Sulphur / 8 Mile Stone's Sheep Project

The SCEK Steering Committee wishes to acknowledge the efforts of the two volunteer committees that supported the Sulphur / 8 Mile Stone's Sheep Project.

North Peace Stone's Sheep Sustainability Steering Committee—an independent working group of industry, government, resource and conservation sector representatives providing direction and oversight of the research program and subsequent management recommendations:

- Bill Oppen (Chair)
- Jason Holland—North Peace Rod and Gun Club (Co-Chair)
- Karrilyn Vince—BC Ministry of Forests, Lands and Natural Resource Operations
- Jason Lawson—BC Ministry of Forests, Lands and Natural Resource Operations
- Richard Bader—BC Ministry of Energy and Mines
- Colleen Colwell—BC Ministry of Agriculture
- Nick Baccante—BC Ministry of Forests, Lands and Natural Resource Operations
- Gerry Fox—BC Oil and Gas Commission
- Carl Gitscheff—BC Wildlife Federation
- Sherry Sian—Canadian Association of Petroleum Producers
- Corrine Porter—Kaska Dene First Nations
- Ross Peck—Muskwa – Kechika Advisory Board
- Andy Johnson—Muskwa – Kechika Advisory Board
- Don Roberts—Muskwa – Kechika Advisory Board
- Wayne Sawchuk—Muskwa – Kechika Advisory Board
- Dixie Hammett—Northern BC Guides Association

Stone's Sheep Science Advisory Committee—providing input and peer review of the research program and management recommendations:

- Brian Churchill, R.P.Bio—Chillborne Environmental Consulting (Chair)
- Chris Addison, R.P.Bio—BC Ministry of Forests, Lands and Natural Resource Operations
- Ray Demarchi—Ecodomain Consulting and Guide Outfitters Association of BC
- Randal Glaholt—Biotechnics International Ltd. and Canadian Association of Petroleum Producers
- Dr. Daryll Hebert—Encompass Strategic Resources
- Dr. Katherine Parker—University of Northern British Columbia
- Dr. Helen Schwantje—BC Ministry of Forests, Lands and Natural Resource Operations
- Dr. Dale Seip, R.P.Bio—BC Ministry of Environment
- Conrad Thiessen, R.P.Bio—BC Ministry of Forests, Lands and Natural Resource Operations

The effort of all committee members is commended. Their perseverance, expertise and patience over the life of the project is greatly appreciated. The leadership and flexibility of Bill Oppen and Brian Churchill in chairing the committees and adapting to schedule changes and issues were tremendous assets in assisting this project to completion. Both committees added tremendous value to the project for which the SCEK Steering Committee is extremely grateful.

SCEK Steering Committee
March, 2012

Sulphur / 8 Mile Stone's Sheep Project

A multi-stakeholder research and planning initiative in the Muskwa-Kechika Management Area, northern British Columbia

Stone's sheep population dynamics and habitat use in the Sulphur / 8 Mile oil and gas pre-tenure plan area, northern British Columbia, 2005 – 2010

Research Summary & Management Considerations, January 2012

Preface

The Sulphur / 8 Mile Stone's Sheep Project is a multi-stakeholder research and planning initiative developed as a result of oil and gas pre-tenure plan requirements in the Muskwa - Kechika Management Area (M-KMA) of northern British Columbia. In the M-KMA, pre-tenure plans are required for areas with high oil and gas resource development potential. These plans define resource management direction and results-based requirements that become legally-binding upon oil and gas tenure proponents.

The North Peace Stone's Sheep Sustainability Steering Committee was established as an independent working group of industry, government, resource, and conservation sector representatives to address commitments made in the pre-tenure planning process. With support from a Science Advisory Committee, the Steering Committee was charged with developing a Stone's sheep research program and providing management recommendations to the M-KMA Advisory Board and the BC Government. Since 2006, the research was managed and implemented by Synergy Applied Ecology (SAE), an independent firm working on behalf of the committees under multiple agreements with project funding partners. Local and traditional knowledge of Stone's sheep ecology was compiled by Ross Peck and the Kaska Dene Institute. Their results are included in this report to provide a comprehensive summary of project results.

Research completed in 2005 – 2010 focused on understanding Stone's sheep population demographics and distribution, adult female survival and mortality patterns, habitat use patterns, and herd health. In 2008, the project expanded to study habitat use by adult males.

This summary document highlights primary results and management considerations for discussion at stakeholder workshops in 2012.

Citation Hengeveld, P.E. and J.C. Cubberley. 2012. Sulphur / 8 Mile Stone's Sheep Project: Research summary and management considerations. Synergy Applied Ecology, Mackenzie BC.

Copies of this summary document and the complete technical report are available for download in PDF format:
www.synergyecology.ca/s8msheep

For further information or to request hard copies, contact:
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Acknowledgments

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[1]MFLNRO: BC Ministry of Forests, Lands, and Natural Resource Operations

Project management and research biologists

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Clint Cubberley, R.P.Bio.	Synergy Applied Ecology

Special thanks to the residents of Toad River for their support.

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BC Integrated Land Management Bureau (now MFLNRO[1])	$ 48,600
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BC Ministry of Environment (now MFLNRO[1])	$ 52,000
BP Canada Energy Company	$ 8,000
Dawson Creek Sportsman's Club	$ 2,500
Habitat Conservation Trust Foundation	$ 353,700
Muskwa - Kechika Trust Fund	$ 190,500
Muskwa - Kechika Voted Funds	$ 100,000
North Peace Rod and Gun Club	$ 20,000
Northeast BC Wildlife Fund	$ 15,000
Northern BC Guides Association	$ 20,000
Science, Community and Environmental Knowledge Fund	$ 650,000
TransCanada Pipelines Ltd.	$ 175,000
Wild Sheep Society of BC	$ 10,000

$ 1,755,300 total

Thank you to all of the individuals and organizations that committed their support to this project

Contents

Introduction Background

Stone's sheep are an icon of rugged northern landscapes.

Most of the world's Stone's sheep (*Ovis dalli stonei*) are in British Columbia (BC), Canada. They are native only to northern BC and south-central Yukon, and have social, cultural and commercial value. Despite their tolerance of extreme montane and climatic conditions, many aspects of their ecology render them vulnerable to disturbance impacts.

Strongly driven by nutrition and security considerations, their distribution is associated with patchy habitats that offer adequate forage opportunity in proximity to escape terrain. In winter, deep snow (>30 cm) further restricts their range by reducing access to grass, sedge, moss, lichen, and the leaves of shrubs on which they feed. Range expansion throughout the remainder of the year includes habitual use of mineral licks and seasonal movement corridors between isolated alpine ranges. Wild sheep show high levels of range fidelity annually and have highly structured social organization. These behaviours make populations susceptible to density-dependent and human influences on survival. Landscape changes can affect forage quantity and quality, disrupt movement corridors, restrict seasonal ranges, change inter-species relationships, and influence pathogen or disease profiles. On the other hand, sheep occupy niche habitats, have predictable range use, and can be reliably monitored with repeated census. This offers real and practical opportunities to define integrated management plans that support Stone's sheep and human interests to coexist in a sustainable way.

In northeast BC, the highest densities of Stone's sheep coincide with suitable winter ranges in the eastern foothills of the Rocky Mountains. The eastern foothills also have oil and gas, mineral, and geothermal potential that is of increasing industrial interest. The Muskwa-Kechika Management Area (M-KMA) was designated by the BC Government as a model for world-class integrated resource management. It was established to maintain the wilderness quality, diversity, and abundance of wildlife and ecosystems while allowing resource use and development in areas designated for those purposes. In the M-KMA, pre-tenure plans are required for areas with high oil and gas resource development potential. These plans define resource management direction and results-based requirements that are legally-binding upon oil and gas tenures.

Despite their iconic status as a premier trophy-hunted species in BC, there is little historic information on Stone's sheep population abundance. Evaluation of population trends has been limited to review of harvest statistics and sparse census data. During M-KMA pre-tenure plan discussions in 2004, public advisory groups expressed concern about apparent Stone's sheep population declines regionally and the potential impacts of industrial resource development. This concern was a major driver of the Sulphur / 8 Mile Stone's Sheep Project.

Introduction Research objectives and general methods

The Sulphur / 8 Mile (S8M) Stone's Sheep Project was implemented as a multi-stakeholder collaborative research program to address Stone's sheep ecology and management concerns in the M-KMA's Sulphur / 8 Mile oil and gas pre-tenure plan area (S8M PTP).

The goal was to support long-term sustainability and science-based management of Stone's sheep populations by providing:

- Site-specific data relevant to the pre-tenure plan currently under consideration for amendments.
- Science-based management guidelines for consideration in other M-KMA oil and gas pre-tenure plans.
- Support for development of a science-based regional Stone's sheep management plan.

Research was prioritized to address key knowledge gaps identified during pre-tenure plan public advisory group discussions and literature reviews (see additional resources on page 59). Primary research objectives were to:

- Develop accurate Stone's sheep population estimates and assess demographic trends.
- Identify limiting factors that influence population dynamics.
- Quantify range use and habitat selection to inform site-specific management plans.
- Integrate local and traditional knowledge of Stone's sheep populations with research results.
- Establish baseline herd health parameters for long-term monitoring programs.

Research completed in 2005 – 2010 focused on understanding population demographics and distribution, adult female survival and mortality patterns, habitat use patterns, and herd health. In 2008 - 2010, the project expanded to study habitat use patterns of adult males.

General methods We evaluated population demographics by multiple aerial censuses using mark-resight analyses for population estimates. Census also provided information on population age and sex structure, distribution, and density of sheep, as well as the number of other ungulates on sheep winter ranges. We determined survival rates and mortality patterns by monitoring 124 collared females over 5 years and 17 collared males over 2 years. We determined seasonal habitat use patterns using GPS collars to collect daily location data for 26 adult females and 17 adult males. Baseline health parameters were assessed during capture for collaring, and during necropsies conducted as part of mortality investigations. Local knowledge of Stone's sheep ecology was compiled by Ross Peck from interviews with 26 long-time residents. These included guides, outfitters, hunters, trappers, packers, pilots and biologists who had lived, worked and recreated in the Toad River area. Their experience in the study area ranged from 1-55 years (average 17.5 years). Historical, archival, and literature sources were examined and information specific to the S8M area was collated and summarized. Kaska Dene traditional knowledge was compiled by Viktor Kisoun from interviews with local members of the MacDonald family.

Study area Exceptional wilderness, wildlife, and resource values

The study area is centered roughly 150 km west-northwest of Fort Nelson BC, within the northeast corner of the M-KMA. The boundary is defined by the Alaska Highway to the south and west, the Liard River Corridor to the north, and the S8M oil and gas pre-tenure plan boundary to the east. The study area includes the communities of Toad River Post and Muncho Lake, most of BC Wildlife Management Unit 7-54, and all of the S8M oil and gas pre-tenure plan area.

Much of the area is undeveloped with motorized vehicle access limited to routes designated by the M-KMA Act. The only backcountry road access in the study area is the Nonda Microwave Tower Rd at Alaska Highway Mile 409 (km 658), approximately 10 km west of Toad River Post. The Nonda Tower road meets the upper 8 Mile Creek corridor.

Commercial and non-commercial recreation opportunities include guide-outfitter tenures, trapping tenures, transporters, hunting, fishing, hiking, camping, river boating, horseback riding, and wildlife viewing.

Cultural heritage includes historic and current Stone's sheep harvest by the Fort Nelson (Treaty 8 signatory) and Kaska Dena First Nations, as well as cultural sites in the study area. There is an historic Kaska Dena gravesite near the confluence of 8 Mile Cr and the Toad River. Contact the Dena Kayeh Institute of Lower Post BC for details.

The study area includes portions of 5 **provincial parks and protected areas**: Muncho Lake Park; Liard River Corridor Park; Toad River Hot Springs Protected Area; Stone Mountain Park; and Northern Rocky Mountains Park (Wokkpash Recreation Area).

The diversity of wildlife includes wolf (*Canis lupus*), grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), moose (*Alces alces*), Rocky Mountain elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), caribou (*Rangifer tarandus*), mountain goats (*Oreamnos americanus*), and Stone's sheep.

Industrial resource interests include moderate to high oil and gas potential, low to moderate mineral potential, and some geothermal potential. Oil exploration surveys have occurred in the area since at least 1968. Forestry operations have been limited to seismic lines and trails, despite the presence of 135 km^2 of merchantable timber. The Alaska Natural Gas Pipeline Project has two proposed routes[1] relevant to the study area. One proposed route follows the highway south from the Liard River crossing, while the other route follows the Liard River east before turning south and passing through the northern portion of the S8M High Elevation Pre-Tenure Plan Zone.

[1]www.emr.gov.yk.ca/oilandgas/ahpp.html and www.thealaskapipelineproject.com

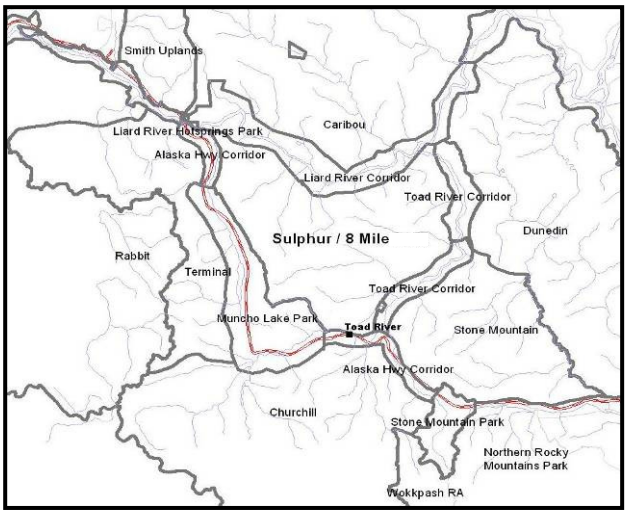


FIGURE Parks and resource management zones identified in the Fort Nelson Land Use Plan.

Study area Oil and gas pre-tenure plan zones

The project study area included the complete S8M PTP boundary, with particular **management focus on the High Elevation Zone where tenures are expected to be available for disposition in 2012.** The complete S8M PTP area extends across all but the Muncho Lake and Stone Mountain Provincial Parks portions of the study area. The PTP area is divided in two by the boundary between moderate (western half) and high (eastern half) oil and gas potential.

The eastern half was further divided along topographic boundaries to identify a mountainous High Elevation Zone and the foothills Low Elevation Zone. **Only the High Elevation Zone is currently under consideration for pre-tenure plan amendments**. The S8M PTP approved in May 2004 applies to tenures in the Low Elevation Zone. Planning processes and opportunities for oil and gas tenure in the western half of the S8M PTP will be addressed when a business case is made for development of the moderate mineral potential.

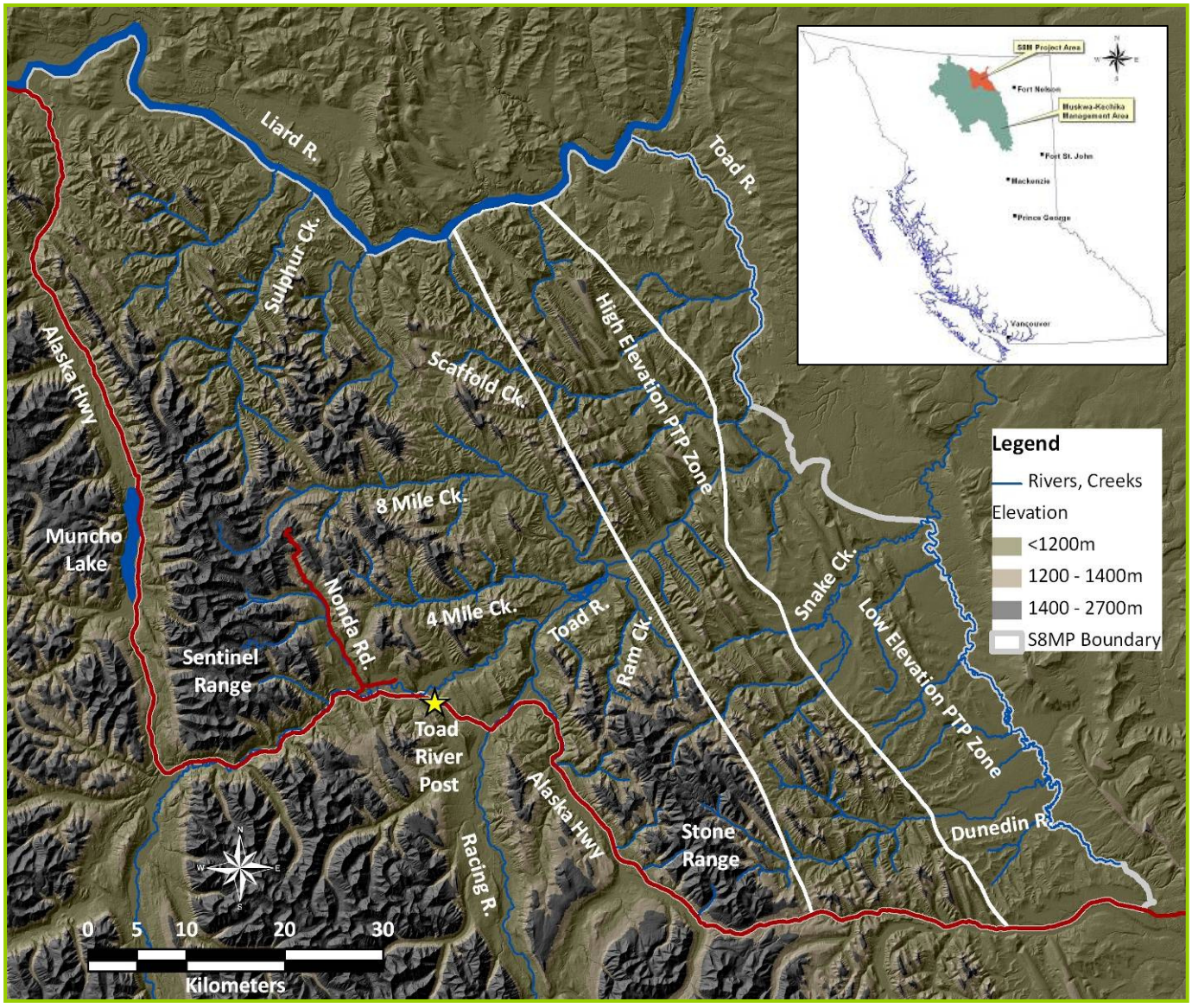


FIGURE Sulphur / 8 Mile Stone's Sheep Project study area. The boundary is defined by the Alaska Highway to the south and west, the Liard River Corridor to the north, and the S8M PTP boundary to the east.

Study area Stone's sheep populations

While the S8M PTP High Elevation Zone was a focal point for the project, the actual study area was defined by the movements of Stone's sheep within and adjacent to the complete S8M pre-tenure plan area.

Stone's sheep in the study area were distributed across two distinct mountain ranges separated by the Toad River. Results are reported for the Sentinel and Stone areas separately due to observed differences in population ecology.

- Sheep north of the Toad River are identified as the **Sentinel population**.
- Sheep south of the Toad River are identified as the **Stone population**.

