Bull River bighorn sheep rams. Photo: TJ Gooliaff

Kootenay Region Bighorn Sheep Management Plan

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

205 Industrial Road G
Cranbrook, BC V1C 7G5

March 2021

BRITISH COLUMBIA

Foreword

This management plan provides guidance and recommendations for the management of bighorn sheep and their habitat in the Kootenay Region of British Columbia. It summarizes the latest science on emerging issues that are affecting bighorn sheep in the Kootenays and across the Pacific Northwest, and provides prioritized management recommendations that address broad-level, region-wide concerns as well as for specific Population Management Units.

Implementation of actions will depend on government priorities, budgetary constraints, and legal, social and economic factors. Successful delivery of bighorn sheep monitoring and management in BC will require the commitment and cooperation of partners across the Province.

In late 2018, Kim Poole[1] and Jeremy Ayotte[2] were contracted by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development to develop the draft management plan. The draft plan was completed in January 2020 after consultation with regional stakeholder groups, First Nations, the Conservation Officer Service, Ministry staff and the general public. Revisions were made to the management plan after internal review by Ministry staff. The final management plan was approved by the Director of Resource Management (Kootenay Boundary) and Associated Deputy Director in March 2021.

Information from this plan will be used to develop an implementation plan, which will outline priority actions and timeline of activities for each PMU. The report does not represent an official position or program of government and may support discussions with Indigenous peoples and stakeholders in the development of specific regional plans and actions.

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Executive Summary

The Kootenay Region bighorn sheep management plan is intended to provide managers and decision makers with scientifically supported guidance for the management of bighorn sheep and their habitat in the Kootenay Region. Management recommendations have been developed from a review of current science on emerging issues that are affecting bighorn sheep in the Kootenays and across the Pacific Northwest.

In consultation with regional stakeholder groups, First Nations, the Conservation Officer Service, Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) staff and the general public, we propose management objectives for bighorn sheep and identify a range of objectives, management tools and harvest regulation alternatives in consideration of human influences on wild sheep and their habitats. Objectives are focused on population, harvest, habitat, health and predation management.

Population status was assessed for bighorn sheep management in 12 Population Management Units (PMUs). Seven PMUs are either below population objectives or are trending downward, although three of the seven are small herds that were either introduced (South Salmo, Lower Arrow) or the result of natural dispersal later aided by a feeding program (Golden).

We provide management recommendations that address broad-level, region-wide concerns as well as for specific PMUs. We also recommend which PMUs and broad-level management actions should be addressed first, and appropriate indicators to monitor the effectiveness of those actions.

An assessment of PMU-specific threats resulted in four PMUs being prioritized for immediate management action (Bull River, Elk Valley West, Columbia-Radium and Wigwam Flats-Elko-Phillips). Common threats that span multiple PMUs include increasing disturbance from humans, declining habitat condition, increased highway/predation mortality and increasing risk of disease transmission from domestic sheep. It is recognized that factors limiting sheep populations are not well understood and a better understanding on the effects of habitat, predation and disturbance impacts are needed for effective implementation. Current hunting seasons are not believed to be affecting population trends, concerns were raised with the impacts of high harvest rates of mature rams and increasing hunting pressure. Alternative harvest management strategies are evaluated in this plan and will help Ministry staff revisit existing hunting seasons.

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Introduction

Bighorn sheep (*Ovis canadensis*) are an important big game species in the Kootenay Region of British Columbia (BC), where most native bighorn sheep are located along the Rocky Mountains from the US border north to the Kicking Horse River valley (Demarchi et al. 2000, Shackleton 2013, Stent et al. 2013). Bighorn sheep in BC were originally considered separate subspecies (Rocky Mountain and California), and although they are generally managed as two separate ecotypes (Kuzyk et al. 2012) they currently are classified as a single species (Wehausen and Ramey 2000). Bighorn sheep are Blue-listed in BC (provincial conservation status ranking S3 – special concern) because there have been substantial declines in some areas and sheep continue to lose good quality habitat (especially native winter range) to various types of direct habitat loss and land conversion, invasive plants and to forest encroachment (BC Conservation Data Centre 2019). Sheep are also vulnerable to a variety of parasites and diseases, particularly respiratory disease introduced from contact with domestic sheep and goats (Schommer and Woolever 2008, Besser et al. 2014, Sells et al. 2015, Cassirer et al. 2018), and may be impacted by changes in distribution and abundance of parasite species resulting from climate- effects (Aleuy et al. 2018).

The conservation and management of bighorn sheep characterizes the challenging issues facing modern wildlife management (Boyce and Krausman 2018). Issues range from devastating disease impacts originating in domestic livestock, road mortality, to declining range condition, to competing [] views on trophy hunting. With fundamental human-induced ecological change across many low-elevation winter ranges, the conversion of fire-maintained grasslands to shrub and conifer ecosystems and management induced divergence from natural wildfire return intervals are exacerbating several bighorn sheep conservation concerns from forage quality (Kinley 2007, Phillips and Crowley 2012), to predation (Rominger 2018).

A mountain sheep management plan for British Columbia was prepared in 1973 (Demarchi et al. 1973) and was updated in 1978 (Demarchi et al. 1978), but there is no current, comprehensive provincial management plan for bighorn sheep (a provincial thinhorn sheep [*Ovis dalli*] plan is being drafted; FLNRORD 2018a). A regional mountain sheep management plan for the Thompson-Nicola region in the 1980s (Ritcey and Low 1986) and various topic-specific plans have been developed (e.g., Demarchi and Demarchi 1994, Harper et al. 2002). Here we present a bighorn sheep management plan for the Kootenay Region developed in consultation with First Nations, stakeholder groups, government staff, and the general public. This plan, which will be in place until new information is added to develop an updated plan, addresses population management and harvest strategies as well as habitat and health concerns, access management, and predator management. Population and harvest trends are presented regionally and by management unit. Background to management issues are summarized, but further information on the ecology of bighorn sheep in general and in the Kootenay Region can be obtained from Demarchi et al. (2000), BC WLAP (2004), Kuzyk et al. (2012), Poole (2013), Stent et al. (2013), Shackleton (2013), Smyth (2014), and Poole et al. (2016). Management recommendations are presented regionally and by Population Management Unit (PMU) and include strategies and indicators to measure progress. The Bighorn Sheep Harvest Management Procedure (FLNRO 2014) was used as the starting point for hunting regulation options and identifies performance targets for monitoring.

Bighorn sheep management plans consulted from other jurisdictions in western North America included: Alberta (AESRD 2015), Montana (MFWP 2010), Idaho (IDFG 2010), Washington (WDFW 2015), Wyoming[3], and Colorado (CDW 2009), with summaries of harvest strategies (Rominger et al. 2008) and a review of sheep conservation challenges and management strategies (Brewer et al. 2014, Boyce and Krausman 2018).

Prior to developing management objectives, population management units (PMUs) were delineated. PMUs represent broad areas where bighorn sheep herds are separated by differences in wintering strategies, habitat differences, assumed or known movements and isolation by distance, and where management objectives should be relatively consistent.

Bighorn sheep management direction for the Kootenay Region was developed using the management plan objectives:

1. Identify risks to maintaining sustainable sheep populations
2. Consult with Ministry staff, First Nations, stakeholders and others to obtain feedback on early draft goals and objectives, and local insight into additional threats, issues and concerns;
3. Identify recommended management tools and strategies;
4. Establish population goals, population objectives, management recommendations and identify threats to recovery by PMU;
5. Finalize recommendations to be actioned within a bighorn sheep implementation plan.

Fulfillment of the recommendations of this plan will provide benefits to habitats that affect other species, restore aspects traditionally delivered by natural wildfire return cycles and increase biodiversity values. For example, ecosystem restoration focussed on bighorn sheep habitat would benefit open habitat types such as grasslands, and other species such as mountain goats, elk, white-tailed deer and mule deer. Ecologically healthy habitats generally translate into resilient populations that can better withstand predation, weather and other population pressures, including human harvest.

Many recommendations in this management plan could have social, economic and environmental impacts (both negative and positive) beyond those solely directed at bighorn sheep. These recommendations should be considered within a collaborative, integrated and balanced decision-making process.

First Nations Consultation

An engagement meeting was held with staff from Ktunaxa Nation Council in December 2018 and the draft management plan was distributed to all bands in the Okanagan Nation Alliance (*Syilx*), Sinixit Nation, Ktunaxa Nation and Shuswap Nation (*Secwepemc*) in March 2020. Comments on the draft management plan were received from Ktunaxa Nation Council, Sinixit Nation and Little Shuswap Indian Band.

[3] https://wgfd.wyo.gov/WGFD/media/content/PDF/Wildlife/Handbook-BioTechniques/06-BigHornSheep.pdf

Public Consultation

Consultation meetings were held with Kootenay Region bighorn sheep stakeholder in December 2018 during the early development of this management plan. These initial consultations helped to identify goals and objectives of the plan and to coordinate local knowledge on threats and concerns impacting specific bighorn sheep populations. The following government and stakeholder groups were represented at these meetings: Conservation Officer Service, BC Hydro Fish and Wildlife Compensation Program, Kootenay National Park, East Kootenay Wildlife Association, Wildsight, Backcountry Hunters and Anglers (BC Chapter), and the Guide Outfitter Association of British Columbia. A draft of this management plan was later reviewed by stakeholders at a meeting in Cranbrook in May 2019. First Nations and stakeholder input was instrumental in developing a comprehensive list of PMU-specific threats and enhancement strategies, which led to the addition of several implementation-related sections on Monitoring and Indicators, Priorities, and Knowledge Gaps, which are included at the end of the report. This feedback also helped identify issues with harvest management approaches and assess alternative approaches. A summary of key points from stakeholder engagement are provided in Appendix 1.

Distribution and Abundance

Population Management Units

Population Management Units have been proposed for bighorn sheep in the Kootenay Region (Fig. 1, Table 1; Poole 2015). PMUs are biologically meaningful population units that represent the year-round

