remains. In terrain types where ground sweeps were ineffective, I approached the cougar prior to its departure from a kill.

Approaching cougars at kill sites was accomplished by stalking using the wind and available cover to the best advantage. Stalking the cougars to their kills was of concern, not only for safety considerations, but for fear of displacing cougars from the kills. If the cougars left kills prematurely, predation rates would have been artificially increased. To minimize such disturbance, I vacated the area as soon as the kill had been located. When radio telemetry indicated the cougar had left, the site was revisited to obtain prey species, sex, and age class data.

The species and sex of all mortalities were recorded; however, only the ages of sheep were estimated by counting horn annuli (Beuchner 1960). The habitat type of kill sites were recorded and the location marked on a 1:50,000 topographical map. The heads of ram kills were collected and measured. Measurements followed Compulsory Inspection Data Sheets (CIDS) forms used by the Wildlife Branch for recording harvest sheep horn sizes.

To assess whether the presence of humans at kill sites affected the cougars’ use of kills, kills of varying degrees of utilization (n=9) were manipulated intentionally. Carcasses were pulled from their cover, dragged in a 5 m arc, and
reburied. All tracks in the area were then swept away. The area was then monitored initially with radio telemetry and, latter, by site examination to see if the cougar returned.

2. Inference Sampling— The spatial segregation of prey species within the Junction enables the partitioning of the home areas of cougars AF4 and AF6 into prey-ranges (Chapter 2). The proportion of relocation points in each prey-range was used to make inferences about prey selection based on that range's prey availability. Relocations associated with known kills were excluded from this analysis.

Confirmation of Cougar Kills

Cougar kills were readily identified by a five criteria: dragging the kill to cover, burying the carcass, puncture wounds in the prey’s throat area, intact removal and separate burying of the rumen, or buried scat mounds near the kill. Tracks and sightings at kill sites also confirmed cougar involvement. I assumed that cougars made, rather than scavenged, any kills showing evidence of cougar involvement for the following reasons:

1. the criteria used to assign kills are specific to the cougar,
2. no other predators in the area prey consistently on adult ungulates,
3. cougars prefer freshly killed meat (Anderson 1983).
Data Analysis

The undetermined mortality sample included all prey remains found on the Junction other than confirmed cougar kills. Species classification of undetermined mortalities for which no head could be found was based on hair colour and hoof configuration while the sex of these mortalities was recorded as unclassified. These mortalities were not included in any comparative analysis (Figure 3.1) because there was no comparable category in the confirmed cougar kill sample.

The confirmed kill sample for all cougars was categorized by habitat type to test if kills were more likely to be found in open habitats. The same five classifications used to define cougar habitat use were used.

Tests for differences between the prey composition of the undetermined mortality and the confirmed kill samples were conducted with G-tests. For this and for the analysis of the confirmed kills by month, the kill data of cougars AF4 and AF6 were analyzed for sample homogeneity and pooled. The coyote sample (Figure 3.1) was dropped from the analysis because the coyote trapping effort (Hebert and Harrison 1988, MOE unpubl.) was not constant throughout the cougar study thereby disrupting normal coyote population dynamics and complicating the estimation of coyote availability as a potential prey species.

The extent of predation on bighorn sheep was determined by varying the estimation of mule deer availability. Winter deer numbers (Table 2.5) were used as an upper limit for deer availability in calculations of prey selection. With lower
estimates of deer numbers, the ram component of the prey population became proportionately larger. This tested the hypothesis that cougars preyed selectively on the ram component of the population. Utilization-availability statistics (Neu et al. 1974) were employed to test for prey selection by cougars.

To determine if the cougars were killing only the mature, full-curl rams, the age and the total horn length of cougar-killed rams were compared to those of the hunter-killed rams killed during the same 1986-1988 period. Ages of neither the cougar-killed nor hunter-killed ram sample were found to be normally distributed; therefore, testing for a difference in age between cougar-killed and hunter-killed rams was done with the Mann-Whitney U-test. Comparison of mean horn lengths was taken from Hirsch (in progress).

Only the ram and deer components were plotted in the monthly distribution of confirmed kills to show trends specifically related to these two prey types. The exact month in which 3 rams and 1 deer were killed could not be determined and they were excluded from the analysis.

RESULTS

A total of 132 prey remains were discovered from May 1986 to June 1988 (Figure 3.1). Of this total, 50 were confirmed as recent cougar kills. This number represents a conservative figure since the majority of the total undetermined mortality sample was found prior to collaring and intensive monitoring of cougars. Moreover, many of the 13 unclassified mortalities in the undetermined mortality
Figure 3.1 - Confirmed kills, made by radio-collared cougars, and undetermined mortalities, for which no positive identification of the cause of death could be made, found in the Junction Cougar Study Area from 1986-1988. Percentages were calculated from the number of kills in each category with sample sizes shown above.
sample were discovered in areas typical of cougar kills such as covered gullies or beneath trees in the more open areas. Forty-three confirmed kills were collected from AF4 and AF6. These 43 kills were used for all statistical analyses except for the classification of kills by habitat type. This analysis used confirmed kills by all cougars (n=50).

Approaching cougars at kill sites had no effect on the utilization of kills. The cougars returned to all manipulated kills. Of the 43 kills discovered, only 3 times (2 of these involved treeing the cougar off the kill with dogs) did study efforts cause the cougar to leave the kill without returning.

No kills of domestic stock by cougars were ever recorded. Cougars were found killing wild ungulates near the Hereford calving grounds. AF6 once stalked through the cow herd to kill a bighorn sheep on the periphery. Only one small prey item, a ruffed grouse, was confirmed as a cougar kill. It was killed by KF7 as she was observed playing with KM8. The grouse was decapitated with a single blow of the front paw but not eaten. It was not included in the analysis.

Classification of cougar kills by habitat type indicated that most kills were found in the forest (42.0%, n=21) and broken sage/forest areas (28.0%, n=14). This pattern not only reflects habitat use by the cougars (Table 2.3a,b), but also shows that the discovery of cougar kills was not biased to more open habitat types.

Tests between the undetermined mortality and confirmed kill samples
demonstrated that the two samples were independent (G=22.4; df=4; P<0.001), and the discovery of prey remains was, therefore, dependent on whether the remains were an undetermined mortality or a known cougar kill.

Analysis of the confirmed kill data for both AF4 and AF6 revealed that prey species were used selectively (Table 3.1a,b: all G-tests; df=3, P<0.001). No cougar-killed bighorn lambs were ever found. These data were corroborated by the inference data on prey-range utilization (Chapter 2) where the use of the ewe/lamb range was low (Figure 2.6c).

Utilization-availability analysis showed that both AF4 and AF6 were selecting bighorn rams (Table 3.2a,b). Although rams were selected, the cougars did not appear to focus on the older or larger rams. The mean age and total horn length for the 20 rams killed by cougars were 5.1 ± 0.6 years and 64.1 ± 9.7 cm. The mean age and total horn length for the 18 rams killed by hunters during the same time period were 6.8 ± 0.3 and 86.4 ± 1.3 cm. The cougars killed a wider range of ages of rams (2-11 years) than did hunters (4-9 years) because hunters were restricted by regulation to kill rams that were full-curl or at least 6 years of age. The data indicate that cougars were killing younger, smaller rams (U’ 18,20 = 93), and although the age structure of the ram population was not known, the hunters sample indicates that older, larger rams were available.