TABLE Study area characteristics

Study subunit	Total area	Elevation range	Alpine (≥ 1,400 m)
Sentinel area	2,460 km^2 (58.1%)	450 – 2,350 m asl	579 km^2 (23.5%)
Stone area	1,777 km^2 (41.9%)	450 – 2,100 m asl	257 km^2 (14.5%)
Total study area	4,237 km^2	450 – 2,350 m asl	836 km^2

PHOTO The rugged Sentinel Mountain Range in the northeast portion of the study area is the northern tip of the Rocky Mountains. Visible at left is Muncho Lake along the Alaska Highway. The Sentinel Mountain Range, including adjacent Mount McLearn, Ewe Mountain, and Toad Mountain, is dominated by steep and rugged bedrock at upper elevations.

PHOTO The Stone Mountain Range in the southeast portion of the study area, is characterized by rounded peaks and increased vegetation at upper elevations. The S8M PTP High Elevation zone includes subalpine habitat visible in the photo foreground.

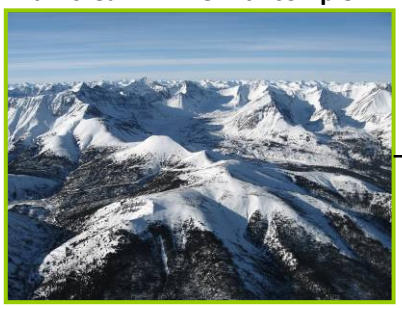
Study area Getting oriented

Trout River mineral licks

Mt Prudence – Mt Rothenburg

Winter range along upper Ram Cr

Mt McLearn – Ewe Mtn complex



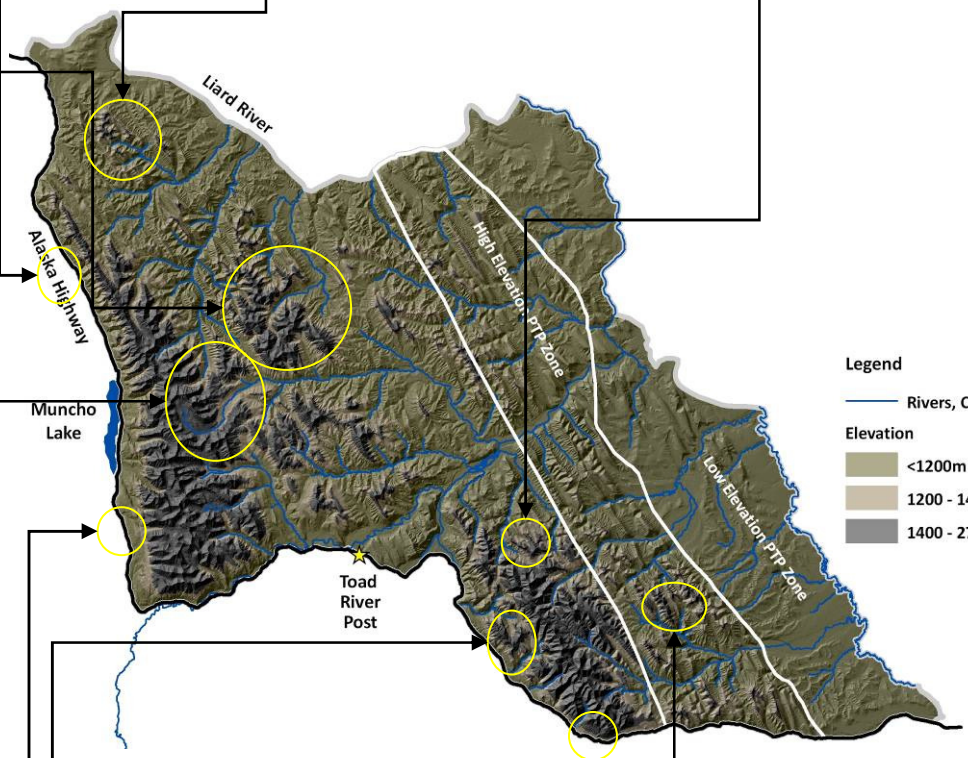
Nonda Tower, Upper 8 Mile Cr and Fire Mountain

Petersen Canyon at the Alaska Hwy

Winter range at One Fifteen Cr

The 'Rock Cut' on the Alaska Hwy

Ram Mtn complex



Study animals Capture and radiocollaring

Two types of motion-sensitive collars were used to study population dynamics and habitat use.

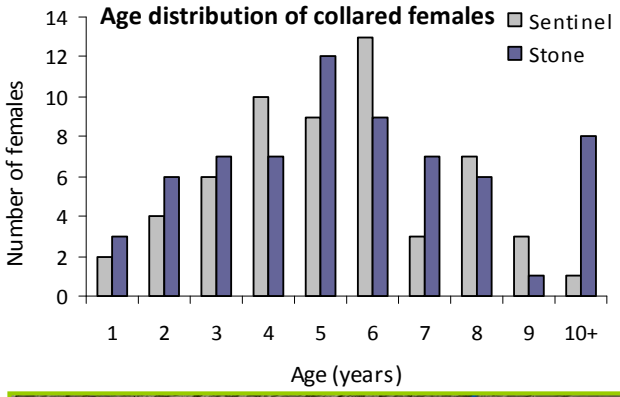
- Regular monitoring of Very High Frequency (VHF) radiocollar signals provide data on sheep survival rates and causes of mortality.
- Global Positioning System (GPS) collars store animal location data at regular intervals, enabling detailed habitat use analyses.

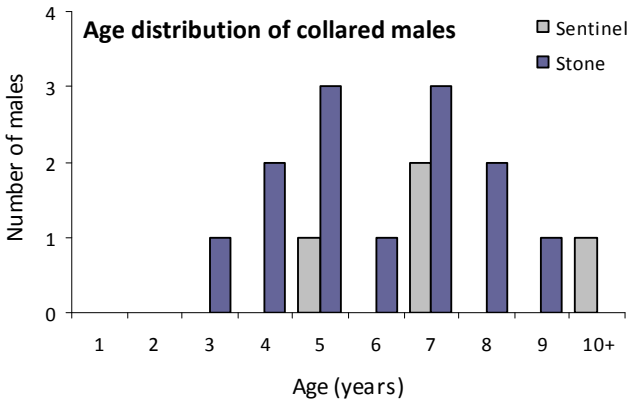
124 collared females were monitored in 2005 – 2010

- 58 in the Sentinel population
- 66 in the Stone population
- 35% of females in each population
- Average age 6.4 yrs, range 2 – 13 yrs
- 40,006 GPS locations for 26 females

17 collared males were monitored in 2008 – 2010

- 3 in the Sentinel population
- 14 in the Stone population
- 2% of Sentinel males and 10% of Stone males
- Average age 6.2 yrs, range 3 – 11 yrs
- 18,929 GPS locations for 17 males





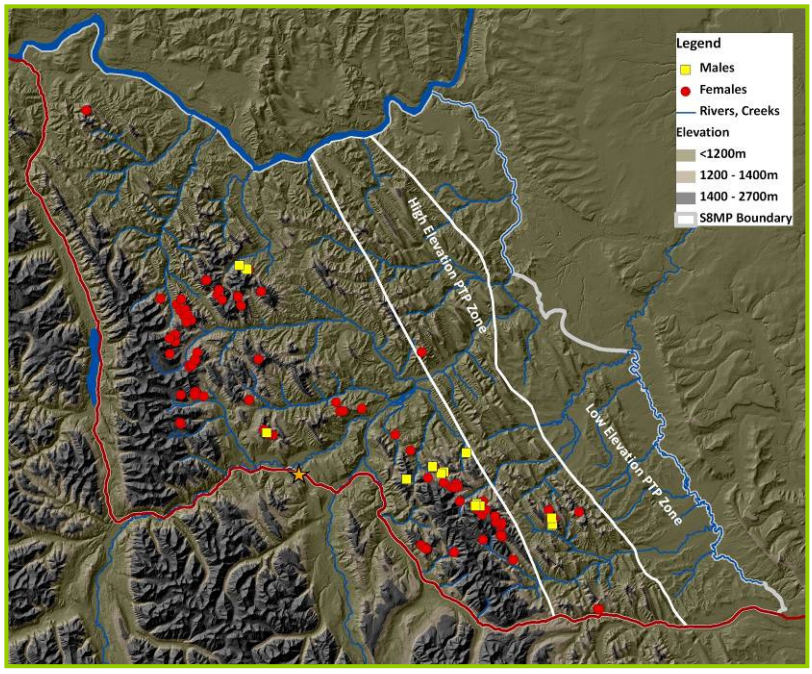


FIGURE (LEFT) Sheep capture locations, winters 2005 - 2009. Priority areas for all sheep captures targeted the High Elevation Zone, but included all of the Sentinel and Stone ranges within the study area.

Study animals Capture and radiocollaring

PHOTO Female S080 was captured and fitted with a VHF radiocollar on April 3 2006, when she was 5 yrs old. She was still alive when monitoring ended in July 2010.

Methods - Capture and collaring Sheep were net-gunned from a helicopter. The risk of injury to animals and crew was mitigated by limiting helicopter pursuit time, minimizing handling time, and conducting capture work only when weather and terrain conditions were suitable for safe and efficient captures. Coloured eartags were applied to females to enable visual identification and monitoring of individuals. Biological samples were collected, body measurements recorded, collars applied, and sheep were released. All field work was conducted under BC Government Wildlife Act research permits authorizing work in the S8M study area, and in accordance with applicable BC Resource Inventory Standards Committee guidelines. All capture-related activities and animal handling were conducted in accordance with the Canadian Council on Animal Care guidelines for the care and use of wildlife.

Population dynamics Population estimates

- The S8M study area supports nearly 18% of northeast BC's Peace Region Stone's sheep.
- Total counts and population estimates are consistent with limited historic data.

In winter 2006/2007, censuses were conducted in December (rut) and March (late winter).

- Census covered all alpine areas (≥1,400 m elevation, approximate treeline).
- Census covered both Sentinel and Stone populations.
- Seventy-seven collared females were available for mark-resight estimation.

In winter 2008/2009, census was conducted in February (early winter).

- Census covered all areas ≥1,200 m elevation, because 80% of sheep groups located by telemetry outside of the census area in winter 2006/2007 were between 1,200 m and 1,400 m elevations.
- Census area was limited to the Stone population, where sufficient numbers of collared males (10) and females (36) were available for mark-resight analyses.

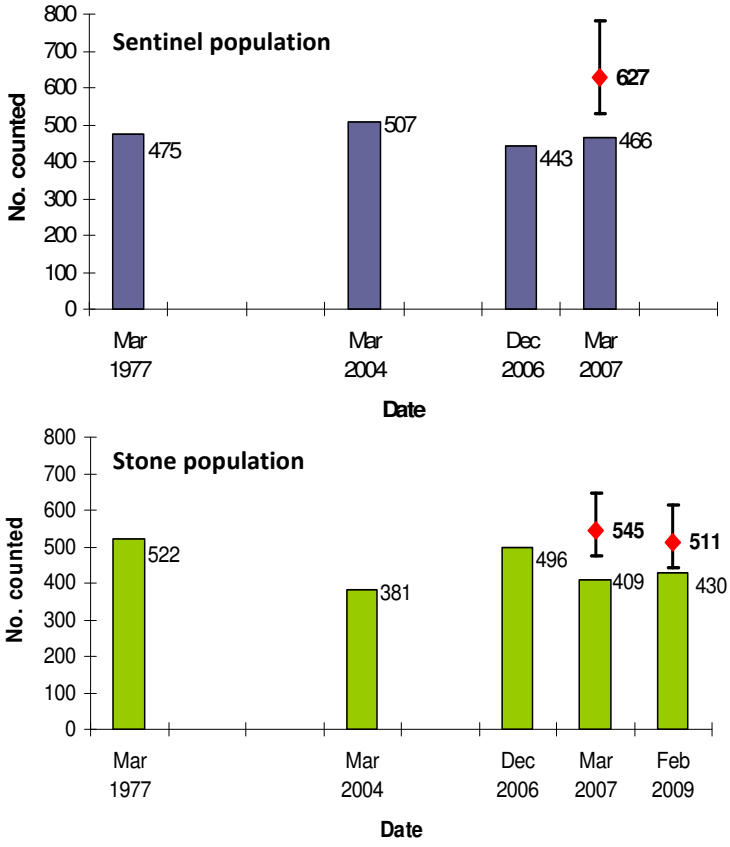
Animals marked with radiocollars provide an opportunity to conduct mark-resight analyses for population estimation. Mark-resight confirms the proportion of collared sheep seen during a census and improves confidence in population estimates.

Overall, census detects 70 – 90% of sheep. Detection of collared females varied between populations and censuses but overall was better in December 2006 (83.5%) than in March 2007 (71.9%) or February 2009 (73.5%). March 2007 was a month of exceptional snowfall, following a cold and dry January. In winter 2008/2009, there was significant early accumulation of snow, with moderate March snowfall.

In February 2009, detection of collared males 4 – 10 yrs old (87.5%) was higher than for collared females >2yrs old (73.5%). Results from all 3 censuses revealed habitat use differences by young males that influenced their detection during census. Detection of young males in the Stone population was lower than for females and older males because younger males were more likely to use subalpine areas in deep snow winters. We did not find the same result in the Sentinel population, likely because population density was lower and winter ranges less limited.

Survey timing has implications for sheep sighting probabilities and population estimation. A greater total number of sheep and a greater proportion of collared sheep were observed in the alpine in December 2006 versus March 2007. Population census during the end of the rut is more effective than late winter census.

Population dynamics Population estimates



FIGURES Total counts and population estimates ◆ for S8M sheep populations.

Estimates are based on the proportion of collared sheep observed during census. 95% confidence intervals are given for the estimates.

Winter 2006/2007 estimates incorporate results from both December and March censuses.

The February 2009 census was limited to the Stone population only.

Minimum count of 939 sheep.

- **443 Sentinel population**
- **496 Stone population**

Estimate of 1200 sheep.

- **95% confidence interval of 1,007 – 1,429 sheep**
- **650 Sentinel population**
- **550 Stone population**

Total count of 997 sheep in March 1977 is within the 95% confidence intervals of our population estimate. The minimum number of 939 sheep observed during this study is 17.9% of 5,244 sheep counted in multiple inventories across the Peace region in 2007 – 2009.

Local knowledge – Population trends "The construction of the Alaska Highway in 1942 brought vehicular access to the area. From a few hunters initially, the area was attracting Stone's sheep hunters from throughout BC and around the world by the late 1960s. A number of guide outfitters offering Stone's sheep hunts became established in the Toad and Racing river areas through the 1950s and 1960s. Sheep numbers were thought to be relatively stable through the 1970s, with possible declines toward the end of the decade. Analysis by BC Fish & Wildlife biologists in the early 1980s suggested declining trends in Stone's sheep and other ungulates. Predator management and habitat enhancement programs were conducted in various areas throughout the northeast through the 1980s and 90s including the S8M area. There was a general consensus that sheep populations were on a downward trend in the early 1980s, but responded positively to management activities, and populations were thought to peak in the early to mid 1990s. By the mid 2000s, Stone's sheep populations were felt to be stable at best in the S8M area". [Excerpt from Peck 2009]

Population dynamics Demographic structure

Census results revealed demographic differences between Sentinel and Stone populations.

Sentinel population

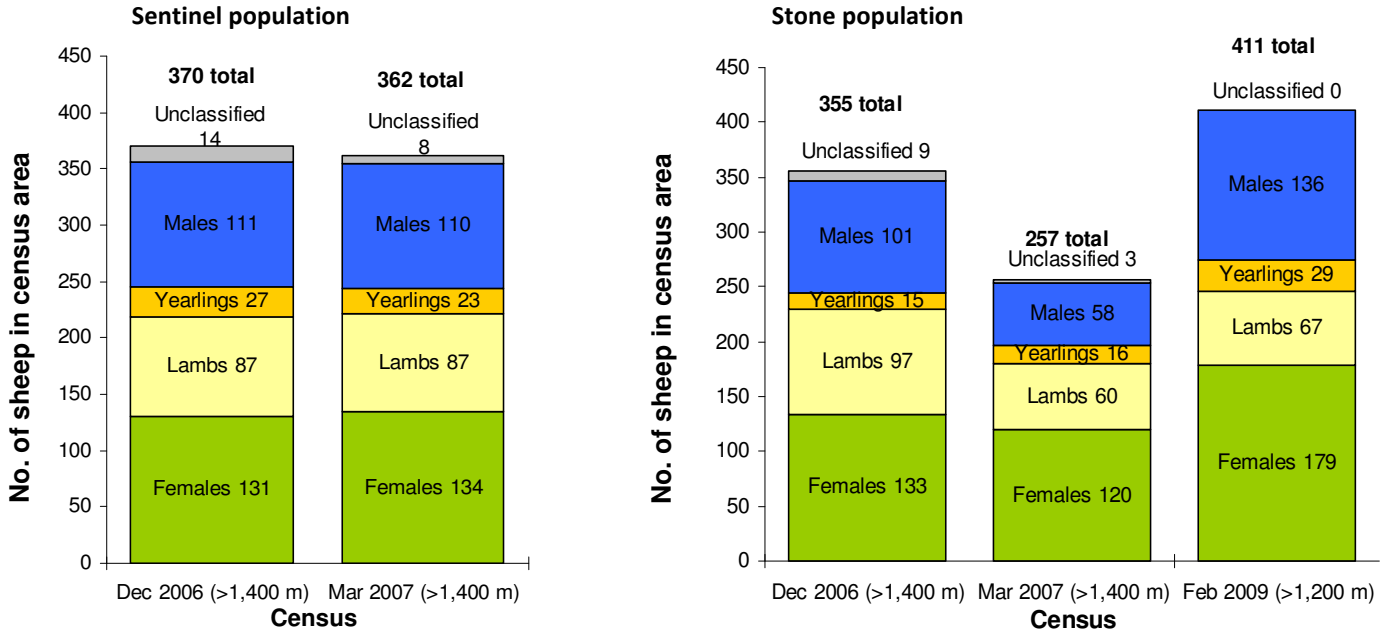
- Counts of all age - sex classes were consistent between December and March censuses.
- High male to female ratios and similar group composition between rut (December) and winter (February – March) censuses suggest most males were sighted and they occupied the same ranges as females.

Stone population

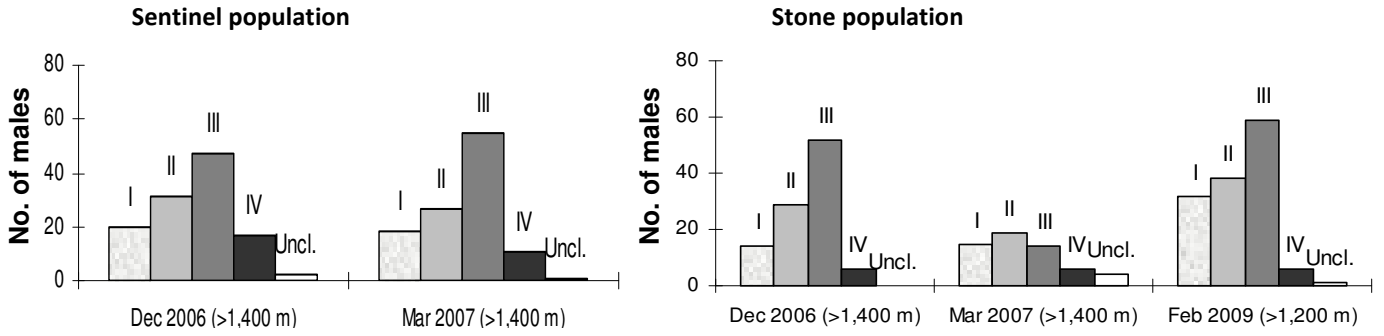
- Similar numbers of females, but less than half the number of young males above treeline in March compared to December of the same winter.
- Similar age - sex class ratios in December 2006 and February 2009 suggest significant mortality was not the reason for fewer young males observed in March 2007. This was supported by survival rates and habitat use data.
- Compared to December census results, both group sizes and site-specific density increased in the Stone Range in late winter.
- Young males in the Stone population use lower elevation areas near treeline (1,200 – 1,400 m) more extensively than females and older males when population density increases on winter ranges.