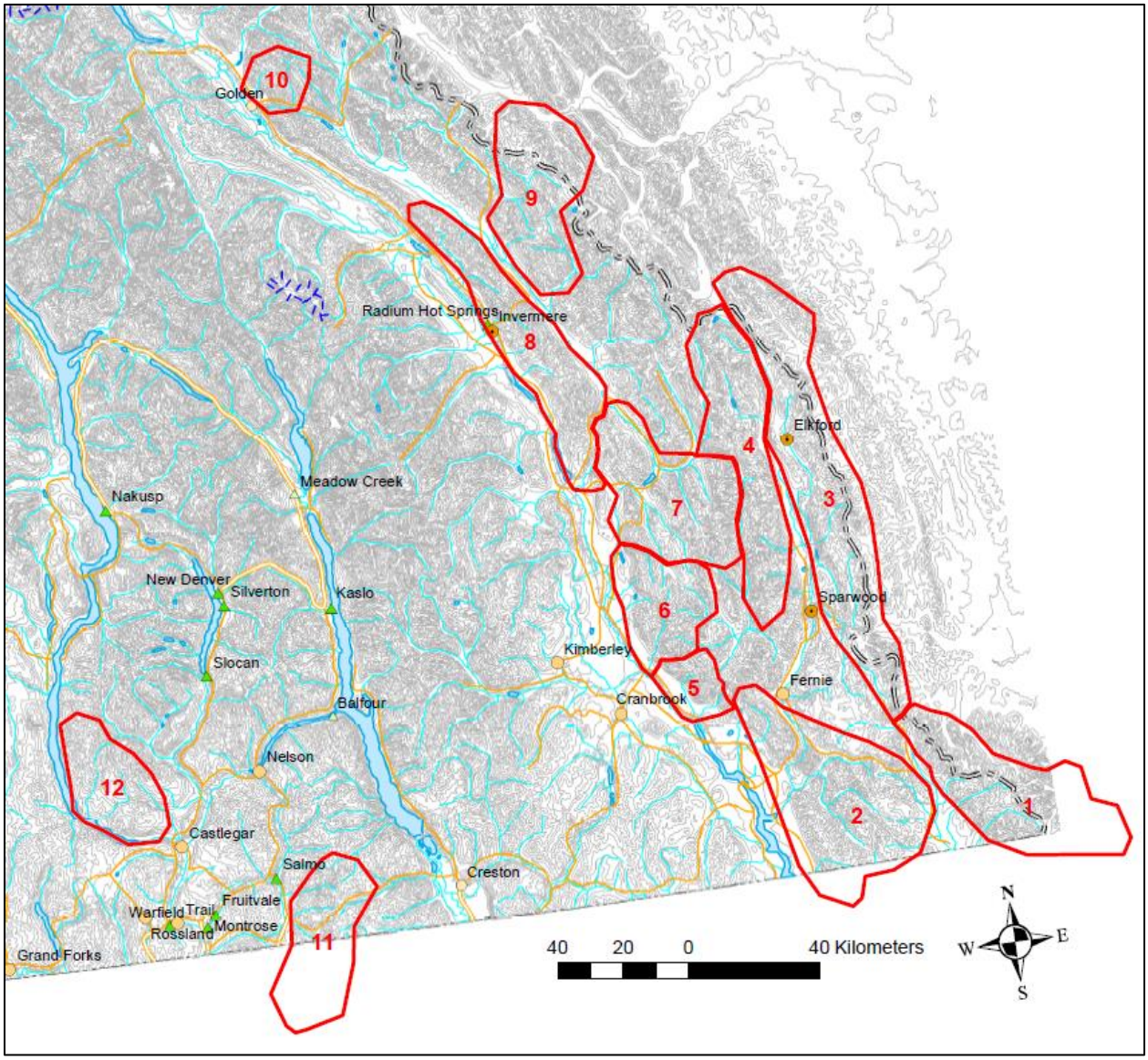

Figure 1. Population Management Units (PMU) proposed for bighorn sheep in the Kootenay Region, BC. See Table 1 for PMU names.

range of a species and are delineated based on minimal interchange (emigration and immigration) with other populations. They were developed using repeatable and scientifically defensible biological/ecological criteria (Poole 2014) and are designed as the main unit for population assessment and management. Bighorn sheep generally exist as metapopulations, where the total population of a geographic area consists of smaller subpopulations (herds) occupying naturally fragmented patches of suitable habitat that are interconnected genetically and demographically by periodic movements of individuals (typically young males) among those subpopulations. Here we consider a PMU to be a metapopulation, and a single PMU may have several subpopulations/herds. The main drivers in PMU designation were assumed movements among subpopulations, similarities and differences in wintering

strategies, broad habitat differences, and isolation by distance. While the PMU is considered the main unit of management, it

Table 1. Delineation of Rocky Mountain bighorn sheep Population Management Units (PMU) in Region 4.

PMU#	PMU Name	Comments
1	Flathead-Waterton	Most sheep winter on the Alberta side of the Divide. Little harvest in BC
2	Wigwam Flats-Elko-Phillips	Encompasses Wigwam Flats, Elko-Lizard Range, Galton (Maguire and Phillips Ck.); some overlap of latter into Montana
3	Elk Valley East	Five subpopulations: Crowsnest North, Erickson/Sheep Mt., Ewin Ck., Fording, Upper Elk East; some overlap into Alberta
4	Elk Valley West	Three subpopulations: Hornaday (Brule Ck.), Crossing Ck., Upper Elk West (Quarrie Ck.)
5	Bull River	Predominantly occupy the watershed of the Bull River valley with winter range confined to the lower slopes of Bull Mountain
6	Premier-Wildhorse	North of Diorite to Wildhorse
7	Whiteswan-Sharktooth	Sharkstooth, Nine Mile, Whiteswan, Van Nostrand, Coyote-Blackfoot
8	Columbia-Radium	Two subpopulations: Columbia Lake, Radium-Windermere
9	Assiniboine	Overlap into Alberta
10	Golden	Kicking Horse
11	South Salmo	Some overlap into Washington. Expansion of introduced herd from Washington into BC.
12	Lower Arrow	Syringa Creek Provincial Park; introduced herd.

does not preclude specific management directed at an individual herd within a PMU or metapopulation. Herd names used in this document are based on bighorn sheep ranges and herd designations updated by FLNRORD staff in May 2012 (D.N. Demarchi, BC Environment, pers. comm.) with refinements provided by I. Teske (FLNRORD, pers. comm.).

Bighorn sheep in the Kootenay Region generally employ one of two seasonal behavioural strategies: those that use lower elevation winter ranges within the Rocky Mountain Trench – escaping deep snow at higher elevations by using grassland or open forested habitats on flat or southerly aspects associated with rocky escape terrain; and those that use higher elevation winter ranges – using mid to high elevation grassland habitats on windswept, southerly facing slopes, again associated with escape terrain (Kuzyk et al. 2012, Stent et al. 2013, Poole et al. 2016).

Population trends

Bighorn sheep population estimates since the mid-1980s within the Kootenay region have ranged from 1,700 to 2,500 sheep, with a peak in 2010 followed by a declining trend (Fig. 2). Survey quality and coverage prior to 2001 is largely unknown. Estimates for individual herds were derived from a

standardized 80% sightability correction for aerial surveys based on sightings of marked/collared animals (Teske and Forbes 2002, Poole 2013; Table 2). No sightability correction was applied to ground counts. Surveys were conducted in January-February 2019 to update most of the estimates.

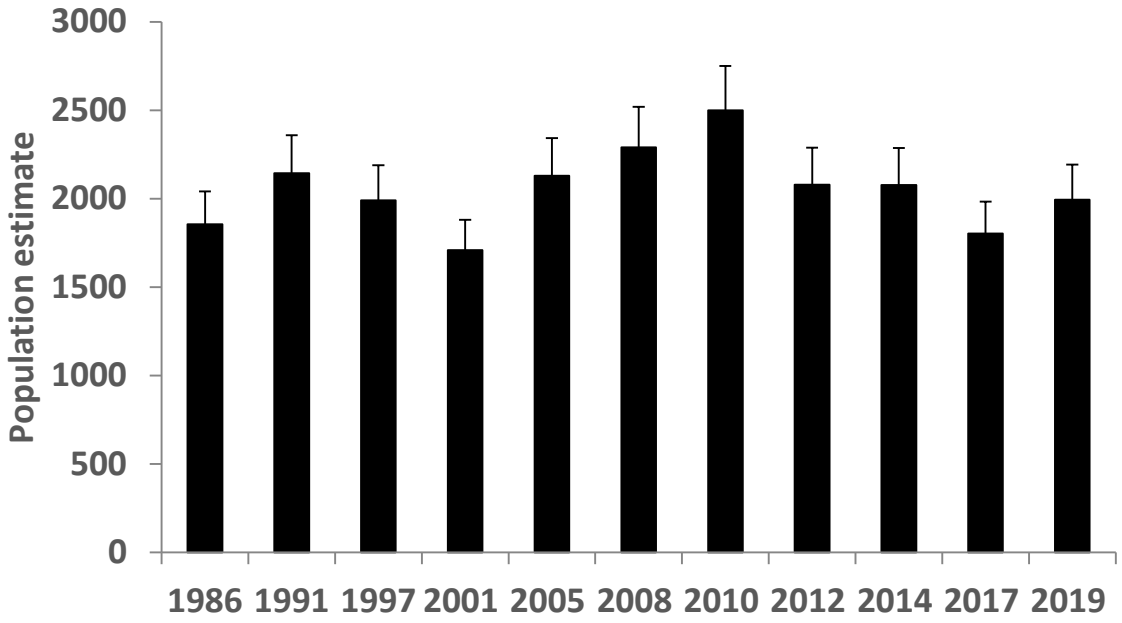

Figure 2. Population estimates for bighorn sheep in the Kootenay Region. The totals were derived from the sum of individual herd survey estimates based on standardized 80% sightability correction for aerial surveys (Teske and Forbes 2002; see Stent et al. 2013 for more background).

Harvest

Resident and non-resident harvest

In British Columbia, the management of bighorn sheep historically has largely been delivered using harvest restrictions based on horn curl (Demarchi 1978). Previous sheep hunting seasons in the East Kootenay have included a 7/8 curl or minimum 8 year old ram season prior to 1977 and a resident LEH ewe season between 1985 and 2002, with the bulk of ewe permits issued from 1986–96 (Kuzyk et al. 2012, Stent et al. 2013). Currently, only full-curl rams[4] are hunted in the Kootenays, with all GOS seasons running from 10 September–25 October (to 20 October in management units [MUs] 4-02 and 4-25 prior to 2009). A quota system regulates non-resident (guided) harvest, while resident hunting is primarily GOS, with a target harvest split of 60 resident:40 non-resident for management units with guide/outfitter territories (FLNRO, 2015). Limited Entry Hunting seasons currently occur for the Salmo herd in the West Kootenay and for three herds in the East Kootenay (Phillips Creek [Galtons], Bull River,

[4] In BC a full curl bighorn ram has at least one horn tip, when viewed squarely from the side at right angles, extending upwards beyond a straight line drawn through the centre of the nostril and the lowest hindmost portion of the horn base.

and Mt. Assiniboine Park); season dates for Mt. Assiniboine Park and Phillips Creek extend into early to mid-November, respectively.

Table 2: Current (January-February 2019 unless otherwise noted) bighorn sheep population estimates and historical range of estimates for the Kootenay Region. Shaded cells denote ground-based counts.

PMU		Estimate	Historical range	Comments
1	Flathead-Waterton	148	40–148	From Alberta and WLNP surveys 2018-19.
2	Wigwam Flats-Elko-Phillips	383	290–470	
3	Elk Valley East (5 subpops)	641	370–800	37 obs. from AB Crowsnest N 2018
4	Elk Valley West (3 subpops)	74	74–175	2019 lowest documented
5	Bull River	84	60–160	
6	Premier, Wildhorse	77	60–255	
7	Whiteswan-Sharktooth	249	133–312	
8	Columbia-Radium	253	230–380	Aerial and ground counts
9	Assiniboine	44	44–90	2019 lowest documented
10	Golden	16	15–45	Ground counts by locals
11	South Salmo	14	14–40	2019 ground count at feeder
12	Lower Arrow	11	4–79	2016 ground count
	Total	**1,994**		

The number of resident sheep hunters peaked in the early 1990s when the greatest numbers of ewe tags were allocated (Fig. 3). The unusually low number of resident hunters in 2004 may have been a data error, as most calculations associated with this year result in patterns that are significantly out of sync with adjacent years. Resident hunter numbers increased during the latter half of the 2000s and largely leveled off. Since the early 2000s the proportion of Kootenay Region sheep hunters who resided in the Kootenay region increased from roughly 80% to 87%, with the bulk of the remainder from the Lower Mainland and Vancouver Island. During 2008–17, 4 management units received 76% of the resident sheep hunters: 4-23 – 35%; 4-22 – 19%; 4-25 – 11%; and 4-02 – 11%. The number of non-resident hunters has declined in the past 5–6 years, possibly related to the full implementation of the allocation policy. Annually since 2008 there were an average of 363 resident and 28 non-resident sheep hunters.