Analysis of the confirmed kills categorized by month showed that the month in which a prey species was killed depended on whether the prey species was a
Table 3.1a - Number of confirmed cougar kills found for radio collared cougar AF4 (May 1986 - June 1988). Expected number of kills were calculated from winter estimations of prey abundance within AF4's home area.

<table>
<thead>
<tr>
<th></th>
<th>Observed # of Kills</th>
<th>Expected # of Kills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Ewes</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Bucks</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Does</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

| Totals | 12 | 12 |

AF4
Table 3.1b- Number of confirmed cougar kills found for radio collared cougar AF6 (May 1986 - June 1988). Expected number of kills were calculated from winter estimations of prey abundance within AF6’s home area.

<table>
<thead>
<tr>
<th></th>
<th>Observed # of Kills</th>
<th>Expected # of Kills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Ewes</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Bucks</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Does</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Totals</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>
Table 3.2a- Observed use of prey types by AF4 compared to prey availability. Data were collected from November 1987 - June 1988.

<table>
<thead>
<tr>
<th>Prey Type</th>
<th>Number of Total Prey Available</th>
<th>Proportion of Total Prey Available</th>
<th>Proportion of Total Use (95% CI)</th>
<th>Relative Use of Category¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams</td>
<td>50</td>
<td>0.07</td>
<td>0.50 (0.41)</td>
<td>More</td>
</tr>
<tr>
<td>Ewes</td>
<td>260</td>
<td>0.38</td>
<td>0.17 (0.31)</td>
<td>NS</td>
</tr>
<tr>
<td>Bucks</td>
<td>171</td>
<td>0.25</td>
<td>0.25 (0.36)</td>
<td>NS</td>
</tr>
<tr>
<td>Does</td>
<td>209</td>
<td>0.30</td>
<td>0.08 (0.23)</td>
<td>NS</td>
</tr>
<tr>
<td>Totals</td>
<td>690</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

¹ The relative use of each prey type compared to its availability. NS = not significant.
Table 3.2b - Observed use of prey types by AF6 compared to prey availability. Data were collected from November 1987 - June 1988.

<table>
<thead>
<tr>
<th>Prey Type</th>
<th>Number of Total Prey Available</th>
<th>Proportion of Total Prey Available</th>
<th>Proportion of Total Use (95% CI)</th>
<th>Relative Use of Category¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams</td>
<td>70</td>
<td>0.09</td>
<td>0.52 (0.28)</td>
<td>More</td>
</tr>
<tr>
<td>Ewes</td>
<td>160</td>
<td>0.22</td>
<td>0.11 (0.17)</td>
<td>NS</td>
</tr>
<tr>
<td>Bucks</td>
<td>225</td>
<td>0.31</td>
<td>0.11 (0.17)</td>
<td>Less</td>
</tr>
<tr>
<td>Does</td>
<td>275</td>
<td>0.38</td>
<td>0.26 (0.24)</td>
<td>NS</td>
</tr>
<tr>
<td>Totals</td>
<td>730</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

¹ The relative use of each prey type compared to its availability. NS = not significant.
ram or deer (G=24.1; df=11; 0.001<P<0.025). The majority of rams were taken during the late fall and early winter months while deer were selected during the mid-winter and spring months (Figure 3.2). This, too, was substantiated by the inference data (see methods) that demonstrated, independently, that the use of both deer and ram ranges peaked during the months in which confirmed cougar kills for each species also peaked.

The lack of samples in August and September reflected a seasonal reduction in field effort and a decreased efficiency finding kills due to changes in cougar movements and distribution resulting from the intraspecific interactions in May 1987 (Chapter 2). The behaviour of AF6 in the following weeks was odd in that she made large, daily movements within her home area. She was probably searching for her kittens that had been killed by another cougar and that I had removed for prompt transport to the veterinary lab in Vancouver, B.C.

Following these movements, she moved out of her home area (Figure 2.4) and was joined by AM9 (radio-relocation data). She was bred during the 5-day encounter and returned alone to her home area. During August and September, AF6 was denned up and moved very little. Her subsequent kittens KM10, KF11, and KF-, were born September 26, 1987. These summer activities altered normal predatory behaviour as reflected in the August and September samples. These changes affected the discovery of summer sheep and deer kills equally.
Figure 3.2 - The annual distribution of ram and mule deer kills collected during The Junction Cougar Study. The ram and mule deer kill data of cougars AF4 and AF6 were pooled. This total (n=30) was used to calculate the proportion of each species killed by month.
DISCUSSION

The number of rams found in the undetermined mortality sample (Figure 3.1) indicates that a high proportion of rams were dying of natural causes, including predation. Although some illegal harvest may have occurred, no evidence of extensive, organized poaching was found. I assumed that just the head and not the carcasses of illegally shot rams would be removed; this is probably valid given that trophy bighorns would be killed for their horns and capes rather than their meat.

The 13 unclassified (headless) sheep carcasses represent animals that may have been poached; however, legal harvest accounted for some of this sample. Hunters are only required to remove the head and one hindquarter under British Columbia hunting regulations for bighorn sheep although most recreational hunters do pack out the entire carcass for the meat. Other unclassified sheep could have died due to natural causes, including predation, with the heads being removed by hikers or previous researchers (MOE unpubl.).

The species composition of in undetermined mortality and confirmed kill samples were independent of each other. In part, this independence reflected the differential species and sex skull perishability of the ungulate species involved (Beuchner 1960, Murphy and Whitten 1976, Harrison and Hebert 1988). However, when the ram category is removed from the analysis, the two samples are not independent (G=6.81; df=3; 0.05<P<0.10) indicating that the species composition of the undetermined sample reflects that of the cougar-killed sample. The high proportion of rams in the confirmed cougar kill sample (Figure 3.1) is not,
therefore, a result of sampling bias for the following reasons:

1. The confirmed kill data were the result of the intensive radio-relocation sampling regime. Kills discovered by tracking the cougars were fresh and not indicative of differences in skull perishability.

2. The species composition of the undetermined and cougar-killed samples, without rams, are not independent. This suggests that the discovery of all other prey species (ewes, deer, and coyotes) is not dependent on the method of their collection.

3. When the entire sample is analyzed, the independence of the undetermined and confirmed kill samples is due to the high proportion of undetermined ram mortalities relative to the proportion of confirmed cougar-killed rams. This, too, suggests that the number of rams in the cougar-killed sample is not an over-estimate resulting from sampling bias.

A bias in both the undetermined and confirmed samples involves small prey species and immature ungulates of either species or sex. The bones of these animals are readily consumed by cougars, coyotes, and eagles (personal observation) a point exemplified by the absence of this age class from either the undetermined mortality or confirmed kill categories. The potential importance of this rapid utilization of lambs in the analysis of cougar predation was countered by the relocation data. These data revealed that cougar use of ewe and lamb areas was
low (Figure 2.6c).