PHOTO Large sheep group observed during census.

Population dynamics Demographic structure



FIGURES Total count of Sentinel and Stone population sheep observed in the census areas.



FIGURES Age class distribution of male sheep in the Sentinel and Stone populations during census of high elevation ranges. Census area in December 2006 and March 2007 was ≥1,400 m elevation; census area in February 2009 was ≥1,200 m.

Age classifications of male sheep are grouped by degree of horn curl in relation to the bridge of the nose, as class I (¼ curl), class II (½ curl), class III (¾ curl) and class IV (full curl). Uncl. = unclassified.

Population dynamics Pregnancy rates and lamb recruitment

- Pregnancy rates and lamb recruitment indicate good population productivity.
- No difference in pregnancy rates between Sentinel and Stone populations, but overwinter lamb survival was lower in the Stone population.

- Pregnancy rate of 88% is within the expected range for thinhorn sheep and indicates good population productivity.
- No difference in pregnancy rates between Sentinel and Stone populations, but overwinter lamb survival was lower in the Stone population.
- With annual survival rate of 70 – 90% for adult females, late winter ratios of at least 35 lambs to 100 adult females will support a stable or growing population.

PHOTOS Female S024 (left) was captured and fitted with a VHF collar on March 29 2005, when she was nearly 4 yrs old. She is seen here nursing a lamb in July 2006. She was killed by wolf predation in February 2007.

A 1 month old lamb (right).

TABLE Estimated Stone's sheep lamb survival to 6 and 9 months of age calculated based on March 2006 pregnancy rates and observed lamb to female ratios for the Sentinel and Stone populations.

Date	Recruitment parameters	Sentinel	Stone
March 2006 captures	Pregnancy rate (76 females tested)	89%	88%
December 2006 census	Lamb to adult female ratio	67%	73%
	Lamb survival to 6 mths	75%	83%
March 2007 census	Lamb to adult female ratio	64%	51%
	Lamb survival to 9 mths	72%	58%
December 2006 - Mar 2007	Overwinter lamb survival	96%	70%

Population dynamics Population density

- Density-dependent effects on population dynamics were observed in the Stone population, where sheep density on alpine areas was nearly double that of Sentinel sheep.
- Sentinel sheep have not yet reached the threshold at which density-dependent effects influence population dynamics.

Differences in Sentinel and Stone population dynamics reflect differences in population densities on alpine winter ranges (>1,400 m elevation).

Sentinel population

- Average density of sheep on alpine ranges was 0.64 sheep/km^2 in December and 0.62 sheep/km^2 in March.
- The highest site-specific alpine winter range densities were 1.5 – 1.7 sheep/km^2 on the Mount McLearn – Ewe Mountain complex and adjacent Fire Mountain along upper 8 Mile Cr.

Stone population

- Average density of sheep on alpine ranges was 1.38 sheep/km^2 in December 2006 and 1.00 sheep/km^2 in March 2007.
- One isolated 3.5 km^2 subalpine ridge along upper Ram Creek supports 20% (87 of 430 sheep counted) of the Stone population in winter, suggesting site-specific density of 25 sheep/km^2. We did not find the same level of concentration on distinct winter ranges or isolated ridges anywhere else in the study area.
- Density on winter ranges at the Ram Mountain complex in the S8M PTP High Elevation Zone and at the 115 Cr headwaters was roughly 3.5 – 4 sheep/km^2.

Map of winter distribution provided on pages 39 and 40.

Population density is an important aspect of ungulate ecology because of its influence on population dynamics. Density-dependent effects are changes in population dynamics in relation to population abundance and habitat carrying capacity. Determining carrying capacity and defining thresholds between low and high densities is difficult, but population responses to changes in density are often easily identified. Theoretically, density-dependence is a way for populations to self-regulate their size, in order to optimize per capita resource use. In the absence of other limiting factors, sheep populations may increase in density until high resource competition reduces the amount of available forage per individual. This can negatively affect individual body condition and population reproductive rates.

Population dynamics Adult survival

- Average annual survival rate of females is 80%. Survival rate of males is 83%.
- No difference in survival rates for Sentinel and Stone population females.
- Higher lamb survival offsets lower adult female survival.

▪ Annual survival rate for adult females was 80% (95% confidence interval of 76% - 83%), with no difference between populations.

▪ Our limited data on adult males suggest 83% (69% – 95%) survival rate, equivalent to adult female survival. This is reflected in high male to female ratios observed during population census.

▪ Survival rate of adult females is 5 – 10% lower than reported for other ungulates, including bighorn sheep, mountain goat, roe deer, and ibex. Higher adult survival rates for adult females and lower juvenile survival is more typical of other ungulates.

▪ Survival rate of adult males is similar to rates reported for other ungulates.

We observed a pattern of survival and recruitment that appears to be strongly driven by spring weather patterns. We found a strong negative correlation between survival of adult females and May precipitation at the end of each monitoring year. More than 40% of adult females mortalities we investigated occurred in late winter, particularly April and May. At this time of year, pregnant females are constrained by several months of limited forage and increasing metabolic demands as pregnancy nears full-term. In contrast, other studies have reported that spring precipitation has a positive influence on newborn survival, lamb mass gain over the summer, and overwinter survival to 1 yr of age.

We found higher lamb survival (0.64 lambs per female in March 2007) in the winter following a year of high female mortality (33%), and more moderate lamb survival (0.37 lambs per female in February 2009) in the winter following a year of low female mortality (10%). In the absence of other limiting factors, both late winter ratios are sufficient to compensate for adult female mortality. If this is consistent over the long-term, the demographic effect of high adult female mortality in years with wet spring weather may be offset by positive population recruitment the following spring.

Population dynamics Adult survival

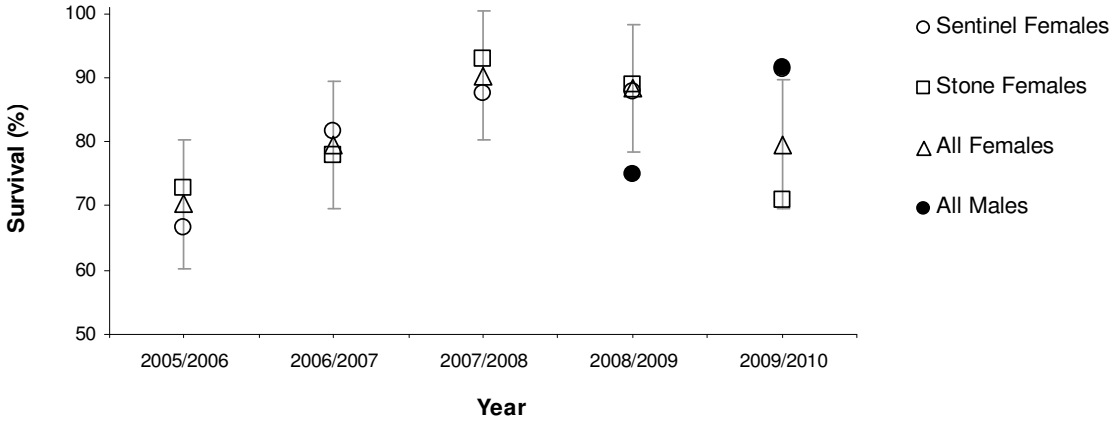


FIGURE Annual survival of 124 female and 17 male Stone's sheep. Confidence intervals (95%) are displayed for all females combined.

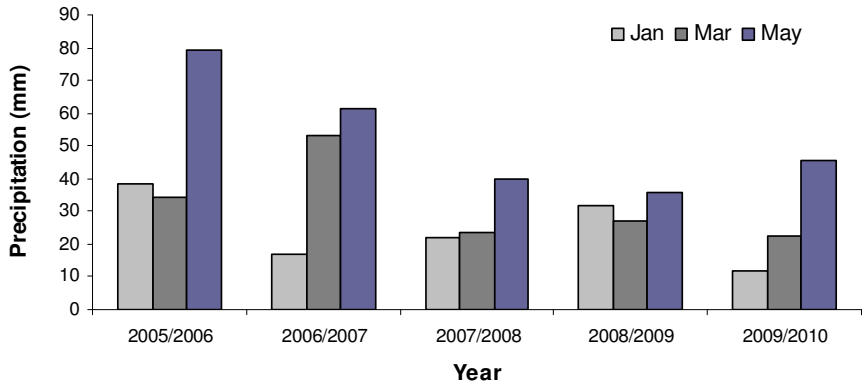


FIGURE There is a strong negative correlation between female survival and high precipitation in May. January and March precipitation are shown for comparison.

Methods – Adult survival rates Collared sheep were located regularly by aerial telemetry done from high altitudes to minimize disturbance to sheep. When collar signals indicated a sheep mortality, site investigations were conducted as soon as possible to assess cause of death. We estimated natural survival rates using a standard method known as the Kaplan-Meier staggered entry analysis, measuring annual survival from June 15 of one calendar year to June 15 of the next year. A total of 68 deaths (61 female and 7 male) were observed during the study. Sheep were excluded from survival analyses if they died before June 15 of their first monitoring year or after June 15 2010, died due to vehicle collisions, or were hunted.

Influence of weather on spring mortalities – We regressed Environment Canada climate data for average monthly temperature, total precipitation, snowfall and rainfall in winter months (November through May) against annual sheep mortality rates.

Population dynamics Natural mortality patterns

- More than 40% of adult female mortalities occur in late winter, particularly April and May.
- Primary cause of death varies between Sentinel and Stone populations.
- Snow conditions, falls, injuries, and health-related factors combined account for more deaths than predation.

- Mortality site investigations confirmed natural causes of death for 48 female and 4 male sheep.
- Poor body condition was more significant in Stone population females.
- Avalanches accounted for a greater proportion of female deaths in the Sentinel population.
- Natural mortalities of 4 males were attributed to avalanche (2), poor body condition in late winter (1), and fall/injury (1).
- Two males and 3 females died in avalanches in winter 2008/2009, when avalanche risk was unusually high across BC.

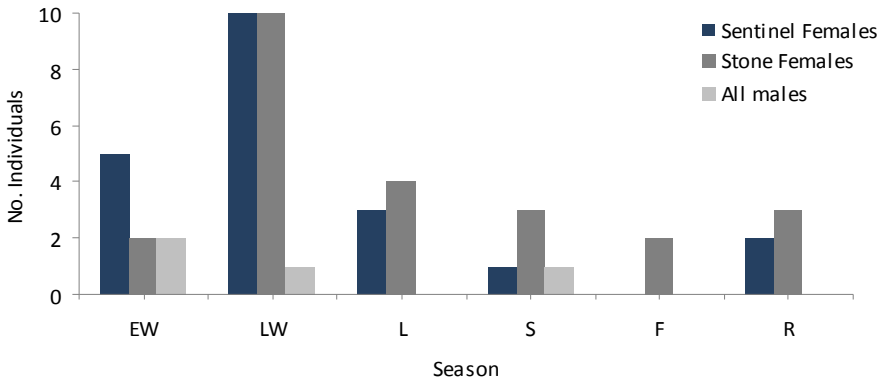
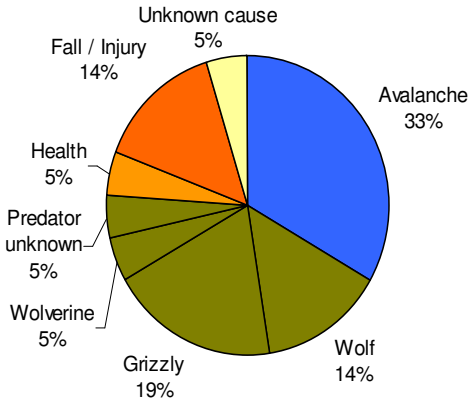


FIGURE Seasonal timing of sheep mortalities due to natural causes: Early winter (EW) January 1 – February 28; late winter (LW) March 1 – May 14; lambing (L) May 15 – June 14; summer (S) June 15 – July 31; fall (F) August 1 – September 30; rut (R) October 1 – December 31.

Population dynamics Natural mortality patterns

Sentinel population



Stone population

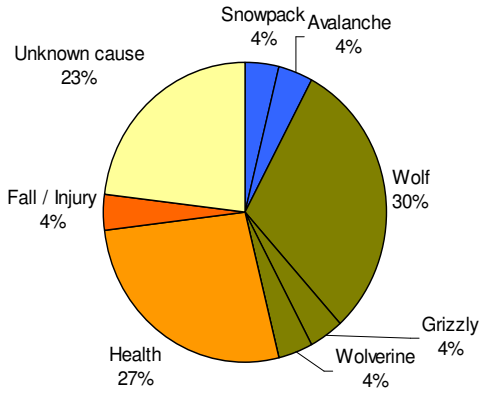


FIGURE Natural causes of mortality for 22 Sentinel females and 26 Stone females.

Methods – Sheep mortality investigations Mortality investigations were conducted for 48 females and 4 males that died between June 15 2005 and June 15 2009. We recorded site conditions, signs of pursuit or struggle, evidence of trauma, other wildlife sign, habitat type, topographic location, and prevailing weather conditions at the estimated time of death. We also considered body condition results from laboratory analyses of biological samples. Full post-mortem exams were performed on all intact carcasses. We looked for evidence of **predation by wolves, coyotes, bears, wolverine, and cougar. Poor body condition** describes non-predation deaths due to health or environmental factors other than snow. The presence of an intact carcass, or carcass with very minimal scavenging and presence of some or all of the internal organs (tissues which tend to be eaten first by predators), indicated condition-related cause of death. This included chronic **health conditions** related to the presence of disease, parasites, poor nutrition, emaciation, and senescence, all of which are often exacerbated by poor weather conditions, as well as acute **injuries** and falls from escape terrain cliffs during non-snow months. **Snow-related** causes include death in avalanches and difficult snowpack conditions.

Population dynamics Natural mortality patterns







PHOTOS **Mature male killed in an avalanche. Evidence at the site suggested that the sheep caused the snow slide as it crossed a narrow draw and the slope below gave way (top left).**

Snow-related mortality of an adult female (top right).

Intact pregnant female found dead in early spring. Post-mortem exams indicated emaciation (middle left).

Bone and tissue remains of bear predation (middle right).

Females killed by wolverine predation (bottom left and right).

Remains of spring wolf predation on an adult female (below).

Local knowledge – Predation "There has been a lot of interest and activity in relation to predator species in the S8M area. Over the past 50-60 years, wolves have been subject to a variety of management programs within and adjacent to the S8M area that have included hunting, trapping, baiting, and direct aerial control. Moderate wolf numbers were characteristic of the 1960s, and increases observed in the 1980s led to an extensive government control program. In recent years, local trappers have maintained an active wolf trapping program. Other predators that were thought to have potential influence on Stone's sheep included increasing grizzly bear populations, and coyote and wolverine on specific sheep ranges".

"Despite anecdotal success, the long history of predator control in the S8M area has left an expectation amongst many that it should be part of future management scenarios. Wolf, bear, cougar, and wolverine numbers were likely depressed in the study area through on-going trapping, hunting, and predator control programs". [Excerpts from Peck 2009]

Population dynamics Highway mortality

- Sheep deaths due to vehicle collisions are additive to natural mortality.
- Vehicle-related mortalities are indiscriminate, affecting all age-sex classes.
- Consistent highway use patterns offer promise for mitigation.

▪ Almost two-thirds of GPS collared sheep licked mineral salts on the Alaska Highway at least once, traveling up to 34 km from winter ranges to do so.

▪ Highway use occurred primarily in June and July, during daylight hours between 1000 and 1600 hrs, coinciding with the heaviest vehicle traffic.

▪ No collared sheep used or crossed the highway in January – March. Highway use and crossings in October through December occurred exclusively at Petersen Canyon, where female sheep use ranges seasonally on the east and west sides of the highway.

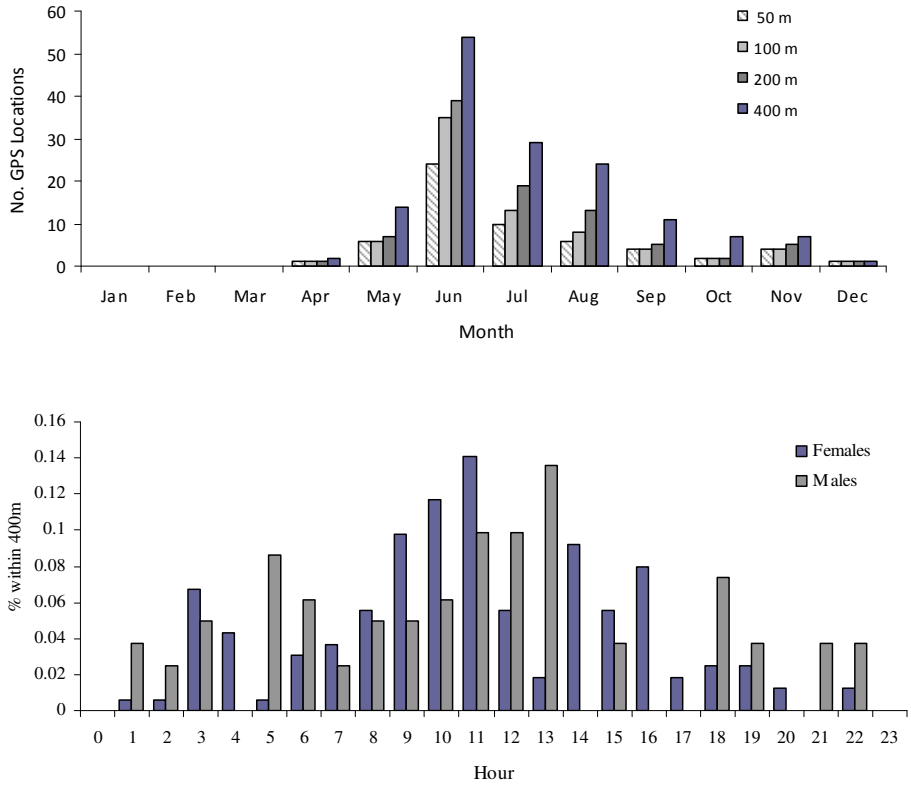
▪ Highway crossing locations are strongly influenced by topographical features such as incised draws, canyons, and stream fans on both sides of the highway.

▪ Highway use data from multiple sources are well correlated. Consistent highway use patterns offer promise for mitigation.