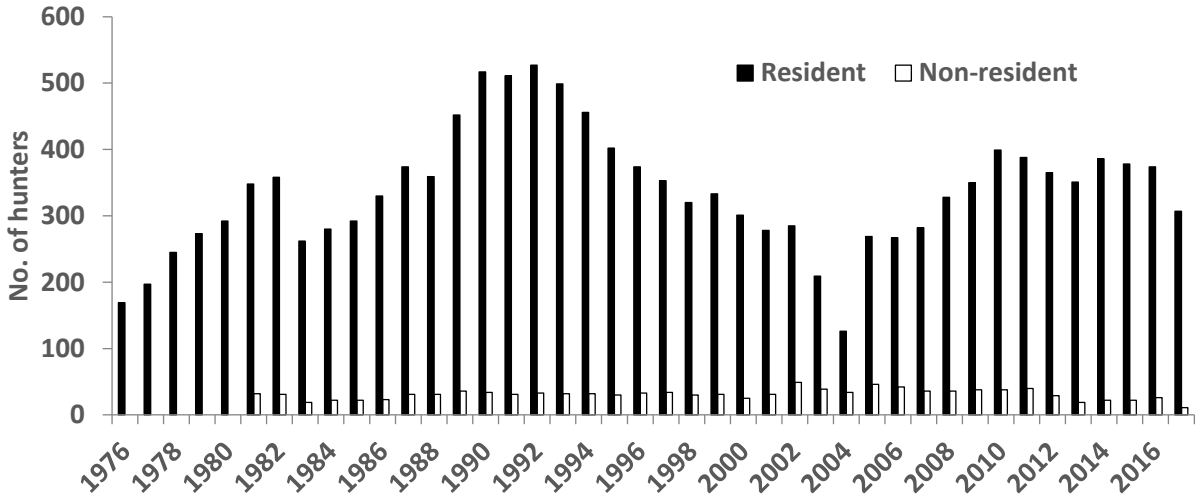

Figure 3. Number of resident and non-resident sheep hunters in the Kootenay Region, 1976–2017. No data were available for non-residents prior to 1981. Data were obtained from the Big Game Harvest Survey (FLNRORD, unpubl. data).

Accurate sheep harvest numbers exist in the Kootenay Region as all sheep harvested must be submitted for compulsory inspection by an inspector (Compulsory Inspection database), at which time they have an alpha-numeric aluminum horn plug installed into the horn. Non-hunter kills are also inspected and recorded in the Ministry's harvest data system. Annual hunter questionnaires (Big Game Harvest Survey) combined with the Compulsory Inspection data provide valuable information regarding hunter numbers, success and effort, which can help infer population trends over time from extrapolated kill-per-unit effort-based analyses (e.g., Hatter et al. 2017). Annual harvest of bighorn sheep in the Kootenay Region has varied, peaking in the late 1980s to mid-1990s due to the ewe harvest and comparatively high ram harvest (Fig. 4). During 2009–18 an average of 32 rams per year were harvested, with residents taking on average 24 rams (75%) and non-residents 8 rams (25%). During this same period sheep were reported killed by the Conservation Officer Service (average of 1.2 sheep annually; generally, to put down injured or unhealthy sheep), by illegal kill (1.2 sheep), by sheep-vehicle collision (7.9 sheep) and by sheep-train collision (0.4 sheep). The highest frequency of highway mortalities generally occurs at Radium and Elko, and most industry-related mortality occurs in the Elk Valley coal mines (Poole et al. 2018; FLNRORD unpubl. data).

Over a 35-year period from 1982–2017, individual resident hunters harvested between 1 and 15 rams each. Seventy-six percent of resident hunters harvested only one ram, comprising 55% of the resident harvest, 20% harvested two or three rams (32% of the harvest), and 3.6% of resident hunters harvested ≥4 rams during this period, comprising 13% of the harvest.

During 2008–17 the average annual resident hunter success (proportion of hunters who successfully killed a sheep) was over four times lower than that of non-resident sheep hunters (7% versus 32%, respectively); the average days-per-kill remained stable for non-residents but increased over time for residents (28 days versus 144 days, respectively).

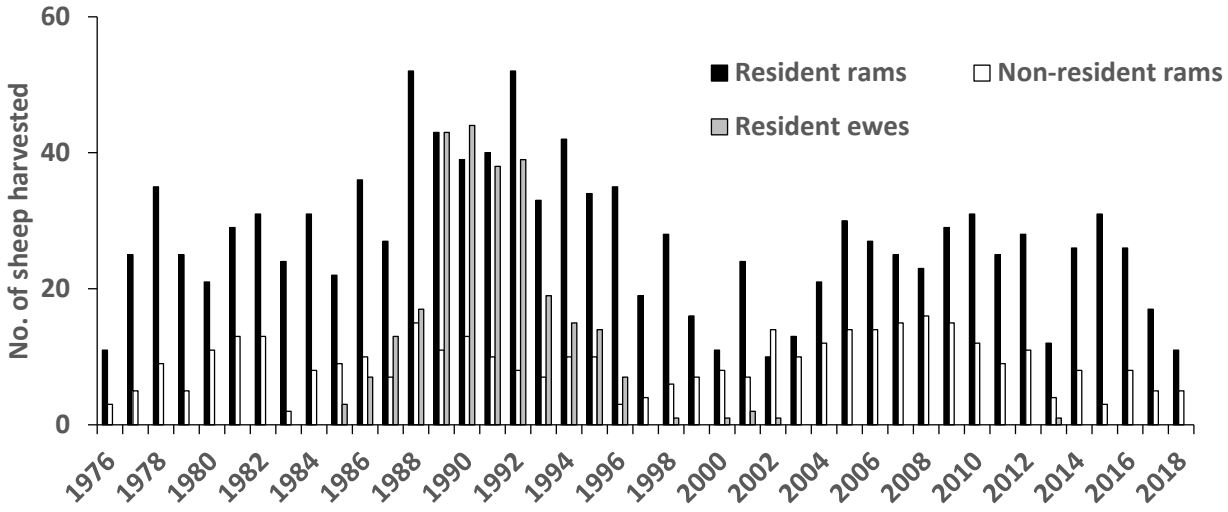

Figure 4. Annual harvest of bighorn sheep in the Kootenay Region, 1976–2018. Data were obtained from Compulsory Inspections.

Age of harvested rams as determined by horn annuli counts (Elbroch 2006) has steadily increased within the Kootenay region over the past 40 years, with an average mean age of 8.2 years since 2009 (Fig. 5), similar to observations from Alberta (Festa-Bianchet et al. 2014). This pattern remained even with sheep from MU 4-23 removed (the influence of the coal mines could potentially have skewed ages to older than the rest of the region). Nearly two-thirds of harvested rams are 7–9 years of age. Average horn length of harvested rams across the region was relatively stable from the mid-1990s to mid-2010s with an increase since 2014. However, horn length for harvested 8-year-old rams (the most frequent age harvested) declined 3.6% between 1995 and 2018, although most of the decline occurred between the mid-1990s and the mid-2000s with little subsequent change. A similar decline of 3.5% in horn length between 1980 and 2010 was observed in 6-year-old rams from Alberta (the most frequent age harvested; Festa-Bianchet et al. 2014). Ram harvest rates as calculated by the ram harvest compared with the total population estimate was ≤2.6% during the mid-1980s to mid-1990s and from 1.4–1.9% from the late 1990s to 2017 (Stent et al. 2013; Compulsory Inspection data). The proportion of rams harvested out of the total ram population in several management units where composition data were available averaged 7.2% in the Elk Valley East and 9.7–11.3% in Wigwam and Bull River PMUs, all <3% of the PMU population estimates (I. Teske and K. Poole, unpubl. data).

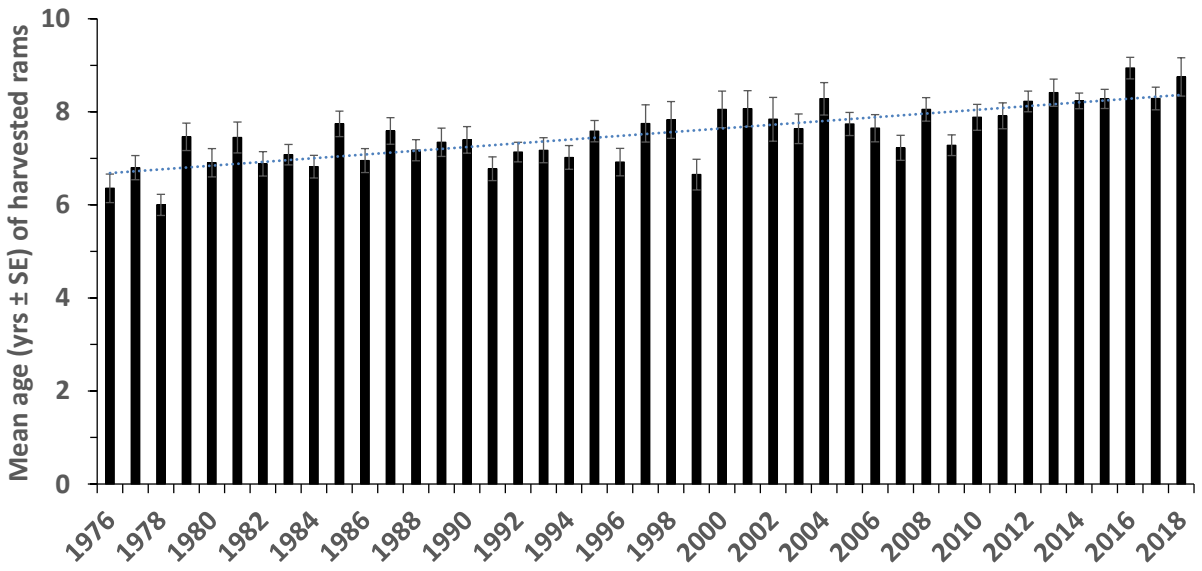

Figure 5. Mean age (±SE) of harvested bighorn sheep rams in the Kootenay Region, 1976–2018. Data originate from Compulsory Inspection reports. Rams were aged by counting horn annuli.

On average, 12% of rams were shot on opening day, 24% were harvested in the first 5 days of the season, 18% were harvested in the last 5 days of the GOS season (21–25 October), and 11% were harvested during 16–20 October (the penultimate 5-day period; Fig. 6). There was a slight increase in mean horn length and mean age of rams shot after 19 October.

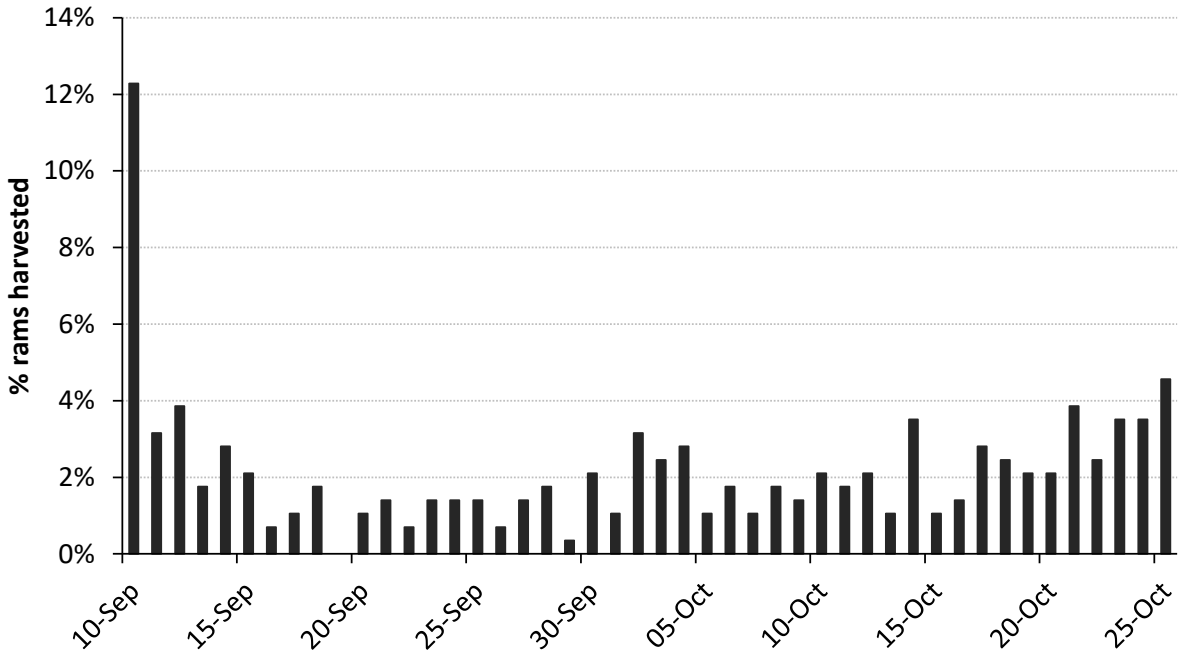

Figure 6. Temporal distribution of rams harvested in the Kootenay Region during the 10 September – 25 October General Open Season, 2009-19.

