Evaluation of bighorn sheep in the Ten Lakes Scenic Area

Steven Johnsen

The University of Montana

Let us know how access to this document benefits you.

Follow this and additional works at: https://scholarworks.umt.edu/etd

Recommended Citation

https://scholarworks.umt.edu/etd/6418
Permission is granted by the author to reproduce this material in its entirety, provided that this material is used for scholarly purposes and is properly cited in published works and reports.

** Please check “Yes” or “No” and provide signature **

Yes, I grant permission  
No, I do not grant permission

Author’s Signature  
Date: 12/8/93
EVALUATION OF BIGHORN SHEEP
IN THE
TEN LAKES SCENIC AREA

by
Steven Johnsen
B. S., University of Montana—Missoula, 1991

Presented in partial fulfillment of the requirements
for the degree of
Master of Science
University of Montana
1993

Approved by

Chairman, Board of Examiners

Dean, Graduate School

Date Dec. 8, 1993
Johnsen, Steven H., M. S., December 1993    Wildlife Biology

Evaluation of Bighorn Sheep in the Ten Lakes Scenic Area

Director: C. L. Marcum

Demographic characteristics, distribution and movements, and habitat use patterns of the Phillipps Creek herd of bighorn sheep (Ovis canadensis canadensis) were investigated during July through September 1991 and all of 1992. The most conservative population estimate for December 1992 was 82 (0.95 C.I. = 49 ≤ X ≤ 106). Lamb:ewe ratio for June 1992 was 90:100 and declined to 47:100 by December. The herd spent winter, spring and the rutting period in British Columbia. Fifty-two percent of observations of mixed groups during winter were in Douglas fir (Pseudotsuga menziesii) habitat types, 19% were in bitterbrush (Purshia tridentata) shrublands and 11% in rough fescue (Festuca scabrella) grasslands. The elevation of the winter range was from 900 to 1,300 m and more than 60% of observations during winter were on south and west aspects. Seventy-seven percent of observations of ram groups on the winter range were in Douglas fir habitat types, 22% were in rough fescue grasslands. The herd's spring range was an enlarged winter range. Two lambing-nursery areas were located in Montana, 17 and 24 km south of the winter/spring range. The first lamb was seen on 19 May. During summer, bighorns traveled throughout the Ten Lakes Scenic Area and as far north as Snowshoe Creek in British Columbia. The habitats used during summer and fall included scree slopes, and alpine and subalpine plant communities. Forty-four percent of mixed groups and 49% of ram groups were observed on scree slopes. Elevation of the summer range extended from 1,800 to 2,300 m. During summer, mixed groups were most often seen on east and south aspects, ram groups used all aspects. The herd returned to the winter range in early November and rutting activity was first observed on 18 November. The Phillipps Creek herd was compared with other bighorn sheep herds to estimate the quality of the herd. An estimate of the number of rams available for harvest, based on published criteria, was made.
ACKNOWLEDGMENTS

Numerous individuals contributed directly and indirectly in this study. I especially want to thank Dr. C. L. Marcum, committee chairman, for his help, guidance, and encouragement. Drs. Kerry Foresman, Bart O'Gara, and Dan Pletscher gave freely of their time, reviewed the study plan, and critiqued the manuscript.

Funding was provided by the Province of British Columbia: Ministry of Environment, Wildlife Branch and the East Kootenay Wildlife Association; The USDA Forest Service: Kootenai National Forest; The Montana Department of Fish, Wildlife, and Parks and The Foundation for North American Wild Sheep.

The Department of Employment and Immigration, Canada, United States Customs, and United States Immigration and Naturalization Service cooperated with the study.

Personnel at the British Columbia Wildlife Branch office in Cranbrook were very helpful. I wish to thank Anna Fontana for all of her efforts on behalf of this study. She also provided the equipment and personnel necessary for the trapping sessions. Thanks also to Rob Neal, Bob Fontana, the Environmental Youth Program, East Kootenay Wildlife Association members and local residents who helped with the trapping.

Guenter Heinz and Lynn Johnson of the Kootenai National Forest, Fortine Ranger District, provided equipment and
arranged for work and living space that were necessary for the success of the project. Lewis Young arranged housing for me at the Eureka Ranger Station during winter, 1992. All staff at both Ranger Stations were extremely helpful and supportive of the study.

Jim Cross and Bruce Campbell at the Montana Department of Fish, Wildlife and Parks, Region 1 headquarters provided vehicles, campers and other equipment necessary for the project. They also answered innumerable questions and contributed substantially to the success of the study. Jerry Brown, Tim Manley, Rick Mace, and everyone at Region 1 Headquarters helped in any way they could. I wish to thank Dr. John P. Weigand for his role in getting the project going. I am grateful to Jim Roberts, Game Warden in Eureka. He made sure I got off on the right foot and was available whenever I needed him.

The Montana Cooperative Wildlife Research Unit handled the funds for the study. I wish to thank "Ginger" Schwartz and Virginia Johnston for keeping me within budget and on track. Sharon Moran, wildlife biology secretary, was always there when I had a question or a problem and was a great help. I wish to thank Meg Langley for helping me with the home range program. I also want to thank the undergraduate and graduate students I have known during my years at the University of Montana. I have learned much from them and will continue to think of them often.
This study could not have been successful without the help of local residents in the Tobacco Valley. Jim and Alice Letcher gave me unlimited access to their property. Andy McDonald and his entire family assisted in any way they could. Blake Serafini generously gave of his time and knowledge concerning the Phillipps Creek bighorn sheep herd and the area. Tim and Phil Proudfoot provided access to their property and provided assistance when needed. Many other residents of both Grassmere, British Columbia and Eureka, MT offered their time, assistance and comments. All were greatly appreciated.

Dave Hoerner of Eagle Aviation and Keith Kinden of Mountain West Aviation are extraordinary pilots and provided excellent service during the study. Davey Bright successfully piloted several fixed-wing flights. Doug Getz, helicopter pilot for the Montana Department of Fish, Wildlife, and Parks, conducted a productive helicopter survey of the study area.

Ed Jenni, Jenni Illustrations, Missoula, produced an excellent map for this thesis.

Finally, I wish to thank my wife Teri for her unending support and confidence. During the past 2 years she has helped in every way possible, working as field assistant, data entry person, proofreader, and sounding board for both good and bad ideas. I cannot thank her enough.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Objectives</td>
<td>2</td>
</tr>
<tr>
<td>II. STUDY AREA</td>
<td>4</td>
</tr>
<tr>
<td>Location and Physiography</td>
<td>4</td>
</tr>
<tr>
<td>Climate</td>
<td>7</td>
</tr>
<tr>
<td>Vegetation</td>
<td>7</td>
</tr>
<tr>
<td>Winter Range</td>
<td>9</td>
</tr>
<tr>
<td>Summer Range</td>
<td></td>
</tr>
<tr>
<td>History</td>
<td>10</td>
</tr>
<tr>
<td>III. METHODS</td>
<td>14</td>
</tr>
<tr>
<td>Trapping</td>
<td>14</td>
</tr>
<tr>
<td>Observations</td>
<td>15</td>
</tr>
<tr>
<td>Habitat Analysis</td>
<td>16</td>
</tr>
<tr>
<td>Population Estimation</td>
<td>18</td>
</tr>
<tr>
<td>IV. RESULTS</td>
<td>20</td>
</tr>
<tr>
<td>Trapping</td>
<td>20</td>
</tr>
<tr>
<td>Demographics</td>
<td>20</td>
</tr>
<tr>
<td>Herd Size</td>
<td>20</td>
</tr>
<tr>
<td>Mortality</td>
<td>21</td>
</tr>
<tr>
<td>Productivity</td>
<td>21</td>
</tr>
<tr>
<td>Use of Habitat Types</td>
<td>24</td>
</tr>
<tr>
<td>Winter</td>
<td>25</td>
</tr>
<tr>
<td>Spring</td>
<td>29</td>
</tr>
<tr>
<td>Lambing</td>
<td>29</td>
</tr>
<tr>
<td>Summer</td>
<td>31</td>
</tr>
<tr>
<td>Fall</td>
<td>34</td>
</tr>
<tr>
<td>Rut</td>
<td>34</td>
</tr>
<tr>
<td>Microsite Characteristics</td>
<td>36</td>
</tr>
<tr>
<td>Overstory Canopy Cover</td>
<td>36</td>
</tr>
<tr>
<td>Aspect</td>
<td>39</td>
</tr>
<tr>
<td>Slope</td>
<td>39</td>
</tr>
<tr>
<td>Elevation</td>
<td>39</td>
</tr>
<tr>
<td>Movements and Travel Corridors</td>
<td>46</td>
</tr>
</tbody>
</table>
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mean monthly temperatures (°C), precipitation (cm), and snowfall (cm), from 1961 to 1990 at the Eureka Ranger Station, Eureka, MT</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>Number of individuals estimated in each age and sex class, December 1992</td>
<td>22</td>
</tr>
<tr>
<td>4.</td>
<td>Percentage (%) of bighorn sheep observations in each habitat type and ecological land unit</td>
<td>28</td>
</tr>
<tr>
<td>5.</td>
<td>Number of observations used for frequency distribution of microsite characteristics, Phillipps Creek, 1992</td>
<td>37</td>
</tr>
<tr>
<td>6.</td>
<td>Mean number of individuals in groups for mixed and ram groups of the Phillipps Creek herd, 1992</td>
<td>49</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Study Area for The Evaluation of Bighorn Sheep in the Ten Lakes Scenic Area research project, 1992</td>
<td>5</td>
</tr>
<tr>
<td>2. Number of lambs:100 ewes and 95% confidence intervals for the Phillipps Creek bighorn sheep herd, 1992</td>
<td>23</td>
</tr>
<tr>
<td>3. Locations of observed seasonal ranges, travel corridors, and lambing-nursery areas</td>
<td>26</td>
</tr>
<tr>
<td>4. Observed winter and spring range, Phillipps Creek bighorn sheep herd</td>
<td>27</td>
</tr>
<tr>
<td>5. Lambing-nursery areas, &quot;No Grizzly Ridge&quot; and Mt. Barnaby</td>
<td>30</td>
</tr>
<tr>
<td>6. Observed summer range, Phillipps Creek bighorn sheep herd south of International Border</td>
<td>32</td>
</tr>
<tr>
<td>7. Observed summer and fall range, Phillipps Creek bighorn sheep herd north of International Border</td>
<td>33</td>
</tr>
<tr>
<td>8. Observed fall range, Phillipps Creek bighorn sheep herd south of International Border</td>
<td>35</td>
</tr>
<tr>
<td>9. Percentage of mixed groups observed in each canopy cover class, Phillipps Creek, 1992</td>
<td>38</td>
</tr>
<tr>
<td>10. Percentage of ram groups observed in each canopy cover class, Phillipps Creek, 1992</td>
<td>40</td>
</tr>
<tr>
<td>11. Percentage of mixed groups observed in each aspect (°), Phillipps Creek, 1992</td>
<td>41</td>
</tr>
</tbody>
</table>
12. Percentage of ram groups observed in each aspect (°), Phillipps Creek, 1992 ........................ 42

13. Percentage of mixed groups observed in each slope class (%), Phillipps Creek, 1992 .................. 43

14. Percentage of ram groups observed in each slope class (%), Phillipps Creek, 1992 .................. 44

15. Percentage of mixed groups observed in each elevation class (m), Phillipps Creek, 1992 ........... 45

16. Percentage of ram groups observed in each elevation class (m), Phillipps Creek, 1992 ........... 47

17. Harmonic mean home range of Phillipps Creek herd, 1992 ............................................. 48
"Lives of the Hunted" by Ernest Thompson Seton, originally published in 1901, is a collection of short stories about several different wildlife species. One of the stories follows the lives of a bighorn ram and a hunter obsessed with the ram. The account, entitled "Krag, The Kootenay Ram", is set in southeastern British Columbia and northwestern Montana during the second half of the 19th century. In the narrative, Seton mentions several well-known topographic landmarks of the area. The region also contains a mountain named for the naturalist and author, as well as a peak with the same name as 1 of the bighorn characters in the tale. The story piqued the interest of local residents and those interested in bighorn sheep because Seton placed the story in an area not commonly known to contain bighorn sheep. In the preface, he states that the latter part, including the location, of the story is accurate (Seton 1967).

The Tobacco Plains is the name given to the portion of the Rocky Mountain Trench in the Eureka area. George Bird Grinnell (1928) suggested that bighorns were found on or near the Tobacco Plains during the 19th century.

In his report on the bighorn sheep of Montana, Couey (1950) does not mention a herd in the Whitefish or Galton Mountain Range. However, he does say that the Ural-Tweed
herd "ranges east as far as the Divide" (Couey 1950). Whether he means the Continental Divide or the Whitefish Divide, the summer range of the Phillips Creek herd would be included in the area.