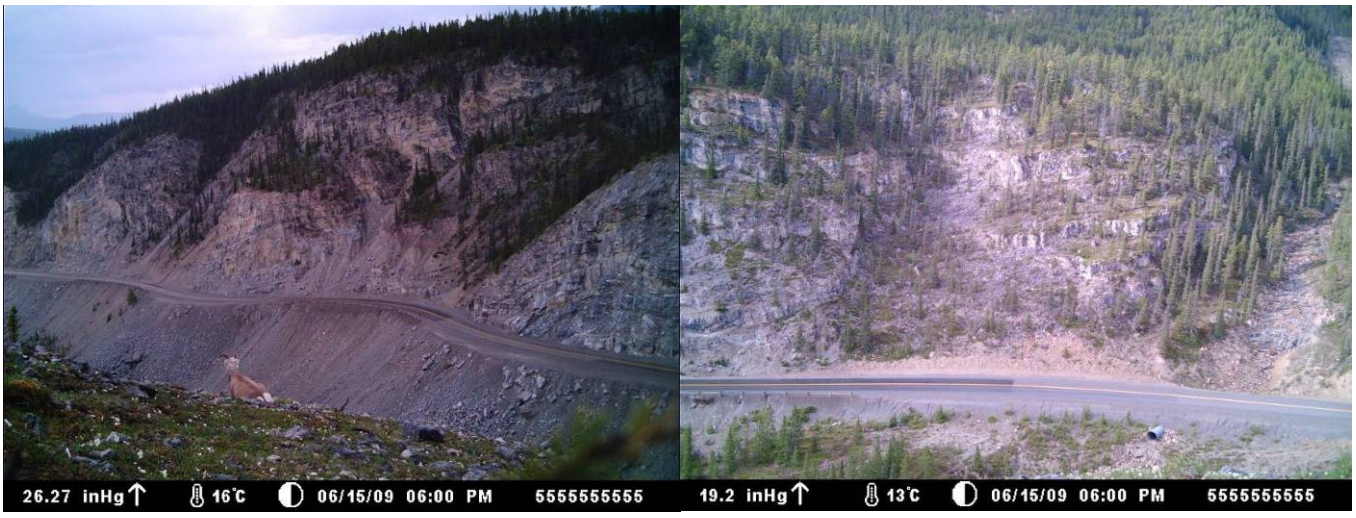
Vehicle collisions accounted for 8% of deaths (3 of 37) for collared females in the Stone population over 5 years. This suggests that 1.6% of adult females are killed annually on the Alaska Highway. One of these deaths occurred in 2007, a year in which 10 vehicle-related deaths of unmarked sheep (7 females, 3 lambs) were observed incidentally. Comparing the number of confirmed mortalities to the estimated population size indicates mortality rates due to vehicle collisions exceed 3% of the adult female population annually (8 of 202 females counted in the Stone population in March 2007).

Incidental observations of unmarked Sentinel females and one unmarked Stone male killed by vehicles suggest that highway mortality is likely significant for both populations and all age-sex classes.

Population dynamics Highway mortality

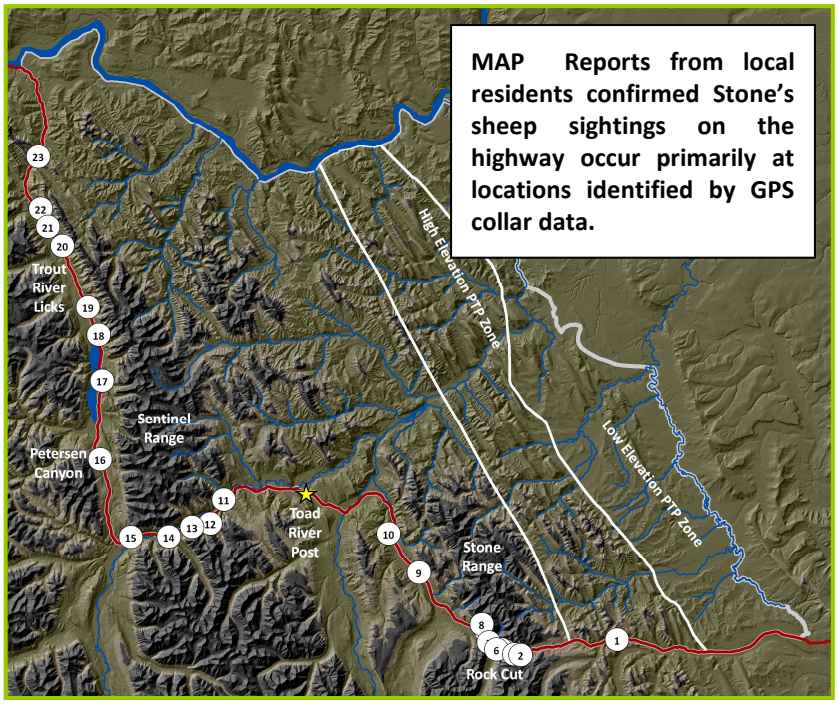


FIGURES Monthly and daily timing of highway use by 21 GPS-collared males and females. Number of locations by month within 400 m or less of the Alaska Highway centre line (top). Proportion of locations within 400 m of the centre line each hour (bottom).



PHOTOS View of the 'Rock Cut' segment of the Alaska Highway. Remote cameras were used to measure timing and frequency of highway use by sheep in May – October 2009. Camera data showed sheep highway use patterns that were consistent with the results of GPS collar data analyses.

Population dynamics Highway mortality



PHOTOS Female killed by a vehicle collision near Trout River mineral licks (top left).

Female hit by motorcyclist at the Rock Cut (far left).

Remains of male with broken femur found at the Rock Cut (left).

Methods – Estimating highway use and mortality risk Location data from GPS collared sheep were analyzed to estimate the proportion of collared sheep that use the highway, whether sheep use the highway incidentally to cross on their way to seasonal ranges, or if they travel to the highway specifically to lick road salts. We also looked at GPS collar data to find trends in timing of highway visits. We supplemented GPS collar data with remote camera data. We photographed a 350 m contiguous segment of the Alaska Highway known as the "Rock Cut", to quantify road use between May and October 2009. This segment of road bisects a naturally occurring mineral lick where sheep congregate and mineral characteristics are enhanced due to road salt application during winter months. We examined insurance claims information supplied by ICBC that included all collision records involving ungulate species along the 282 km stretch of highway between Fort Nelson and the Liard Hot Springs between 1996 and 2005. Local highway maintenance crews and Toad River residents provided reports of live and dead sheep observed on the road in 2006 – 2010. Project biologists also opportunistically surveyed the highway.

Population dynamics Hunting mortality

Harvest of mature males exceeds conservative limits.

- Harvest limits of 8% of the total number of male sheep ≥1 yr old, or up to 15% of observed minimum ¾ Curl (Class III) males, have been suggested for conservative management[1].
- Applied to the December 2006 census counts across the study area, this implies a maximum of 21 sheep available for harvest in fall 2007 (8% of 268 males ≥1 yr old or 15% of 141 Class III and IV males). In fall 2007, 28 males were harvested in WMU 7-54.
- The data indicate 50% harvest pressure on mature males that are legal by degree of horn curl, presuming that most hunters select males with minimum full curl horn growth. In fall 2006, 26 males were harvested. This is equivalent to the number of full curl males estimated during winter 2006/2007.
- Improved or increased access to backcountry areas is likely to be the most significant factor influencing harvest pressure and the potential need for more restrictive harvest regulations in the future.

[1] Toweill, D. 1999. Northern Wild Sheep and Goat Council Proceedings, page 59.

PHOTO Most males collared in the S8M sheep project were not of legal harvest age or horn size. One male that became legal by horn size during the study was shot the year he became legal. He traveled 17.5 km away from winter ranges between June 15 – 17, returning August 20 – 21. The following year he made the same trip on June 11 – 12 and was legally harvested on August 2.

Methods – Estimating harvest pressure The S8M study area overlaps all but the far northeast corner of BC Wildlife Management Unit (WMU) 7-54. In the study area, mature male Stone's sheep (Class IV "Full Curl" or ≥8 yrs old) may be hunted between August 1 and October 15 annually by licensed hunters that purchase a sheep permit. Harvest in WMU 7-54 varies annually, with 10 – 37 mature male sheep legally killed each year since compulsory inspection began in 1976. BC Government data for WMU 7-54 indicate an average annual harvest of 17 males from 1976 – 1989, 31 males per year in the 1990s, and 22 per year in 2000-2008. Comparing fall harvest records with the number of full curl males counted during the following winter census gives an estimate of harvest pressure on legal males. This estimate can be refined if harvest ages are available and accounted for.

Local knowledge – "By the mid 2000s, Stone's sheep populations were felt to be stable at best in the S8M area, and overall legal ram numbers appeared to be declining in the face of fairly consistent high hunter numbers and sheep harvests. Management of access on and adjacent to sheep ranges was a key theme raised by all respondents". [Excerpt from Peck 2009]

Population dynamics Sheep health

Observations during capture, census and mortality investigations found no widespread hhealth concerns.

Body condition

- Body condition was assessed by the amount of external body fat and signs of injury or disease.
- Females assessed during late winter captures in 2006 and 2007 were generally in good body condition. Six of 76 females were visibly thin. No data were available for 2005 captures. No visible signs of disease were observed. The left hind leg of one female appeared to have been broken and healed previously.
- Males were generally in good body condition. Only 1 male was visibly thin. No other signs of disease or prior injuries were noted.

Winter ticks

- Adult winter ticks (*Dermacentor albipictus*) were found in small numbers on 4 male sheep in the Stone population.
- No ticks were found on females during capture, but an engorged tick was found on one Stone female during a mortality investigation in spring 2009.
- No ticks were noted on Sentinel sheep.
- Small numbers of ticks likely have minimal impact on sheep health.
- Severe infestations of winter ticks, causing hair loss and emaciation, are common on moose and elk.

Horn abnormalities

- Five males with unusual horn growth were sighted in the Sentinel population during census.
- No abnormalities were observed in the Stone population.
- Unusual growth may be caused by horn breakage, infection in the horn core or sheath, or possible deficiencies in nutrients required for horn growth.
- The most severe abnormality was observed in a sheep of mature age, suggesting little or no impact on survival.

PHOTOS Engorged winter tick found on a female sheep (top). Male with 'stub' growth of left horn and uneven horn bases (middle). Male with right horn growing into its right eye and stunted left horn growth (bottom left). Male with left horn growing from forehead (bottom right).

Population dynamics Sheep health

Dentition

- The loss of functional teeth can be a significant problem for some sheep as they get older.
- Of 76 females, 3 had heavy tooth wear with only a minimal amount of incisors above the gum line; 7 had broken or absent incisors; and 2 had very long incisors that protruded when their mouths were closed.
- Four males had broken incisors and one had very long incisors.
- *Mandibular osteomyelitis*, an infection commonly known as 'lumpy jaw', has been reported in most subspecies of wild sheep in western North America, particularly in thinhorn sheep.
- Mandibles collected during sheep mortality site investigations were observed for bone deformities, bone recession, and abnormal tooth wear, as indicators of lumpy jaw.
- Lumpy jaw is common in S8M sheep, particularly in the Stone population.
- The most severe case of lumpy jaw observed in this study was in a mature female (>10 yrs old), suggesting limited impact on survival of affected individuals. Lumpy jaw may, however, have implications for chronic health conditions.

PHOTOS Female S078 was 10 yrs old at capture in April 2006. She was predated by wolves that fall (top). Female S094 was 10 yrs old at capture in April 2006. She died of poor health in March 2007, due to severe 'lumpy jaw' infection (second from top). Female S054 was 4 yrs old at capture in March 2006. She died of unknown cause in winter 2009/2010 (left).

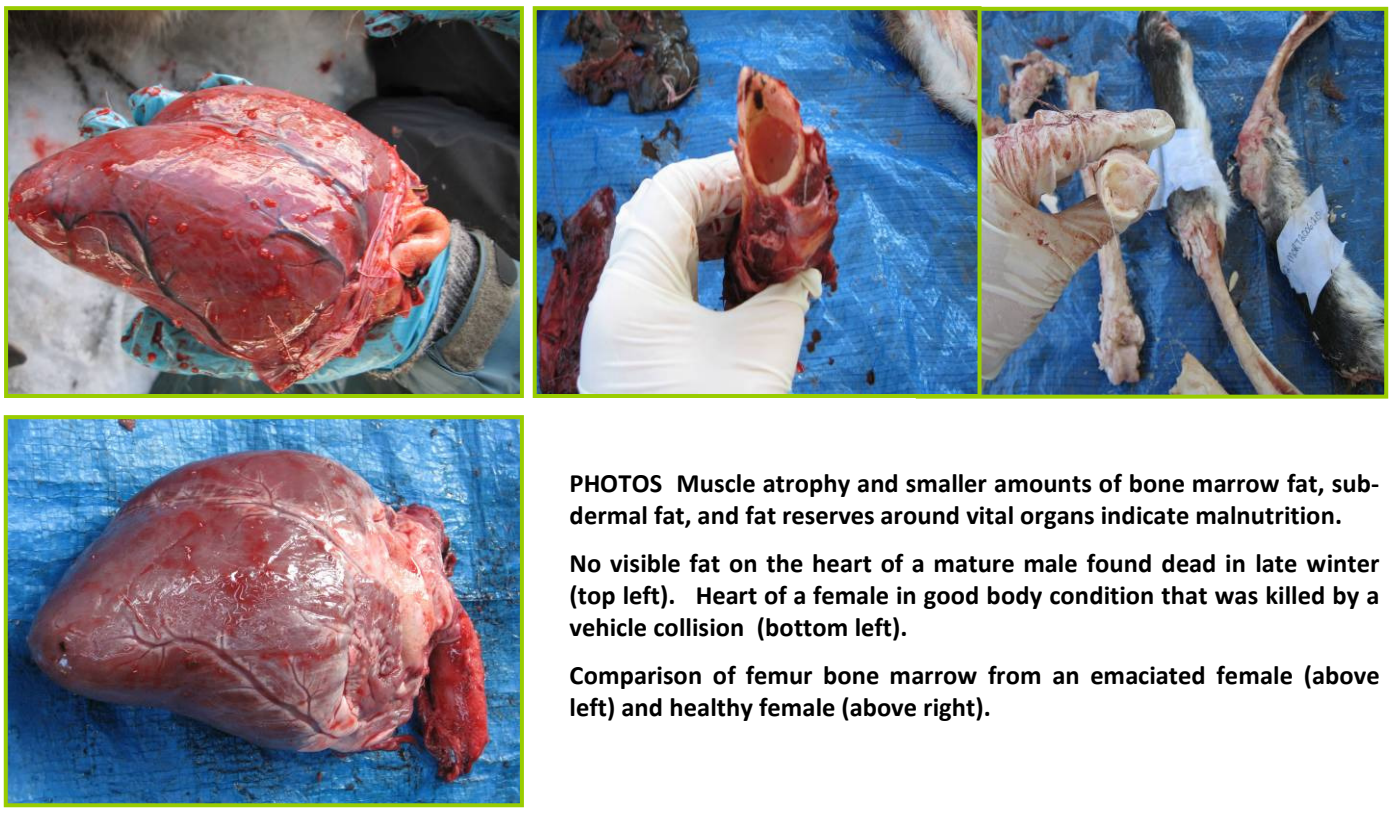
PHOTOS Evidence of lumpy jaw infections in profile view of mandibles from a 6 yr old female.

Population dynamics Sheep health

PHOTO Histology revealed mild lungworm lesions in the lungs of a male lamb.

Internal parasites

- Gastro-intestinal nematodes and protostrongylids are common in wild sheep and other ungulate species.
- Fecal samples collected from females captured in March 2006 were analyzed for parasite loads. We estimated the percentage of females in the population infected with parasites (prevalence) and the average number of parasite eggs or larvae shed in the feces of individuals (intensity).
- S8M sheep did not have unusually high prevalence or intensity of parasite shedding relative to other wild sheep populations.
- Fecal parasite prevalence among females was similar between populations, although average intensities tended to be higher in Sentinel sheep.
- Lungworm (*Protostrongylus spp*.) is common in wild sheep, and causes chronic lung damage. However, lungworm lesions were incidental to, not the cause of, death in S8M sheep that were examined.



PHOTOS Muscle atrophy and smaller amounts of bone marrow fat, sub-dermal fat, and fat reserves around vital organs indicate malnutrition.

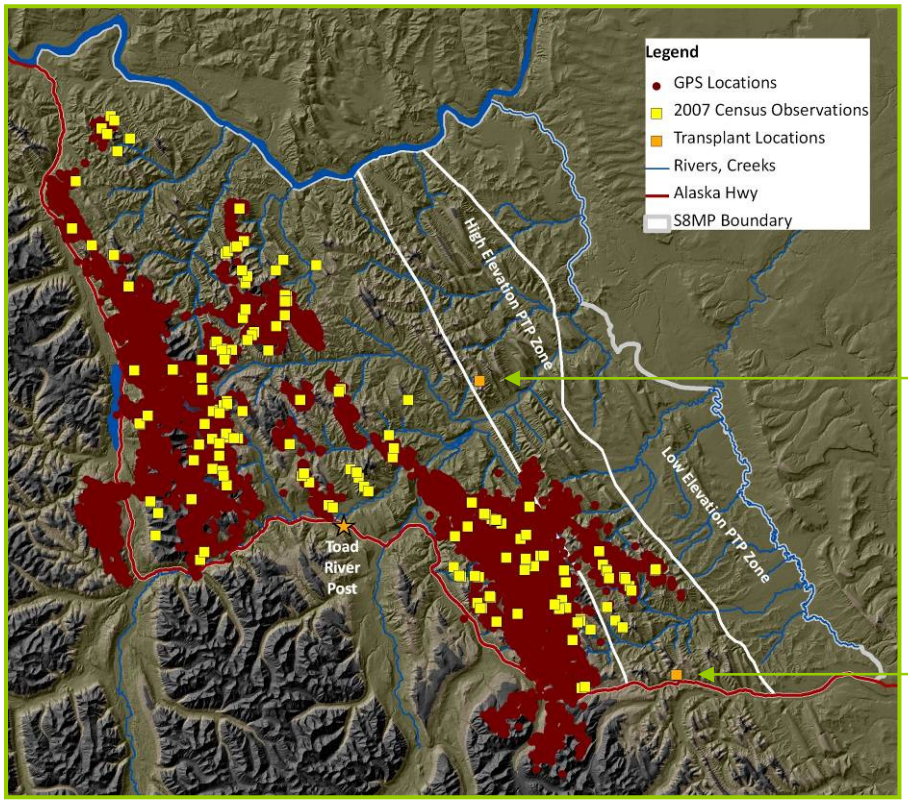
No visible fat on the heart of a mature male found dead in late winter (top left). Heart of a female in good body condition that was killed by a vehicle collision (bottom left).

Comparison of femur bone marrow from an emaciated female (above left) and healthy female (above right).

Habitat use General distribution

Sheep in the S8M study area belong to at least 2 populations separated by the Toad River.

- Within the study area, there was no evidence of sheep crossing the Toad or Racing Rivers. S8M sheep belong to at least two distinct populations separated by the Toad River.
- Only transplanted sheep were observed in the S8M PTP area north of the Toad River. Absence of sheep from alpine ranges in this area is consistent with sheep harvest records and local knowledge reports.
- Seasonal movement to ranges outside the study area occurred regularly at the Alaska Highway 'Rock Cut' in Stone Mountain Provincial Park, and the Alaska Highway 'Petersen Canyon' in Muncho Lake Provincial Park.
- Both the Rock Cut and Petersen Canyon, heavily used as mineral lick complexes, appear to be links for migration and dispersal among adjacent populations.
- Occasional observations of sheep on the highway at the Trout River mineral licks and south end of the Sentinel Mountain Range suggest these locations may also be links for genetic exchange among adjacent sheep populations to the south and west.