The direct sampling method was particularly effective for locating kills of females with young, collared kittens. The kittens would remain at the kill site while the female moved off to hunt. As the kittens became older, the rate at which kills were located declined despite the fact that the utilization rate and likely the kill rate were increasing (Harrison and Hebert 1988). An increase in the mobility of the kittens around kills made it more difficult to rely solely on the kittens' location to mark the site. The central area of kitten activity could be approached using circling ravens (*Corvus corax*), bald and golden eagles as distant markers (100-200 m radius) and magpies (*Pica pica*) as more exacting markers (5-10 m radius) of the kill site (Harrison 1987).

The absence of domestic stock from the prey sample contrasts the work of Shaw (1975) who found cougars in Arizona selected domestic calves over mule deer. The continual availability of calves in Arizona due to year-round calving may have resulted in the cougars learning to key in on this particularly vulnerable prey type. At the Junction, calving occurs during the winter and coincides with high deer numbers.

Prey such as snowshoe hares and grouse may be killed frequently by cougars; the predatory responses observed in any felid, including domestics, when confronted with a small, darting object supports this. However, these prey items would be consumed quickly with few remains. I feel that it is unlikely that these prey items
provide little more than learning opportunities and sport for healthy cougars. The frequency with which adult ungulates are killed and utilized (Chapter 4) suggests that cougars have energetic requirements that exceed those provided by a regular diet of small prey items.

Evidence of Selective Predation

Selective predation occurs when the relative frequencies of prey types in a predator's diet differ from the relative frequencies in the environment (Chesson 1978). Inherent in the examination of prey selection is the need for an understanding of prey availability. Difficulties in determining the availability of the prey base have precluded definitive statements on cougar prey selection. This is particularly true when examining intraspecific selection of deer by the cougar.

The availability and structure of deer populations are difficult to document, particularly in forested habitats. Although several deer census techniques have been developed (Lewis and Farrar 1968, Floyd et al. 1979, McCullough 1982), they are often prohibitively expensive or ineffective in the terrain types of most cougar study sites. Indices of relative deer abundance, however, are readily obtained through seasonal spotlight counts and can provide valuable information in the examination of cougar prey selection under two conditions:

1) interspecific rather than intraspecific prey selection is being examined, and

2) good population composition data are available for the alternative prey species.
In this study, bighorns represented the alternative prey for which population data were available (Ashcroft 1986, MOE unpubl., this study). Relative abundance of deer was important only in determining if selective predation by cougars on sheep was occurring.

Winter prey numbers (Tables 3.2a,b) represented a conservatively low estimation of the prey base wintering on the study site from late October to April. Rams were clearly utilized by a significantly greater proportion (AF4: 50%; AF6: 52%) than they were available (AF4: 7%; AF6: 9%) in the total prey population. It is purposeful to consider these statistical results in the context of this study. The key point is that not only were rams utilized in greater proportion to their availability, but that they were utilized in greater proportion than all alternative prey sources, and all other prey species were utilized as expected or less than expected.

**Reasons for Selective Predation**

Cougars are capable of killing a wide range of prey species (Anderson 1983) under a wide range of conditions. Reports of a 43 kg female cougar killing 6-point bull elk (Hornocker 1976) and observations of cougars stalking and killing prey on open grasslands (this study) attest to the cougar’s predatory abilities. The functional responses of predators to varying prey densities have been demonstrated in foraging experiments (Holling 1965, Abrams 1982, Lacher et al. 1982). Prey palatability was an important component determining the predator’s prey selection in Holling’s system; however, he also recognized that behavioural and physiological characteristics of the prey may be important in determining prey choice in other
The solitary nature of male mule deer and their preference for rugged, dense habitats have been cited as behavioural factors that increase the bucks' vulnerability to the stalking attack of cougar (Robinette et al. 1959, Hornocker 1970, Spalding and Lesowski 1971). For rams at the Junction, however, group size and habitat use were stable year-round outside of the October rut (Ashcroft 1986). Moreover, the annual concentration of cougar-killed rams suggests that while both prey group size and habitat selection were undoubtedly important parameters in determining prey vulnerability and cougar hunting success, these factors alone do not adequately explain the observed pattern of cougar predation observed at the Junction. The selection of rams occurred during November and December when poor condition following the October rut would have been an important factor underlying ram vulnerability to predation.

The rut represents a time of high energy demands for rams (Beuchner 1960, Geist 1971). Despite the long, intense battles throughout the rut, rams do little or no foraging (Geist 1971). The poor post-rut condition of rams is likely to have predisposed them to the observed cougar predation.

It has been suggested that bucks' pre-occupation with rutting activity increases their vulnerability to cougar predation (Robinette et al. 1959). This was not the case for Junction rams as no cougar-killed rams were found during the rut. One obvious difference between the rutting behaviour of sheep and deer is the greater
temporal and spacial distribution of the mule deer rut. Small groups of 3-15 deer are distributed over large areas for their rut that lasts about 40 days in the Chilcotin (MOE unpubl.). In contrast, upwards of 300 sheep may gather on a single field during the height of the 14-day bighorn rut (personal observation). During this period, rams receive more protection against predators than do rutting bucks or the same rams later in the year when they have left the rutting areas.

Ashcroft's (1986) work done on sexual segregation and group sizes of the Junction bighorn sheep showed that the group sizes for rams outside the rutting period were not different than group sizes for ewes. I believe that for the rams after the rut, it is their physical condition-- not their group size-- that increases their vulnerability to cougar predation.

Another series of factors that may affect cougar selection of rams relates to sheep horn growth. Data collected from cougar-killed rams suggest that a large total horn length does not predispose a ram to cougar predation. Comparison of mean lengths of hunter-killed and cougar-killed rams during the 1986-1988 period demonstrated that the horn length of cougar-killed rams was less than hunter-killed sheep taken during the same period (Hirsch in progress). The difference between these samples rejects the notion that cougars were only killing the large, trophy class rams. Smaller rams may have been more vulnerable to cougar predation because of the defensive strategies of bighorns. Often, when sheep are grazing or resting, the larger, more dominant rams are found towards the center of the group (personal observation). The smaller rams on the periphery are more likely to be
chosen as prey by the cougar.

Although social dominance in bighorn sheep is related to horn size with the larger, dominant rams believed to perform most of the active rutting (Geist 1971), it remains an untested hypothesis that these large rams enter the post-rut period in poorer condition (Festa-Bianchet 1987). Younger, smaller horned rams may expend as much energy attempting to gain access to estrous ewes by means other than head-to-head rutting combat (Hogg 1984). My data show that young rams are also vulnerable to cougar predation. This suggests that young rams may be active enough during the rut to increase their vulnerability to cougar predation later in the year.

The general configuration of the horn spiral (Clark 1964) may be more important in determining which rams are more vulnerable to cougar attack. The cougar stalks its prey to within some critical distance (Hornocker 1970) and then pounces on the back of the prey and biting at the base of the neck (Robinette et al. 1959). Rams, more than any other ungulate species, would be particularly vulnerable to this form of attack because of inhibited rear and peripheral vision. A tight, short horn spiral could obstruct the ram’s vision as much as a long, flaring horn spiral.

Horn structure may have also been responsible for the low cougar utilization of ewes. The short, relatively straight horns of the ewes permit better rear and peripheral vision and also may represent greater injury potential for a cougar biting
at the base of the neck. By throwing her head back, even if an uncontrolled response, a ewe’s horns are more likely to injure the cougar.