During the past 14 years, the Montana Department of Fish, Wildlife, and Parks (MDFWP) has been gathering reports of bighorn sheep in the Ten Lakes Scenic Area (TLSA) of northwest Montana (MDFWP, unpubl. data). The Fortine Ranger District of the Kootenai National Forest also has received reports of sheep in the area for many years and documented their presence during an aerial survey in 1989 (G. Heinz, U.S. For. Serv., pers. commun.). The existence of this herd of sheep has been known for at least 40 years, by the local residents in British Columbia (A. McDonald, pers. commun.).

The purpose of this study was to gather data to be used in the development of a management plan and harvest strategy for this herd of bighorn sheep.

Objectives

1. Conduct ground surveys during all seasons of the year to determine abundance, composition, and productivity of the bighorn sheep population.

2. Conduct ground surveys during each season to determine habitat use by age and sex groupings.
3. Conduct aerial surveys during each season to supplement and confirm ground survey data on population and habitat use.

4. Develop records and maps to display population and habitat use data during all seasons of the year.

5. Develop a tentative harvest strategy that would be appropriate to maintain growth of the bighorn sheep population and be considerate of the ongoing management program in British Columbia.

This project was initially designed as an observational, field study. After the first field season, the cooperators decided that due to the limited access and rugged topography of the area, certain aspects of the project could be enhanced by putting radio-collars on some bighorns. However, because of a limited flying budget, the basic study plan was not altered following the addition of the radio-collars.
CHAPTER II
STUDY AREA

Location and Physiography

The study area lies at the northwestern end of the Whitefish Range in Lincoln County, Montana, United States and the southwestern end of the Galton Range in British Columbia, Canada (Fig. 1). Map coordinates are 115°03' - 114°53'W longitude and 49°08' - 48°54'N latitude. The Montana portion of the study area includes the Ten Lakes Scenic Area and adjacent Kootenai National Forest lands. The Canadian portion includes the Elk Forest and adjacent private lands.

The study area is bounded on the west by the Rocky Mountain Trench, a glacially carved valley with a mean elevation of 884 m in this area. The valley extends over 1,609 km, from northwestern Montana into the Yukon. Peaks within the area reach an elevation of 2,134-2,391 m and valleys within the mountainous areas range from 1,219 to 1,524 m. This results in a maximum relief of 1,500 m in the study area.

The rocks underlying the area are of the Precambrian Belt series and include argillites, quartzites, limestone, and basalt (Smith 1963, U.S. For. Serv. 1975).

During the late Paleocene to early Oligocene epochs (63-25 million years before present) the region underwent several periods of deformation. Initially, large, open, symmetric folding occurred. The next stage of deformation,
Fig. 1. Study area for The Evaluation of Bighorn Sheep in the Ten Lakes Scenic Area research project, 1992.
called the Ten Lakes Thrust, resulted in a stratigraphic displacement of approximately 1,524 m and horizontal movement of at least 13 km of the Belt rocks. The final stage of faulting resulted in westward-dipping, high-angle faults with a stratigraphic displacement of 3,048 m, that trend to the northwest (Smith 1963).

The region underwent significant glaciation during the ice ages. Early ice sheets may have covered the entire mountain range as evidenced by furrows and notches in the tops of several ridges in the area (Smith 1963). During the Wisconsin stage, it is estimated that the ice in the Rocky Mountain Trench, near the International Border was 1,524 m thick (Alden 1953). This would have covered all but the very highest peaks in the study area (Barnes 1963).

The results of glaciation are the wide, u-shaped valleys common throughout the region. Glacial cirques, many containing small lakes, are common, especially on northwest, north, and northeast aspects. Steep walls are characteristic of ridges and cirque side- and headwalls (Smith 1963, U. S. For. Serv. 1975).

Soils on the mountain slopes are very thin and developing from bedrock material. Soils are deeper in the valleys. The uppermost layer is loess that has been deposited during the preceding 6,500 years. Those soils developing from glacial debris have a sandy loam texture and are 60-80% rock (U.S. For. Serv. 1975).
Climate

The region is dominated by continental weather patterns that flow into the area on northwesterly air masses (Demarchi 1971). Weather data are recorded at the Eureka Ranger Station, located approximately 16 km from the center of the study area at an elevation of 792 m. At this weather station the yearly mean temperature is 7° C (30 year mean). Highest average temperature occurs during July or August (19° C) and lowest occurs during the month of January (-6° C) (Table 1). Precipitation averages 37 cm per year, with 5 cm falling in June and 3 cm falling in January (Table 1). The greatest amount of snow, 34 cm, falls during December, and an average 112 cm of snow falls at the Ranger Station each winter (Table 1) (U.S. For. Serv. unpubl. data). At higher elevations (within the Ten Lakes Scenic Area) more than 203 cm of precipitation falls during the year, primarily as snow (U.S. For. Serv. 1975) and temperatures are likely more severe due to the increase in elevation.

Vegetation

Winter Range. The Phillipps Creek herd winters north of the International Border in British Columbia, on the hillsides and benches above the Rocky Mountain Trench at elevations between 900 and 1,300 m. The area is made up of coniferous forest interspersed with grass and shrublands. The grasslands are extensions of the Agropyron-Festuca
Table 1. Mean monthly temperatures (°C), precipitation (cm), and snowfall (cm), from 1961 to 1990 at the Eureka Ranger Station, Eureka MT.

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Precipitation</th>
<th>Snowfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>-6</td>
<td>3.2</td>
<td>34</td>
</tr>
<tr>
<td>February</td>
<td>-1</td>
<td>2.1</td>
<td>17.5</td>
</tr>
<tr>
<td>March</td>
<td>3</td>
<td>2.1</td>
<td>12.2</td>
</tr>
<tr>
<td>April</td>
<td>8</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>May</td>
<td>12</td>
<td>4.2</td>
<td>0.0</td>
</tr>
<tr>
<td>June</td>
<td>16</td>
<td>5.2</td>
<td>0.0</td>
</tr>
<tr>
<td>July</td>
<td>19</td>
<td>3.2</td>
<td>0.0</td>
</tr>
<tr>
<td>August</td>
<td>19</td>
<td>3.1</td>
<td>0.0</td>
</tr>
<tr>
<td>September</td>
<td>13</td>
<td>3.0</td>
<td>0.1</td>
</tr>
<tr>
<td>October</td>
<td>7</td>
<td>2.3</td>
<td>0.4</td>
</tr>
<tr>
<td>November</td>
<td>1</td>
<td>2.9</td>
<td>13.0</td>
</tr>
<tr>
<td>December</td>
<td>-4</td>
<td>3.2</td>
<td>34.0</td>
</tr>
</tbody>
</table>
grasslands of central British Columbia, described by Tisdale (1947). Bluebunch wheatgrass (*Agropyron spicatum*) and rough fescue are co-dominant species. A variety of perennial forbs occur on the range including: balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus sericeus*), and geranium (*Geranium viscosissimum*) (see Appendix A for list of plant species found on sites used by bighorn sheep).

The forest is a Douglas fir climax (Pfister et al. 1977). However, prior to fire control the area was maintained at a sub-climax stage. Ponderosa pine (*Pinus ponderosa*) was the dominant tree species and many large individuals remain. Seral shrublands occur interspersed within the forest. The dominant shrub on the area used by sheep is bitterbrush. Associated species in the shrublands and forest are snowberry (*Symphoricarpos albus*), Oregon grape (*Berberis repens*), woods rose (*Rosa woodsii*), Kentucky bluegrass (*Poa pratensis*), bluebunch wheatgrass, pinegrass (*Calamagrostis rubescens*), and cheatgrass (*Bromus tectorum*).

**Summer Range.** The herd summers east and southeast of their winter range in the mountains of British Columbia and Montana, at elevations between 1,800-2,300 m. Much of the area included in the summer range is upper subalpine and alpine (Pfister et al. 1977). The dominant species include subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), whitebark pine (*Pinus albicaulis*), and alpine larch (*Larix lyallii*). The lower canopy is composed of whortleberry (*Vaccinium scoparium*), dwarf huckleberry (*V._
caespitosum), woodrush (Luzula hitchcockii), beargrass (Xerophyllum tenax), and a variety of forbs.

History

There is no accurate estimate of the number of bighorn sheep in the region prior to or immediately after European settlement. However, several authors have presented evidence that the arrival of European man and the settlement of the west, during the late 19th and early 20th century, significantly reduced the number of bighorn sheep throughout western North America (Buechner 1960, Stelfox 1971, Trefethen 1975). There is no reason to believe that the effects of settlement on sheep numbers at the southern end of the Rocky Mountain Trench and the Kootenay River Valley was different.

The native inhabitants of the region are the Kutenai Indians. They lived a hunting and gathering lifestyle and moved throughout the Kootenay River Valley and the intermountain region prior to their settlement on reservations (Baker 1955). European man began to settle and establish ranches and lumber mills in the valley during the early 1880's. The number of people in the valley continued to increase through the late 19th century. Early in the 1900's, a railroad spur was built along the Kootenai River, and a station was established at Eureka. This permitted local log mills to expand and begin shipping logs outside the Valley. Logging quickly became an important industry throughout the region. By 1925, the best and most
accessible timber stands had been harvested and the timber industry began to decline (U.S. For. Serv. 1975).

Mining activity also began with the settlement of the area. Copper was the primary ore sought along with gold and silver. Numerous unpatented and patented claims still exist within the Ten Lakes Scenic Area (U.S. For. Serv. 1975).

The 1930's saw an expansion of ranching activity in the area. A new addition to the local assortment of livestock was domestic sheep. Throughout the decade, as many as 2,000 domestic sheep were summered in the Ten Lakes Basin and upper Wigwam drainage (Manley 1986), an area encompassed by the present study area.

In response to the spruce bark beetle (*Hylurgus* sp.) outbreak of the early 1950's, roads were extended much deeper into the mountains and the harvest of the affected timber began. This revitalized the local timber industry and the new roads transformed areas of the forest that previously could only be reached on foot or by horseback (U.S. For. Serv. 1975).

The Ten Lakes Scenic Area was established in 1964 by the Regional Forester to maintain the scenic attributes of the area (R. Williams, U.S. For. Serv., pers. commun.). Currently, the Ten Lakes Scenic Area is 2,603 ha in size and provides recreation activities such as wildlife viewing, hiking, fishing, berry picking, and hunting. The area is accessible for non-motorized recreation during May through December and open to snowmobiling from January through
April. There are 2 developed campsites on the southeastern boundary of Ten Lakes Scenic Area at Big and Little Therriault Lakes (U.S. For. Serv. 1975).

An outbreak of pneumonia-lungworm complex occurred in the bighorn sheep of the East Kootenay Mountains in 1963. The Galton Range is part of the East Kootenays. The disease started in a herd at Elko, British Columbia and decimated herds during the next 2 winters as it moved north through most of the herds wintering in the Rocky Mountain Trench. By the time the die-off ended, the total population of sheep in the region was reduced from 2,000 animals to fewer than 750 (Demarchi and Demarchi 1967). In their report on the outbreak, Demarchi and Demarchi (1967) stated that the Phillipps Creek Herd had not been affected by the outbreak. They estimated the size of the population at 30 animals at that time (Demarchi 1972). Bighorn populations recovered throughout the region until 1982, when another pneumonia die-off began. This outbreak began at Maguire Creek, British Columbia, approximately 18 km north of my study area, and eventually spread throughout the southern portion of the Rocky Mountain Trench and into southern Alberta and Glacier National Park (Onderka and Wishart 1984). Factors contributing to the 1981, as well as the 1963, disease outbreak were found to be high animal densities, poor nutrition, parasitism, and trace mineral deficiencies (Schwantje 1986). Apparently, the Phillipps Creek herd was
involved in the 1982 die-off and the size of the population was estimated at 35 animals in 1984 (Hebert et al. 1985).
CHAPTER III
METHODS

Trapping

The objective of trapping for this project was to attach radio-collars to 10 bighorns. From 5 February until 11 March 1992, 4 bait sites were maintained on the herd's winter range in British Columbia. Sites were baited daily with alfalfa hay and apple mash or whole apples. The southern portion of the Rocky Mountain Trench has been shown to be deficient in selenium (Hebert and Cowan 1971). Consequently, mineral blocks and a pan of granular minerals, containing selenium, were provided at each bait site. Bighorns used 2 of the bait sites. When bighorn sheep began coming into a bait site, I remained on site all day, to condition the animals to the presence of humans. A drop-net was erected once the bighorns were consistently using a site, and it was dropped by detonating blasting caps placed within the support ropes. The explosives were handled by a certified explosives expert. The trapping operation was supervised by B.C. Wildlife Branch personnel and performed with the help of many local residents.