First Nations harvest

Current levels of First Nations harvest of bighorn sheep are not well understood as First Nations are not required to submit harvested animals for compulsory inspection. Ministry staff are aware of one full-curl ram harvested in the Elk Valley in Fall 2019 by a Ktunaxa hunter but no other harvest information exists. Determining First Nations harvest interests area key component for bighorn sheep management in the Kootenay Region.

Management Background

Population monitoring

Results from population surveys are used to evaluate the population trend and herd demographics and to assess whether population management objectives are being met (i.e., ram and lamb ratios). Bighorn sheep population monitoring in the Kootenays is conducted following standardized provincial protocols (RISC 2002). The herd as defined by distribution on winter range is used as the basis for surveys. To estimate abundance and age/sex ratios most sheep surveys are conducted during mid- to late winter when sheep are visible and generally concentrated on winter range (e.g., Phillips and Stent 2012). Surveys are typically conducted by helicopter and use standard survey methodology (Poole 2013, Stent et al. 2013) to obtain a total count, which is then corrected for incomplete sightability using sighting rate of marked animals (Teske and Forbes 2002, Poole 2013), application of a logistic regression model (Bodie et al. 1995, Unsworth et al. 1998, Phillips and Stent 2012), or a standardized sightability correction value to obtain trend estimates. Where possible, sheep are classified to lambs, ewes, and Class I – IV rams (Level 4 classification; RISC 2002). Digital photographs aid in the accuracy of counts and composition of larger groups. Grounds counts (with no sightability correction) are used to monitor abundance trends in several herds in the Kootenays (e.g., Radium, Golden, South Salmo, Lower Arrow). Annual survival is best determined from collar data when available (e.g., Kinley 2007, Poole 2013, Ayotte 2019).

Sightability is likely relatively consistent in alpine habitats but varies more widely in timbered habitats (George et al. 1996). Collar-derived sightability estimates within the East Kootenays range from 0.77–0.82 and model-derived sightability estimates range from 0.50 in closed forests up to 0.83 in open habitat (Phillips and Stent 2012, Poole 2013, Stent et al. 2013). Variation in sightability of 6% from collared sheep was detected between surveys in the Elk Valley East (Poole 2013) suggesting that survey-specific sightability should be modelled for all sheep surveys. Alternatives to aerial or ground counts when suspected population size is low and sightability is poor and highly variable could include faecal DNA-based inventories (e.g., Poole et al. 2011).

Survey frequency among herds varies widely, ranging from annually to every 3–4 years for many herds, and up to 10 years for others (Stent et al. 2013). Annual wildlife surveys consistently conducted by Teck Coal Ltd. up to 2018 within the Elk Valley East PMU provided excellent trend data. Herds with the highest hunting pressure tend to be monitored more frequently.

Sheep distribution during the fall hunting season generally differs from distribution during winter inventories, providing challenges to “assigning” sheep to management units and guide/outfitter

territories. Seasonal movements of these shared populations across borders with Alberta and the states challenge harvest management, especially as curl restrictions are less stringent in adjacent jurisdictions.

As noted above, the Compulsory Inspection database provides relatively accurate data on hunter and other sheep mortalities, harvest date and location, and age, while the annual Big Game Harvest Survey provides hunter success and effort data. The accuracy of Compulsory Inspection data is increased when regional staff review the data and photographs for possible errors.

Harvest management and hunting

Management objectives of the Big Game Harvest Management procedure (Ministry of Environment 2010) are to "maintain post-hunt numbers for each PMU at or near current levels", and to "maintain desired age structure in the harvest". This procedure also states in part that hunting regulations should maximize hunting opportunity wherever possible within the constraints of conservation and other socio-economic considerations. Management objectives within the Bighorn Sheep Harvest Management procedure (FLNRO 2014) state that hunted populations should be managed to avoid population declines and to "maintain sufficient mature rams[5] in the population to ensure that older rams fulfill their social and biological roles (e.g., do most of the breeding)". Management objectives should also take other values, such as wildlife viewing, into consideration. Harvest management rules within this procedure include:

- Populations with <75 ***observed*** sheep over three consecutive surveys should not be hunted;
- The Annual Allowable Harvest (AAH) for rams should typically be ≤3% of the total population ***estimate***;
- Where composition data are available, the AAH for rams may be up to 8–10% of the ***estimated*** number of rams;
- A reduced harvest rate should be considered where the mean age of harvested rams is <7 years of age (likely not applicable in the Kootenay Region because of the full curl regulation);
- Ideally a harvested population should have ≥30 rams:100 ewes and ≥30 lambs:100 ewes during mid- to late winter surveys;
- Lamb and/or ewe harvest seasons should be considered where it is deemed necessary to maintain population health, to aid in the reduction of agriculture-related conflicts, [and] to reduce potential for disease outbreaks.

Bighorn sheep populations in many areas within the Kootenay Region are declining, with the possible factors attributed to habitat loss, reduced habitat quality, increased habitat fragmentation, predation, and disturbance on critical ranges. Demand for ram harvest opportunities is great and although the mean age of harvested rams remains high and the ram harvest rate is below target levels, in a few areas the harvest of rams is greater than the recommended 8–10% and the overall harvest has declined; the 2018 harvest was tied with the lowest since the early 2000s. Hunter competition and over-crowding on quality sheep hunting areas has been reported in several areas, reducing the quality of hunting

[5] In BC a mature bighorn ram has a horn tip, when viewed squarely from the side at right angles to the sagittal plane of the skull, extends dorsally beyond the nose bridge plane. Here we use the term 'mature' to indicate older rams unless we specifically refer to mature curl rams with horn tips that extend beyond the nose bridge plane.

experiences and pushing sheep into non-preferred habitats which may increase predation risk and reduce the intake of preferred forage.

Hunters of bighorn sheep rams seek infinite opportunity to access a finite resource, and the current demand for bighorn sheep hunting opportunity and harvestable rams often exceeds the allowable harvest for sustainable populations. Generally, four or five ¾ curl rams could be produced annually from a population of 100 sheep during periods of rapid population growth, but only two to three ¾ curl rams/year once a population starts to decline (AESRD 2015). Therefore, annual harvest rates in the 3–4% range (rams to total estimated population) means most legal rams are harvested each year with low escapement.

There is ongoing debate whether selective hunting of large rams has the potential to reduce horn size via artificial selection against rams with rapidly growing horns (Boyce et al. 2019, Festa-Bianchet 2019). The one camp suggests that selection has to be intensive over several generations to produce a measureable evolutionary response, but that the intensity of selection by trophy hunters is seldom high enough and other factors (e.g., nutrition [affected by population density], habitat and environmental condition) usually confound responses (Coulson et al. 2018, Heffelfinger 2018, LaSharr et al. 2019). The other camp suggests that selection through unlimited (GOS) phenotype-based (4/5 or full-curl regulations) hunting is indeed intense enough in many areas of British Columbia and Alberta for harvest-caused evolutionary change (Festa-Bianchet 2019). Options for genetic rescue by older rams from protected areas may be thwarted by late season closing dates that makes these rams vulnerable to harvest. In the Kootenay region mean age of harvested rams has increased (Fig. 5) and horn size of 8-year-old rams appears to have declined, suggesting that rams are attaining legal size at older age. Harvest intensity, regardless of curl restriction, may be the most critical factor driving artificial selection (Hengeveld and Festa-Bianchet 2011, Douhard et al. 2016). Harvest rates of legal rams above 30–40% may lead to reduced average horn size and a shifting age distribution of males toward younger individuals (Schindler et al. 2017). Both camps recognize that better data on the harvest rate of legal males under different harvest regulations are required to quantify selective pressures and advance this discussion.

Harvest management in other jurisdictions

A review of bighorn sheep hunting regulations in other jurisdictions provides range-wide context. Demand for sheep hunting is high; across the western U.S. >90 hunters apply for each available bighorn tag (IDFG 2010). High valuations given for special auction tags (up to $200,000 US in some cases) underscores the desirability for an opportunity to hunt a ram. There are 20, 99 and 165 ram permits available annually in Washington, Idaho and Montana respectively. Most states restrict individuals to 1 permit/lifetime, 1 harvest/lifetime, or the ability to apply for permits only once every 5–10 years. Hunter success is high – often approaching 90%.

All states regulate bighorn sheep hunting using an LEH-type lottery system, often coupled with a ½ or ¾ curl, “any ram”, or > 4 years of age regulation, enabling tight monitoring and control over the number of rams harvested and remaining within the population post-hunt. Montana has an open license system in a few select areas with a “legal ram” horn curl restriction (essentially a ¾-curl regulation), but hunting closes within 48 hours when the assigned harvest quota for the hunting district is approached or passed.

Only BC and Alberta have open harvest regulations for rams (although LEH regulations are applied in some areas in both provinces), using minimum horn curl restrictions (full curl for BC, and 4/5 curl for Alberta except full curl south of Highway 3) to restrict the potential proportion of rams harvested, regulate the distribution of the harvest at a scale finer than the management unit, improve older age cohort representation in the ram cohort and maintain adequate sex ratios. Evidence from the states suggests that under LEH-type regulations hunters target larger and older rams regardless of legal designation ("any ram" through to minimum ¾ curl), however this may be partly a function of generally increased numbers of rams on the landscape, thus supporting improved success and hunter selection of rams. "Any ram" regulations have proven successful in eliminating citations and court cases for "short" rams and reduced abandonment of sub legal rams (CDW 2009). All states have the option to conduct ewe harvests under LEH-type regulations; these are generally enacted to manage populations over habitat limitation or disease concerns. At Ram Mountain, Alberta, about 10% of the winter ewe population could be removed annually (conditional upon good productivity and survival rates) to maintain the population at a level where forage was not limiting population and body growth (Jorgenson et al. 1993).

End of season dates across all jurisdictions are generally at or near the end of October, before the major rutting period begins, to control harvest of older rams migrating from protected or inaccessible areas. Montana allows a 2.5 month season from mid-September to the end of November. Harvest of rams generally depends on population level relative to population objective, ram:ewe ratios, and the proportion of mature rams (often defined as ≥½ or ≥¾ curl). For example, Washington has a sliding scale of permits for 20% of mature (≥½ curl) rams when the ram ratio is >50:100 ewes, down to 10% of mature rams at <25 rams:100 ewes. Montana has a target of >30% mature (≥¾ curl) rams in the population post-hunt, and Idaho has a target of restricting harvest to <20% of the mature (≥¾ curl) rams.

Minimum population size required to initiate a harvest among jurisdictions in North America ranges from 50 total/estimated population excluding lambs, to ≥75 observed sheep (not estimated), to ≥100 estimated sheep. Montana also requires ≥30 rams:100 ewes, ≥30 lambs:100 ewes and ≥30% of rams at least ¾ curl prior to opening a hunt (MFWP 2010). Idaho considers allowing harvest in herds <100 estimated bighorn sheep under conditions of observed or likely range overlap with domestic sheep and goats, or where analysis indicates a population is unlikely to reach 100 individuals (IDFG 2010).