In 2005, during the initial sheep capture sessions for the this project, BC Government staff moved 9 sheep (6 females ≤3 yrs old; 1 female lamb; 2 males ≤3 yrs old) from upper 8 Mile Creek and the Stone Mountain Range to a recently burned site in the north PTP area. Two of the females were fitted with VHF collars prior to release. S8M project advisory committees were not made aware of this initiative until 2008; no rationale for the action was provided. These were the only sheep found during the study in the S8M PTP High Elevation Zone north of the Toad River.

In 1996, BC Government staff moved 8 sheep from the Toad River Post area to the south end or the Stone Mountain Range.

FIGURE Distribution of GPS locations for 26 females and 17 males. Sheep observations from winter census in March 2007 are provided for comparison.

With the exception of highway crossings at the Rock Cut and Petersen Canyon, GPS-collared sheep did not move beyond the distribution of Stone's sheep observed during winter censuses in the S8M study area.

Habitat use General distribution

PHOTO Stone's sheep nursery group.

Habitat use Annual and seasonal range sizes

Most sheep used more than one core area in their annual home ranges.

▪ Home range estimates for S8M females (average 135 km^2) were 3 – 4 times larger than those reported for the Besa-Prophet and Dunlevy Stone's sheep populations in northern BC. Average home ranges of S8M males (237 km^2) were 1.5 times larger than Dunlevy males.

▪ There was no difference in home range sizes between Stone and Sentinel females.

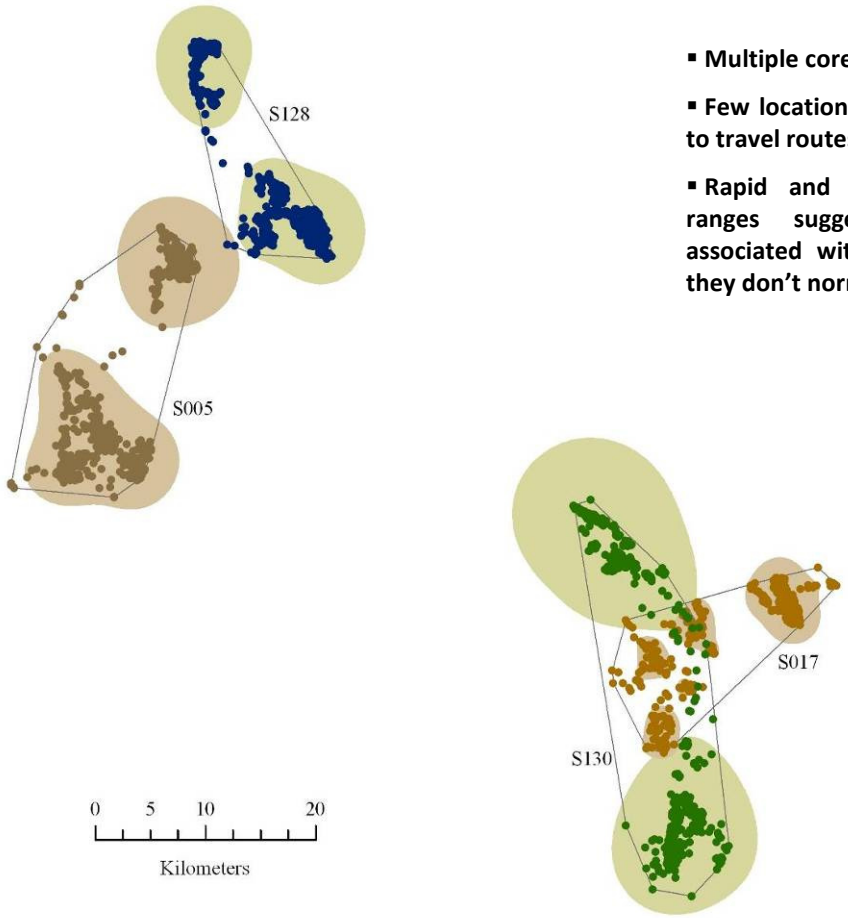
▪ Two-thirds of GPS-collared males and females used more than one core area in their home range each year. For some individuals this reflected movements between distinct seasonal ranges. For others, multiple core areas resulted from range expansions in April – December associated with repeated use of known mineral licks.

▪ Average home range size of males was nearly twice that of females (237 km^2 vs 135 km^2), but size of core areas were equivalent.

TABLE Seasonal range sizes were smallest in early winter for both males and females.

Season	Date interval	Females	Males
Early winter	Jan 01 – Feb 28	9.7 km^2	9.2 km^2
Late winter	Mar 01 – May 14	21.1 km^2	54.6 km^2
Lambing	May 15 – Jun 14	111.7 km^2	100.5 km^2
Summer	Jun 15 – Aug 14	88.7 km^2	97.2 km^2
Fall	Aug 15 – Oct 31	98.5 km^2	63.0 km^2
Rut	Nov 01 – Dec 31	15.3 km^2	105.4 km^2

Habitat use Annual and seasonal range sizes



- **Multiple core ranges within annual ranges**
- **Few locations between core ranges and fidelity to travel routes between core ranges.**
- **Rapid and direct movement between core ranges suggest individuals perceive risks associated with these movements across areas they don't normally occupy.**

FIGURE Example of GPS locations and home range estimates for 2 males (S128 and S130) and 2 females (S005 and S017). Home ranges are 100% minimum convex polygon outlines with 95% fixed kernels highlighting distinct core ranges.

Methods – Calculating home range sizes We computed annual home range size estimates for GPS-collared sheep that provided at least 12 consecutive months of location data. Minimum convex polygons (MCPs) connect the outermost locations of an animal's distribution. We estimated home range sizes with 100% MCPs and estimated core range sizes using 95% kernel density estimation (KDE) probability contours. MCPs are standard measures of home range size that can be easily compared across studies. However, sheep locations tend to be clustered on one or more core ranges that can be much smaller in size than home ranges estimated by MCPs, so MCPs can overestimate the size of ranges typically used by sheep. Core (KDE) range size estimates are based on the distribution and density of location data and reflect areas of concentrated use within an individual's annual (MCP) home range. The number of core ranges within an MCP home range can vary among individuals – a single area of high density use was interpreted as a single core range, whereas multiple non-overlapping clusters of high density use indicated multiple core ranges.

Habitat use Winter ranges

- Seasonal ranges are smallest in early winter.
- Males and females are interspersed on the same winter ranges.

Suitable winter ranges tend to be a limiting factor for sheep distribution and abundance because deep snow (>30 cm) restricts access to forage.

Sentinel population

- **Core winter ranges** for both sexes were concentrated at the Mount McLearn – Ewe Mountain complex that extends north along Sulphur Cr; Mount Prudence; Fire Mountain (local name) at the Sulphur Cr – 8 Mile Cr headwaters; and the Nonda Cr headwaters.
- Herds also winter on the mountains between the Toad River, 4 Mile Cr, and 8 Mile Cr.
- A few small, scattered groups of sheep were observed in winter along the west and north extremities of the Sentinel Mountain Range.

Stone population

- **Core winter ranges** for both sexes were concentrated at One Fifteen Creek; upper Ram Creek; upper Snake River; and the Ram Mountain complex in the S8M PTP High Elevation Zone.
- Herds also winter in isolated groups at the northwest extremity of the Stone Mountain Range.
- A few small, scattered groups of sheep were observed in winter along the east and west slopes of Airplane Valley (local name) at the Dunedin River headwaters along Stone Mountain, south to Stone Mountain Provincial Park.
- A small group of sheep, the result of a sheep translocation done by Ministry of Environment in 1996, is resident on south-facing slopes above the Alaska Highway, along the Tetsa River.

Habitat use Winter ranges

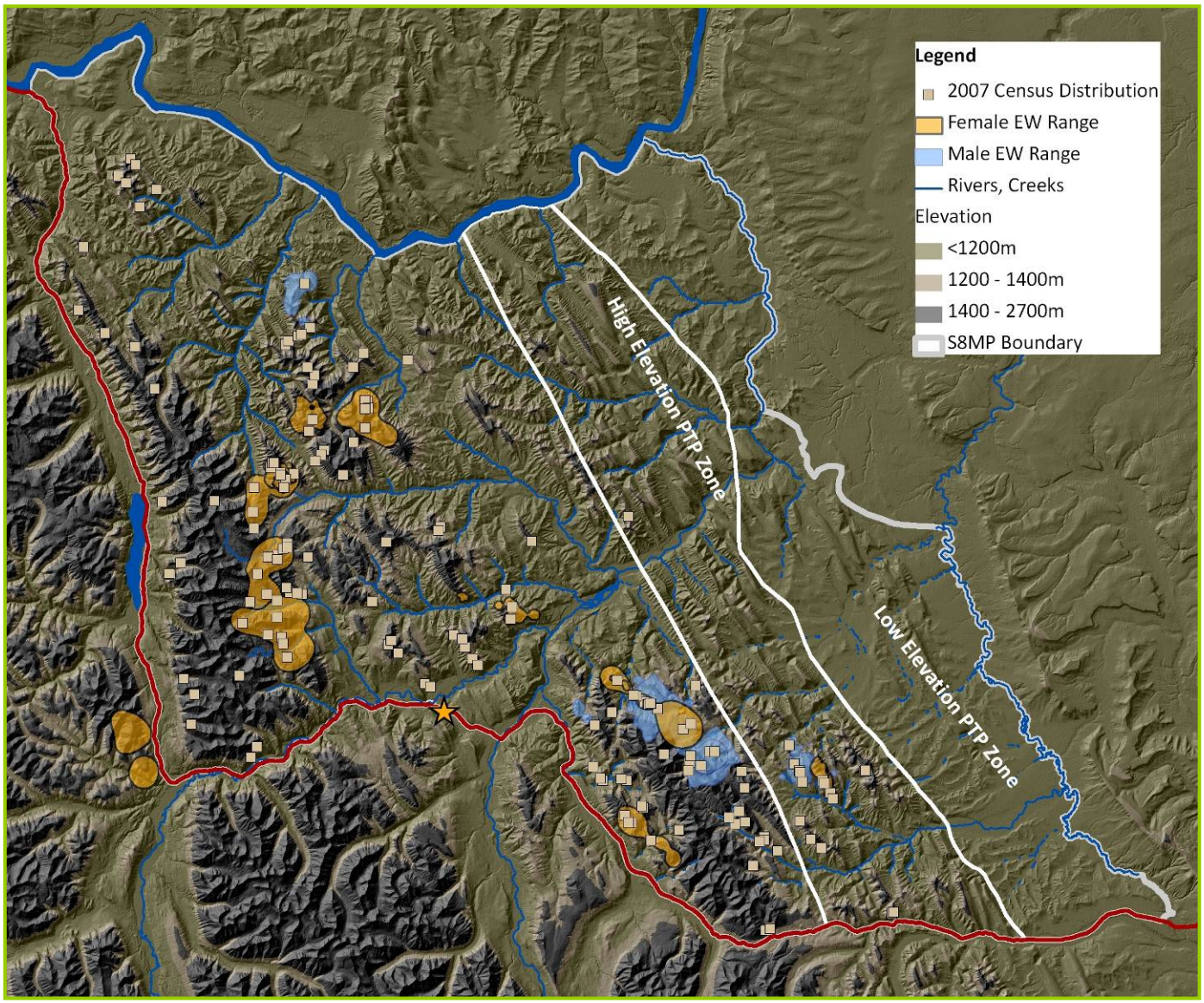


FIGURE Distribution of early winter ranges estimated from GPS collar location data for 24 females and 13 males. Stone's sheep observations from the March 2007 census are provided for comparison.

Habitat use Winter distribution of other ungulates

Elk and moose were common on sheep ranges in the S8M PTP High Elevation Zone south of the Toad River.

- Species interactions may contribute to density-dependent changes in sheep population dynamics.
- Sheep are the most common ungulate on alpine ranges, with winter densities of 0.62 sheep/km^2 across the Sentinel population and 1.00 sheep/km^2 across the Stone population.
- On Sentinel ranges caribou were the most abundant other ungulate. A minimum of 177 caribou were observed in March 2007 with 0.20 caribou/km^2 density on alpine ranges.
- On Stone ranges, elk and moose were the most abundant other ungulates, particularly in the S8M PTP High Elevation Zone, where density on sheep ranges was 0.22 moose/km^2 and 0.44 elk/km^2 in February 2009.
- A minimum of 82 mountain goats were observed; 35 on Sentinel ranges in March 2007 and 47 on Stone ranges in February 2009.
- Sentinel sheep that visit the Trout River mineral licks have potential for interactions with Nordquist herd bison.

TABLE Number and density (animals per km^2) of ungulates sighted incidentally in the Stone Range study area (1,904 km^2), within the census area (504 km^2 above 1,200 m elevation), and within the S8M PTP High Elevation Zone (559 km^2 with 144 km^2 above 1,200 m elevation), during the February 2009 census.

	Entire Stone Range			Pre-Tenure Plan High Elevation Zone only		
Species	Total counted	Total above 1,200 m	Density above 1,200 m	Total counted	Total above 1,200 m	Density above 1,200 m
Sheep	430	411	0.82	82	82	0.57
Moose	138	54	0.11	105	32	0.22
Elk	88	79	0.16	65	64	0.44
Goat	47	46	0.09	1	1	0.01
Caribou	53	53	0.11	18	18	0.13
Deer	6	3	0.01	4	1	0.01

Habitat use Winter distribution of other ungulates

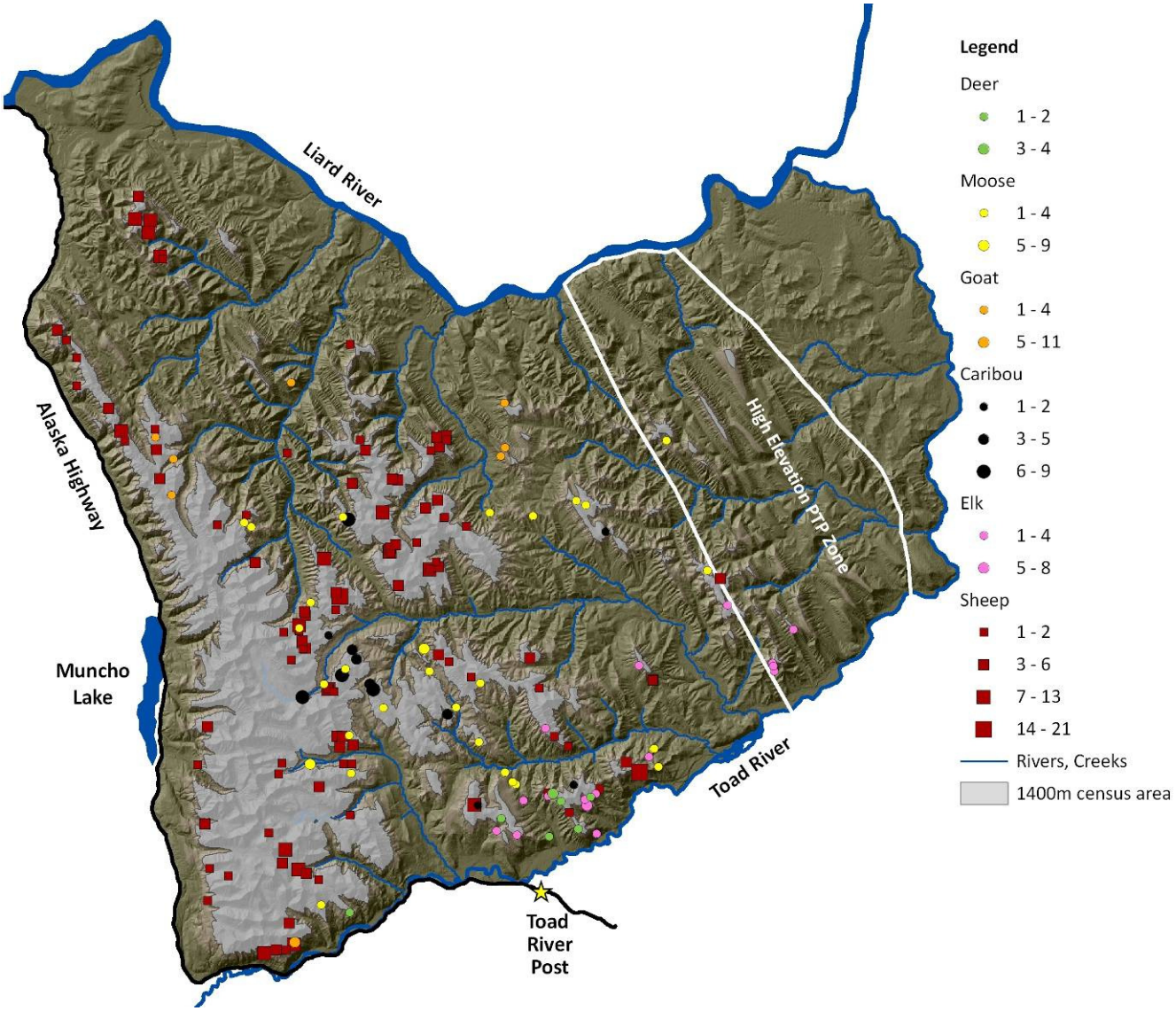


FIGURE Distribution and group size of sheep and other ungulates observed during December 2006 census of Sentinel ranges. Distribution in March 2007 was similar.

Habitat use Winter distribution of other ungulates

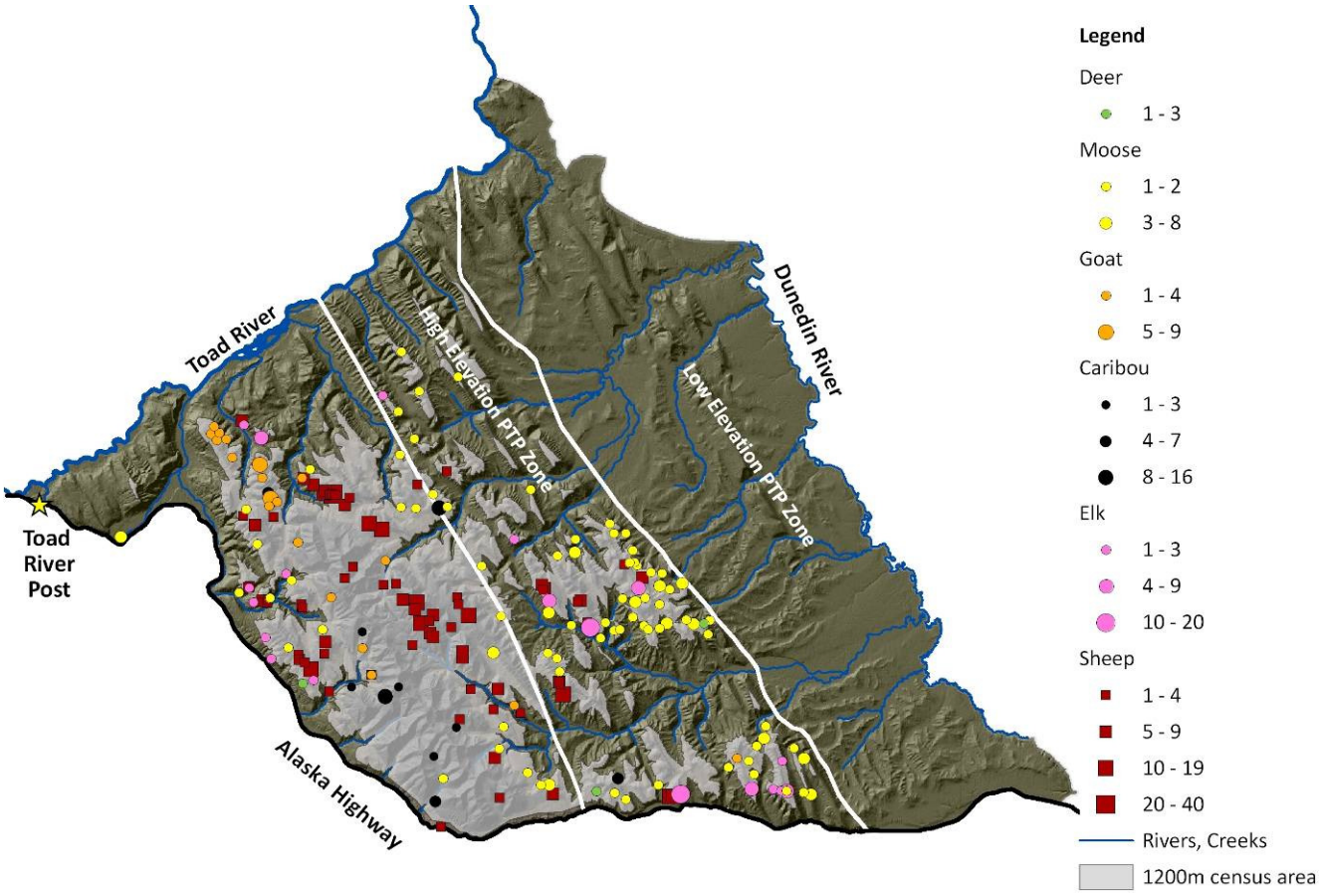


FIGURE Distribution and group size of sheep and other ungulates observed during February 2009 census of Stone ranges. February 2009 results are presented because total counts were highest and general distribution was similar to December 2006 and March 2007 census.