Each bighorn captured was hobbled by all 4 legs and blindfolded. This calmed the animals enough to allow removal of the net and permitted us to handle them. Data were collected on the sex, age, and any identifying marks
All animals captured were marked with a numbered ear-tag, given a dose of a topical wormer (ivermectin®), and a shot of vitamin E-selenium (1 cc adults, 0.5 cc lambs) to guard against capture myopathy (Hebert and Cowan 1971, Dalton et al. 1978, Kock et al. 1987). The radio-collars were sized for adults, therefore they were placed on the oldest individuals captured.

Observations

Initially, I located bighorn sheep by hiking or driving to likely locations within the study area and looking for them with a 7x binocular or a 15-60 variable power telescope. Additionally, aerial survey flights in fixed-wing or rotary-wing aircraft were made approximately once per month to observe bighorns and identify locations where they could be found. Later, radio telemetry was used to locate bighorns during fixed-wing surveys. Radio-signals also were monitored on the ground to determine which bighorn sheep were in the area.

Once located, the animals were observed to determine the number in the group and to assign each individual to an age and sex class according to their horn size and shape, and body size (Geist 1971). All data were recorded on the data sheet in Appendix C. Additional data were gathered on the activity of the bighorns, the length of the observation, and the weather conditions at the time of the observation. More than 1 observation was recorded for most groups of sheep. A new observation was considered to have begun when
the group changed activity. The locations of all observations were recorded on aerial photographs or topographic maps so they could be visited later.

**Habitat Analysis**

I attempted to return to each observation site and document habitat characteristics of the areas used by bighorns. This was done by establishing a 0.04 ha (0.1 acre) plot at the location considered to be the center of the group's activity. Habitat characteristics recorded included: dominant vegetative life form; landform; slope shape; special feature; ecotype; shrub form; the 2 dominant plant species in the upper, mid, and lower canopies; and the plant species consumed by the bighorns. Aspect was measured with a compass and percent slope with a clinometer. The percentage of ground cover and canopy cover in the upper, mid, and lower canopies were visually estimated. I also estimated the canopy cover in the nearest adjacent cover type. Canopy and ground cover estimates were recorded as the median value of the cover class. Calculations of canopy and ground cover characteristics use the median value and represent the cover class. Habitat type was determined by using keys by Pfister et al. (1977) and Mueggler and Stewart (1980) for winter and spring ranges. Once the animals were on the summer range and began using alpine and subalpine areas these keys no longer adequately described the habitat types used by bighorn sheep. The areas were very rocky, and had < 25% overstory canopy cover and no recognized climax
plant community. For lambing, summer, and early fall habitats I used the Craighead et al. (1982) manual, which identified ecological land units (ELU) on the basis of dominant plant community and geomorphic characteristics of the site (see Appendix D for a description of habitat types and ELU's). Universal Transverse Mercators (UTMs), elevation and distances to water, closed or open road, hiking trail, secure area, and ecotone were determined using 1:24,000 ortho-photo quad maps when the location was in Montana and 1:50,000 topographic maps when in British Columbia. Occasionally, it was not possible to get to the actual location used by bighorns, so slope and aspect were calculated from the maps. Habitat analysis was only conducted on those sites where I actually saw bighorn sheep. Observations of bighorns were divided into 2 categories for analysis of habitat data; mixed groups include ewes, lambs, and rams of any age. Ram groups include only male bighorns.

A yearly home range was calculated for the herd using the harmonic mean method (Dixon and Chapman 1980). The accurate determination of a harmonic mean home range is dependent on 2 assumptions: locations are independent of each other and the probability of detecting an animal is proportional to the amount of time the animal spends in that area (Samuel et al. 1985). Further, the use of less than 50 locations to determine harmonic mean home range results in an enlarged home range (Jaremovic and Croft 1987). These requirements were addressed by using 84 observations and
radio-locations obtained during monthly aerial surveys. The calculation of seasonal home ranges would have required the division of the 84 locations into at least 2 groups. Therefore, it was decided that the most accurate home range that could be determined was a yearly home range.

Statistical calculations were performed using the SPSS/PC+ studentware package (Norusis 1991).

### Population Estimation

The Schumacher-Eschmeyer equation (Caughley 1977) was used to estimate the size of the population because it is designed to be used with repeated observations over a period of time (Davis and Winstead 1980). This method may be more accurate than the Maximum Likelihood method because it depends less on random mixing of individuals (Caughley 1977). Two assumptions are needed for the method: the population must be closed and individuals must be equally catchable (Caughley 1977). I obtained the 12 observations used in the population estimate between 3 and 22 December 1992, while the bighorns were mating on their winter range. Between those dates the maximum number of radio-collared animals were on the winter range. I did not use the receiver to locate any radio-collared animals during this period. I assumed the presence of all collared animals was correlated with the presence of the majority of the population. I chose a relatively short time span for the observations to minimize problems with animals leaving the area or dying. I also used the technique developed by
Miller et al. (1987) to estimate the size of the bighorn population. The authors modified the standard capture-recapture technique so that the geographic closure requirement was not necessary. The new method provides the researcher with the number of animal-days the study area was occupied. The average number of animals inhabiting the study area was determined by dividing the number of animal-days by the number of days in the search period (Miller et al. 1987).

The maximum number of bighorn sheep observed in each age and sex class during the same period was used to visually estimate the size of the population and calculate the percentage of the population in each age and sex class. Lamb/ewe ratios with 95% confidence limits were calculated according to Bowden et al. (1984).
CHAPTER IV
RESULTS

I spent 297 days in the field and obtained 491 observations of bighorn sheep, between 16 July and 17 September 1991 and 5 January until 23 December 1992.

Trapping

Sixteen bighorn sheep were captured and marked during 2 trapping sessions (Appendix E). On 22 February 1992, 8 animals were captured; 3 ewes and the 2 oldest rams were radio-collared. On 11 March 1992, 8 more animals were captured and 3 ewes and 1 ram were radio-collared. The mean length of time animals were restrained was 36 minutes (range 31 to 42 minutes). Upon release, no bighorns showed any symptoms of capture myopathy, as described by Dalton et al. (1978). No animals were injured or killed during the trapping or handling procedure.

Demographics

Herd Size. Using the Schumacher-Eschmeyer equation, I estimated the size of the population to be 92 individuals during December 1992 (SE = 15.8, 0.95 CI = 70 ≤ X ≤ 132). The technique developed by Miller et al. (1987) provided an average population estimate of 82 (0.95 CI 49 < X ≤ 106) during the rutting period. Data used to calculate population estimate is in Appendix F.

Based on the size of each age and sex group I observed during November and December 1992 and the conservative
population size of 82, I estimated the population contained 34 females, 32 males and 16 lambs (Table 2) during December 1992.

In the course of the literature review and in discussions with A. Fontana (wildlife biologist, B.C. Wildl. Br.), 5 other estimates of population size of the Phillipps Creek herd were obtained (Table 3). These estimates were based on aerial surveys of the winter range, harvest records and information from area Conservation Officers.

Mortality. Two dead bighorn sheep were found during the study. An 11 month old lamb skull was found on 10 May 1992. I was unable to locate an ear-tag or any other bones from this animal. The second dead animal was a ewe, found on 4 November 1992. This animal had been dead at least 4 days. The skeleton was intact but most of the tissue had been consumed and the hide was in several pieces. I was unable to determine the cause of death. The dead ewe carried a radio-collar and ear-tag that showed she belonged to a group of sheep that had been transplanted the previous spring to an area approximately 30 km to the northeast. She was not part of the Phillipps Creek herd. She first appeared on the Phillipps Creek winter range in late October and local residents who saw her said she appeared sick, coughing and lethargic (B. Serafini, pers. commun.).

Productivity. The observed lamb/ewe ratio for February 1992, was 34:100 (0.95 CI, 19 ≤ X ≤ 49) (Fig. 2). By
Table 2. Number of individuals estimated in each age and sex class, total population 82, December 1992.

<table>
<thead>
<tr>
<th>Male Yrlng.</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>Female Yrlng.</th>
<th>Female Adult</th>
<th>Lambs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>8</td>
<td>13</td>
<td>5</td>
<td>3</td>
<td>31</td>
<td>16</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Year of estimate</th>
<th>Number of sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965 (Demarchi 1972)</td>
<td>30</td>
</tr>
<tr>
<td>1984 (Hebert et al. 1985)</td>
<td>35</td>
</tr>
<tr>
<td>1984 (Thorne et al. 1985)</td>
<td>40</td>
</tr>
<tr>
<td>1986 (BCWB* unpubl. data)</td>
<td>55</td>
</tr>
<tr>
<td>1991 (BCWB unpubl. data)</td>
<td>70</td>
</tr>
<tr>
<td>1992 (present study)</td>
<td>82</td>
</tr>
</tbody>
</table>

* British Columbia Wildlife Branch
Fig. 2. Number of lambs: 100 ewes and 95% confidence intervals for the Phillipps Creek bighorn sheep herd, 1992.

* Number of observations used to calculate value.
April it had dropped to 10:100 (0.95 CI, 0 ≤ X ≤ 22). Productivity during 1992 was high. The first lamb was observed on 19 May. The observed lamb/ewe ratio for June was 90:100 (0.95 CI, 70 ≤ X ≤ 100). The lamb/ewe ratio declined throughout the summer and by December it was 47:100 (0.95 CI, 41 ≤ X ≤ 53).

Use of Habitat Types

Chi-square analysis indicated a lack of independence ($\chi^2 = 19.7$, df = 3, $p < 0.0002$) between observation type (ground or air) and ecotype. The lack of independence was due to the limited number of observation sites evaluated on the herd's summer range in British Columbia. My summer field activities were concentrated in the Ten Lakes Scenic Area and I only observed bighorns on the British Columbia portion of the summer range during aerial surveys. Therefore, aerial observations were not included in the analysis of habitat data and the results for summer habitat use (including microsite characteristics) apply only to the area south of Galton Pass in British Columbia. This left 394 ground observations for analysis. Data were not gathered on all variables at all sites because of conditions that existed at some sites or time restraints. Therefore, the number of observations used to determine the value in each table or figure have been included. Radio-assisted observations and unassisted observations were found to be
independent in regard to ecotype ($\chi^2 = 2.33$, df = 5, p < 0.8), so those observations were combined for analysis.

**Winter (1 January-15 April).** Mixed groups of bighorn sheep (ewes, rams, and lambs) wintered on the hills and benches 3 km north of the International Border and east of Highway 93 in British Columbia (Figs. 3-4). Douglas fir habitat types (see Appendix D for a description of habitat types) were the dominant cover types in the area (Table 4). The tract used by bighorns was interspersed with small, isolated bitterbrush shrublands and fescue (*Festuca* spp.) meadows.

Phillipps Creek bisects the winter range (Fig. 4). A portion of the area used by bighorn sheep south of the Creek is private land. Within the private property is an alfalfa field (*Medicago sativa*) and a large rough fescue/bluebunch wheatgrass meadow. Much of the forest on private land has been logged. The remaining overstory canopy cover on the logged tract is less than 10%. Orchard grass (*Dactylis glomerata*) and timothy (*Phleum pratense*) have been planted on the skid trails and landings of the unit. The area used by bighorns north of the creek is primarily Crown Land.

Bighorn sheep were primarily seen feeding and bedded in or near the shrub and grass openings within the forest, during winter. The bitterbrush/rough fescue habitat type contained 19% of observations of mixed groups. Seventeen percent of observations were made in both the alfalfa field and the Douglas fir/ninebark (*Physocarpus malvaceus*) habitat
Fig. 3. Locations of observed seasonal ranges, travel corridors and lambing-nursery areas.
Fig. 4. Observed winter and spring range, Phillipps Creek bighorn sheep herd.
Table 4. Percentage (%) of bighorn sheep observations in each habitat type and ecological land unit, Phillipps Creek herd, 1992.

<table>
<thead>
<tr>
<th>Group</th>
<th>Winter</th>
<th>Spring</th>
<th>Lambing</th>
<th>Summer</th>
<th>Fall</th>
<th>Rut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mixed</td>
<td>Ram</td>
<td>Mixed</td>
<td>Ram</td>
<td>Mixed</td>
<td>Ram</td>
</tr>
<tr>
<td>Sample size</td>
<td>72</td>
<td>9</td>
<td>19</td>
<td>1</td>
<td>22</td>
<td>99</td>
</tr>
<tr>
<td>Habitat types</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough fescue/bluebunch wheatgrass</td>
<td>11</td>
<td>22</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitterbrush/rough fescue</td>
<td>19</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglas fir/pinegrass</td>
<td>11</td>
<td>33</td>
<td>26</td>
<td></td>
<td>9</td>
<td>36</td>
</tr>
<tr>
<td>Douglas fir/elk sedge</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Douglas fir/rough fescue</td>
<td>15</td>
<td>11</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglas fir/ninebark</td>
<td>17</td>
<td>33</td>
<td>32</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Douglas fir/snowberry</td>
<td>7</td>
<td>10</td>
<td>100</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglas fir/dwarf huckleberry</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subalpine fir/elk sedge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Subalpine fir/dwarf huckleberry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Subalpine fir/beargrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Alpine larch/subalpine fir</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Whitebark pine/subalpine fir</td>
<td>9</td>
<td>1</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scree</td>
<td>41</td>
<td>44</td>
<td>49</td>
<td>49</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Ecological land units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry forb grassland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Parent rock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>Ridgetop glade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Slab rock steps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Snowslide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>Alfalfa field</td>
<td>17</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
type. Mixed groups were also observed in the Douglas fir/rough fescue, Douglas fir/pinegrass, and rough fescue/bluebunch wheatgrass habitat types (Table 4). Mean shrub canopy cover on sites used by mixed groups during winter was 22%. Graminoid and forb canopy cover averaged 54 and 34%, respectively.