Implications of Selective Predation

I found that cougars were selecting rams at the Junction following the rut as cougars focused on the exhausted and less wary rams. The relation surmised here between reproductive effort (the rut) and the associated costs (an increased vulnerability to predation) has implications for the ecological fitness of rams. Here, fitness refers to a ram’s lifetime reproductive success (Clutton-Brock 1988). The more off-spring sired over the life-time of a ram, the greater that ram’s reproductive fitness. Given the pattern of predation observed at the Junction, it may be ecologically beneficial for rams to expend less energy during any one rut. The cost of such a strategy may be a decrease in short-term breeding success while the benefit may be an increase in survival resulting in extended breeding and greater overall fitness.

Selective cougar predation on the ram component also has implications for the basis of sexual segregation in bighorn sheep. Ashcroft (1986) concluded that sexual segregation in the Junction herd was not nutritionally based. He suggested that the segregation of rams and ewes may be related to differential predation experienced by the sexes (Ashcroft 1986). Geist and Petocz (1977) similarly proposed that predation affected sexual segregation in bighorn sheep; however, these authors felt that predators would focus on the female groups. They argued that the males, in a weakened post-rut condition, would move away from the female groups
to avoid this increased threat of predation (Geist and Petocz 1977).

My data dispute this latter claim given that the rams, not ewes, suffered higher predation; however, cougars are only one of a host of predators capable of killing bighorn sheep (Beuchner 1960, Sugden 1960, Kelly 1980). The documentation of differential predation presented here suggests that cougar predation is not the basis for sexual segregation: it is unlikely that rams voluntarily separate from the ewes as an altruistic act to protect the ewes from predation, and it is equally improbable that the ewes force the more dominant rams to leave.

Sexual segregation in the Junction bighorn sheep herd does not appear to be related to nutrition (Ashcroft 1986) or predation (this study). I believe that the separation between rams and ewes reduces aggression within the population. The social structure of both the ram and ewe segments of the bighorn population are based on a dominance hierarchy (Geist 1971); however, if the rams and ewes remained together year-round, it seems unlikely that ewes could gain a dominance ranking any higher than the lower ranking rams. This, in turn, would have ramifications for the well-being of the ewes and the reproductive capabilities of the herd. Similarly, the constant presence of ewes, could lead to inter-ram aggression that extended beyond the period of the rut. Such aggression could continue year-round, as the rams tested the receptiveness of ewes. The result would be poor ram condition throughout the year and an increased vulnerability to predation. With sexual segregation, rams live in bachelor groups, and the presence of ewes as a stimulus to fight is removed.
Another consequence of selective cougar predation addresses the trend of declining horn size in the harvested population of rams (Hirsch in progress, MOE unpubl.). Although cougars did not focus on the larger rams, cougar predation of smaller horned rams has consequences for the overall recruitment of rams into the harvestable stock (full-curl or 6 years of age). Removing young rams obviously reduces the potential for more larger rams. Cougar predation, however, is only one component of the overall Junction system affecting recruitment. Coyotes were found to play an important role in reducing the recruitment of lambs to the general sheep population (Hebert and Harrison 1988) thereby reducing the number of young rams entering the ram population. Coyotes affected the nature of cougar predation in other ways as discussed in Chapter 4.
CHAPTER SUMMARY

Cougars were selecting prey on the basis of prey species and sex but not age. Bighorn rams comprised about 50% of the cougar kill yet constituted only 9% of the available prey population. Most rams were taken in the late fall while most deer were taken in the early spring. This suggests that cougars were keying on rams following the fall bighorn rut. Although the mean age and horn size of cougar-killed rams were less than those sheep in the hunter-killed sample, horn configuration of the rams may predispose them to cougar predation. Poor rear and peripheral vision for rams increases their vulnerability to the rear attack of the cougar.

These results suggest that cougar predation alone is not the basis for sexual segregation in bighorn sheep; however, the risk of increased predation after the rut has implications for breeding strategy and reproductive fitness of rams.
CHAPTER FOUR - COUGAR PREDATION AND KILL UTILIZATION RATES

The extent of predation on a prey population depends on factors such as selection of prey types and the frequency of predation events. Cougar predation rates have been estimated using a variety of methods and range from 12-91 deer/year (Anderson 1983). Often these rates are calculated from consumption rates of captive cougars; documentation of predation rates in the field is limited because the prerequisite of time continuity hinders the collection of these sorts of rate data. The discovery of cougar kills was key to my analysis of cougar predation, and, by incorporating a time component in the reconnaissance for cougar kills, predation rates could be determined (Harrison 1989). My investigation of predation rates revealed that a number of factors, particularly interactions between coyotes and cougars, played an important role in determining the extent of cougar predation within the Junction system.

METHODS

Cougars

Predation rates of AF4 and AF6 were sampled by monitoring the cougars continuously throughout a day and occasionally throughout a 24 hour period. Relocations were supplemented with tracking efforts to obtain information on cougar movements rather than spot relocations. A sample period commenced on the day that a confirmed kill had been made and continued until relocation continuity was interrupted. Contact was considered to have been broken if the time between
successive relocations exceeded six hours. Six hours was chosen based on experience with previous cougar kills (this study) as a conservative estimate of the minimum period within which the cougar could stalk, kill, consume, and abandon an ungulate prey.

Upon discovery of a confirmed cougar kill, prey sex and age information were collected and time of death was estimated using cougar movement information (when had the cougar moved into that area?), kill site information (when was the prey killed in relation to the last rain or snowfall?), or the condition of the carcass (had the blood congealed? were scavengers present?). The proportion, by weight, of the edible carcass remaining was estimated. The edible portion of a carcasses was determined by examination of previous confirmed kills (this study, Hornocker 1970). The kill site was monitored with radio telemetry to check for the cougar's return. If the cougar or her kittens were absent, the site was inspected for scavenger activity. If no cougar activity was recorded within 1 km of the area for 2 days, the carcass was considered abandoned. The utilization rate of kills was measured as the period from the killing of the prey to the last time the cougar was known to be at the kill site.

**Coyotes**

Indicators of general coyote abundance including tracks, howling frequencies (measured as the number of times/month coyotes were heard), and the number of visitations to bait stations were monitored. During the winters of 1986-87 and 1987-88, a coyote removal program was conducted on the W.M.A. and Deer Park
portions of the Junction (Hebert and Harrison 1988, MOE unpubl.). Coyotes were trapped by a registered trapper under permit from the Wildlife Branch and shot by hunters attracted by high pelt prices. The traditional shooting of coyotes by the cowboys of the Cotton and the Deer Park ranches continued throughout the study. The number of coyotes removed under these programs provided information on coyote distribution within the area.

RESULTS

Cougars

Examination of the confirmed cougar kills revealed that the muscle tissue, heart, liver, and lungs represent the edible portions of the carcass (this study, Anderson 1983). These edible portions account for approximately 70% of the weight of an adult sheep (this study) or deer (Hornocker 1970). The skeleton, usually the ribs, were occasionally chewed; however, the rumen, intestinal tract, or the hide were never consumed in any of the kills examined. As mentioned previously (Chapter 3), a higher proportion of the carcass of a young ungulate or small prey animal would have been consumed.