Habitat

Human-induced impacts to bighorn sheep habitat are generally more widespread, varied in intensity and type, and significant for low-elevation wintering herds than herds that winter at high elevation; the exceptions are impacts primarily associated with coal mines in the Elk Valley (Smyth 2014, Poole et al. 2018), including physical removal (e.g., surface mining), invasive plant species dominance, and overgrazing. Extensive logging and burning in the late 1800s and early 1900s increased the quality and quantity of forage and in response, domestic livestock use spread and wildlife populations grew and expanded. Populations of white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), elk (*Cervis canadensis*), and bighorn sheep all generally reached peak population distribution and abundance in the 1950s (Pitt 1982).

Forest fire suppression beginning in the 1930s eventually resulted in conifer tree and shrub encroachment across low-elevation grasslands. Forest encroachment, especially near cliffs and escape terrain, creates relatively rapid change in winter range quality for bighorn sheep (Demarchi et al. 2000) by reducing availability of winter forage plants, increasing interspecific competition (increased mule deer densities), and increasing predation risk (decreased open sight lines). To address forest encroachment issues, nearly 2,000 ha of bighorn sheep habitat enhancement projects were completed in the 1980s; primarily prescribed burning, selective logging and slashing (Davidson 1994). These ecosystem restoration/enhancement efforts have attempted to re-establish areas of open range/open forest throughout the East Kootenay Trench and dry ecosystems of the West Kootenay to support bighorn sheep conservation (Rocky Mountain Trench Ecosystem Restoration Program 2013). An additional 2,000 ha of restoration directed at bighorn sheep –slashing and burning – has been conducted by the Fish and Wildlife Compensation Program (FWCP) in the East Kootenay since the late 1990s (L. Ingham, unpubl. data). Additional restoration work led by Parks Canada has been conducted from 2003 to present on the Redstreak benches, Redstreak Mountain, and Sinclair Canyon areas of Kootenay National Park (S. Wrazej, Parks Canada, pers. comm.).

Current threats to low-elevation bighorn sheep winter range in the Kootenay Region include forage competition from other grazing ungulates (both wild and domestic). Forage competition occurs when forage resources cannot meet the combined demands of multiple users. As grazing ruminants, livestock and wild ungulates can exhibit direct competition for several forage species. Some native forage plants may not support summer grazing by cattle if they are also supporting bighorn sheep during the winter and spring. Livestock overgrazing has been shown to cause reduced body condition, reproductive rate, and survival in several wild ungulate species including bighorn sheep (Chaikina and Ruckstuhl 2006). Competition between livestock and bighorn sheep on overgrazed habitat can be significant as bighorn sheep are dependent upon that winter range, often remaining on low-elevation winter range until mid-spring (up to 5 months) depending on high elevation snow depth. The relatively long duration of time that bighorn sheep spend on winter range increases the importance of maintaining high forage quality in these areas (Kinley 2007).

Most studies on the effects of cattle on wildlife have focused on competition for forage and the decrease in forage plant quality/quantity that often results from increased grazing pressure (Chaikina and Ruckstuhl 2006). There are also negative behavioural responses of wildlife due to the physical presence of livestock, including increased vigilance, reduced resting periods and reduced foraging benefits, especially for ewes (Mattiello et al. 2002, Findholt et al. 2004, Browne et al. 2010). Although difficult to quantify in population limiting terms, these behavioural responses, along with the potential for complete abandonment of ranges, can have a long-term impact on the reproductive success of bighorn sheep (Bissonette and Steinkamp 1996).

Logging at all elevations tends to increase numbers of alternative prey, such as white-tailed deer and elk, which support increased predator numbers that could lead to higher predation rates on bighorn sheep (apparent competition; Johnson et al. 2013). Cougar and wolf numbers in the Kootenays are likely higher than historically occurred within the region (Mowat 2007, FLNRORD unpubl. data).

The quality and quantity of grass and shrub ecosystems in the Rocky Mountain Trench are in decline, which threatens the persistence of grassland-dependent species and ecosystems and the long-term health of several wild ungulate populations that depend on them (Phillips and Crowley 2012). A key factor contributing to this degradation is invasive plant spread. The aggressive nature of many non-native plants allows them to out-compete the native flora. These changes in native plant communities can reduce the ability of winter ranges to support bighorn sheep (Kinley 2007). Invasive plants that are currently threatening natural grasslands on many bighorn sheep winter ranges throughout the Kootenay Region include St. John's wort (*Hypericum perforatum*), yellow hawkweed (*Hieracium caespitosum*), knapweed (*Centaurea* spp.), blueweed (*Echium vulgare*) and sulphur cinquefoil (*Potentilla recta;* Phillips and Crowley 2012). Effective treatment and removal methods are expensive and long-term. The Fish and Wildlife Compensation Program and Habitat Conservation Trust Foundation have funded several long-term projects in the Kootenay Region to control and manage invasive plants on bighorn sheep winter ranges (East Kootenay Invasive Plant Council 2015, Murphy 2017, Teske 2018).

High elevation grasslands in the Elk Valley provide unique winter range habitat for bighorn sheep, because most populations commonly winter at low elevations. These grassland systems are typically south-facing and located on windswept slopes, which prevent high snow accumulation (Poole et al. 2016). In a review of habitat attributes within the Elk Valley East PMU, these grasslands were the highest ranked winter range cover class (Poole 2013, Poole et al. 2016). The main communities that characterize these high elevation grasslands are Idaho fescue – Sulphur buckwheat – Sandwort, and Rough fescue – Sulphur buckwheat – Sandwort. Both of these grassland communities were provincially red-listed in March 2018 (http://a100.gov.bc.ca/pub/eswp/). Bighorn sheep populations in the Elk Valley are of provincial significance because of their selection for these unique, high elevation grassland systems (Demarchi 1968). However, 44% of these grasslands overlap with existing coal leases and licences and approximately 28% have already been lost due to surface mining between the early 1980s and 2000s (Poole et al. 2018).

Artificial habitats including golf courses, cleared highway rights-of-way, and urban lawns and gardens may have attracted some herds away from traditional fall and winter ranges. In the case of the Radium herd, these artificial habitats have the disadvantages that: (1) the sheep are pulled away from escape terrain and therefore are presumably more vulnerable to predation; (2) there is increased potential for harassment by dogs and other forms of negative sheep-human interactions; (3) highway mortality and injury risk are increased; (4) natural sheep seasonal movements, patterns of use and habitat linkages are fragmented by lawns, roads and other infrastructure; and (5) there is likely a progressive loss of natural migratory behaviours exacerbated by the human-induced landscape fractures.

Protected areas, which include national and provincial parks as well as Conservation Lands (parcels of low elevation private land secured to create landscape-level habitat for wildlife) occur throughout the Kootenays, some specifically supporting bighorn sheep populations (Table 3). Livestock grazing, industrial use, and motorized access are generally restricted in these areas. Hunting is permitted in most but not all provincial parks (including protected areas, recreation areas, and conservancies), restricting the areas of refugia from hunting. A significant area of year-round sheep range in the Elk Valley (MU 4-23) overlaps with Teck Coal properties; due to safety-related issues, hunting is prohibited in active mine

sites (L. Amos, Teck Coal, pers. comm.). Consequently, the high proportion of private land in the Elk Valley East PMU is mainly owned by Teck Coal, and provides important refugia for bighorn sheep rams during the hunting season.

Table 3. Area based assessment of land-use/ownership in Kootenay Region bighorn sheep Population Management Units (PMUs). "Protected" denotes protection of land from development, not non-hunting areas (national parks and Teck Coal lands); "ER" denotes ecosystem restoration planning area (may or may not be targeted at bighorn sheep). [Private land spatial data source: Data BC Integrated Cadastral Fabric, accessed February 20, 2019]

PMU		Area (Ha)	Private %	Protected %	Conservation Land %	ER %
1	Flathead-Waterton	186,840	0.1	5.6		
2	Wigwam Flats-Elko-Phillips	221,784	7.8	0.1	4.4	18.7
3	Elk Valley East	247,707	19.0			
4	Elk Valley West	146,277	0.4	30.3		89.6
5	Bull River	32,349	10.6	0.3	1.1	5.1
6	Premier-Wildhorse	81,509	2.6	11.2	0.2	28.1
7	Whiteswan-Sharktooth	156,320	0.8	1.7		
8	Columbia-Radium	140,335	6.9	19.2		7.9
9	Assiniboine	129,754	0.0	46.7		
10	Golden	31,244	3.1	12.3		
11	South Salmo	115,972	3.2	1.0	7.6	
12	Lower Arrow	81,493	0.8	5.5	0.6	

There are several pieces of provincial legislation that provide habitat management or protection for bighorn sheep. Under the *Forest and Range Practices Act* (FRPA; 2002), certain land designations or stewardship measures can be created for bighorn sheep as guided by Government Actions Regulations (GAR; 2018) on Crown land or private land subject to a tree farm or woodlot license (BC WLAP 2004), however these GAR designations have limited jurisdiction over tenures issued under other pieces of legislation such as the *BC Mines Act* and *Lands Act*. Specific to GAR, these land designations and stewardship measures include wildlife habitat areas (WHAs), ungulate winter range (UWR), and wildlife habitat features (WHFs). WHAs for sheep are used to maintain important bighorn sheep habitat in a defined area and include legislated 'general wildlife measures' that limit or exclude activities by FRPA-governed land base users (e.g., no forest harvest or road construction within a sheep WHA). Currently there are no bighorn sheep WHAs in the Kootenay Boundary Region. UWRs for sheep are similar to WHAs but are only designated for *critical* winter range habitat where an area is established for this designation under the current Timber Supply Review process and the location of those protected habitats meet four specific GAR tests, the most significant being that protecting the area does not

unduly reduce the supply of timber from BC's forests. There are two UWR Orders in the Kootenay region that include bighorn sheep but their protective measures are weak and not all bighorn sheep winter ranges have been included under Orders (U-4-006 and U-4-008; British Columbia 2019b; I. Teske, FLNRORD, pers. comm.). WHFs are point features on the landscape that are protected from being damaged or rendered ineffective by authorized person(s) carrying out primary forest or range activities. In July 2018 a WHF Order was signed for the Kootenay-Boundary region and includes 'significant mineral licks' as one of the listed features, including those frequented by bighorn sheep (British Columbia 2019a). WHAs, UWRs and WHFs can also be legislated as Orders under the Oil and Gas Activities Act (OGAA; 2008) as guided by the Environmental Protection and Management Regulation (EPMR; 2016). These Orders can restrict OGAA-governed operations from occurring within WHAs, UWRs and WHFs unless they will not have a material adverse effect on the species or community the Order(s) were designated for.

Two other legislative tools that could be used to maintain or protect sheep habitat stem from the *Wildlife Act* and the *Land Act*. Regulations that can be made under the *Wildlife Act* (Sections 108 and 109) include "*prohibiting, restricting or allowing access by members of the public to designated areas of British Columbia, for the purposes of wildlife management*" (Wildlife Act 1996). In the Kootenay Boundary Region, these regulations have been employed as 'Access Management Areas' (AMAs) and 'Motor Vehicle Hunting Closed Areas' (MVHCAs) which restrict motorized access on specified roads within seasonal timing windows in a given area (FLNRORD 2018b). There are currently 32 AMAs and 48 MVHCAs in the Kootenay Boundary Region (FLNRORD 2018b), many of which were established, in part, to protect bighorn sheep habitat. Sections 15, 16, 17 and 66 of the *Land Act* can be established on Crown land to delineate areas where applications for development, recreation, etc. cannot occur, or where only compatible uses can be considered (Land Act 1996). The rationale for these sections of the *Land Act* can include protecting important sheep habitat or other components of wildlife habitat that would be negatively impacted by human disturbance. There are currently 82 Section 15, 16 and 17 *Land Act* designations in the Kootenay Boundary Region (BC Geographic Warehouse 2017); some of which were likely established to protect bighorn sheep habitat values.