Ram groups (all male) were seen regularly during January. However, after 5 February, few mature rams were encountered on the winter range. A group of rams was seen on 24 March, on the ridge north of Rainbow Creek. Subsequent visits revealed several rams using that area and I inferred they had been there since February. Douglas fir/pinegrass and Douglas fir/ninebark habitat types each contained 33% of the winter observations of ram groups. Ram groups were also observed using the rough fescue/bluebunch wheatgrass and Douglas fir/rough fescue habitat types (Table 4).

**Spring (16 April-15 May).** During spring, 32% of mixed groups were observed in Douglas fir/ninebark and 26% were seen in Douglas fir/pinegrass habitat types. Ewes, lambs and rams continued to use the bitterbrush/rough fescue and Douglas fir/snowberry habitat types. Only 1 ram group was observed during spring. They were bedded in a Douglas fir/snowberry habitat type on the ridge above Rainbow Creek.

**Lambing (15 May-20 June).** Two lambing-nursery areas were identified south of the International Border (Fig. 5). Ewes with their lambs used the south face of Mt. Barnaby and
Fig. 5. Lambing-nursery areas, 'No Grizzly Ridge'

Mt. Barnaby
the south face of "No Grizzly Ridge", 24 and 17 km southeast of Phillipps Creek, British Columbia. Ewes and lambs rested on the parent rock ELU of the cliff faces (Table 4). When feeding, they moved to the top of the cliffs and fed in the ridgetop glade ELU or subalpine habitat types adjacent to the cliff faces. During this period, 41% of observations occurred in the scree habitat type. However, few lambs were observed on the scree slopes with ewes. They generally remained on the cliffs. Mean graminoid canopy cover on sites used during the lambing period was 8%. Forb canopy cover averaged 25%.

**Summer (21 June-30 September).** During summer, mixed groups moved throughout the Ten Lakes Scenic Area and in British Columbia between Galton Pass and the headwaters of Snowshoe Creek (Figs. 6-7). Forty-four percent of observations of ewes, lambs, and immature rams were in the scree habitat type, where they fed and bedded. Mixed groups were also seen using dry forb grassland, slab rock steps and snowslide ELU's (Table 4). The parent rock ELU was primarily used as escape terrain and bedding sites. Mixed groups were seen feeding and walking in the subalpine forest habitat types and in the ridgetop glade ELU. Sites used by mixed groups during the summer had a mean graminoid canopy cover of 16% and mean forb canopy cover of 34%.

The summer season (15 May-30 September) is longer for rams than for females, because it is not interrupted by a lambing period. Rams were seen in similar habitat types and
Fig. 6. Observed summer range, Phillipps Creek bighorn sheep herd south of International Border.
Fig. 7. Observed summer and fall range, Phillipps Creek bighorn sheep herd north of International Border.
ELU's as mixed groups. They fed and bedded in the scree habitat type (49% of observations) and dry forb grassland, and slab rock steps ELU's. Parent rock was used primarily as escape and bedding areas. Ram groups were also observed in the whitebark pine/subalpine fir habitat type, during summer (Table 4). Mean graminoid cover on sites used by ram groups during summer was 5% and mean forb canopy cover was 27%.

Fall (1 October-14 November). Snow began accumulating in the upper elevations of the Ten Lakes Scenic Area during this season. Some mixed groups moved north into British Columbia and remained there. Others remained in the TLSA and then moved onto the west face of the mountains (Fig. 8). While they remained in the upper elevations, mixed groups were observed feeding and bedded on scree slopes and snowslides (Table 4). As they moved to lower elevations, feeding and bedding occurred within Douglas fir/pinegrass and Douglas fir/ninebark habitat types.

Ram groups were seen using dry forb grasslands and slab rock steps during fall. As fall progressed, mixed groups and rams began returning to the winter range.

Rut (15 November-22 December). Rutting activity occurred on the herd's winter range (Fig. 4). Prior to the onset of peak mating activity, mixed groups were observed using the same habitat types they had used the previous spring (Table 4). Twenty-six percent of the groups observed were in the Douglas fir/pinegrass habitat type. The rough
Fig. 8. Observed fall range, Phillipps Creek bighorn sheep herd south of International Border
fescue/bluebunch wheatgrass and bitterbrush/rough fescue habitat types each contained 20 and 19% of observations, respectively. Douglas fir/snowberry, Douglas fir/ninebark, and Douglas fir/rough fescue habitat types were also used. Mature rams circulated among the mixed groups checking for estrus females. Much of the mating activity appeared to take place south of Phillipps Creek, in the rough fescue/bluebunch wheatgrass meadow and adjacent Douglas fir habitat types. After mid-December mixed groups began redistributing themselves over the winter range.

**Microsite Characteristics**

Table 5 shows the number of ground observations of mixed and ram groups by season and these values are the basis for the frequency distributions of microsite characteristics. Due to the limited number of observations of ram groups the seasonal categories were combined into 2 groups, winter/spring and summer/fall.

**Overstory Canopy Cover.** Most observations of mixed groups were on sites with 25% overstory canopy cover or less (Fig. 9). However, during each season some mixed groups were seen on sites with greater amounts of canopy cover. More than 25% of observations during spring, lambing, and fall were on sites with 26-50% canopy cover. Eleven percent of winter and 5% of spring observations were on sites with more than 50% overstory canopy cover. Ram groups were also observed on sites with an overstory canopy cover.
Table 5. Number of observations used for frequency distribution of microsite characteristics, Phillipps Creek, 1992

<table>
<thead>
<tr>
<th>Season</th>
<th>Mixed Groups</th>
<th>Ram Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>72</td>
<td>9</td>
</tr>
<tr>
<td>Spring</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Lambing</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Summer</td>
<td>99</td>
<td>55</td>
</tr>
<tr>
<td>Fall</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Rut</td>
<td>89*</td>
<td></td>
</tr>
</tbody>
</table>

* Mixed and ram groups combined
Fig. 9. Percentage of mixed groups observed in each canopy cover class, Phillipps Creek, 1992.
greater than 25% (Fig. 10). As stated previously, radio-assisted observations and unassisted observations were independent in regard to ecotype ($\chi^2 = 2.33$, df = 5, $p < 0.8$).

**Aspect.** Mixed groups were regularly observed on south and west aspects (Fig. 11). Greater than 50% of lambing, summer, and fall observations were on south-facing slopes, and >60% of spring and rut observations were on west-facing slopes. North aspects were used consistently and almost 40% of the winter observations were on this aspect. Eighteen percent of observations during the lambing period and 30% of observations during summer were on sites with an east aspect. During summer/fall, ram groups used all aspects, but >60% of the observed use was on north or east aspects (Fig. 12).

**Slope.** All observations during winter and spring were on sites with $\leq 79\%$ slope (Fig. 13). During summer and fall, many mixed groups were seen on sites with a 40-79% slope. Sites with a slope of 80% or more were used primarily during the lambing period and summer. Ram groups were observed using all slope classes, during summer/fall (Fig. 14), however 75% of these observations were on slopes of 40-79%.

**Elevation.** During each of the winter, spring and rutting seasons, >70% of mixed group observations were at lower (<1,200 m) elevations (Fig. 15). Most observations during the lambing period and summer, were on sites with an
Fig. 10. Percentage of ram groups observed in each canopy cover class, Phillipps Creek, 1992.
Figure 11. Percentage of mixed groups observed in each aspect (°), Phillipps Creek 1992.
Fig. 12. Percentage of ram groups observed in each aspect (°), Phillipps Creek, 1992.
Fig. 13. Percentage of mixed groups observed in each slope class (%), Phillipps Creek, 1992.
Fig. 14. Percentage of ram groups observed in each slope class (%), Phillipps Creek, 1992.
Fig. 15. Percentage of mixed groups observed in each elevation (m) class, Phillipps Creek, 1992.
elevation > 2,000 m. Fall observations were common at both high (>2,000 m) and low (<1,200 m) elevations; observed use of intermediate elevations by mixed groups (1,201-2,000 m) was ≤25% in any season. Ninety-three percent of observations of ram groups during summer/fall, were at elevations greater than 2,000 m (Fig. 16).

**Movements and Travel Corridors**

The movements of each radio-collared animal between February and December 1992 are displayed in Appendix G. Figure 17 depicts the 0.95 harmonic mean home range (Dixon and Chapman 1980) of the herd. The area included in the yearly 0.95 harmonic mean home range was 207 km².

During winter, mixed groups were large (Table 6) and moved throughout the winter range. In early May, radio-collared ewes began making movements off the winter range, but returned to the core winter range. On 14 May, they began moving to lambing-nursery areas. However, 1 mixed group remained north of Rainbow Creek until 18 May, when they moved to lambing-nursery areas or their summer range.

Throughout the summer, most radio-collared ewes moved back and forth across the International Border several times. Mixed groups spent approximately 4-5 days at a location before moving to another area. Group size and composition was variable during this period (Table 6).
Fig. 16. Percentage of ram groups observed in each elevation (m) class, Phillipps Creek, 1992.
Fig. 17. Harmonic mean home range of Phillipps Creek herd, 1992.
Table 6. Mean number of individuals in groups for mixed and ram groups of the Phillipps Creek herd, 1992.

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Lambing</th>
<th>Summer</th>
<th>Fall</th>
<th>Rut</th>
<th>Mixed &amp; Ram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>95</td>
<td>9</td>
<td>19</td>
<td>1</td>
<td>22</td>
<td>99</td>
<td>65</td>
</tr>
<tr>
<td>Group Size</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
Ram groups appeared to move less than mixed groups. They spent most of the early and late summer in the Ksanka Peak area. The Ten Lakes Basin and Poorman Mountain were used during mid-summer. Individual rams (both radio-collared and unmarked) were observed in other parts of the range throughout the summer. All 3 radio-collared rams associated with mixed groups until the lambing period. During the lambing period, ram 74 was observed at the "No Grizzly Ridge" lambing-nursery area and radio-located at Mt. Barnaby. Throughout the summer, the radio-collared rams appeared to move between mixed and all-male groups. Rams 66 and 69 were most often seen associated with mixed groups. Ram 74 usually was seen in the company of rams. The last observation of ram 66 was on 29 August 1992. I did not see ram 66 or locate his transmitter signal during the rut. I was unable to locate ram 69 for long periods during the summer.

Travel corridors are areas used by bighorns during specific times of the year for moving between seasonal ranges (Geist 1971:127). Typically, bighorn sheep do not remain at a specific location for several days when using travel corridors as they do on seasonal ranges. During a flight on 22 May 1992, 10 bighorns were observed on their summer range, 11 km east of their winter range. Another group of 6 bighorns was observed on the north side of Phillipps Creek between the winter range and the group seen previously. These observations combined with similar
observations made in November 1992 indicate that this is probably a major travel corridor between the winter and summer ranges. Sheep move east along the ridge north of Phillipps Creek until they reach the divide between the Kootenai and Wigwam River drainages (Fig. 3). From there they move north or south throughout their summer range.

Another travel route was identified along the west side of the mountains (Fig. 3). On 24 April 1992, a ewe was radio-located south of the International Border, near Independence Peak. Throughout late October and November 1992, I received reports from several hunters of rams moving through the area bisected by the closed road immediately south of the International Border. I was unsuccessful in several attempts to observe these rams on the ground. However, radio-locations and aerial observations indicated that bighorns were using the area.
CHAPTER V
DISCUSSION

Demographics

The accurate estimation of the size of wildlife populations is one of the most difficult tasks in wildlife management. Cryptic coloration and the wariness of wildlife species make them difficult to observe. Their continual movements make it very difficult to be sure that animals are not counted more than once. Mark-recapture methods of population estimation have been used to estimate the size of other bighorn sheep populations (Furlow et al. 1981, Leslie and Douglas 1979). The Schumacher equation (Schumacher-Eschmeyer 1943) is one of a number of techniques based on the mark-recapture method. All of these techniques include several assumptions that must be met to produce an accurate estimate. The assumptions are; geographic and demographic closure of the population, correct identification of marked animals, an independent probability of capture and no loss of marks (Caughley 1977, Neal et al. 1993). The method developed by Miller et al. (1987) is also based on mark-recapture techniques. However, it has been modified to correct for a lack of geographic closure. In this project the 2 methods produced similar estimates of the size of the Phillipps Creek herd, resulting in increased confidence in the estimate.
In unhunted populations, bighorn rams may equal or outnumber ewes (Buechner 1960, Woodgerd 1964). A nearly equal male:female ratio (0.9:1) has been reported for a lightly hunted bighorn population (Cowan and Geist 1971). The Phillipps Creek herd has a sex ratio similar to lightly hunted bighorn populations.