Three sampling periods were undertaken for each of the females and the mean predation rate over all three sampling periods were calculated (Table 4.1). Comparisons of some of the factors affecting utilization and predation rates are shown (Table 4.2). Examination of kill sites during the predation rate sampling periods revealed that the cougars utilized 100% of the edible portions of 9 of the
Table 4.1 - Comparison of mean predation rates\(^1\) and sampling periods between radio-collared cougars AF4 and AF6. Data were collected for the Junction Cougar Study in central British Columbia during 1986 and 1987.

<table>
<thead>
<tr>
<th></th>
<th>AF4</th>
<th>AF6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Predation Rate (kills/wk ± SE)</td>
<td>2.6 ± 0.2</td>
<td>1.1 ± 0.2</td>
</tr>
<tr>
<td>Number of Sample Periods</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Consecutive Days Followed</td>
<td>26</td>
<td>41</td>
</tr>
<tr>
<td>Number of Kills Found</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

\(^1\) Predation rates were calculated from the mean number of kills/week for each of the 3 sample periods to reflect changes in the factors affecting predation rates. The predation rates are significantly different ($U'_{33} = 0$).
Table 4.2 - Comparison of the factors affecting cougar kill utilization and predation rates. Data were collected for radio-collared cougars AF4 and AF6 during sampling periods in 1986 and 1987 in the Junction Cougar Study Area, British Columbia.

<table>
<thead>
<tr>
<th>Cougar</th>
<th>AF4</th>
<th>AF6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Kittens</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Age of Kittens</td>
<td>5-19 months</td>
<td>4-18 months</td>
</tr>
<tr>
<td>Coyote Removal From Area</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of Times Displaced by Coyotes</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

1 Ages of kittens at beginning and end of sample periods.
16 kills found during predation rate sampling (Table 4.1). The cougars were displaced by coyotes from 5 kills (Table 4.2). The edible portions remaining on these five carcasses at the time the cougar was displaced ranged from 25-100%.

Utilization rates for kills from which the cougars were not displaced ranged from 12 hours to 5 days. Two kills, probably abandoned because of the tainting of the meat in hot summer conditions, had 40 and 60% of the edible carcass remaining.

Coyotes

Indicators of population abundance revealed that coyotes were distributed throughout the study area. The removal program removed 130 coyotes from the W.M.A. and Deer Park areas during the winters of 1986-87 and 1987-88 (Hebert and Harrison 1988). This number represents a minimum value because the exact number of coyotes taken by hunters was unknown. Pelt prices averaged $60.00 each through these winters (D. Lay pers. comm., MOE unpubl.), and the hunting effort was high in areas of public access. The Wineglass ranch, however, was outside of the removal area, the ranchers there did not shoot coyotes, and the area received little hunter effort because of poor public access. The high number of coyotes removed indicates that coyotes from other areas replaced those removed under coyote control.

The marked difference in coyote harvest effort between the Junction/Deer Park and the Wineglass areas likely resulted in greater coyote abundances west of the
Farwell Canyon road (Figure 2.1). Indicators of relative coyote abundance substantiated this presumption. In the removal area, all pre-removal indices of coyote abundance were higher than those levels following the program: track counts along road transects (Figure 2.2) immediately following snowfalls dropped from 5-6 sets of tracks to 0-1 set, howling frequencies dropped from 16-20 howling sessions/month to 1-2/month, and sightings of coyotes dropped from 5-6/month to 1/month. Indices in the non-removal area remained constant at high levels.

Superimposed on the effect of coyotes scavenging cougar kills was the occurrence of coyotes displacing cougars from kills. This was first noted during telemetry relocations of AF4. She had be relocated on a hill-side approximately one kilometre upwind without her radio-collared kittens indicating that she was probably hunting. While waiting to determine if she was still on the move or if she had already made a kill, a coyote was heard near AF4's location. The coyote barked repeatedly in a manner quite distinct from the usual coyote yip. After 10 minutes, the signal from the radio collar indicated that AF4 was moving off, and within another 15 minutes, the signal was gone.

The site was approached, and a single coyote was observed sniffing around a fresh doe carcass. Examination of the kill site revealed AF4's tracks and the one set of coyote tracks. The deer was still warm and had been dead less than 30 minutes; the cougar had just dragged it to that spot and had begun to remove the rumen. Four hours later, only the coyote and 3 ravens had returned to the site. AF4 never did return and killed another deer two days later. This incident
revealed that harassment from a single coyote was sufficient to cause the cougar to abandon a fresh kill. Sometimes, more than one coyote was involved; however, all observed incidents were characterized by the persistent barking of the coyotes. Five observations of coyotes displacing cougars from kills were recorded.
DISCUSSION

Predation Rates

The cougar is an intermittent feeder with a tremendous capacity for storing a temporary excess of food in the form of fat so that they can go without food for surprisingly long periods. (Scott 1968:21). Estimates of the period between kills from other field studies range from 7-14 days (Connolly 1949, Hornocker 1970, Shaw 1975) yielding predation rates of 0.5-1.0 mule deer/week. It was difficult, however, to determine if single or mixed sex and reproductive classes of cougars were studied or if the predation rates were averaged with consumption rates of captive cougar. Both could be important biases in the determination of wild predation rates.

In this study, both AF4 and AF6 had higher predation rates than the maximum 1.0 kills/week reported previously. Reproductive status was obviously a factor here because, as Scott (1968) noted, the feast/famine regime of feeding behaviour of cats can only be adopted provided they are fully adult and not feeding young. Assuming that a solitary cougar kills less frequently than a female raising kittens, combining predation rates of various sex and reproductive classes would lower the average predation rate calculated for females raising young. The use of consumption rates of captive cougars would similarly lower calculations of predation rates. Members of the Florida Panther Captive Breeding Program found that after less than one year in captivity, a 4-6 year old wild-caught male cougar was physically unable to catch wild females during courtship in a 10 hectare enclosure (M. Roelke pers. comm.). This suggests that the physical abilities and likely the
corresponding energy requirements of captive cougars are below those of their wild counterparts.

Two key difficulties are associated with all field-based predation rate work: maintaining relocation contact and ensuring the discovery of all kills. I dealt with the continuity of relocations by ending my sampling period when the time between relocations exceeded six hours. The second difficulty was addressed through tracking vigilance. This task was simplified by the geographic nature of the Junction study area as outlined previously (Chapter 3); it is unlikely that any kills of ungulates were missed during the predation rate sampling. However, the predation rates measured here may represent only minimum values due to the compounding effects of the factors affecting the utilization of kills.

The relationship among individual kills and the overall predation rate was not the clean cyclic pattern presented by Holling (1965). Holling’s model describes the essential features of predation by cougars; however, factors relating to the utilization of individual cougar kills prevents complete tracking of the search-pursue-consume-digest cycle. Much of the variation from Holling’s (1965) cycle resulted from the cougars killing prey that were larger than could be consumed as a single morsel. Factors relating to spoilage or the pressures of scavenging become important in the equation; hence, the cougar’s kill utilization was found to have two main components: the extent of carcass use and the rate of carcass use.
Utilization Level of Kills

The majority of kills (9 of 16) found during predation rate sampling were utilized completely by the cougars. The capture of ungulate prey species represents a high expenditure of energy, and it follows that the cougar, particularly when feeding young, should take full nutritional advantage of each kill. Litters that range from 1-6 kittens (Anderson 1983) and yearling males that frequently outweigh their mothers (personal observation) also promote thorough utilization of prey. When kills were not fully utilized, it was usually because either the meat had spoiled or the cougar had been displaced from the kill by coyotes. Human presence at the kill sites had no apparent effect on the utilization of kills (Chapter 3).