Local knowledge – Trend in number of other ungulates "From occasional sightings in the early 1970s, elk have shown dramatic increases within the past 10-15 years. Opinions varied on the impact of increasing elk numbers on Stone's sheep, but all informants felt it was a crucial factor. Other species dynamics have changed as well. Goat populations appear to have increased in recent years. Although caribou were never abundant in the S8M area, they have rebuilt somewhat from lows in the 1970s. It was felt that moose numbers have remained relatively stable over the past 20 years". [Excerpt from Peck 2009]

Habitat use Seasonal movements

- East to west movements across the Sentinel Range and north to south movements along the Stone Range in summer follows the orientation of major ridges and drainages.
- High fidelity to seasonal ranges with no evidence of range abandonment.

Males and females moved away from core winter ranges or expanded their ranges seasonally, traveling to distinct summer ranges or to visit mineral licks.

- East to west movements across the Sentinel Range follow the orientation of major ridges and high-elevation passes
- North to south movements along the Stone Range follow orientation of major ridges and drainages.

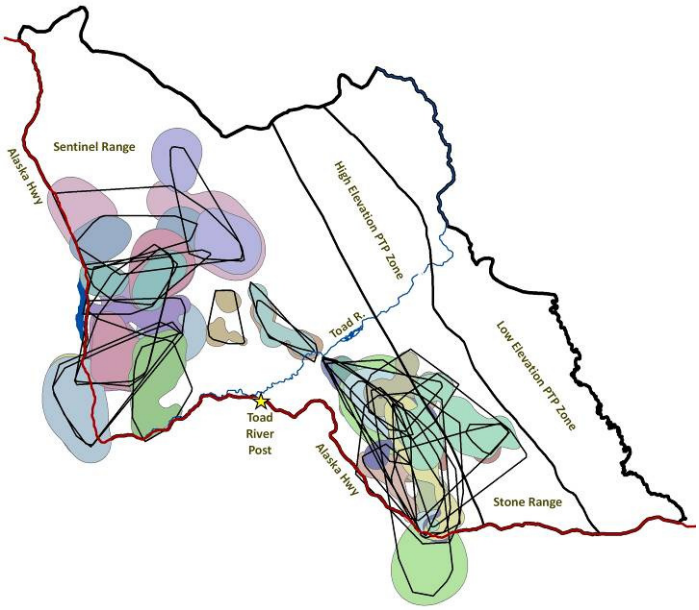


FIGURE Home ranges (black outlines) and core areas for 19 females and 8 males that had more than 1 yr of GPS locations.

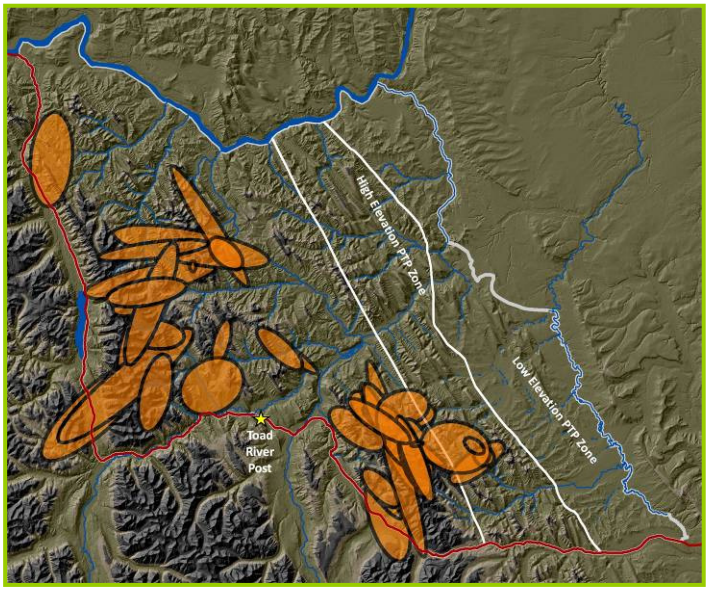


FIGURE General movement patterns for 19 females and 8 males. Rounded distributions are typical of "resident" sheep that use a single core range year-round. Elongated distributions are typical of "migratory" sheep that use distinct, non-overlapping core ranges seasonally. Sentinel sheep tend to move west from winter ranges, to mineral licks and summer ranges. North-south movements are typical of Stone males and females.

Habitat use Seasonal movements

Regularly used trails area clearly visible and often easily identified from the air.

- Average movement distances of 10 - 14 km (maximum 34 km) from winter ranges to mineral licks and between distinct seasonal ranges
- Initial movements from winter ranges occurred between April 16 and June 28.
- Final return to winter ranges occurred between June 27 and December 10.
- Individuals showed high fidelity to seasonal ranges and travel routes.
- 95% of sheep movements were at rates <300 m/hr, with 99% at rates <550 m/hr.
- Maximum movements of 1.6 km/hr for both males and females were typically associated with travel between core ranges, including travel to mineral licks.

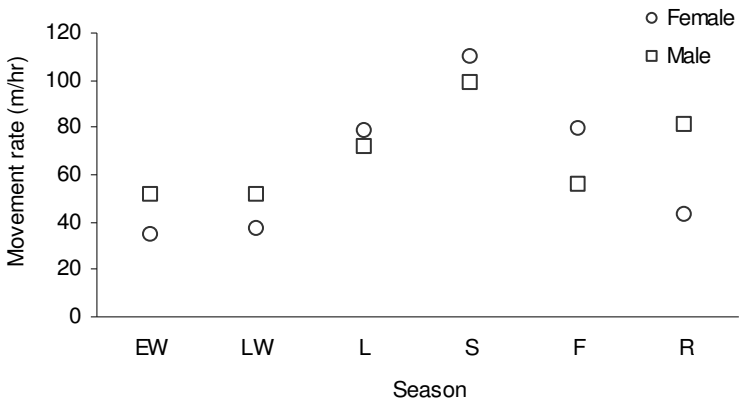


FIGURE Average seasonal movement rates (metres per hour) for male and female sheep.

PHOTO Regularly used trails are clearly visible and often easily identified from the air.

Habitat use Seasonal movements

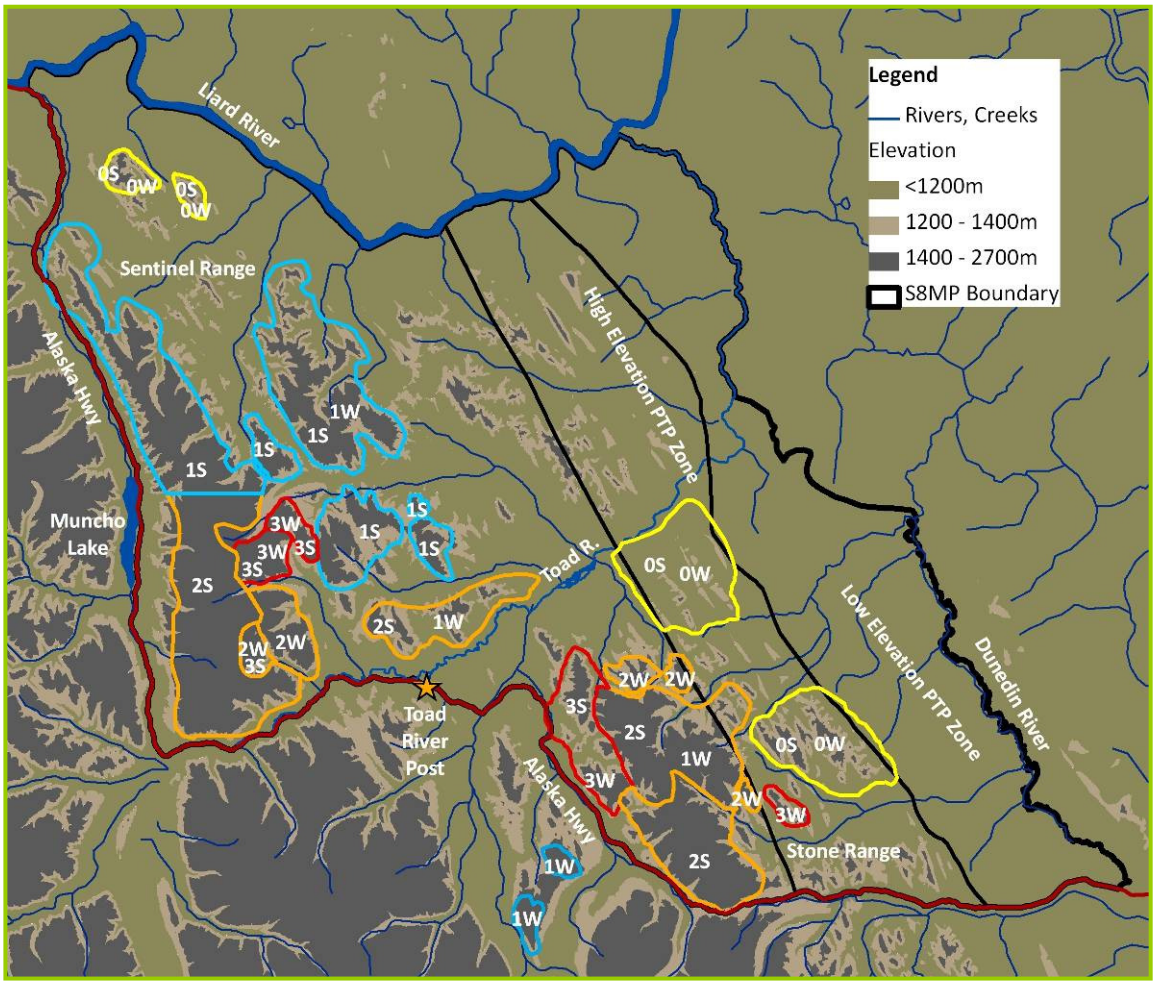


FIGURE Historic BC Fish & Wildlife Branch information on the wildlife resources of the area was limited, although sporadic aerial surveys from 1968-78 had documented some of the key Stone's sheep ranges in the S8M area. Stone's sheep summer (S) and winter (W) habitat ratings from Keller and Peck 1974. Ratings range from poor (0, yellow) to high value (3, red). [Excerpt from Peck 2009]

Local knowledge – Seasonal distribution and movements "Some 166 locations were identified where Stone's sheep had been observed within the S8M area, and there was considerable consistency between respondents. These areas included critical habitats such as mineral licks and seasonal ranges. Although there appeared to be core central ewe-lamb areas within both the southern and northern S8M area, there were a number of accounts of considerable movement by rams within and beyond the S8M area. Rams were also observed to frequent 'fringe ranges', whose locations are a closely guarded secret within the hunting community, but were characterized by being adjacent to traditional sheep ranges, often in timbered lower mountain or foothills habitats. It was noted that effective use of these ranges was enhanced when predator numbers were low". [Excerpt from Peck 2009]

Habitat use Mineral lick use

- Nearly all males and females used at least one known natural mineral lick in the study area.
- Most mineral licks were at the periphery of sheep home ranges.

- Known licks at the periphery of ranges were heavily and consistently used by most collared sheep and all age-sex classes. Very few sheep had mineral licks in the core of their home ranges.
- Natural backcountry mineral licks were exposed mineral deposits along valley-bottom river and creek corridors.
- Important mineral licks along the Alaska Highway include the Rock Cut (Stone Mtn Provincial Park), Petersen Canyon (Muncho Lake Provincial Park), and the Trout River mineral licks (Muncho Lake Provincial Park).

PHOTO Female with lamb, licking mineral salts from cutbanks along the Alaska Highway.

On-going enhancement activities by government and non-government groups included placement of mineral salt blocks in undisclosed locations throughout the study area. Salt blocks were deployed prior to and during this study by BC Parks and the Northeast BC Wildlife Fund along the Alaska Highway corridor in an attempt to discourage sheep from congregating on the highway to lick road salts. The BC Government, local guide-outfitters, and hunters have deployed salt blocks and excess hide-tanning salts at remote sites in backcountry ranges. The timing, extent, and ultimate effect of these activities is unknown.

It is common for sheep to use artificial licks when they are made available, either as salt blocks or by-products of road maintenance and industrial activities. Industrial by-products can have lethal toxicities and air-borne dust can aggravate lumpy jaw prevalence. Potential use of artificial licks as displacement or enhancement tools has been discussed but their effectiveness and ecological implications have not been sufficiently addressed. Such manipulations are experiments and, if implemented, should only be conducted in a controlled way to test and monitor impact hypotheses.

Habitat use Mineral lick use

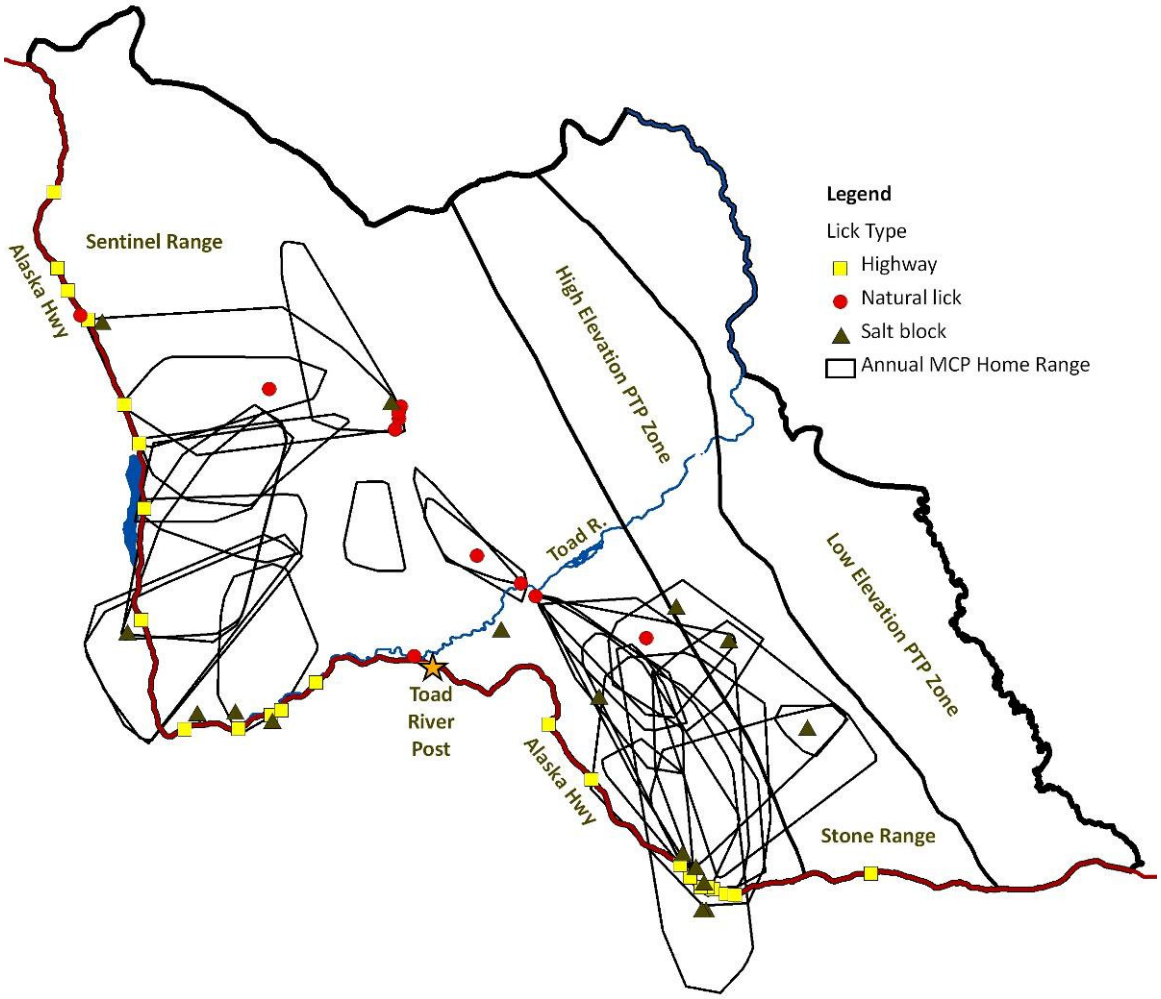


FIGURE Sheep home ranges relative to mineral lick distribution.

Methods – Estimating mineral lick use Mineral licks used by sheep were identified incidentally during aerial and ground surveys in 2005 – 2010 and from local interviews. Lick sites included naturally-occurring mineral sources with evidence of sheep use (i.e., tracks, pellets, well-defined access trails), highway locations where road salts were known to be exploited by sheep (based on GPS-collared sheep locations, observations, and local knowledge), and salt blocks observed or reported in sheep ranges. Highway and salt block locations known to be associated with natural mineral licks were defined as 'enhanced licks'; salt block locations not associated with known natural mineral licks were designated 'artificial'. We determined mineral lick use by intersecting location data from GPS collared sheep with an analysis buffer around known mineral licks, or from observations of unmarked sheep. We selected a 400 m buffer distance based on average movement rate per hour for male and females combined. Topographic detail was removed from report figures that include mineral lick distribution because the BC Government treats natural lick locations as sensitive data.

Habitat use Habitat selection

- Sheep are predominant on alpine and subalpine ranges, with 93% of locations above 1200m elevation.
- No geographic separation but fine-scale habitat differences between males and females.

Resource selection functions (RSFs) are statistical analyses useful for evaluating habitat use by animals.