Caughley (1974) demonstrated that age ratios do not necessarily reflect changes in wildlife population trend. He showed that both increasing and decreasing populations could have similar age ratios. The use of age (lamb:ewe) ratios with bighorn sheep is further complicated by the behavior and appearance of the species. Bighorn ewes isolate themselves in secure areas to give birth and then move their lambs to secure lambing-nursery areas during May and June. Rams and barren ewes generally are not found at lambing-nursery areas at this time. Surveys that do not intensively search the entire range of the herd may not locate all the lambing-nursery areas or the groups of barren bighorns. Either result produces a lamb:ewe ratio that does not accurately reflect the total number of lambs in the population (Geist 1971). The similar appearance of yearling ewes and rams and 2 year-old ewes further compromises the accuracy of bighorn lamb:ewe ratio estimates. Distinguishing yearlings and 2 year-old ewes from reproductively mature ewes often is difficult (Festa-Bianchet 1992, Jorgenson 1992). The result is that the younger female age classes and yearling males are included
in the mature ewe age class. These problems have no doubt influenced my estimates of lamb:ewe ratios of the Phillipps Creek herd. June lamb:"ewe" (adult ewes plus 2 year-olds and yearlings) ratios have been shown to have no correlation with recruitment or population changes (Festa-Bianchet 1992).

During this study, the known range of the entire herd was surveyed from the air on 4 and 16 June 1992. No other lambing-nursery areas were located. Nor were any concentrations of ewes without lambs found. One radio-collared ram is known to have been at both lambing-nursery areas during June. The high lamb:"ewe" ratio documented for this population during June 1992 indicates that most of the females in the population produced viable offspring.

Geist (1971, 1983) proposed that there are 2 types of bighorn sheep populations. High quality or dispersal phenotypes and low quality or maintenance phenotypes. High quality populations are made up of individuals that have a high reproductive rate and produce large, vigorous lambs that mature early. Rams in high quality populations have large skulls and horns, begin using dominance display behaviors earlier, and die at a relatively young age. These characteristics are the result of abundant resources, usually due to reductions in sheep density (such as after a pneumonia-induced die-off) or the establishment of populations in new areas (Geist 1983).
Geist (1983) suggests that low quality or, more appropriately, maintenance phenotypes, are found where sheep densities are at or above carrying capacity. Individuals are small, have a low reproductive rate, are lethargic and long lived. Maintenance individuals minimize all energy expenditures to make the most efficient use of available limited resources (Geist 1983).

Shackleton (1976) studied 6 bighorn populations and found that rams from expanding populations had significantly larger horns that grew faster during the first 4 years of life than rams from stable populations. Rams from expanding populations also used mature behaviors at a younger age than rams from stable populations. There was some evidence to suggest that mean age at death was younger for rams from expanding populations than stable populations (Shackleton 1976). Bunnell (1978) found that horn growth and recruitment were correlated with forage quantity and quality among Dall sheep (*Ovis dalli*). Poor ewe nutrition during the spring prior to parturition resulted in depressed horn growth for up to 5 years in offspring (Bunnell 1978). However, Heimer (1980) examined 2 Dall sheep herds in Alaska, and found no nutritional difference between a high and a low quality population. Brown (1974) studied the Thompson Falls, Montana herd while it was increasing in size and found that few rams reached 8 years of age and no rams were older than 8. Uhazy et al. (1973) suggested a mechanism for the maintenance of high quality populations
under natural predator conditions. He found that lungworm \textit{(Protostrongylus stilesi)} infections increase with the age of the animal. Heavily parasitized individuals lose lung capacity. He suggested that wolf predation would have been concentrated on old, heavily parasitized, individuals because they would not be able to withstand a long chase. In this scenario, predation would be concentrated on the older age classes, leaving younger bighorns unaffected.

Unpublished data from the British Columbia Wildlife Branch indicates that some rams from the Phillipps Creek population reach Class IV (full curl) by 5 years of age, and few rams are older than 9 (A. Fontana, B. C. Wildl. Br., pers. commun.). The mean age of 12 Class IV rams harvested from the Phillipps Creek herd was 6.8 years-old.

Ewes in expanding populations are capable of giving birth to their first lamb at 2 years of age (Woodgerd 1964, Horesji 1976, Smith and Wishart 1978, Butts 1980, Jorgenson et al. 1993). Stelfox and Poll (1978) found that following a pneumonia die-off, ewes in the recovering population were 20.8% heavier than they had been during the die-off. Wishart and Brochu (1982) found that not only were ram horns larger in high quality populations, but that skulls of both sexes were significantly larger than those of low quality populations in 4 characteristics. Ewe skulls alone were larger in 5 additional characteristics and high quality rams had significantly larger palates than low quality rams.
The bighorn sheep herd at Ram Mountain, Alberta was maintained at 100 individuals from 1975 to 1981 by the harvest of both rams and ewes (Jorgenson and Wishart 1986, Jorgenson et al. 1993). Hunting of ewes was stopped in 1980. By 1985, the population had increased 31%, to 142 individuals. The density of bighorns on the range had increased from 2.6 to 3.6 animals/km$^2$. In conjunction with the increase in population size, the median age of ewes rose from 3 to 4 years of age and more barren ewes and fewer 2 year olds were giving birth than there had been between 1975 and 1981 (Jorgenson and Wishart 1986). These data suggest that overall sheep density increased because of higher survival of ewes. The increase in density resulted in decreased availability of quality forage and a decline in productivity. Horesji (1976) found that lambs spent less time playing and more time grazing during years of poor forage quality. They began grazing at an earlier age and replaced their juvenile coats at a later age than lambs born during years of high forage quality.

The high lamb:"ewe" ratio (90:100) of the Phillipps Creek herd for June suggests the possibility that 2 year-old ewes produced lambs. During summer 1991 and summer and fall 1992, lambs of the Phillipps Creek herd were frequently engaged in play activities and their juvenile coats were replaced by late August. These characteristics (the rapid growth of rams, lack of rams older than 9 years-old, high fecundity rate, and vigorous lambs) suggest that the
Phillipps Creek herd has many of the characteristics of a high quality population.

**Use of Habitat Types**

Bighorn sheep habitat commonly is thought of as open grasslands adjacent to steep rocky terrain. Geist (1971), after studying a Stone's sheep (*Ovis dalli stonei*), a Dall sheep, and a Rocky Mountain bighorn sheep population, described the habitat of mountain sheep as stable, long lasting, climax grasslands. The winter ranges of 2 of the largest populations of Rocky Mountain bighorns are east of the Continental Divide in Montana and Wyoming. The Sun River Herd in Montana was found to use grassland habitat types in winter as well as old burns and the "reef type" habitat common to that area (Erickson 1972). The bighorn winter range at Whiskey Mountain, Wyoming is made up of grasslands (30%), coniferous forest (21%), sagebrush (*Artemisia* spp.)-grass types (19%), conifer-sagebrush-grass type (17%), perennial forb-grass type (9%), and meadow (3%). The grassland was the most heavily used portion of the range, 59.5% of all bighorn observations occurred on this type. Escape cover in this study was found to include forested areas (Thorne et al. 1979).

The habitat use patterns of other bighorn populations east of the Divide have been studied, including the bighorn sheep herds in 3 national parks in Alberta. Stelfox (1976) found that bighorns in Waterton, Banff, and Jasper National Parks wintered on grassland habitat types or shrub savannas
and made no use of forested areas during winter (Stelfox 1976). The bighorn sheep that inhabit the Beartooth Mountains, in southcentral Montana, were found to use alpine grasslands as well as subalpine forests and Douglas fir habitat types (Stewart 1975). Riggs and Peek (1980) found that seral communities, containing elk sedge (Carex geyeri), pinegrass, bluegrass (Poa spp.) and white spirea (Spirea betulifolia), were selected by bighorns during the winter because some forage species remained green all winter. In Wyoming, Arnett (1990) found that bighorns in the Sierra Madre Mountains selected wind-blown ridges during winter and spring, containing a black sagebrush (Artemisia nova) and grass community and an old burn. Ewes avoided conifer and aspen (Populus tremuloides) communities during his study.

In Yellowstone National Park, 78% of all sheep activities on the winter range took place in grassland vegetation types. Forest types were used as escape habitat (Oldemeyer et al. 1971). At Waterton Canyon, Colorado, Risenhoover and Bailey (1985) found that bighorn sheep preferred to forage in mountain shrub types and grassy openings. The authors found that bighorns avoided Douglas fir forest, oakbrush (Quercus spp.), and conifer-rock habitat types.

In summer, bighorns follow the "green-up" to high elevations where grasses and forbs are more nutritious than species at lower elevations (Johnston et al. 1968, Stelfox 1976). The summer range of the Sun River herd was primarily bare rock with scattered bunchgrasses and shrubs (Erickson
Arnett (1990) found that bighorns in southcentral Wyoming selected clearcuts and a snowbrush ceanothus (Ceanothus velutinus)/chokecherry (Prunus virginianus) community during summer. He suggested that the use of burns and clearcuts by bighorns is determined by their proximity to escape terrain. In Rocky Mountain National Park, Colorado, bighorns used both alpine and subalpine habitat types during summer. While using the subalpine spruce-fir forest, bighorns foraged in avalanche paths, rockslides, and boulderfields (Goodson and Stevens 1988).

Habitat use patterns of bighorn populations found west of the Continental Divide have also been examined. In southeastern British Columbia, Schuerholz (1984) found that the bighorn sheep of the Elk Valley winter in alpine and subalpine meadows above 2,400 m elevation. Slope steepness on the winter range varies from 26° to 40°. A portion of the population was found to lamb within Engelmann spruce-subalpine fir forest adjacent to the winter range. During summer, the herd showed no elevational preference. Berwick (1968) found that 43% of the winter range of the Rock Creek herd in Montana was grassland. However, 47% of the range was timbered and served as bedding and escape cover. At Thompson Falls, Montana, 94% of observations of bighorn sheep were in ponderosa pine-Douglas fir/scree or subalpine fir-whitebark pine/scree habitat groups (Brown 1974). Tilton and Willard (1982) found that most of the forage on
the Thompson Falls winter range was in the open forest and shrub-grassland cover types.

Klaver (1978) studied the bighorn sheep herd that winters along the West Fork of the Bitterroot River and summers in the Selway-Bitterroot Wilderness. On the winter range, this herd used ponderosa pine/Idaho fescue, Douglas fir/bluebunch wheatgrass and Douglas fir/pinegrass habitat types. Smith (1954) found that bighorns along the Middle Fork of the Salmon River in Idaho used the ponderosa pine and Douglas fir zones during the winter and the subalpine and alpine zones in the summer.

This brief review of the literature indicates that bighorn sheep habitat requirements are not as restrictive as generally thought. Similar to other bighorn populations, the Phillipps Creek herd winters in an area containing seral shrublands, grasslands, and Douglas fir habitat types. The bighorns graze on grasses and low vegetation while they are available. When the low vegetation becomes buried beneath snow, they rely on shrublands and either feed beneath the shrub canopy or browse the shrubs themselves.

During summer, migration to upper subalpine and alpine areas enables bighorns to forage on a variety of nutritious plant species (Johnston et al. 1968, Stelfox 1976). While on their summer range, Phillipps Creek bighorns use scree slopes and avalanche chutes. Plant communities on these landforms are always in "early" seral stages. In the case of scree slopes, this is due to the constantly shifting
substrate and variable conditions (Pfister et al. 1977). The result is an extremely variable community. Avalanche chutes experience regular disturbances from avalanches that maintain the chutes in a grass-shrubland community (Craighead et al. 1982).

**Microsite Characteristics**

It is generally accepted that as tree canopy cover increases bighorn use of an area decreases (Shannon et al. 1975). I observed bighorns using sites with an overstory canopy cover as high as 80% during winter and spring. Similar use of forested areas was observed for the Ural-Tweed herd (Brown 1979). During summer, overstory canopy cover values on sites used by the Phillipps Creek herd declined, while those of the Ural-Tweed herd remained high (Brown 1979).

Shrubs are an important component of bighorn habitat, providing forage (Smith 1954, Shannon et al. 1975, Tilton 1977, Rominger et al. 1988) and intercepting snow that would otherwise make grass inaccessible (Goodson et al. 1991). However, too many tall shrubs may make areas uninhabitable to bighorns (Risenhoover and Bailey 1980, Wakelyn 1987).