Human access into sheep ranges can influence the harvest vulnerability of sheep, the quality of the hunt, and habitat quality (via introduction of invasive plant species), as well as facilitate access by predators along road and trail networks or cleared right-of-ways. Area closures can reduce access by predator hunters, notably cougar hunters, or can provide for protection from specific types of human disturbance. Industrial road development and land clearing mainly related to forestry and mining, can increase the year-round "visual vulnerability" of herds such that sheep ranges can be readily 'glassed' for activity from open roads and trails; summer access can increase disturbance and provides knowledge on sheep distributions ahead of the fall hunting season. Motorized vehicles using roads that access alpine areas can further facilitate the introduction and spread of invasive plants where ground disturbance has occurred.

Bighorn sheep may respond to human disturbance by increasing vigilance and temporary or permanent abandonment of an area, which may displace sheep to less optimal habitats, decreasing foraging efficiency, increasing energy expenditure, and increasing risk of predation (IDFG 2010, Courtemanch et

al. 2014). Increased stress levels, lowered disease resistance, interference with breeding activities and lower rates of reproduction may also result with combined cumulative impacts reducing fitness and decreasing population survival and productivity. Off-road vehicles (e.g., ATV's, quads, snowmobiles) may be particularly disturbing (Ciuti et al. 2012). The cumulative disturbance from hunting and motorized recreation vehicles resulted in the highest levels of vigilance in elk (Ciuti et al. 2012). However, even hiking (Papouchis et al. 2001) and backcountry skiing (Courtemanch et al. 2014), particularly if the humans are accompanied by a dog during the activity, may result in higher stress, habitat alienation, use of poorer quality habitats and higher energetic costs. Sheep are particularly bothered by helicopter over-flights (Frid 2003) and do not appear to habituate (Bleich et al. 1994). The Kootenays have seen an increase in ecotourism and recreation applications since 2012 which may also contribute to disturbance on seasonal ranges.

Health and Disease

Bighorn sheep across western North America are susceptible to a variety of infectious and parasitic diseases that have their origin in domestic livestock, the most important of which are respiratory infections that result in pneumonia following contact with domestic Caprinae, particularly domestic sheep (*Ovis aries*) (Goodson 1982, George et al. 2008, Wehausen et al. 2011, Cassirer et al. 2018) and goats (*Capra aegagrus*; Besser et al. 2017). Pneumonia-caused mortality events occur across all age classes, with documented loses of 60–75% of entire herds in BC with even higher rates of die-offs occurring in some US populations. These events are often followed by years of chronically depressed lamb recruitment (Besser et al. 2008, TWS and AAWV 2015, Cassirer et al. 2018). The pattern of pneumonia epizootics in bighorn sheep is influenced by social behaviour where males are more likely associated with the initial domestic sheep/goat contact event as well as any subsequent spread among connected populations (due to larger home ranges and longer distance movements), whereas ewe-lamb and lamb-lamb interactions appear to be more important routes of transmission and persistence within infected populations (Manlove et al. 2014). Mountain goat populations that are sympatric with infected bighorn sheep have also experienced pneumonia outbreaks and die-offs (Wolff et al. 2014, Anderson et al. 2017). Disease transmission between mountain goats and bighorn sheep should consequently be considered where range overlap occurs. The demographic costs of disease persistence long after contact with domestic Caprinae occurs can be more significant than the original die off, with up to 100% lamb mortality when late summer weaning occurs and lambs become susceptible to respiratory pathogens carried by chronically disease-shedding ewes (Cassirer et al 2018). Juvenile survival after the first 4 months of life is considered a useful demographic indicator of health status of a herd and specifically ≤20 lamb:100 ewes is a strong indicator of an un-healthy herd and possibly the result of pneumonia-induced mortality (WAFWA 2015). The importance of respiratory disease in the historic decline of bighorn sheep across most of their range from BC to Mexico is unique among North American ungulates (Cassirer et al. 2018). Due to the preponderance of evidence associating domestic sheep with pneumonia epidemics in wild sheep, The Wildlife Society and the American Association of Wildlife Veterinarians published a Joint Issue Statement recognizing that disease transmission from domestic sheep and goats to wild sheep continues to be a significant risk factor for the conservation and restoration of wild sheep populations (TWS and AAWV 2015).

Many factors contribute to the virulence of this disease, such as high sheep density, poor nutrition, parasitism and trace mineral deficiencies (Schwantje 1986), however *Mycoplasma ovipneumoniae* (Movi) has been identified as the key pathogenic bacterium of pneumonia in bighorn sheep (Besser et al. 2008, 2012). Movi is a host-specific bacterium commonly carried by domestic sheep and goats (Manlove et al. 2019). Testing protocols to detect respiratory pathogens such as Movi have been standardized and prioritized by the international Western Association of Fish and Wildlife Agencies – "*Wild Sheep Working Group*" in an attempt to provide managers with recommendations for assessing herd health and developing response plans in the event of observed clinical disease and mortality events (WAFWA 2015). All wild sheep research in BC now employs these protocols, collecting nasal swabs and blood samples to test for Movi as a key component of herd health monitoring. DNA of Movi can be detected in deep nasal swab samples and analyzed by the BC Ministry of Agriculture Animal Health Centre Lab (Abbotsford). Movi antibodies can be detected in blood serum samples analyzed by the Washington Animal Disease Diagnostic Lab (Pullman, Washington). Strain typing of Movi positive samples also provides the ability to track new strains, which are often associated with new contact events and higher virulence (i.e., more lethal) (Cassirer et al. 2017).

Historically, bighorn sheep herds wintering at low elevations in the East Kootenays experienced all-age die-offs roughly every 20–25 years from the 1920s to the 1980s (Stelfox 1976, Schwantje 1988). Known contact had occurred between bighorn and domestic sheep during three of these die-offs in the 1940s, 1960s and 1980s, with a common pattern of northward progression of the outbreak among herds sharing winter range in the Rocky Mountain trench, extending as far as the Radium herd within and adjacent to Kootenay National Park including. Carcasses of bighorn sheep from Bull River, Wigwam, Maguire Creek, Premier Ridge, Wildhorse, and Lussier ranges in the late 1980s confirmed acute to chronic pneumonia (Schwantje 1988). Years of poor lamb recruitment followed, with the demographic costs of disease persistence outweighing impact of the initial outbreak. Although diagnostic capabilities to detect Movi were limited at the time of these pneumonia outbreaks, the pattern is consistent with respiratory disease caused by contact with domestic sheep. Recent examination of the prevalence of Movi on domestic sheep farms in BC, found that the Kootenay Region had the highest prevalence of Movi on domestic sheep farms (5/9 domestic sheep farms in the Kootenay Region were Movi positive) compared to the Thompson Region (3/10), and Okanagan Region (1/10; Mann 2017).

Risk buffer distances to separate bighorn sheep from domestic sheep and goats vary from 13.5–26 km across jurisdictions. Research into bighorn sheep foray behaviour identified long distance movements outside of home ranges were common up to 10 km, however less than 25% of long-distance movements exceeded 15 km (O'Brien et al. 2014). Although not well publicized, preliminary guidelines for grazing domestic sheep and goats on Crown lands in the Kootenay-Boundary Region prohibit their use within 15 km of occupied or historic bighorn sheep habitat.

Although there is a prohibition against domestic sheep and goat grazing on Crown Land in the Kootenay Region, a high-risk of disease transmission has been identified on private properties across low-elevation bighorn sheep winter ranges from Radium south to the US border. High risk private lands encompass about 6% of private lands in the East Kootenays. Developing effective and socially acceptable ways to minimize contact between free-ranging wild bighorn sheep and domestic sheep on private land

continues to challenge wildlife and agriculture managers across western North America. The BC Sheep Separation Program (BCSSP) is considered to be at the forefront of these efforts. The BCSSP is a collective of wild sheep conservation groups, government staff, and members of the domestic sheep industry and has been working since 1999 to educate domestic sheep owners, develop effective disease management options, and create agricultural policy that supports effective separation between wild and domestic sheep. The BCSSP has completed several fencing projects, the largest of which was construction of 4 km of 8 ft paige wire fence around a large commercial sheep farm in the Bull River in 2013. The limitations of fencing as a mitigation option have become more and more apparent due to the high costs, low long-term effectiveness and the appearance to some as an incentive to farm sheep in order to acquire "free" fencing. Movi transmission between sheep has also been documented up to 30 m distance, which complicates installation of an effective "no-contact" fence design.

BC currently has a protocol in place when contact is observed between bighorn sheep and domestic sheep; the provincial Conservation Officer Service (in conjunction with regional biologists and the provincial wildlife veterinarian) will euthanize the bighorn sheep that have comingled with domestics in order to avoid further transmission of pneumonia-causing bacteria into the remaining wild herd.

The use of domestic sheep and goats to assist with managing vegetation growth along industrial rights-of-way and in forest cut blocks occurs in some areas in BC. Domestic goats can be used to target and control invasive plants along linear corridors and the popularity of this is increasing, as this method is considered a more ecologically sensitive approach with the benefit of avoiding the use of herbicides and other chemicals. Similar to domestic sheep, domestic goats commonly carry *Mycoplasma ovipneumoniae* and captive comingling research has shown that although it may be less lethal, bighorn sheep will develop pneumonia when exposed to domestic goats (Besser et al. 2017).

Other infectious disease and parasite concerns that could affect bighorn sheep conservation in BC include Contagious Ecthyma, Blue Tongue, and Psoroptes mites. Contagious Ecthyma (CE; soremouth, orf) is caused by a parapoxvirus and can cause painful lesions and scabs around the face and mouth. CE may remain viable in the soil for up to 22 years (Jessup and Boyce 1993). CE has been observed in bighorn sheep herds in the southern Rocky Mountains and is typically more severe in young animals, primarily affecting them by interfering with suckling. Outbreaks in older animals have also been observed and are typically associated with increased stress, with persistent CE infections associated with access to salt blocks that facilitate viral transmission among individuals (Schwantje 1988). Although not verified in the Kootenay Region, Blue Tongue and Psoroptes have affected bighorn sheep herds in other areas of BC. Blue Tongue is a viral disease transmitted by biting midges where infected bighorn sheep can die acutely or show clinical signs such as weakness, diarrhea, and hemorrhages in organs (Thorne et al. 1982). Parasitic mites (*Psoroptes* spp.) can cause Scabies infection of the skin, especially the ears, head, and neck and has been responsible for bighorn sheep declines in the South Okanagan as well as Montana.

In 2015, a further effort to reduce disease and parasite transmission risks associated with domestic stock was established through prohibitions under the *Wildlife Act*'s Hunting Regulation, Section 18 making it illegal to hunt in BC while accompanied by, or with the use or aid of, a goat, sheep or camelid, including by using these animals as a pack animal. The enabling *Wildlife Act* legislation is limited in scope

to only hunting activities, so recreational or other above-noted uses that include these domestic stock animals are not yet limited in many portions of the province.