The importance of spoilage and pressure from scavengers in the examination of predation rates is demonstrated by behaviour the cougar has evolved. Whenever the cougar makes a kill, the prey is immediately dragged to cover and buried. Kills are dragged under trees or bushes, into ravines or under stumps, and then covered with needles, dirt, grass, or snow (Hornocker 1970, Seidensticker et al. 1973, Shaw 1975, this study). Such efforts are often extensive, particularly when kills are made in relatively open habitats. This behaviour is useful in limiting losses of prey items because the areas chosen are dark and cool, retarding spoilage, and the concealment slows the discovery of the carcass by scavengers. So complete is this concealment that persons searching for a carcass but not familiar with cougar burial piles can pass the carcass repeatedly without noticing it (personal observation).
Utilization Rates

The rate at which the cougars could consume a carcass was staggering. Regularly, the 3-member families stripped kills of all edible portion within 36 hours (this study). Even for solitary cougars, consumption rates of kills are high. Hornocker (1970) reported two cases of males eating 10-15 kg of meat in a single night. Moreover, a female with two 6-month-old kittens consumed an adult ewe in 12 hours (this study). This highlights the importance of relocation vigilance during predation rate work. The rapidity of the cougars' utilization rate increased when scavengers were involved.

The utilization rates presented here were collected primarily during the fall, winter, and spring when temperatures were low and spoilage was not a problem. Most of the kills that I found during the summer months were utilized completely; however, this season was when the abandonment of tainted carcasses was noted. The abandonment of carcasses with 40-60% of the edible carcass remaining has implications for the overall predation rates. Although such an increase in the summer predation rate may be moderated by a decrease in the energetic requirements of the cougar during this season, it seems unlikely that the drop in energetic requirements is sufficient to enable the cougar to survive largely on small mammals. The summer is also a time when pressure from scavengers probably increases given the insurgence of the young of such species.
Pressures from Scavengers

Social carnivores are able to protect their kills against scavengers on a continual basis (Schaller 1972, Parker 1986, Corbett and Newsome 1987). Lions (*Panthera leo*) have been reported to leave one member at the kill site to ward off scavengers while the rest of the pride travelled to water (Wright 1960). For a solitary predator however, travelling to water or to retrieve young leaves the carcass unattended. To provide some protection from scavengers, the cougar buries its kills. The evolution of this behaviour alone suggests that scavengers play an integral role in the predatory life of the cougar. The main scavengers of any consequence on the Junction, in that they can quickly consume large portions of a carcass, were ravens, magpies, bald and golden eagles, and, of course, coyotes.

Observing how scavengers interact to find cougar kills was best done at the bait stations established at the beginning of the coyote control program. The carcasses were usually discovered by ravens and magpies on what appeared to be regular patrols of the Junction area. Ravens flying over kills, humans, equipment, and, probably, the cougars and coyotes, usually circled back to examine the site. It was evident that these birds were keying in on visible blood or red meat. Even small scrapes of meat or patches of blood were checked by ravens. Coyotes found the stations more quickly when drags were laid. Even when meat was trailed behind an All Terrain Vehicle or snowmobile for distances of 7 km, the trail was always marked with coyote tracks within 24 hours. Even without drags, the presence of birds at the bait stations seemed to increase the rate at which coyotes found the sites. How coyotes find kills marked by ravens is easy to understand
when listening to the noise generated by the ravens and magpies at a kill site. The eagles also appeared to converge on the activity of the other birds.

The rate at which the scavengers could utilize a carcass was, like that of the cougars, astounding. It was not uncommon for 5-10 magpies, 5-10 ravens, 2-3 eagles, and 2-3 coyotes to be around the carcass simultaneously. This was true of bait stations and abandoned cougar kills alike. The time for scavengers to reduce a complete adult sheep or deer carcass to bone was around 48 hours (this study). Moreover, the carcass quickly becomes soiled by the scavengers to the point where a cougar would not eat the remaining meat. The selective pressures for a predator to keep scavengers at bay are high. Dragging kills to cover and then burying them conceals the prey, particularly any exposed red meat, and slows the rate at which ravens can find the site. In turn, without large flocks of ravens, fewer coyotes are attracted to the site from afar. As scavengers, coyotes played an important role, and they warranted special consideration in the examination of predation rates.

**Cougar/Coyote Interactions**

Why should a cougar abandon a fresh kill when harassed by a coyote—particularly when the cougar has kittens to feed? The answer may be two fold. Firstly, and simply, felids do not like canids. Although seemingly trivial, cougars flee the barking of dogs despite the fact that cougars are well equipped to kill canids. Perhaps the ancestor of the present-day cougar was, itself, preyed upon by a carnivore that barked during the hunt. The cougar's fear of barking has persisted. It is unlikely that the cougar relates the barking specifically with the collaring
procedure because even cougars that have never been collared run from dogs.

The second consideration is tied to the dynamics of the entire cougar population. It became apparent through the monitoring of all age classes of cougars that kitten mortality was high: 9 of 11 kittens known to be on the Junction were killed. Intraspecific interactions were documented in the kitten deaths recorded here. Male cougars killing kittens is a well documented phenomenon (Hornocker 1970, Seidensticker et al. 1973, Pall et al. 1988); therefore, it follows that female cougars should demonstrate strong maternal instincts to protect their young. This, too, is borne out by the actions of females. Treed females with kittens are notorious for jumping out of the tree and leading the hounds away from her kittens. Males, on the other hand, will lay in the branches for hours. Females in the presence of very young, less mobile kittens will also show aggression towards humans ranging from growling and posturing (Seidensticker et al., this study) to full charges (this study). Aggression, however, is usually a last resort (personal observation).

At the kill site, harassment from coyotes may simply signal to the female cougar that the kill has already been discovered and soon more scavengers will arrive and the carcass will soon be soiled and then gone. Given the cougar’s prowess as a predator, it may pay, in terms of the kittens’ survivability, for the female to kill another sheep or deer. Taking the kittens to a site where scavengers are already present may be exposing them to the risk of predation. The female could kill the coyote rather than leave, yet for some reason perhaps relating to the barking, this was never found to happen. All the cougar-killed coyotes found were
hunted down as a prey species independent of other kills by solitary females. These coyotes probably unwittingly crossed the path of a cougar on the hunt. Regardless of why a cougar gives up its kills when harassed by coyotes, the result is that coyotes can displace a cougar from a fresh kill. The potential of a cougar abandoning a carcass that is partially consumed may be even greater because the cougar would be partially satiated.