The Phillipps Creek winter range contains several isolated shrub communities that were used by bighorns during January. However, no snow accumulated on the ground after 5 February 1992 and observations of bighorns using these areas declined as winter progressed. Bighorns returned to shrub communities during spring.
Bighorn sheep avoid predation by fleeing to inaccessible terrain (Geist 1971). They have evolved short, thick leg and foot bones that are adapted to climbing and are less likely to bend or break on impact than the long thin leg and foot bones found in most Artiodactyls (Dailey and Hobbs 1989). However, several researchers have noted the use of forested areas as escape terrain (Berwick 1968, Oldemeyer et al. 1971, Frisina 1974, Matthews 1973, Thorne et al. 1979). Oldemeyer et al. (1971) and Thorne et al. (1979) included forests in their definition of escape terrain. I used the definition of escape terrain given by Brundige and McCabe (1986), an area with a slope greater than 100% and containing large rock outcrops, because it accurately represents typical bighorn escape terrain. I did not include forest. According to the Brundige and McCabe (1986) definition, 14% of observations on the Phillipps Creek winter/spring range were within 100 m of escape terrain. This is much less than has been documented by other researchers. Oldemeyer et al. (1971) found 86% of bighorns within 100 yds. (91 m) of escape terrain. Frisina (1974) documented 86% of bighorns observed within 150 yds. (137 m) and Thorne et al. (1979) found 72% of bighorns within 45 m of escape terrain. If I include forested areas as escape habitat, 63% of all groups observed during winter and spring, were within 100 m of escape terrain. It appears that the Phillipps Creek herd uses coniferous forest as escape terrain, particularly during winter, when their
affinity for rocky escape terrain may be compromised by low forage quality (Pallister 1974, Arnett 1990).

Demarchi (1971) clearly described the processes affecting the big game winter ranges in the southern portion of the Rocky Mountain Trench. These processes are reflected in the dominant vegetation species found on sites used by the Phillipps Creek herd during winter, spring, and the rut. Prior to 1930, periodic underburning resulted in open ponderosa pine forests encompassing seral bitterbrush communities and grass-forb meadows. The last large forest fire burned in the area in 1931. Subsequent fire prevention and control methods have minimized the area burned each year and allowed forest succession to progress. The result is that open ponderosa pine savannas and seral shrub communities are being replaced by closed canopy Douglas fir forest (Demarchi 1971). The most common tree species encountered on sites used by Phillipps Creek bighorn sheep during winter and spring was Douglas fir. Ponderosa pine was dominant on only 1 site used by bighorns.

Aspect is an important factor in determining accumulation of snow, exposure to radiant energy, vegetation quality, and forest cover (Shannon et al. 1975). Bighorns avoid areas with snow depths greater than 30 cm (2/3 chest height for lambs) (Stelfox 1976). The use of south and southwest exposures by bighorn sheep during winter and spring has been documented by several researchers (Brown 1974, Hudson et al. 1976, Shannon et al. 1975, Tilton 1977,
Brown 1979). At Thompson Falls, Tilton (1977) found bighorns avoided east and southeast aspects during winter. I observed only 1 mixed group using those aspects during winter. Although, the Phillipps Creek winter range has limited areas with an east aspect.

Goodson and Stevens (1988) found that bighorns used south to west aspects in late spring and early summer; in late summer they used north to southeast exposures. My observations generally agree with the findings of these researchers.

The use of steep slopes, for other than escape terrain, by bighorn sheep is not completely understood. Shannon et al. (1975) and Wakelyn (1987) suggest that bighorns may select the biotic and abiotic conditions that exist on a slope, i.e. decreased snow depth and greater forage availability, rather than the steep terrain itself. Gionfriddo and Krausman (1986) suggested that flat areas are too far from escape terrain to be usable to bighorns. In general, bighorns use the steepest terrain during lambing, early summer, and winter. Tilton (1977) found that wintering bighorns preferred areas with slopes greater than 80% and avoided areas with 10-35% slope. I did not observe bighorns on the Phillipps Creek winter or spring range using areas with 80% slope. However, there are not many areas on the Phillipps Creek winter-spring range that are that steep.

During the lambing period, ewe groups began using areas with slopes greater than 100%. The affinity mixed groups
showed for escape terrain appeared to decrease as summer progressed.

The benefits of having seasonal ranges at different elevations have been demonstrated by several authors. Johnston et al. (1968) showed that alpine vegetation has higher percentages of crude protein, phosphorus, and digestibility at all growth stages than low elevation species. Hebert (1973) demonstrated that altitudinal migration is beneficial to bighorn sheep nutrition. In Colorado, lower minimum elevations and greater range in elevation of bighorn ranges was associated with larger sheep herds (Wakelyn 1987). The area used by the Phillipps Creek herd spans 1,300 m elevation. The herd winters at elevations from 900 to 1,300 m and summers from 1,800 to 2,300 m.

**Movements**

Bighorn sheep are social animals and typically found in groups of various size. Risenhoover and Bailey (1985) found that larger groups of sheep (more than 6) moved further from escape terrain to forage than small groups (5 or fewer). In groups of 5 or fewer, foraging efficiency of bighorns declines because they often interrupt feeding to scan their surroundings (Berger 1978, Risenhoover and Bailey 1985). Shannon et al. (1975) found that group size was largest during the rut, then declined rapidly and was smallest in the winter. Klaver (1978), Butts (1980), and Kopec (1981) reported the largest groups during the lambing-nursery
period. I observed the largest mixed groups of sheep during the rut and winter.

Within their home range, bighorn sheep have several seasonal ranges, areas used only during specific times of the year. Bighorns are very traditional in their use of these areas. They arrive and leave at approximately the same time every year. The only age classes that vary from this pattern of range use, to any substantial degree, are yearling to 3 year-old rams. Between those ages, rams move from mixed groups, where they are dominant, to all-male groups, where they are subordinate (Geist 1971). During this period, they move back and forth between the 2 types of groups. This is also the age at which rams explore their home range. The erratic movements and disappearance of the young rams radio-collared during this study could be explained as exploratory movements. The movements of the radio-collared ewes in this study reflect the traditional nature of the movements of mature animals.

Harvest

The size of the population is not the only factor to be weighed when considering whether or not to hunt a population. The trend of the population must be determined. Is the population increasing or decreasing? Usually, trend can be determined by examining population estimates from several years. The 5 population estimates done previous to this study indicate the population is increasing. However, it is difficult to say if the increase is real, the result
of more reliable survey techniques, or of higher visibility due to the logging of a portion of the winter range. The population does, however, exhibit many of the characteristics of a high quality population. Therefore, it is likely that the increase shown in the population estimates is real. The effect of harvesting large numbers of Class IV rams on the survivorship of younger rams remains unresolved. Rams become sexually mature between 1 and 2 years of age and attain full body size between 3 and 8 years old (Blood et al. 1970, Geist 1971, Stelfox and Poll 1978, Jorgenson and Wishart 1984). While growing, rams put large amounts of energy into the development of bones, horn, and body tissue. Geist (1971) proposed that fully (physically and sexually) mature Class IV rams did the majority of breeding and prevented young rams from participating. Removal of excessive numbers of Class IV rams would permit young, physically immature, rams to breed ewes. Breeding before they are fully grown would be an additional drain on the already limited energy reserves of young rams. The loss of additional energy during the late fall could result in increased over-winter mortality of this age class (Geist 1971). A study done by Heimer and Watson (1990) on Dall sheep supported this thesis.

However, Hogg (1984) showed that subdominant rams do actively participate in the rut. He found that bighorn rams use 3 different mating strategies. Dominant rams defended individual estrous ewes in a strategy called tending.
Coursing rams were subdominant rams that attempted to gain access to tended ewes by fighting the defending ram. The final strategy used by low-ranking rams was labeled blocking. In this strategy, rams attempted to sequester ewes on the periphery of the traditional tending area (Hogg 1984). Evidence suggests that both the coursing and blocking behavior do result in successful breeding by subdominant rams (Hogg 1984, 1988).

Murphy et al. (1990) found no significant difference in survival of young rams in heavily and lightly hunted herds of Dall sheep. Mortality of rams 1 to 8 years of age has been presumed to be 2 to 4% per year (Geist 1971). However, Stewart (1980) found the natural mortality rate of yearling and 2 year-old bighorn rams, in an expanding population, to be 33% and 31%, respectively. Festa-Bianchet (1989) found the natural mortality rate averaged 33% for yearlings and 18% for 2 year-olds. He proposed that mortality of young rams may be more common than previously thought. This mortality may be the result of inadequate forage and a greater susceptibility to disease, due to a young ram's high forage and energy requirements, rather than the result of their participation in the rut (Festa-Bianchet 1989).

Sugden (1961, cited from Cowan and Geist 1971) reported that 25 sheep are required to produce a trophy ram. I estimated 82 individuals in the Phillipps Creek herd in December 1992. Using Sugden's guidelines this would suggest a sustainable harvest of 3-4 rams per year. Geist (1977)
noted that bighorn sheep herds can sustain a harvest of 4 to 5 rams per 100 rams. I estimated the population contained 32 rams in December 1992, which would suggest a sustainable harvest of 1-2 rams per year. Based on these 2 sources it appears that at 1992 population levels the Phillipps Creek bighorn sheep herd could support a harvest of 3-4 Class IV rams.

The British Columbia Wildlife Branch has a limited entry hunt in place on the Phillipps Creek herd. Hunters who receive permits are limited to harvesting Class IV rams. From 1983 through 1990, 3 permits were issued per year. In 1991, the number of permits issued was increased to 7. A mean of 1.25 rams was taken during the 1983-90 period, and a mean of 2 rams during 1991-92 (BCWB unpubl. data).

The Montana Department of Fish, Wildlife, and Parks is shifting emphasis, from restricting hunters with a curl regulation, to allowing them to harvest either-sex bighorns. The number of licenses issued for each herd is determined by the number of Class III rams available for harvest in the population. However, the license allows the hunter to harvest a ram of any size or a ewe. These licenses tend to lessen the hunting pressure on the Class IV ram segment of the herd. Many hunters still pursue a full curl ram, but the hunter has the option of harvesting a younger ram or a ewe (McCarthy 1986). This regulation, if used on the Phillipps Creek herd, would have the effect of distributing additional hunting pressure from licenses issued by Montana
across the entire herd, rather than solely on the Class IV rams.
CHAPTER VI
RECOMMENDATIONS

This study was a product of cooperation between the Montana Department of Fish, Wildlife, and Parks, the British Columbia Wildlife Branch, and the United States Forest Service in the management of the Phillipps Creek bighorn sheep herd. British Columbia allowed 3 hunting permits/year on this herd for full-curl rams from 1983 through 1990, and 7 permits from 1991 through 1993. A mean of 1.25 rams was taken during the 1983-90 period, and a mean of 2 rams during 1991-93. Montana Department of Fish, Wildlife, and Parks, plans to offer one either-sex permit starting in 1994.

Bighorn sheep population estimates made during this project, existing data on harvest rates, and harvest rate recommendations found in the literature indicate that the Phillipps Creek herd can support the current and planned number of hunting permits. This herd should be monitored to ensure that the population trend remains stable or continues to increase. If the harvest of Class IV rams exceeds 4 animals in any year and the population trend is stable or downward, consideration should be given to a reduction in permits in the subsequent year.

During spring 1992, 90 lambs:100 ewes were recorded for the Phillipps Creek bighorn sheep population, but this ratio had declined to 47:100 by December 1992. A study of lamb and yearling survival would reveal mortality factors which
could possibly be reduced by management activities to further increase the population.

It may be possible to improve the Phillipps Creek bighorn sheep range by manipulation of the vegetation. However, a single year of observational study cannot provide definitive data on which to base such recommendations. For instance, logging or prescribed fire could be used to reduce the forest overstory on the winter range and increase forage production. However, increased snow depths in created openings could reduce forage availability. This would be detrimental to the herd, especially if forested areas are important as escape cover on this winter range. Thus, I recommend that additional studies be conducted on the habitat requirements of the Phillipps Creek herd, as well as the characteristics of the habitat available to them. These studies would provide data on which to base future recommendations on habitat modifications to benefit the bighorn sheep population.

Several unimproved roads provide access to the winter range of the Phillipps Creek herd, and a portion of the winter range is private land. Closure of roads on the winter range during winter and spring would reduce harassment of the bighorn sheep and likely reduce the possibility of illegal harvest of bighorns and the spread of noxious weeds. Also, if the possibility presented itself, purchase of the privately owned portion of winter range would provide the British Columbia Wildlife Branch with the
ability to manage the winter range in a way that would be more beneficial for the bighorn population.
REFERENCES CITED


measure of animal activity areas. Ecology 61(50): 
1040-1044.

Erickson, G. L. 1972. The ecology of Rocky Mountain 
bighorn sheep in the Sun River area of Montana with 
special reference to summer food habits and range 
movements. Job Compl. Report, Proj. W-120-R-2, 3, 
Montana Dept. Fish and Game, Helena. 50pp.