- RSFs compare habitat attributes measured at sheep GPS locations to habitat measured at random locations.
- Selection means use of a habitat attribute more than it is randomly available. Avoidance is inferred when habitat attributes are used less than they are available. Neutral use indicates use in proportion to availability.
- We used RSFs to identify seasonal variation in habitat preferences, relative to the habitat choices sheep make in their daily movements, seasonal use of home ranges, and distribution across the study area.
- Topographical attributes known to be good predictors of sheep distribution were measured from freely available map data called Digital Elevation Model (DEM) layers: elevation, slope, aspect, ruggedness, distance to escape terrain, solar radiation, surface curvature, slope position.
- Landcover attributes were determined from satellite image maps. Burned areas were interpreted from satellite imagery and government data.

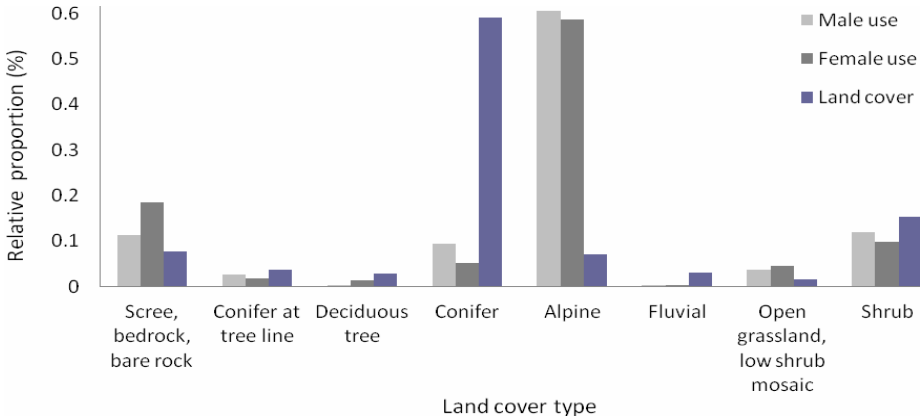


FIGURE Availability of each land cover type relative to the proportion of sheep GPS locations in each land cover type.

Interpreting the figures on the following pages - Positive RSF values that are statistically significant* indicate preference for the habitat attribute (i.e., use more than it is randomly available). Negative values that are statistically significant* indicate avoidance (i.e., use less than it is randomly available). No data indicates that the habitat attribute was not used by sheep in that season.

Season dates: Early winter (**EW**) January 1 – February 28; late winter (**LW**) March 1 – May 14; lambing (**L**) May 15 – June 14; summer (**S**) June 15 – July 31; fall (**F**) August 1 – September 30; rut (**R**) October 1 – December 31.

Habitat use Habitat selection

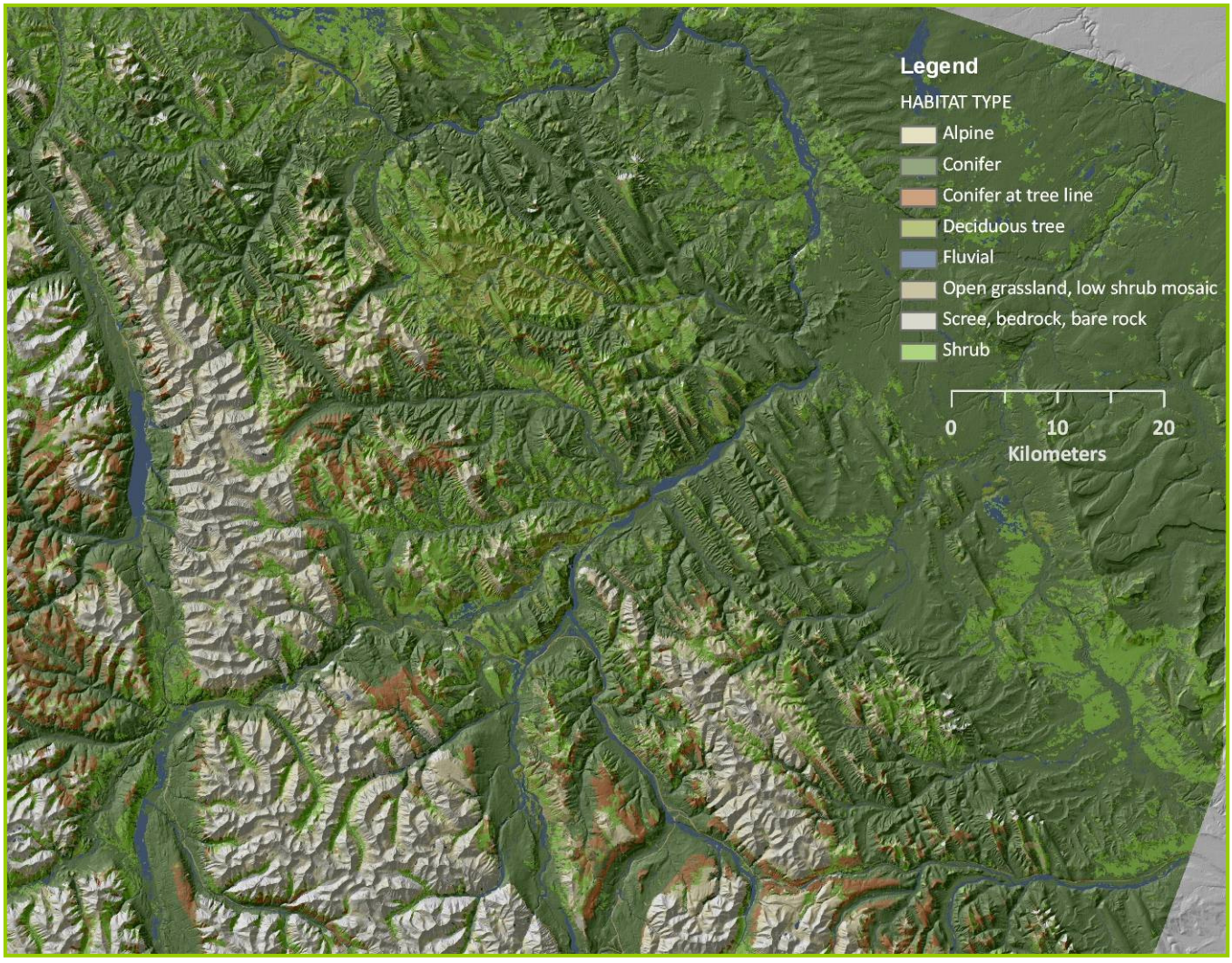
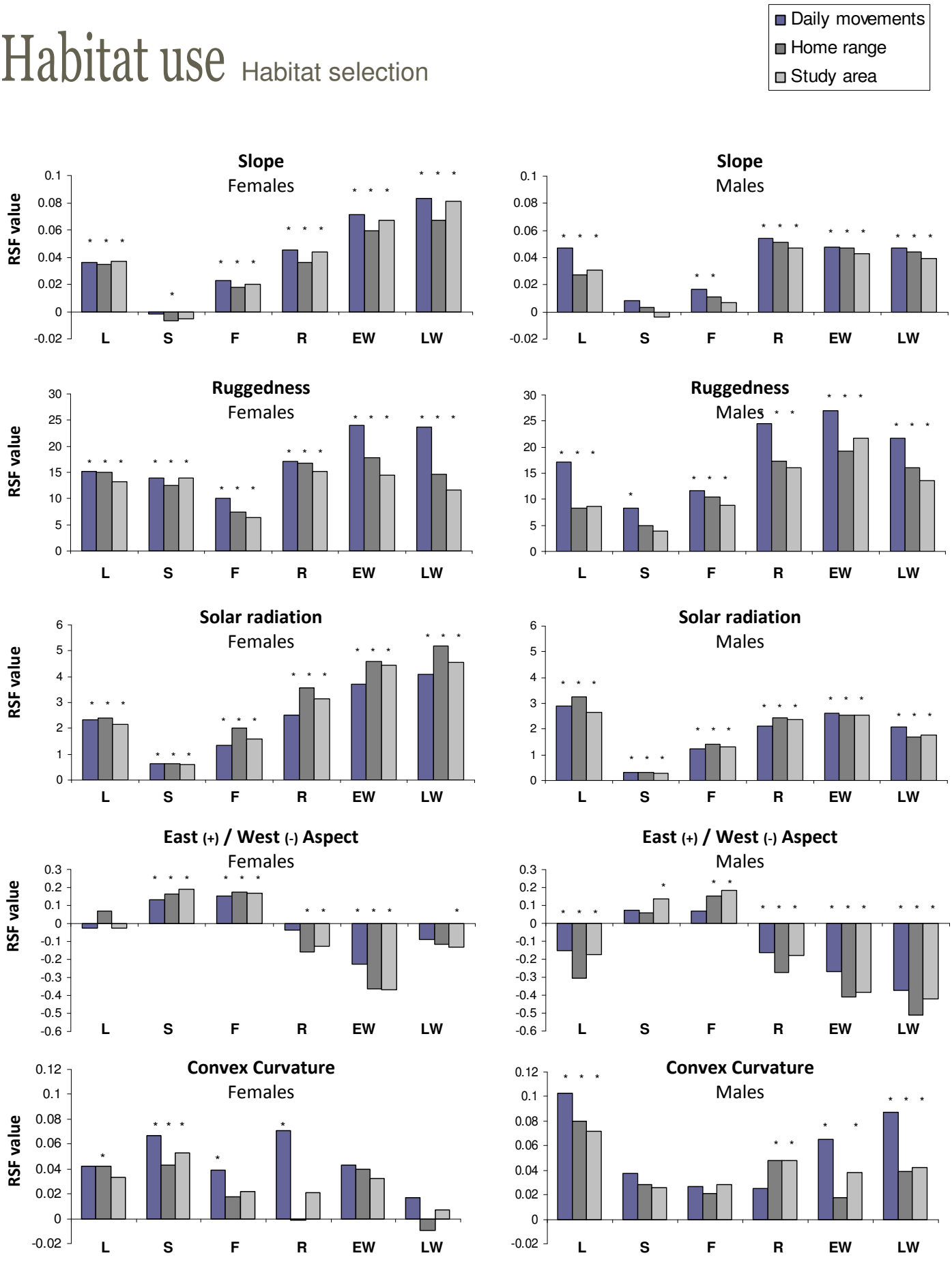


FIGURE Map of land cover classes used in RSF analyses.

Local knowledge – Prescribed fire Range burning by the BC Government and by guide-outfitters has been widespread since the 1940s with some burns targeting Stone's sheep winter range enhancement and trophy production. Prior to and during this study, ranges were regularly burned during spring along the lower Toad River. "A diversity of opinion over the role and utility of prescribed fire in relation to Stone's sheep varied from conducting smarter prescriptions to no intentional burning on Stone's sheep range". [Excerpt from Peck 2009]

Prescribed fire and wildfire has burned 21% (880 km^2) of the study area; 6% (265 km^2) of the study area was burned between 1990 and 2005. Other studies have found that range burning intended to improve winter forage for sheep has had limited benefits, at least partially because burned areas were not available to sheep in winter. Thinhorn sheep are adapted to winter nutritional limitations, and winter habitat enhancement is often less important than managing other influences on sheep population dynamics, such as habitat loss, displacement, harvest pressure, and disease.

Habitat use Habitat selection



Habitat use Habitat selection

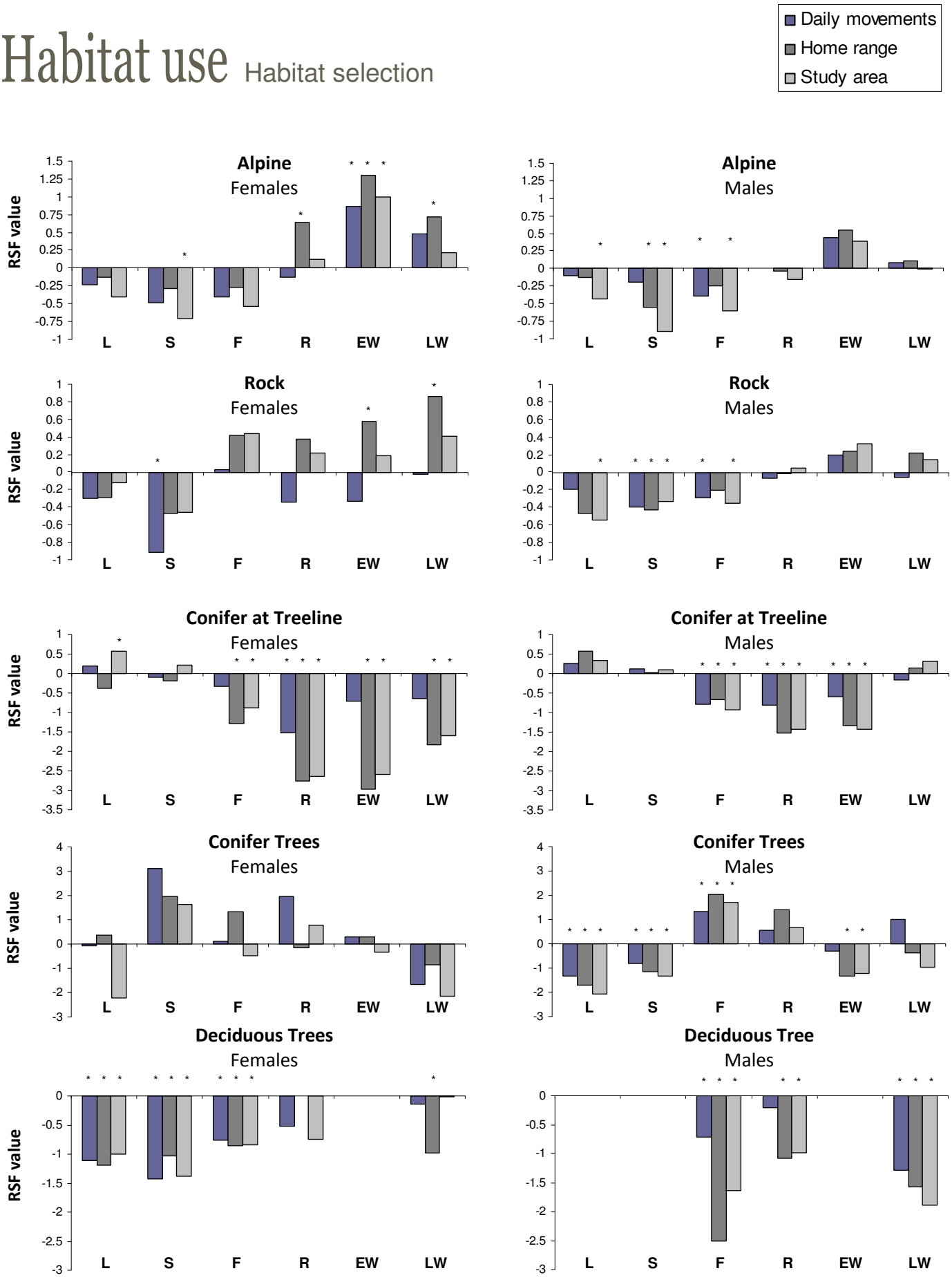
General characteristics of Stone's sheep habitat

- Sheep used steep (mean 29° – 37°), rugged, convex sites with high solar radiation, at mean elevations ranging 1,404 m during lambing to 1,706 m in summer.
- Most (93%) GPS locations for males and females were above 1,200 m elevation. For males in the S8M PTP High Elevation zone, this percentage was reduced to 86.7%.
- Selection for steep, rugged, warm sites defines their distribution year-round, but is especially important November through mid-May (R, EW, LW seasons), likely because these sites hold less snow. East aspects are favoured in summer and fall only.
- Selection for steep rugged sites is particularly important in daily movement decisions. This is widely recognized as a predator avoidance strategy.
- Conifer at treeline is used less than it is available, except in mid-May to mid-August (L and S seasons), likely because it provides cover, forage, and bed sites.
- Use of deciduous forest is rare and avoided in all seasons.
- Alluvial fans and riparian areas are rare in the study area but favoured in all seasons. They are likely used as travel routes and possible feeding sites.
- Selection for burned areas was most apparent in seasonal range use decisions. Avoidance of burns was common in daily movement decisions, except in summer and fall. Both males and females used burns most often in fall.

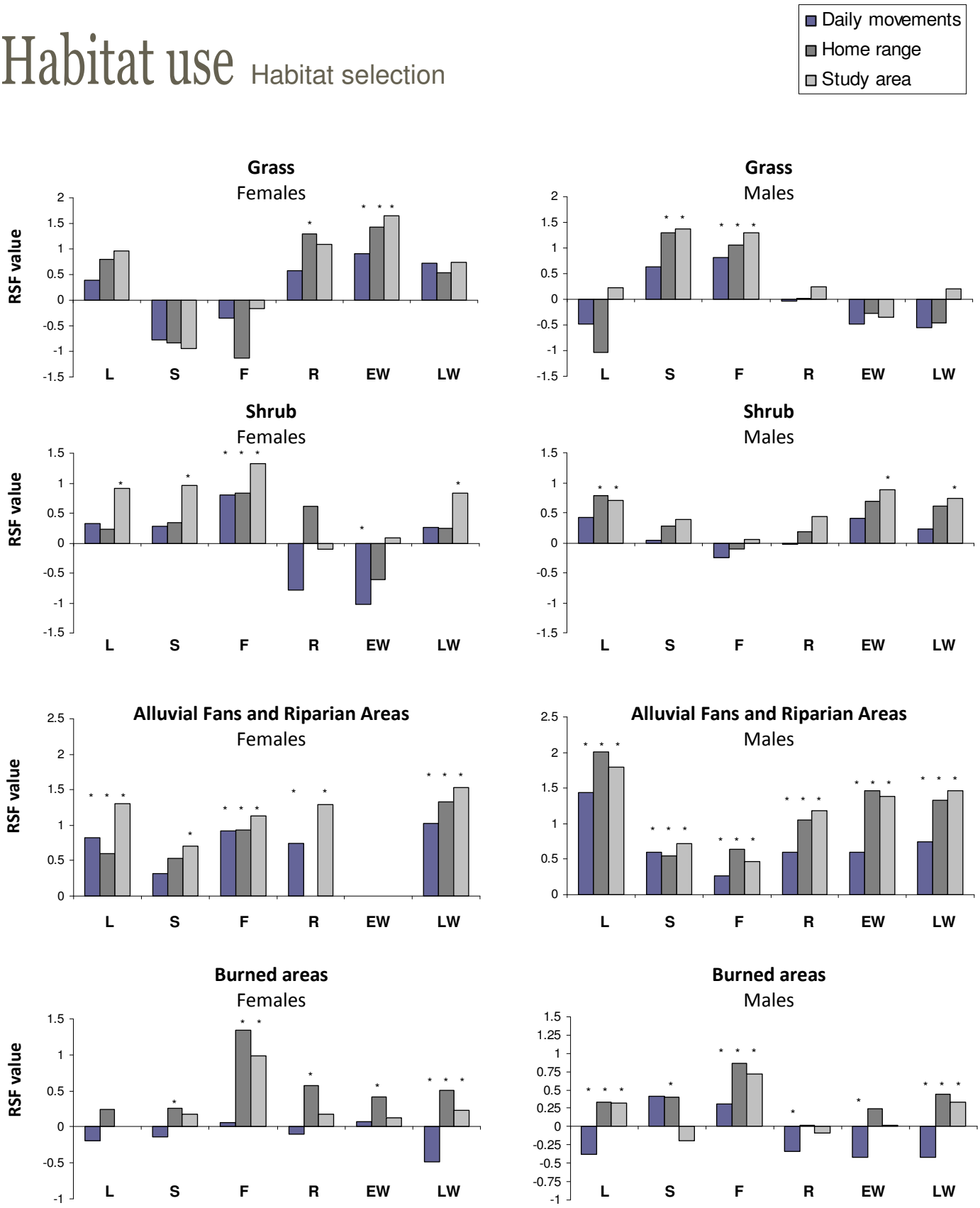
Differences in habitat selection by males and females

- Females were more closely associated with escape terrain and showed greater use of habitat attributes thought to reduce predation risk and provide thermal cover.
- Selection for rock was more important in defining seasonal distribution of females than males, especially from mid-August through mid-May (F, R, EW, LW seasons).
- Conifer had a bigger influence on the distribution of males, favouring it in August – September (F season), whereas females were generally neutral in their use of conifer.
- Warm, dry (convex) sites were especially important to males in May – June (L season), but less important for females.
- Shrub was most important to females, and least important to males, in August – September (F season).
- Grassy sites were favoured by females in November – February (R and EW seasons) and by males in June – September (S and F seasons).