Coyotes do displace cougars from kills, but the extent to which this affects the overall predation rate remains unclear. Without pre-coyote control predation rate information, the data presented here are only suggestive of such an effect. Comparison of factors other that the presence of coyotes influencing the kill utilization rate and the predation rate (Table 4.2), suggested that AF6 would have been expected to kill more often, yet her predation rate was less than half that of AF4. When displaced, the cougars had to replace kills. This compensatory predation, the rapid use of kills, and the compounding effect of pressure from scavengers could quickly inflate the number of kills the cougar needed to make.
CHAPTER SUMMARY

Cougar predation rates were dependent on the rate and extent of carcass utilization. The rate of carcass use by cougars was found to be as rapid as 1 ungulate in 12 hours. Cougars utilized 100% of the edible portion of a carcass which represented about 70% of the total body weight of the ungulate species available. Predation rates for cougars were affected by the presence of coyotes. For AF6 with a home area within the coyote removal area, the predation rate was significantly less than that of AF4 living outside the coyote removal area. Coyotes increased cougar predation rates by scavenging cougar kills and, importantly, by displacing the cougars from kills.
Wildlife research and wildlife management are distinct; however, they should not operate in seclusion. The challenge of conducting good field research and incorporating the results of that research in management decisions has been dealt with by a number of authors (Romesburg 1981, Hurlbert 1984, Macnab 1983, Fraser 1985, Gill 1985). Wildlife management decisions are made for a variety of ecological, economic, social, and political reasons; a researcher cannot simply disregard these agenda when suggesting management strategies.

A management agency may wish to achieve a number of goals for a public resource such as a bighorn sheep herd. The herd may be managed to encourage public viewing, to increase the herd size after re-establishing sheep on a former range, to increase harvest opportunities, to increase the number of transplants from the herd, to improve range condition (forage availability and protein content, or consistency in seasonal use), or to minimize intervention with a hands-off approach.

The Junction is a unique ecological system given its northern latitude. Studies of plant, bird and other mammalian species within the area reflect the Wildlife Branch's mandate to manage the entire system and maintain species diversity. However, the Junction Wildlife Management Area was established to preserve habitat for North America's largest herd of California bighorn sheep. The international significance of the Junction California bighorns ordains them as the W.M.A.'s management priority. General management objectives for the Junction
have been aimed at improving sheep habitat and sheep numbers for viewing, harvest, and transplants (Sugden 1961, Demarchi and Mitchell 1973, MOE unpubl.). Improving recruitment, and stabilizing the age structure of the sheep herd are more specific objectives (MOE unpubl.).

Doing nothing is an option; however, this option does not address the problems affecting the sheep herd. The Junction bighorns, as with most wildlife populations, live under pressures that are the result of human activity. Habitat losses, changes in competing wildlife population numbers, changes in predator numbers, competition with domestic stock, harvest, or harassment from viewing groups represent some of the more obvious pressures that man controls. A hands-off approach to management means all factors go unchecked.

This study has shown that cougars are present within the Junction, and that they are prominent predators of the bighorns rams. Coyotes were also found to be an important part of the system as they increased the predation rates of cougars. Coyotes also were implicated as important predators of the lamb component when lamb/ewe ratios nearly doubled in the year following the coyote removal program (Hebert and Harrison 1988). Given these results and the management objectives for the Junction, a number of predator management scenarios appear feasible.

Three prominent predators of bighorns were recognized in this study: cougars, coyotes, and man. The number of bighorns killed annually by each of these predators was calculated to show the relative impact on the sheep herd of each
predator (Table 5.1). The annual number of sheep killed by coyotes each year is striking. Coyotes kill between 3-4 times as many sheep as do cougars or hunters; this is important when considering the appropriate management strategy for this system.

Managing the harvest of sheep is a question of sheep allocation. Sheep are allotted to the hunters relative to the number of sheep required to maintain a stable or increasing population after natural mortality factors have been accounted for. Although restrictions on the quantity or conditions of the sheep harvest do not have ecological ramifications for the hunters, the effects of different hunting policies on the sheep population are not conclusive. Mountain sheep (bighorns—*Ovis canadensis* spp. and thinhorns—*O. dalli* spp.) have long been managed as trophy species: only males of a certain horn size (usually full- or 3/4-curl) are allowed to be taken. Changes in this harvest strategy have been discussed elsewhere (Demarchi 1978, Heimer 1988). I will deal with the management of wild predators here.

Increasing political and social pressures are important considerations for wildlife managers. Arguments for or against predator removal programs often contain as much emotion as they do knowledge about wildlife populations; however, both sides are important in the management process. Usually, a removal program is opposed most vehemently when it involves the large, high-profile species such as wolves, cougars, or grizzly bears (*Urus arctos*). For cougars and grizzly bears, relatively low productivity and the importance of intraspecific dynamics (Anderson 1983,
Table 5.1 - Estimates of the minimum and maximum number of bighorn sheep killed in one year by each of the three predators.

<table>
<thead>
<tr>
<th>Predator</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunters</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Cougars</td>
<td>12</td>
<td>57</td>
</tr>
<tr>
<td>Coyotes</td>
<td>103</td>
<td>205</td>
</tr>
</tbody>
</table>

1 Minimum value taken from harvest records (MOE).
Maximum value is maximum number of harvest permits issued per year.

2 Minimum value is the number of cougar-killed sheep (this study).
Maximum value is an estimate of cougar kills based on 1.1 kills/week and a diet of 50% sheep (this study).

   Cougar kill = 52 weeks * 1.1 kills/week * 0.50 sheep * 2 cougars

3 Minimum value uses 0.25 and Maximum value uses 0.50 as estimates of the proportion of lambs killed by coyotes (Hebert and Harrison 1988) in the following equation:

   Coyote kill = 420 ewes * 0.98 pregnancy rate (Ramsay and Sadlier 1979) * proportion of lambs killed by coyotes
various authors in LeFranc et al. 1987) provide additional arguments against removal. The dynamics of cougar populations can make it difficult to predict what will actually happen if a cougar removal program is implemented.

Cougars breed year-round and usually have 2-3 kittens every 2\textsuperscript{nd} or 3\textsuperscript{rd} year (Hornocker 1970, Seidensticker et al. 1973, Pall et al. 1988, this study). If an area is relatively inaccessible resulting in a low cougar harvest, as is the Junction, the female cougars within that area may produce kittens that disperse to adjacent areas where harvest pressures or other cougar mortality factors may be greater. Disruption of the stable kitten producing area by the removal of females may result in a decline of cougars over a larger area.

Conversely, and more likely, disruption of the land tenure system and the intraspecific dynamics of a cougar population will increase, rather than decrease, the number of cougars in an area. Removing cougars, particularly males, may result in increased kitten survival as the incidence of the kittens being killed by males is reduced. Moreover, Power (1976) reported an influx of transients into an area from which 26 of 30 cougars were removed during one winter and 39 more cougars were removed over the next 6 winters. High levels of production were noted throughout the capture efforts as these transients settled in the area as reproducing territory holders. Further support for the maintenance of a stable resident cougar population comes from New Mexico where the Department of Game and Fish found that cougar removals were ineffective in reducing cougar predation of desert bighorn sheep (Evans unpubl.).
Another option is to remove all but one of a female cougar’s kittens. This may lower the predation rate of the females without disrupting the cougar population as a whole. One kitten must be left or the female will come into estrous within one month (this study). There are a number of problems with this approach. Firstly, the program would be very intensive and involve the radio-collaring of the females and regularly checking their reproductive status. Secondly, the public outcry over a kitten-killing program would probably be analogous to the killing of harp seal (*Phoca groenlandicus*) white-coats on the east coast. Finally, my study has shown that the number of kittens is not as important to cougar predation rates as other factors, namely scavenging pressures from coyotes.