Festa-Bianchet, M. 1989. Survival of male bighorn sheep in 

____. 1992. Use of age ratios to predict bighorn sheep 
and Goat Counc. 8:227-236.

River area of Montana during fall and spring. M. S. 

Estimating a bighorn sheep population by mark- 

Geist, V. 1971. Mountain sheep: a study in behavior and 

____. 1977. On the management of mountain sheep. Pages 
The Boone and Crockett Club and the Nat. Rifle Assn. of 
Am., Washington, D. C.

____. 1983. On phenotype reproductive strategies in 
mountain sheep and some criticisms of conventional 
population biology. Pages 83-92 in F. L. Bunnell, D. 
S. Eastman and J. M. Peek, co-editors. Symp. on 
Natural Regulation of Wildlife Populations. Forest, 

Gionfriddo, J. P. and P. R. Krausman. 1986. Summer habitat 
use by mountain sheep. J. Wildl. Manage. 50(2):331- 
336.

Goodson, N. J., and D. R. Stevens. 1988. Home ranges, 
habitat use and productivity of bighorn sheep in the 
Wild Sheep and Goat Counc. 6:254-267.

____, ___, J. A. Bailey. 1991. Effects of snow on 
foraging ecology and nutrition of bighorn sheep. J. 


APPENDIX A

VERNACULAR AND SCIENTIFIC NAMES
OF PLANTS MENTIONED IN THESIS
Nomenclature follows Hitchcock and Cronquist (1973).

**FAMILY**

<table>
<thead>
<tr>
<th>Vernacular</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td></td>
</tr>
<tr>
<td><strong>CUPRESSACEAE</strong></td>
<td></td>
</tr>
<tr>
<td>common juniper</td>
<td><em>Juniperus communis</em></td>
</tr>
<tr>
<td>Rocky Mountain Juniper</td>
<td><em>Juniperus scopulorum</em></td>
</tr>
<tr>
<td><strong>PINACEAE</strong></td>
<td></td>
</tr>
<tr>
<td>subalpine fir*</td>
<td><em>Abies lasiocarpa</em></td>
</tr>
<tr>
<td>alpine larch</td>
<td><em>Larix lyallii</em></td>
</tr>
<tr>
<td>tamarack</td>
<td><em>Larix occidentalis</em></td>
</tr>
<tr>
<td>Engelmann spruce</td>
<td><em>Picea engelmannii</em> (includes P. glauca)</td>
</tr>
<tr>
<td>white bark pine</td>
<td><em>Pinus albicaulis</em></td>
</tr>
<tr>
<td>lodgepole pine</td>
<td><em>Pinus contorta</em></td>
</tr>
<tr>
<td>ponderosa pine</td>
<td><em>Pinus ponderosa</em></td>
</tr>
<tr>
<td>Douglas fir</td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td><strong>SALICACEAE</strong></td>
<td></td>
</tr>
<tr>
<td>narrow-leaved cottonwood</td>
<td><em>Populus angustifolia</em></td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
</tr>
<tr>
<td><strong>ACERACEAE</strong></td>
<td></td>
</tr>
<tr>
<td>Rocky Mountain maple*</td>
<td><em>Acer glabrum</em></td>
</tr>
<tr>
<td><strong>BERBERIDACEAE</strong></td>
<td></td>
</tr>
<tr>
<td>creeping Oregongrape</td>
<td><em>Berberis repens</em></td>
</tr>
</tbody>
</table>

* Species bighorn sheep were observed to eat.
<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BETULACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitka alder</td>
<td><em>Alnus sinuata</em></td>
<td>Sitka alder</td>
</tr>
<tr>
<td><strong>CAPRIFOLIACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snowberry</td>
<td><em>Symphoricarpus albus</em></td>
<td>Snowberry</td>
</tr>
<tr>
<td>Mountain snowberry</td>
<td><em>Symphoricarpus oreophilus</em></td>
<td>Mountain snowberry</td>
</tr>
<tr>
<td><strong>COMPOSITAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoary sagebrush</td>
<td><em>Artemisia cana</em></td>
<td>Hoary sagebrush</td>
</tr>
<tr>
<td>Dragon sagewort</td>
<td><em>Artemisia dracunculus</em></td>
<td>Dragon sagewort</td>
</tr>
<tr>
<td><strong>ELAEAGNACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffalo-berry</td>
<td><em>Shepherdia canadensis</em></td>
<td>Buffalo-berry</td>
</tr>
<tr>
<td><strong>ERICACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinnikinnick</td>
<td><em>Arctostaphylos uva-ursi</em></td>
<td>Kinnikinnick</td>
</tr>
<tr>
<td>Dwarf huckleberry</td>
<td><em>Vaccinium caespitosum</em></td>
<td>Dwarf huckleberry</td>
</tr>
<tr>
<td>Globe huckleberry</td>
<td><em>Vaccinium globulare</em></td>
<td>Globe huckleberry</td>
</tr>
<tr>
<td>Dwarf bilberry</td>
<td><em>Vaccinium myrtillus</em></td>
<td>Dwarf bilberry</td>
</tr>
<tr>
<td>Whortleberry</td>
<td><em>Vaccinium scoparium</em></td>
<td>Whortleberry</td>
</tr>
<tr>
<td><strong>GROSSULARIACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prickly currant*</td>
<td><em>Ribes lacustre</em></td>
<td>Prickly currant*</td>
</tr>
<tr>
<td>Mountain gooseberry</td>
<td><em>Ribes montigenum</em></td>
<td>Mountain gooseberry</td>
</tr>
<tr>
<td><strong>ROSACEAE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western serviceberry</td>
<td><em>Amelanchier alnifolia</em></td>
<td>Western serviceberry</td>
</tr>
<tr>
<td>Ninebark</td>
<td><em>Physocarpus malvaceus</em></td>
<td>Ninebark</td>
</tr>
<tr>
<td>Shrubby cinquefoil</td>
<td><em>Potentilla fruticosa</em></td>
<td>Shrubby cinquefoil</td>
</tr>
<tr>
<td>Bitterbrush</td>
<td><em>Purshia tridentata</em></td>
<td>Bitterbrush</td>
</tr>
<tr>
<td>Wood's rose*</td>
<td><em>Rosa woodsii</em></td>
<td>Wood's rose*</td>
</tr>
<tr>
<td>Thimbleberry*</td>
<td><em>Rubus parviflorus</em></td>
<td>Thimbleberry*</td>
</tr>
<tr>
<td>Mountain ash</td>
<td><em>Sorbus scopulina</em></td>
<td>Mountain ash</td>
</tr>
</tbody>
</table>
shiny-leafed spirea  
Spiraea betulifolia

Grasses, Grass-like Plants and Forbs

BORAGINACEAE

alpine bluebells  
Mertesia alpina

CARYOPHYLLACEAE

mountain sandwort  
Arenaria capillaris

COMPOSITAE

common yarrow  
Achillea millefolium

mountain-dandelion  
Agoseris glauca

woolly pussy-toes  
Antennaria lanata

raceme pussy-toes  
Antennaria racemosa

heart-leafed arnica  
Arnica cordifolia

mountain arnica*  
Arnica latifolia

showy aster  
Aster conspicuus

leafy aster*  
Aster foliaceus

arrowleaf balsamroot*  
Balsamorhiza sagittata

nodding helianthella*  
Helianthella quinquenervis

mountain butterweed  
Senecio fremontii

arrowleaf groundsel  
Senecio triangularis

CRASSULACEAE

lanceleaved stonecrop  
Sedum lanceolatum

CYPERACEAE

elk sedge*  
Carex geyeri
**GRAMINEAE**

bluebunch wheatgrass*  
smooth brome  
cheat grass  
pinegrass*  
Orchard-grass*  
mountain hairgrass  
tufted hairgrass  
Idaho fescue*  
rough fescue*  
Timothy  
bluegrass*  

**JUNCACEAE**

Parry's rush  
smooth woodrush*  

**LEGUMINOSAE**

silvery lupine*  
alfalfa*  
clover  

**LILIACEAE**

yellow fawn-lily*  
beargrass  

**ONAGRACEAE**

fireweed*  

**POLYGONACEAE**

cushion buckwheat  

Aarror'ion soicatum  
Bromus inermis  
Bromus tectorum  
Calamagrostis rubescens  
Dactylis glomerata  
Deschampsia atropurpurea  
Deschampsia cespitosa  
Festuca idahoensis  
Fesuca scabrella  
Phleum pratense  
Poa spp.  
Juncus parryi  
Luzula hitchcockii  
Lupinus argenteus  
Medicago sativa  
Trifolium spp.  
Erythronium grandiflorum  
Xerophyllum tenax  
Epilobium angustifolium  
Eriogonum ovalifolium
**RANUNCULACEAE**
western pasqueflower
yellow columbine
western meadowrue*

**ROSACEAE**
strawberry

**RUBIACEAE**
fragrant bedstraw*

**SAXIFRAGACEAE**
roundleaf alumroot
small-leaved alumroot
spotted saxifrage

**SCROPHULARIACEAE**
scarlet paintbrush*
rhexia-leaved paintbrush
bracted lousewort
sickletop lousewort
elliptic-leaved penstemon
mountain penstemon
common mullein

**UMBELLIFERAE**
Lyall's angelica*
cow-parsnip*
Sandberg's lomatium*
lomatium*

**VALERIANACEAE**
Sitka valerian*
VIOLACEAE
violet* viola spp.

Lower Plants

MUSCI
moss Ceratodon spp.

POLYPODIACEAE
Holly fern Polystichum lonchitis
APPENDIX B

TRAPPING DATA SHEET
BIGHORN CAPTURE DATA

1. __/__/__ Date
2. ___ __ Time start
3. ___ ___ Time released
4. M F Male or Female
5. ___ Age
6. T C Tagged or collared
7. ___ ___ Animal number
8. 153. ___ ___ Trans. freq.
9. Identifying marks:
APPENDIX C

DATA SHEET
### SHEEP OBSERVATIONS

<table>
<thead>
<tr>
<th>Observation</th>
<th>Observer</th>
<th>Month</th>
<th>Day</th>
<th>Year</th>
<th>Start Time</th>
<th>Stop Time</th>
<th>Quad</th>
<th>Aerial Photo</th>
<th>Type Observ</th>
<th>N. U.T.M.</th>
<th>E. U.T.M.</th>
<th>Zone</th>
<th>Dom. Life</th>
<th>Landform</th>
<th>Slope Shape</th>
<th>Aspect</th>
<th>Slope %</th>
<th>Elevation</th>
<th>Spec Feature</th>
<th>Prox Ecotone</th>
<th>Ecot Canopy</th>
<th>Temperature</th>
<th>Cloud Cover</th>
<th>Precip Code</th>
<th>Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>87.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>G or A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ECODATA:

141. ___:__: Eco-Type 181. ___:__: Low Shrub
143. ___:__: PVC Ref. 183. ___:__: Total Shrub
149. ___:__: Ind. Sp. I 185. ___:__: Total Gram.
155. ___:__: Ind. Sp. II 187. ___:__: Total Forb
161. ___:__: Ind. Sp. III 189. ___:__: Total Moss

CANOPY COVER:

167. ___:__: Pole 191. ___:__: Bare Ground
169. ___:__: Sapling 193. ___:__: Gravel
171. ___:__: Seedling 195. ___:__: Rock
173. ___:__: Ttl Tree Cvr 197. ___:__: Litter
175. ___:__: Tall Shrub 199. ___:__: Wood
177. ___:__: Form 201. ___:__: Moss & Lichen
178. ___:__: Mid Shrub 203. ___:__: Basal Veg.
180. ___:__: Form 205. ___:__: Water

EXISTING VEGETATION:

207. ___:__: Upper Level Dominant Species I
213. ___:__: Upper Level Dominant Species II
219. ___:__: Mid Level Dominant Species I
225. ___:__: Mid Level Dominant Species II
231. ___:__: Lower Level Dominant Species I
237. ___:__: Lower Level Dominant Species II
243. ___:__: Plant Species used by Sheep
249. ___:__: Plant Species used by Sheep
255. ___:__: Plant Species used by Sheep
261. ___:__: Plant Species used by Sheep
APPENDIX D

DESCRIPTION OF HABITAT TYPES AND ECOLOGICAL LAND UNITS
USED BY THE PHILLIPPS CREEK BIGHORN SHEEP HERD
HABITAT TYPES

Mueggler and Stewart (1980)

The Festuca scabrella/Agropyron spicatum habitat type occurred primarily as a large meadow with a south and west aspect, south of Phillipps Creek in British Columbia. Elevation of the meadow was from 1,067 m to 1,280 m and slope ranged from 25 to 38%. Idaho fescue and rough fescue were the dominant herbaceous species. The bunchgrasses were old and decadent and contained a lot of litter. Woods rose and buffalo-berry (Shepherdia canadensis) were found in clumps throughout the area. Douglas fir was found on the periphery and scattered throughout the meadow.