Habitat use Habitat selection



Habitat use Habitat selection



Management considerations Primary conclusions

1 The Sulphur / 8 Mile study area supports nearly 18% of northeast BC's Peace Region Stone's sheep, with no evidence of declining populations in the study area.

Population census during the end of the rut is more effective than late winter census.

Conduct census regularly, using consistent standard protocols and reporting of results. Monitor changes in density of sheep and other ungulates in spatially-defined census areas.

2 Sheep in the S8M study area belong to at least 2 populations separated by the Toad River, with ecological differences between Sentinel and Stone population sheep and density on winter ranges a key factor.

Manage as two distinct populations and maintain integrity of links to adjacent populations south and west of the study area.

3 Density-dependent effects on population dynamics were observed in the Stone population, where sheep density on alpine ranges was approximately double that of Sentinel sheep.

4 Evidence of density-dependence in the Stone population included lower over-winter lamb survival, a greater proportion of health-related mortalities, and more use of subalpine habitats by younger males.

5 Evidence of density-dependent responses in Stone population dynamics suggests potential for rapid changes in sheep population dynamics even without any industrial development, if resource limitations (e.g., habitat capacity) or changes in other limiting factors (e.g., predation, harvest pressure) emerge.

6 Elk and moose were common on sheep ranges in the S8M PTP High Elevation Zone south of the Toad River.

Monitor density-dependent changes in sheep population dynamics and changes in multi-species dynamics.

Adopt conservative approaches to management actions or resource development that may influence distribution and density of other ungulates and predators on sheep ranges.

7 Pregnancy rates and lamb recruitment indicate good population productivity and balance survival rate of adult females.

Site-specific weather data should be part of population monitoring programs as an indicator of recruitment and survival.

8 Primary cause of death varies between Sentinel and Stone populations. Snow conditions, falls, injuries, and health-related factors combined account for more deaths than predation.

9 More than 40% of adult female mortalities occur in late winter, particularly April and May.

Minimize stressors in this period.

Management considerations Primary conclusions

10 Sheep deaths due to vehicle collisions are significant, preventable, and add to natural mortality.

Monitor and mitigate vehicle-related mortalities at the Rock Cut and Petersen Canyon Highway crossings.

11 Harvest of mature males exceeds conservative limits.

Monitor and manage harvest pressure commensurate with changes to backcountry access.

12 Herd health parameters are within reported normal range.

Encourage opportunistic sampling of wildlife health indicators.

Avoid contact with domestic livestock to reduce disease risks.

Limit dust and artificial mineral sources.

13 Most sheep use more than one distinct core area in their annual home ranges, with predictable fidelity to seasonal ranges.

14 Seasonal ranges are smallest in early winter, with males and females on the same winter ranges.

Protect and monitor high density winter ranges.

Minimize disturbance to sheep when use of alternate habitats and ranges is limited by snow depth.

15 East to west movements across the Sentinel Range and north to south movements along the Stone Range follows the orientation of major ridges and drainages. Regularly used wildlife trails are clearly visible.

Do not disrupt or impede wildlife use of trails.

16 Mineral licks at the periphery of sheep populations influence home range size and are important links between populations that share use of these licks.

Protect and monitor natural mineral licks.

17 Sheep use steep (29° – 37°), rugged, warm aspect alpine and subalpine ranges, with 93% of male and female locations above 1,200m elevation year-round.

Management for sheep is also likely to serve mountain goats.

Management priorities to support long-term sustainability of S8M sheep populations should address the most practical management-relevant components of Stone's sheep ecology, with a focus on core ranges and high density areas where disturbance impacts are likely to be most acute.

Management considerations Importance of the PTP area

S8M PTP High Elevation Zone **north** of the Toad River

- Little use by Stone's sheep and other wildlife.
- Only one group of 4 sheep, including a collared female transplanted to the area by the Ministry of Environment in March 2005, was observed during the December 2006 and March 2007 censuses.
- Capture efforts (winters 2004/2005-2008/2009) to collar males and females in this area were not successful as no sheep were sighted.
- Reconnaissance flights in November 2007 and July 2008 did not detect any sheep.
- Absence from alpine ranges is consistent with BC Government sheep harvest records and local knowledge reports.
- GPS-collared sheep did not move beyond the distribution of winter census observations in the S8MP area.
- 7 elk (Dec 2006), 5 moose (Dec 2006), and 3 goats (Mar 2007) were observed.

All data indicate **low risk for potential impacts** of industrial development on sheep populations.

S8M PTP High Elevation Zone **south** of the Toad River

- All age-sex groups use ranges in the south S8M PTP High Elevation Zone.
- Males, particularly young males, use the High Elevation Zone more extensively than females do. This was reflected in higher ratio of males to females in the High Elevation Zone than average across the Stone Range.
- The Ram Mountain complex provides winter range for sheep of all age-sex classes. Some female nursery groups are resident year-round.
- During winter census, the ratio of lambs to females was higher in the south PTP (55%) than the average for all Stone population sheep (37%).
- Most (93%) GPS locations obtained for males and females were above 1,200 m elevation. For males in the High Elevation Zone this percentage was reduced to 86.7%.
- Moose and elk were the most abundant ungulates observed incidentally during winter census, especially near treeline. Density of elk (0.44/km2) above 1,200 m elevation was close to sheep density (0.57/km2). Moose density above 1,200 m was 0.22/km2.
- 18 caribou and 1 goat were observed (Feb 2009).
- The Dunedin River corridor is subject to higher levels of human activity than other areas of the High Elevation Zone due to user maintained trail access that originates at the Alaska Highway.
- There are a number of unmapped seismic lines.
- As in other parts of the study area, the High Elevation Zone has been subject to ad hoc management activities, including placement of mineral salts, prescribed burns, and predator control. The timing, extent, and ultimate effect of these activities is unknown.

All data indicate **moderate to high risk for potential impacts** of industrial development on sheep populations.

Management considerations Pre-Tenure Plan Framework

Summary of the M-KMA pre-tenure plan framework[1]

Pre-tenure plans are part of a results-based sustainable management framework for oil and gas operations in the M-KMA. They apply to areas of development as well as associated site access. **Results that must be met are identified as Objectives, Indicators, and Targets**. Indicators provide a means of measuring progress in achieving objectives. Targets define the expected results and identify acceptable disturbance limits, but do not specify where disturbance may or may not occur. PTPs are subject to review and potential amendments as new information becomes available to refine criteria, elements, objectives and indicators.

Vegetation maps based on Predictive Ecosystem Mapping (PEM) have been completed for pre-tenure plan areas. These form the basis of winter habitat capability maps for 5 species of PTP management interest: Stone's sheep, mountain goat, elk, moose, plains bison.

There is 6-class habitat rating system for each species, with separate digital map layers for each species. These were combined to create biophysical zone designations in each PTP area. **Stone's sheep and mountain goat high capability winter habitat is predominantly within the Steep Slope-Warm Aspect Biophysical Zone.**

S8M High Elevation PTP management direction

For the S8M PTP area, the following elements have been identified under management direction for Conservation of Wildlife Diversity, which aims to maintain the integrity, function and habitat of wildlife.

Element 1.1 Conservation of Stone's sheep in the High Elevation Zone

Objectives, indicators, and targets to be defined through a PTP amendment process, incorporating information available from the S8MP Stone's sheep study and other applicable information.

Element 1.2 Conservation of mountain goat diversity in the High and Low Elevation Zones

Objective: Habitat is sustained in winter habitat capability classes that range from 1-6 within each biophysical zone.

Indicator: The amount (% and ha) of disturbance by habitat capability class.

Target: 98% of the winter habitat remains undisturbed in moderately high to high capability habitat.
95% of winter habitat remains undisturbed in moderate to nil capability habitat.

[1] MSRM 2004. Muskwa-Kechika Oil and Gas Pre-Tenure Plans.

Management considerations Pre-Tenure Plan Considerations

Development of objectives, indicators, and targets for the S8M PTP High Elevation Zone could incorporate:

- a defined Stone's sheep zone similar to the Caribou zone defined in the M-KMA Halfway-Graham PTP
- maximum disturbance limits associated with PTP biophysical zones, and
- identification of specific areas with special biological significance.

Wildlife managers and industry proponents should also be aware of the general management considerations on pages 52 – 53 and existing best management practices (see additional resources on page 58).

Defining a Stone's Sheep Management Zone

The Halfway-Graham Caribou Zone is recognized as a distinct element under Criterion 1. It highlights the area known to be inhabited by caribou during winter, but it does not contribute to or reduce the total hectares in the PTP or each PTP biophysical zone.

A Stone's sheep zone could be defined by a buffer on the locations obtained from GPS-collared sheep. Buffering the GPS locations overlaps the distribution of winter census observations and includes summer range for sheep that are resident in the S8M study area.

Additional consideration could be given to the elevations at which sheep are typically found. Stone's sheep are predominantly an alpine-dwelling species, but use subalpine elevations (1,200 – 1,400 m) seasonally. Most (93%) GPS locations obtained for males and females were above 1,200 m elevation. For males in the High Elevation Zone this percentage was reduced to 86.7%.

In most cases, locations below 1,200 m elevation are likely associated with seasonal movements between core high-elevation ranges and use of low-elevation mineral licks. Trails encountered at any elevation should be maintained such that wildlife use is not disrupted or impeded.

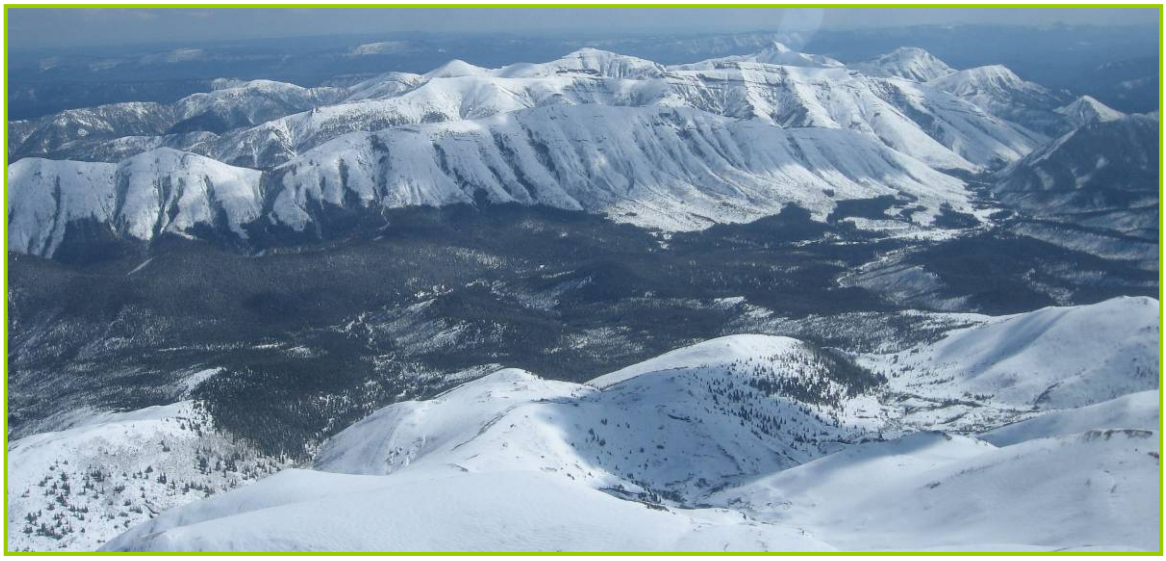


PHOTO View of the Ram Mountain complex from the Stone Mountain Range.

Management considerations Pre-Tenure Plan Considerations

Pre-Tenure Plan Biophysical Zone Disturbance Limits

High use of warm, steep biophysical zones in the S8M PTP High Elevation Zone reflects the strong correlation between sheep distribution, solar radiation and steep slopes.

▪ Of 2751 locations obtained **for 6 GPS-collared males** that used the S8M PTP High Elevation Zone, **66.9% were in the Steep (>45% slope) Warm Aspect biophysical zone year-round**. An additional 23.0% of locations were in the Steep Cool Aspect biophysical zone, primarily in Summer and Fall seasons (June 15 – October 31).

▪ Of 3100 locations obtained for **2 GPS-collared females** that used the S8M Pre-Tenure Plan High Elevation Zone south of Toad River, **79.5% were in the Steep Warm Aspect biophysical zone year-round**, and 20.3% were in the Steep Cool Aspect, primarily in May through December. Results from the Besa-Prophet Stone's sheep study found 70.3% of female locations in the Steep Warm Aspect zone and 27.6% in the Steep Cool Aspect zone.

Areas of Special Biological Significance

The Ram Mountain complex provides winter range and year-round habitat for male and female sheep.

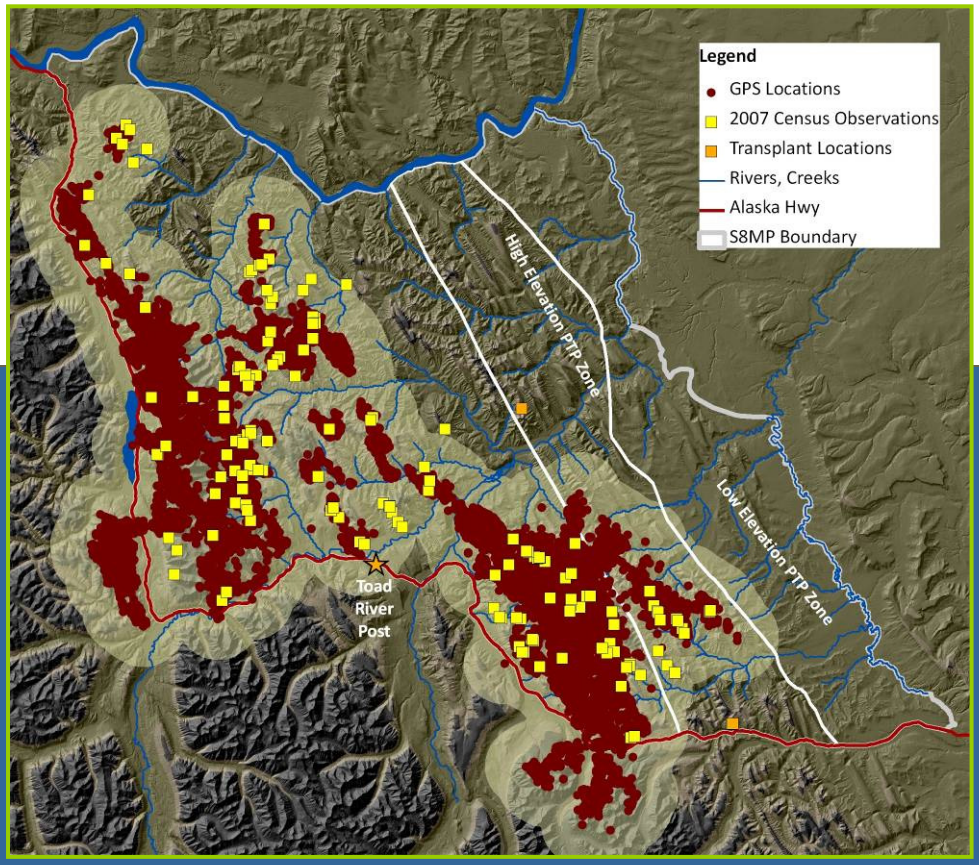


FIGURE Example of a potential 'Stone's sheep management zone' defined by a buffer on sheep GPS locations. This buffer includes summer and winter range for sheep in the S8M study area. Winter census observations are provided for comparison.

Management considerations Additional resources

Documents are available for download from www.synergyecology.ca/s8msheep

Local management plans and guidelines

Muskwa-Kechika Oil and Gas Pre-Tenure Plans (MSRM 2004).

Muskwa-Kechika Wildlife Strategy (MoE 2009).

Fort Nelson Land and Resource Management Plan (MSRM 1997).

Muskwa-Kechika Management Area Management Plan (Oct 1997).

BC Parks Management Plan for Muncho Lake Park (2003).

BC Parks Management Plan for Stone Mountain Park (2003).

Best management practices

Muskwa-Kechika Wildlife Strategy technical manual (MoE 2009).

Recommendations for industry practice guidelines for Stone's sheep in northeastern BC. Pages 50 – 58 *in* Problem analysis of the Stone's sheep situation in northeastern BC (AXYS 2005).

Flying in sheep country (MWLAP 2003, Churchill 2003, Laberge 2002).

Wildlife guidelines for commercial backcountry recreation (MWLAP 2002).

Management recommendations for bighorn sheep in forestry contexts (MWLAP 2004).

General considerations

Status of thinhorn sheep in British Columbia (Demarchi 2004).

Stone's sheep – preparing for the future. An action plan for Stone's sheep (GOABC 2007).

Stone's sheep of the Northern Rockies: the effects of access (Paquet and Demarchi 1999).

A working hypothesis for thinhorn sheep management (Heimer 1999).

A working hypothesis for bighorn sheep management (Toweill 1999).

Alaska Pipeline Project proposed routes

www.emr.gov.yk.ca/oilandgas/ahpp.html and www.thealaskapipelineproject.com

Management considerations Additional resources

Documents are available for download from www.synergyecology.ca/S8Msheep

Project reports

Stone's sheep population dynamics and habitat use in the Sulphur / 8 Mile oil and gas pre-tnure plan area, northern BC, 2005 – 2010 (Hengeveld and Cubberley 2011).

Sulphur / 8 Mile Stone's sheep community knowledge project (Peck 2009).

M-KMA data report on habitat mapping (Wheate 2007).

S8M Stone's sheep survey, March 2004 (Elliott 2004).

Problem analysis of the Stone's sheep situation in northeastern BC (AXYS 2005).

Other data sources for Stone's sheep populations in north-east BC

Peace region Stone's sheep inventory, March 2007 (Thiessen, draft).

Peace region WMU 7-52 Stone's sheep inventory, March 2009 (Thiessen 2009).

Habitat selection and behavioural strategies of Stone's sheep in the Besa-Prophet. Summary report for the Muskwa-Kechika Advisory Board (Parker and Walker 2007).

Habitat selection and behavioural strategies of Stone's sheep in the Besa-Prophet area (Walker 2005).

Ecological importance of licks to Stone's sheep, elk, moose, mountain goats in the Besa-Prophet area (Ayotte 2004).

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Sulphur / 8 Mile Stone's Sheep Project

A multi-stakeholder research and planning initiative in the Muskwa-Kechika Management Area, northern British Columbia

Stone's sheep population dynamics and habitat use in the Sulphur / 8 Mile oil and gas pre-tenure plan area, northern British Columbia, 2005 – 2010

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