I believe the greatest results towards improved recruitment and the stabilization of the sheep herd age structure would be achieved through the removal of coyotes. The removal of coyotes is desirable in that both the lamb and adult components of the sheep population benefit. More lambs enter the population and the number of ewes and rams increases; moreover, fewer rams from this increased population are killed because of lower cougar predation rates. In contrast, a program to remove cougars only attempts to address the loss of rams and not the problem of poor lamb recruitment.

Coyote removal can be implemented through a variety of methods (Sterner and Shumake 1978); however, I suggest trapping or shooting as removal techniques because these methods are straight-forward, and can be implemented with minimal impact on non-target species. Coyote trapping efforts can be concentrated spatially
and temporally to provide maximum benefit to the sheep population in the least amount of time. Coyotes have a specific mating season that lasts from about February to late March at the Junction with the pups being whelped through April and May (Knowlton 1972, Kleiman and Brady 1978). A trapping program during this 4 month period would be additive to natural winter coyote mortality and would reduce recruitment to the next year’s coyote population (Knowlton 1972).

Another important consideration is that coyote removal can be aimed at specific areas of the sheep range. Bighorn sheep sexes are segregated, and the ewes have traditional lambing grounds (Geist 1971, Ashcroft 1986, Festa-Bianchet 1988). Traps could be set in the proximity of the lambing grounds to remove only those coyotes that have learned to focus on killing lambs. Finally, the resilience and social flexibility of coyote populations (Bowen 1982) reduces public opposition to the removal of this species. This is an important consideration for the manager trying to address the problem of a declining bighorn population.

A cost associated with a coyote removal program is the need to continue removal efforts. The resilience of coyotes enables them to return to pre-removal levels through immigration and increased pup survival (Kleiman and Brady 1978, Connolly 1978). If coyote removal is necessary in an area, the program should be conducted in a monitored, experimental format with pre- and post-removal spring, summer, fall, and early March lamb counts. Poor lamb recruitment may be do to some other factor and the collection of these data should be ongoing so that removal programs can be evaluated throughout their operation.
I suggest that coyote removal be conducted on a two-year on, two-year off basis until sheep recruitment counts in March stabilize above 20 lambs/100 ewes throughout a four year cycle. If the population never reaches 20 lambs/100 ewes within the four years, the program should be re-evaluated.

An additional requisite for stabilization of the age structure of the Junction herd is the removal of older ewes. Selective removal of this cohort will ease competitive pressures within the population. Continuation of the transplant program or an increase in the number of harvest permits are two effective ways to remove ewes. Transplants, particularly using a drop-net (Hirsch 1988), are somewhat more desirable in that they can be more selective than harvest in ensuring older ewes are removed.
CHAPTER SIX - CONCLUSIONS

Hypotheses Test Results

Presented here are the four central hypotheses of my thesis and the conclusions that I have drawn from the results of this study.

1. Selective Predation

   $H_1$: Cougars in the Junction select prey on the basis of prey species, sex, or age class.

   This hypothesis was not rejected. Cougars were selecting particular prey species and sexes from the Junction prey base. I found that bighorn rams were killed more frequently than would be expected based on their availability. Selection of rams during periods of high deer numbers also indicated that the cougars were selecting prey for reasons other than prey availability. I believe that poor physical condition following the rut and limited peripheral vision were important factors in determining ram vulnerability to cougar predation.

2. Predation on Lambs

   $H_2$: Poor recruitment of lambs to the Junction sheep herd is a result of cougar predation.

   This hypothesis was rejected. No cougar-killed lambs were ever found. Moreover, the radio-relocation data revealed that the cougars spent very little time in the areas associated with the lamb population. These data suggest that cougars do not utilize the lamb component of the population to any great extent. Work
done on the Junction coyotes, however, revealed that they play an important role in lamb dynamics (Hebert and Harrison 1988).

3. Predation on Rams

\[ H_3: \] The decline in mature, full-curl rams in the hunter-killed sample is a direct result of predation by cougars.

This hypothesis was rejected. The mean age and horn length of cougar-killed rams were less than those of the hunter-killed sample. The trophy-orientated hunter-killed sample represented the larger-horned animals and indicated that cougars were not keying in on the available large rams. Cougar predation of smaller rams and extensive coyote predation of lambs, however, affected the number of mature, full-curl rams indirectly by reducing recruitment to the mature ram component of the bighorn population.

4. Cougar/Coyote Interactions

\[ H_4: \] Predation rates for cougars are affected by the presence of coyotes.

This hypothesis was not rejected. When coyotes were removed from a portion of the study area, predation rates for the cougar within the removal area were half those of the cougar outside the removal area. Experimental replication was not conducted, however, factors such as the number and age of kittens were similar for both cougars. Documentation of coyote aggression towards cougars demonstrated that even a single coyote was capable of displacing a cougar from its kill. In this study, I found that cougar kittens suffered a high rate of intraspecific mortality, and
I believe that female cougars abandon kills to coyotes to avoid exposing their kittens to further threats of mortality.

**General Conclusions**

Although my intention was to examine the specifics of the Junction predator/prey system, my results have implications for other predator/prey systems and the perception of predation in a more general sense.

Wild ungulate biology often involves the examination of the factors affecting population dynamics. Discussions of escape terrain and predator avoidance behaviour are commonplace in this examination (Beuchner 1960, Sugden 1961, Demarchi and Mitchell 1973, Gionfriddo and Krausman 1986, Festa-Bianchet 1988); yet, actual predation is rarely documented. This often leads to the conclusion that predation is a minor or nonexistent component of even the most intensively studied populations.

Predators and the act of predation are extremely difficult to observe, quantify, and document. To accomplish this requires a different approach to field work. Dead ungulates are found in markedly different places than live ones. The discovery of these mortalities requires reconnaissance of the thickets and gulley bottoms: places office-based biologists rarely venture. Regular, systematic searches of this sort are required to find mortalities within the one or two days of death that enables a realistic assessment of the cause of death. The time and physical constraints of such searches are obviously high; however, simply not seeing
predators in an area neither confirms their absence nor defines their importance. Without intensive field studies, little can be concluded about the extent or impact of predation on wild ungulate populations.
LITERATURE CITED


1. Jack Lay - Jack worked for the B.C. Fish and Wildlife Branch as a Game Warden/Predator Control Officer from 1955-1978. He specialized in hunting cougar and was instrumental in obtaining cougar hounds for the Branch from the Lee brothers in Arizona. He established a breeding program for these dogs and hunted with them for many years.

2. Dan Lay - Inheriting the dogs from Jack, Dan continued the breeding program and used the dogs during his 12 years as a Predator Control Officer for the B.C. Fish and Wildlife Branch from 1974-1986. Dan’s dogs were used for all the capture work for this study.

3. Melody Roelke - Melody is veterinarian for the Florida Panther Recovery Program currently underway in that state.

4. Ministry of Environment (MOE) - The Wildlife Branch section of the Ministry has many unpublished reports, data sets, and memos on file. These files contain information on wildlife numbers, locations, and movements, harvest information, and management priorities.