Climate Change

Climate change has and is predicted to continue to result in increased frequency of stochastic weather events, elevated overall temperatures, changes in precipitation patterns, shifts in the seasonal timing of plant growth, altered parasite life-cycles and longer virus/bacteria persistence in the environment, in addition to other potential environmental influences. Climate change – primarily increasing temperatures and declining precipitation – was implicated in the loss of over one third of desert bighorn sheep populations in California over the past 60 years (Epps et al. 2004). Warming temperatures may result in intensification of forest encroachment up-slope where moisture is not limiting. Longer and drier growing seasons also largely benefit invasive plants over native plants, given invasives are generally more flexible and drought-resistant[4] and can respond to unusual environments more quickly than do native species (Brewer et al. 2014). Kootenay Region climate projections predict increasing temperatures, lower summer and higher winter precipitation, lower snowpack, and longer growing conditions[6]. Variability in extreme weather events will intensify; for example, frequency of icing events may increase leading to higher mortality risk and reduced availability of forage resources. Reduction in winter snowpack or availability of surface water and more rapid spring snowmelt, together with earlier onset of spring vegetation and changes in forage quality and availability, are some of the more pronounced habitat changes that have been suggested (National Wildlife Federation 2013), such that the carrying capacity for bighorn sheep on some ranges likely will shrink (Brewer et al. 2014).

Although winter severity was shown to have little effect on sheep survival in Alberta (Jorgenson et al. 1993, Portier et al. 1998), exceptionally long and cold winters could increase lamb mortality, especially at higher densities (Portier et al. 1998) and from more numerous icing events with climate change (Brewer et al. 2014). Winter severity – generally snowfall and temperature – can be tracked at the regional or finer scale using high-elevation snow-pillow data or a winter severity index (e.g., Poole 2013) and correlated to estimates of winter related mortality and effects on recruitment.

Predation

Bighorn sheep have evolved with a full suite of sympatric predators, both mammalian and avian (golden eagles; *Aquila chrysaetos*). High fidelity to steep, rugged escape terrain and gregarious instincts are notable predator evasion behaviours of bighorn sheep, along with their keen eyesight to detect predators at distance. Based on a literature review, Sawyer and Lindzey (2002) observed that cougars and coyotes are the most common predators of bighorn sheep across their full range (BC south to Mexico), with coyote predation more restricted to lambs and most often reported in areas that lack escape terrain for sheep.

Both wolf and cougar abundance appear to have increased markedly in the Kootenays since the late 1990s with likely higher abundance since the late 2000s (Figs. 7, 8). Cougar harvest and control kill data

[6] https://pacificclimate.org/sites/default/files/publications/Climate_Summary-Kootenay-Boundary.pdf

likely reflect cougar abundance with a possible year or two lag, and a similar assumption could be made for wolf harvest data. It is likely that increased effort by cougar hunters was in part responsible for the spike in harvest during 2018-19.

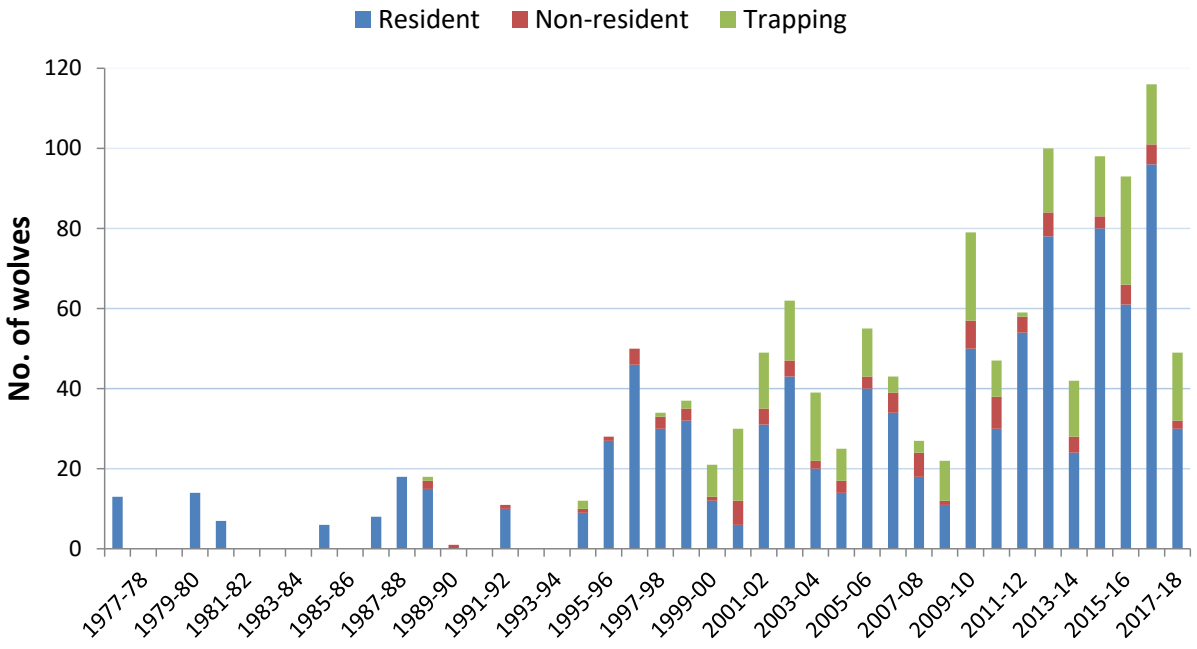

Figure 7. Harvest of wolves in the East Kootenay by resident and non-resident hunters from the Big Game Hunter Survey database, 1976-77 to 2017-18. Non-resident harvest data and trapping data were not available prior to 1988. Data from FLNRORD, Cranbrook.

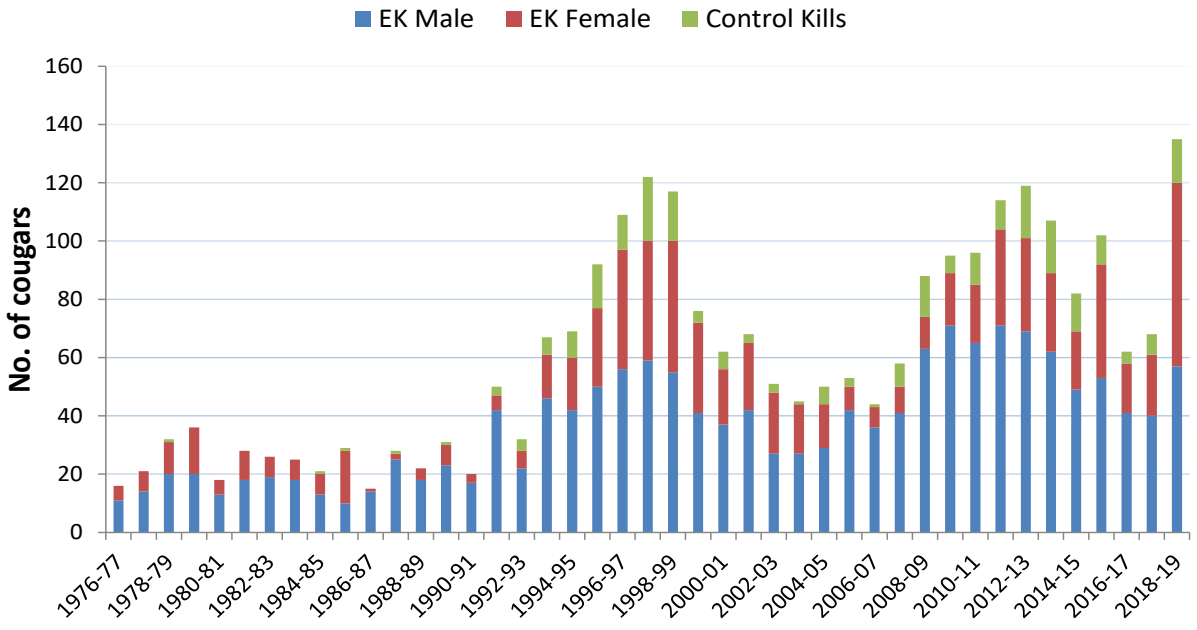

Figure 8. East Kootenay cougar harvest and control kills from 1976-77 to 2018-19. Data obtained from FLNRORD Compulsory Inspection data.

Cougars are considered to be the primary proximate cause of mortality for many bighorn sheep populations (Ross et al. 1997, Sawyer and Lindzey 2002, Festa-Bianchet et al. 2006, Jokinen et al. 2008, Rominger 2018). In west-central Alberta, younger cougars and females tended to select smaller prey (deer or sheep), but mature cougars, especially adult males, tended to consume larger prey (Knopff 2010). Thus, reducing the number of mature males in a cougar population may benefit larger ungulates such as moose and elk, but may result in increased predation pressure on smaller ungulates like deer and bighorn sheep (Knopff et al. 2010, White et al. 2011). Most cougars appear to specialize, focusing on a single prey type for which they selected strongly (Knopff and Boyce 2007, Widmeyer 2019). Cougar predation on bighorn sheep at Ram Mountain in Alberta ceased abruptly in 2003 and Festa-Bianchet et al. (2006) suggested that the reason for this was the death or emigration of an individual specialist. There were 21 documented cougar predation events on the Radium bighorn sheep herd during winter 2017-18 that appear to have been largely related to a single female and her young (S. Wrazej, Kootenay National Park, pers. comm.). Specialization by cougars on bighorn sheep has been documented on reclaimed coal mines in west-central Alberta (Beale 2019). Predation was more likely to occur where escape terrain was in close proximity to forest edges. Detection of specialization by individual, un-collared cougars is difficult to identify; stable isotope analysis may be a reliable method to identify specialization (Widmeyer 2019).

Predation episodes by specialist cougars also appears to reduce size of lambs, recruitment and overall reproduction through indirect effects (Bourbeau-Lemieux et al. 2011). Stochastic (random) episodes of elevated predation by cougars specializing on bighorn sheep (Knopff 2010) that last for several years at a time suggest that a population of about 125 sheep would be required to obtain a 95% probability of persistence (Festa-Bianchet et al. 2006).

Rominger (2018) theorized that the population limiting effect of cougar predation on bighorn sheep is due to the expansion of alternative prey (mainly mule deer and elk) as fire suppression efforts shifted grasslands to shrublands, the extirpation of two dominant apex carnivores (wolves and grizzly bears) in areas impacted by human development, and the cessation of intensive predator control. High levels of predation can extirpate small, isolated groups of bighorn sheep (Rominger and Weisenberger 2000) especially when declining number of bighorn sheep do not result in a numerical response of cougar populations due to being supported by much more numerous sympatric mule deer (Schaefer et al. 2000, Johnson et al. 2013). Recent relatively rapid declines in white-tailed deer populations (as a result of more liberal hunting regulations combined with two severe winters) may have led to prey switching by cougars to sheep (apparent competition; *cf* Johnson et al. 2013), but distinguishing prey switching from individual prey specialization is difficult. Scavenging and kleptoparasitism of cougar kills by other predators may additionally increase kill rates by cougars and support higher populations of other predators (Elbroch et al. 2015). Cougar predation on bighorn sheep is highly sporadic and variable annually. Variability is likely due to small sizes of bighorn sheep populations, unique specialization by individual cougars, and availability of alternative prey.

Population viability

Few data are available on minimum population size for bighorn sheep population persistence, and any suggested numbers need to be placed in context. There are theoretical reasons to expect higher risk of extirpation for smaller populations, but this depends in part on the degree of isolation (Wehausen 1999). As noted, Festa-Bianchet et al. (2006) suggested that about 125 sheep would be required to obtain a 95% probability of persistence under sustained cases of specialist cougar predation episodes. Under other conditions, populations that have declined from higher numbers to less than about 80 sheep would have higher risk of extirpation, whereas those that have been in the 80 individuals range for longer periods of time and with some genetic exchange (outside rams arriving for the rut) would be at less risk (M. Festa-Bianchet, Université de Sherbrooke, pers. comm.). Wehausen (1999) found that sheep with initial populations >50 individuals had about 90% chance of persistence over 50 years, and even 60% of populations of ≤15 individuals persisted. If cougar predation is not a concern and the population is not fully isolated inbreeding may only impact numbers at roughly fewer than 60 individuals (Rioux-Paquette et al. 2011). Inbreeding may lead to lower probability of overwinter survival for inbred female lambs (Rioux-Paquette et al. 2011). Although often used interchangeably in the literature, a viable population – healthy and productive – would presumably be preferable to one that merely persists.