The Purshia tridentata/Festuca scabrella habitat type occurred north of Phillipps Creek as irregular isolated patches surrounded by Douglas fir forest. The patches have a west aspect and were found between 945 m and 1,189 m elevation. Slope of the area ranged from 40 to 60%. Bitterbrush constituted approximately 50% of the canopy cover on the sites used by bighorn sheep. Shrubs ranged from vigorous to decadent and were generally less than 1.5 m tall. Shrub form was generally moderately hedged to clubbed. The most common undergrowth species were cheat grass and bluebunch wheatgrass. Rough fescue made up less than 30% of the graminoid community. Mature ponderosa pine and Douglas fir of various age classes were sporadically located within the shrub fields.
Pfister et al. (1977)

The **Pseudotsuga menziesii/Calamagrostis rubescens** habitat type occurred both north and south of Phillipps Creek. It appeared to be more common south of the Creek, in an area that has been logged within the previous 5 years. It was found on northerly aspects, between elevations of 914 and 1,707 m. Slope on the sites examined ranged from 0-45%. The areas of this habitat type that had not been logged had an upper level canopy cover of 10-60%. Canopy cover in the logged area was 1-5%. Shrubs were scarce within this type, grasses and forbs were common. Ponderosa pine and western larch were found in addition to Douglas fir. The most common shrubs were ninebark, woods rose, buffalo-berry, and chokecherry. Pinegrass, elk sedge, and cheatgrass were found in the understory. Orchard grass and Timothy were seen in the logged area.

Bighorn sheep locations that occurred in the **Pseudotsuga menziesii/Carex geyeri** habitat type were north of Phillipps Creek road at elevations of 914 to 1,000 m. The aspect of the habitat type ranged from 211-218°, slope was generally flat. The locations were in a strip of forest between Phillipps Creek Road and the Douglas fir/pinegrass type on the slopes. Canopy cover was approximately 50-70%. Douglas fir and ponderosa pine were the dominant conifer species. Woods rose was the most common shrub species and
cheat grass and elk sedge were the most common herbaceous species.

The *Pseudotsuga menziesii*/*Festuca scabrella* habitat type was found on both sides of Phillipps Creek, primarily on the convex areas of the hillsides. It was found between 914 and 1,280 m in elevation, on south to northwest aspects. Upper level canopy in the type was usually greater than 60% and dominated by Douglas fir and ponderosa pine. Bitterbrush and woods rose were the common shrubs. Idaho fescue and cheat grass were the graminoids most often seen on sites used by bighorn sheep. Arrowleaf balsamroot was a common forb.

The *Pseudotsuga menziesii*/*Physocarpus malvaceus* habitat type occurred throughout the winter range, at elevations of 914 to 1,250 m and on 0 to 72% slopes. Overstory canopy coverage ranged from 0-80%, with ponderosa pine codominant north of Phillipps Creek and western larch codominant south of the Creek. A variety of shrub species grew in this type including ninebark, woods rose, bitterbrush, and mountain maple (*Acer glabrum*). Pinegrass and cheat grass were abundant in the ground cover. South of the Creek this type had been logged.

The *Pseudotsuga menziesii*/*Symphoricarpos albus* habitat type occurred south of Phillipps Creek, on west to north
facing moderately steep (0-45%) slopes. Elevation of the sites examined was from 792 to 1,250 m. Portions of this type have been logged and overstory canopy coverage ranged from 0-70%. Western larch was the codominant conifer species. Those areas not logged had as much as 90% mid-level canopy cover of buffalo-berry, snowberry and ninebark. Pinegrass and elk sedge were most abundant in the unlogged areas, orchard grass and clover in the logged areas.

Only 1 bighorn sheep location occurred in the Pseudotsuga menziesii/Vaccinium caespitosum habitat type. It was located south of Phillipps Creek on a northeast aspect. The elevation of the site examined was 1,250 m and the slope was 33%. Upper level canopy cover was only 20%. Shrub and graminoid cover were 40 and 60%, respectively. Shrubby Cinquefoil (Potentilla fruticosa) and buffalo-berry were the dominant shrubs and pinegrass and kinninkinnic (Arctostaphylos uva-ursi) were common in the understory.

Bighorn sheep were observed in the Abies lasiocarpa /Carex geyeri habitat type once. The site examined was within the Ten Lakes Scenic Area (TLSA) at an elevation of 2,012 m. It was located on coarse avalanche debris at the base of a cliff. Aspect was east and slope was 67%. Gravel and rock made up 40% of the ground cover. Subalpine fir and Engelmann spruce produced 50% upper level canopy cover. Prickly currant (Ribes lacustre) was the only shrub present.
Elliptic-leaved penstemon (*Penstemon ellipticus*) and strawberry (*Fragaria virginiana*) were common in the undergrowth.

The single bighorn observation within the *Abies lasiocarpa*/*Vaccinium caespitosum* habitat type was on a south facing ridge within the TLSA at an elevation of 2,073 m. Slope of the site was 77%. The 20% upper level canopy cover contained subalpine fir and whitebark pine. Subalpine fir seedlings and buffalo-berry made up the mid-level canopy. Dwarf huckleberry and beargrass were the common ground cover.

The lone observation site within the *Abies lasiocarpa*/*Xerophyllum tenax* habitat type was located on the south facing slope of St. Clair Peak at an elevation of 2,073 m. Slope of the site was 73%. Upper level canopy cover was 50% and made up of subalpine fir and whitebark pine. The undergrowth of the site contained globe huckleberry, juniper, beargrass, and strawberry.

The *Pinus albicaulis*/*Abies lasiocarpa* habitat type occurred throughout the TLSA at elevations from 2,012 to 2,256 m. Slope within this type was from 26 to 125% and aspect was predominantly south to west. It occurred on ridge tops and mountain slopes. Rock and gravel made up 0 to 60% of the ground cover. Upper level canopy cover ranged
from 10 to 70% on the sites examined. Common juniper, huckleberry, and prickly currant were commonly found in the mid-level canopy. Beargrass, spotted saxifrage (*Saxifraga bronchialis*), and mountain penstemon (*Penstemon montanus*) were typically included in the lower level canopy.

The *Larix lyallii/Abies lasiocarpa* habitat type was located at elevations greater than 1,981 m within the TLSA. Aspect ranged from northwest to northeast and slope was between 40 and 85%. It occurred on ridgetops, cirque walls and mountain slopes. Upper level canopy cover was 10 to 50% and was made up of alpine larch, whitebark pine and subalpine fir. Sites with this habitat type contained from 30 to 50% gravel and rock ground cover. The most common shrubs were whortleberry and prickly currant. The ground cover vegetation included woodrush, Sitka valerian (*Valeriana sitchensis*), and cushion buckwheat (*Eriogonum ovalifolium*).

The Scree habitat type occurred throughout the TLSA on all aspects. Elevation of this type ranged from 1,859 to 2,225 m and slope was from 0 to 160%. The dominant lifeform of vegetation on this type ranged from herbaceous to coniferous. Total tree canopy cover was 40% or less on sites visited and made up of alpine larch, whitebark pine, and subalpine fir. Total shrub cover ranged from 0 to 60% and included a variety of shrub species. The lower level
canopy also was extremely variable, but dominated by forbs. Gravel and rock made up 30 to 80% of the ground cover on the sites visited.

**ECOLOGICAL LAND UNITS (ELU)**

Craighead et al. (1982)

The Dry Forb Grassland ELU was encountered throughout the TLSA at elevations from 1,951 to 2,286 m. Aspect of the sites where this type was encountered ranged from northeast to southwest and slope was between 50 and 100%. The designation describes those upland areas dominated by forb cover, yet containing some graminoid cover. Total tree canopy cover was less than 20%. Total forb canopy cover ranged from 20 to 70%, the most common species being beargrass, fawn lily (*Erythronium grandiflorum*), buckwheat, paintbrush (*Castilleja miniata*), and penstemon.

The Parent Rock ELU was common within the TLSA. Slope of this type was 50 to 200%. It was generally found on northwest to southwest aspects and elevations of sites used by bighorn sheep were from 2,012 to 2,256 m. Locations assigned this designation were a bare rock cliff face, with a canopy cover of rooted vascular plants less than 10%.

The Ridgetop Glade ELU was seen on ridgetops at elevations greater than 2,000 m. The aspect was northeast to southeast and slope was 60-65%. Locations assigned this classification occurred in the linear herbaceous areas that
occur along ridgetops between the end of the forest cover and the cliff face. Tree and shrub canopy cover was 20% or less. Herbaceous ground cover was dominated by forbs.

The Slab Rock Steps ELU was common within the TLSA at elevations of 2,012 to 2,194 m. Aspect ranged from east to south and slope varied from 35 to 132%. This ELU was assigned to those sites that had some soil development over a rock substrate. Due to the presence of soil, most sites contained scattered subalpine fir, Engelmann spruce, or whitebark pine. Mid-level canopy cover was 20% or less on all sites within this unit and maximum forb and graminoid cover was 50%. Beargrass, arrowleaf groundsel, and round-leaved alumroot (*Heuchera cylindrica*) were the most common ground cover species.

The Snowslide ELU was located on a south facing ridge in the TLSA. The slope of the sites used by sheep was from 60 to more than 100% and the elevation was from 1,951 to 2,073 m. This designation was used to further define areas within the scree habitat type. Shrubs, including thimbleberry (*Rubus parviflorus*) and mountain maple. Total tree canopy cover was less than 20% on those sites used by sheep. The lower level canopy was extremely variable, but usually included beargrass and elk sedge. Bare ground, gravel and rock usually accounted for more than 50% of the ground cover.
APPENDIX E

BIGHORN SHEEP CAPTURED DURING TRAPPING OPERATIONS ON THE PHILLIPPS CREEK WINTER RANGE, 1992.
<table>
<thead>
<tr>
<th>Date Captured</th>
<th>Sex</th>
<th>Age</th>
<th>Ear-tag Number</th>
<th>Trans. Freq. (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/22/92</td>
<td>female</td>
<td>0.5</td>
<td>64</td>
<td>N.A.</td>
</tr>
<tr>
<td>2/22/92</td>
<td>male</td>
<td>2</td>
<td>67</td>
<td>N.A.</td>
</tr>
<tr>
<td>2/22/92</td>
<td>male</td>
<td>2</td>
<td>75</td>
<td>N.A.</td>
</tr>
<tr>
<td>2/22/92</td>
<td>male</td>
<td>2</td>
<td>66</td>
<td>153.030</td>
</tr>
<tr>
<td>2/22/92</td>
<td>male</td>
<td>3</td>
<td>69</td>
<td>153.010</td>
</tr>
<tr>
<td>2/22/92</td>
<td>female</td>
<td>2</td>
<td>63</td>
<td>153.060</td>
</tr>
<tr>
<td>2/22/92</td>
<td>female</td>
<td>2</td>
<td>72</td>
<td>153.070</td>
</tr>
<tr>
<td>2/22/92</td>
<td>female</td>
<td>4</td>
<td>71</td>
<td>153.100</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>0.5</td>
<td>55</td>
<td>N.A.</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>0.5</td>
<td>68</td>
<td>N.A.</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>0.5</td>
<td>70</td>
<td>N.A.</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>0.5</td>
<td>102</td>
<td>N.A.</td>
</tr>
<tr>
<td>3/11/92</td>
<td>male</td>
<td>2</td>
<td>74</td>
<td>153.040</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>2</td>
<td>31</td>
<td>153.050</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>2</td>
<td>73</td>
<td>153.110</td>
</tr>
<tr>
<td>3/11/92</td>
<td>female</td>
<td>4</td>
<td>65</td>
<td>153.080</td>
</tr>
</tbody>
</table>
APPENDIX F

DATA USED TO CALCULATE POPULATION ESTIMATES FOR PHILLIPPS CREEK BIGHORN SHEEP HERD, 1992.
<table>
<thead>
<tr>
<th>M</th>
<th>Number of marked animals in the area</th>
<th>m</th>
<th>Number of recaptured animals in each sample</th>
<th>n</th>
<th>Number of animals in each sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>4</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>4</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>4</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

MOVEMENTS OF 9 RADIO-COLLARED BIGHORN SHEEP, PHILLIPPS CREEK HERD, 1992

* = radio location
• = observation
-•-- = home range of herd
* = radio location
* = observation
--- = home range of herd

* = radio location
• = observation
- • - • = home range of herd

* = radio location
* = observation
- o -- = home range of herd

* = radio location
• = observation
-••- = home range of herd

* = radio location
• = observation
- - - - = home range of herd
* = radio location
• = observation
- • - = home range of herd

- = radio location
- = observation
- - - = home range of herd

* = radio location

= observation

--- = home range of herd