Broad-level Management Goals and Objectives

The following list captures the range of goals and objectives expressed by stakeholder groups and various levels of government.

1. Maintain viable and ecologically sustainable populations of bighorn sheep throughout suitable native range for ecological, cultural, economic and social benefits using science-based management.
    a. Maintain or improve population resiliency;
    b. Maintain viable population size;
    c. Maintain appropriate sex/age ratios;
    d. Reduce risk of respiratory disease outbreaks due to contact with domestic sheep/goats;
    e. Implement a ewe harvest where it is deemed necessary to maintain population health or to reduce potential for disease outbreaks.
2. Manage populations to provide quality hunting opportunities.
    a. Management objectives should be defined for each PMU and consider the Provincial Big Game Harvest Management Procedure;
    b. Manage harvest for quality experience (availability of rams, hunter crowding, hunter success) for resident and non-resident hunters;
    c. Ensure sufficient escapement of mature/older rams after hunting season to ensure that mature/older rams fulfill their social and biological roles;
3. Protect and enhance the quality and quantity of bighorn sheep habitat throughout native range, targeting human access, forest encroachment, logging, spread of invasive plants, and livestock forage competition.

   a. Maintain integrity of occupied native winter and summer ranges, lambing areas, migration routes;
   b. Reduce road access and visibility to sheep ranges;
   c. Minimize the adverse impacts of forage competition through management of domestic livestock and other native wildlife;
   d. Manage recreational disturbance to bighorn sheep populations on both summer and winter ranges.
4. Manage impacts of predation on bighorn sheep populations while preserving ecosystem integrity.
   a. Apply predator management as an option where a predator/species is targeting small or declining sheep populations and where predation is determined to be a factor limiting populations.

Management Issues, Tools and Recommendations

Despite very limited ewe harvest since the mid-1990s and full curl regulations on ram harvest, sheep numbers have declined in several PMUs in recent years. Management options to increase population size and resilience include (see sections below for further details):

- Continue improving bighorn sheep habitat through ecosystem restoration programs primarily in areas with minimal invasive plants;
- Conserve bighorn sheep winter range and migration corridors through Government Actions Regulation (GAR)
- Conduct effective long-term control and management of invasive plants;
- Minimize disturbance to winter ranges, summer ranges and migration routes;
- Ensure sufficient escapement of mature rams to ensure that older rams fulfill their social and biological roles;
- Eliminate the non-trophy (ewe) harvest (none currently in place);
- Verify separation between domestic sheep and goats and wild sheep populations to reduce risk of disease transmission;
- Adjust hunter harvest to reduce harvest of adult male cougars and increase harvest of females, specifically targeting cougars suspected to be specializing on bighorn sheep.

Population management

The **population management objectives** are to maintain each PMU and subpopulation within 20% of the median estimate and ≥30 lambs:100 ewes and ≥30 rams:100 ewes as determined from the last 5 aerial surveys. If a continuous decline of >40% from the peak estimate is observed, the median estimate will be calculated by dropping the most recent (low) surveys. Although there is limited information on sheep abundance relative to habitat capacity for each PMU, upper population limits represent an approximation of the maximum number of sheep the habitat can support. Intensified management actions will be implemented in PMUs where population objectives are not being met.

These objectives and strategies should be re-evaluated at least every 10 years.

1. Survey sheep winter ranges mid-winter during appropriate survey conditions. If resources to survey sheep are limited, we recommend that herds to be surveyed be prioritized by:
    a. PMUs with a declining population trend or most recent estimate >20% below the population objective;
    b. PMUs with the highest hunter effort and harvest; and
    c. PMUs with the longest time interval since the previous survey.

    (*Benefits: Enables tracking of trends in population size and demographics. Allows prioritization among PMUs;*
    Challenges: Costly to conduct; survey of some low-elevation herds challenging)
2. Work with Ministry of Transportation and Infrastructure to reduce vehicle-sheep strikes through reductions in speed limits, fencing, intercept salting, aversive conditioning, warning signs, under or over-passes, and education. For example, researchers recommended a combination of wildlife fencing and overpass/underpass to reduce sheep-vehicle strikes near Radium and Elko-Morrisey (Huijser et al. 2008, Clevenger et al. 2010).
    (*Benefits: Potential to reduce vehicle-related mortalities;*
    Challenges: High complexity, requires long-term funding and collaboration with Ministry of Transportation and Infrastructure
3. Review and update industrial best management practices to minimize industry-related sheep mortalities
    (*Benefits: Potential to reduce industry-related mortalities;*
    Challenges: Requires discretionary implementation of changes to practises in industrial setting)
4. Consider sheep population targets in all land use decisions that may impact sheep and their habitat (i.e., industrial development and recreational tenures).
    (*Benefits: Integrates sheep management interests into land use planning. Reduces future impacts to sheep and their habitat;*
    Challenges: Requires support, effort and coordination among land use decision-makers)
5. Track indices of winter severity at an appropriate sub-regional level that may correlate to mortality and recruitment.
    (*Benefits: Can be compared to estimates of winter-related mortality and recruitment to add context to changes in population and hunting success. Can help separate winter kill from disease and predation related mortality when drawing inference from lamb ratios;*
    Challenges: Trailing indicator, Requires resources to implement)

Harvest management

The **harvest management objectives** are:

- ram harvest rate ≤3% of the total population estimate,
- ram harvest of up to 8–10% of the estimated number of rams (where composition data are available), Bighorn Sheep Harvest Management procedure; FLNRO 2014)
- ram harvest of <40% of legal rams annually (Schindler et al. 2017).

Another metric that could be considered is the Idaho target of restricting harvest to <20% of the mature (≥¾ curl) rams (IDFG 2010). The current demand for harvestable rams exceeds supply, and the quality of the hunt is reduced in some areas through low numbers of legal rams and high numbers of hunters disturbing sheep and other hunters. The ram harvest has declined, despite stable to increasing age of harvested rams and apparently moderate harvest rate. Any increases in resident hunting of rams likely cannot be met by presently accessible sheep populations without a further decline in hunter success or increased limitations on hunter opportunity (e.g., shortened seasons, access restrictions, implementation of LEH, increase horn curl restrictions, etc.). Harvest management options will be further evaluated by Ministry staff and recommended options will be presented in the regional implementation plan.

6. FLNRORD to continue to monitor trends in harvested rams (using horn annuli, horn measurements and hunter effort and success). Inspectors should record how long a ram was legal before it was harvested. FLNRORD to calculate ram harvest rates and escapement using various metrics;
   (Benefits: Valuable trend data obtained, including harvest rate of legal rams;
   Challenges: Some labour and data management requirements; inspectors need to have continual training).
7. ***Harvest management options:*** The following regulations could be considered to manage the harvest rate, hunting pressure, and to allow greater escapement of older rams:
   a. Apply region-wide GOS regulations, maintaining full curl restriction:
      (Benefits: Maximum hunting opportunity and opportunity for ram harvest;
      Challenges: Limits ability to ensure ram harvest rate and older ram escapement. Reduced hunter success and quality of hunting experience. Potential for disturbance and displacement with unlimited numbers of hunters. Strong potential for highly accessible areas to become harvested to a level well beyond the harvest objectives. May disrupt herd social structure, impact pregnancy and fitness outcomes and the distribution of sheep across the landscape. Under intense hunting pressure may result in reduced horn size via artificial selection against rams with rapidly growing horns).
   b. Apply region-wide GOS regulations, implementing a mature curl bighorn ram restriction:
      (Benefits: Will allow rams to attain older age (perhaps 1–3 years) compared to full curl regulations before being vulnerable to harvest, and allow older rams to be involved in breeding and social structure. Will improve the quality of the rams 'trophy' value. Maximum hunting opportunity;
      Challenges: In the short term (1–3 years), hunter success and harvest will be severely reduced as full curl rams are recruited to mature curl rams. Given brooming of horns of older rams some older rams will never attain legal horn size, likely reducing the ram harvest by more than half (C. Proctor, FLNRORD, pers. comm.). Likely greater enforcement issues).
   c. Apply region-wide LEH regulations, maintaining full curl restriction;
      (Benefits: Greater control on harvest, especially in areas with high visibility/vulnerability of sheep and the ease of access. Quality of hunt and hunter success will increase.

Reduced hunter disturbance of sheep. Reduced disturbance of landowners. Better distribution of the harvest. Increased opportunity to harvest a trophy;
Challenges: Greatly reduced licensed hunter opportunity (likely in the 75–80% range). More costly for government to administer).

d. Retain current GOS full curl season but restrict hunting opportunity through LEH regulations in specific PMUs where the population is well below objectives and there are indications of low escapement of mature rams;
(Benefits: High hunting opportunity but provides greater control on hunters and harvest in those areas of greatest concern. Reduction in disturbance of sheep by hunters in PMUs where LEH implemented;
Challenges: Some reduced resident hunter opportunity. More costly for government to administer. Increased application of LEH regulations for bighorn sheep hunting in only portions of the region will most likely divert hunting pressure to other GOS areas more quickly. Higher potential for disturbance and displacement in areas left as GOS).

e. Apply region-wide LEH regulations but allow 'any ram', ≥½ or ¾ curl restrictions;
(Benefits: Full curl restrictions unnecessary for LEH seasons to direct ram harvest to older age classes and using the younger ram harvest option will recruit more older rams into the herd. This could reduce wastage and compliance and enforcement challenges, and may reduce the chance of harvest-caused evolutionary change in horn size;
Challenges: Greatly reduced licensed hunter opportunity if LEH regulations applied. The number of LEH permits likely would be reduced compared with full curl regulations).

f. Implement an LEH draw priority system which increases for each year you apply and are not drawn (similar to system in place in Alberta);
(Benefits: Provides greater likelihood that a hunter will ultimately be drawn for a particular LEH hunt, and may encourage better acceptance of LEH regulations;
Challenges: Must be implemented provincially. May not help older hunters who may not acquire enough points to get their guaranteed draw before they are too old to hunt.).

g. Retain current GOS full curl season but close the season within a PMU when the recommended harvest/quota is reached (e.g., when 8-9% of the estimated number of rams are harvested or some other value based on other data). Would require changing Compulsory Inspection from current 30 days to perhaps 48–72 hours reporting.
(Benefits: Reduces risk of overharvest of rams and increases survival of larger rams that primarily reside in protected areas. Retains hunter opportunity albeit within a shortened season;
Challenges: More challenging for government to administer and enforce. Delay in CI checks may result in over-harvest in some situations. Concentrates hunting and disturbance into a shorter season at the front end).

h. Shorten end of current GOS season (25 Oct) by 5 or10 days (some rams typically tend to move out of less accessible or protected areas to rutting areas near the end of the current hunting season; early winter weather can encourage this movements and increase vulnerability to harvest);
(Benefits: Will enable hunting opportunity but within a shortened time period. Will likely

reduce harvest of (and disturbance of) rams during the vulnerable pre-rut movement period and increase survival of larger rams that primarily reside in protected areas. Assuming some shift of kills to earlier in the season, the overall harvest may decrease by about 5 or 8% for a 5- or 10-day shorter season, respectively;
Challenges: Reduces available hunting days by 11–22% based on current season length).

i. Limit the number of rams that can be harvested in a hunter's life-time;
(Benefits: Will reduce hunting pressure, with greater reductions with lower limits to the numbers of rams;
Challenges: If less than full curl regulations and more first-time hunters are recruited into sheep hunting, it may place more pressure on younger rams. Will reduce the opportunity and experience to hunt sheep. Must be implemented provincially).

j. Implement a species-specific (bighorn or thinhorn) sheep tag in the province and allow hunting of only one sheep species per year;
(Benefits: Acknowledges the limited resource of sheep hunting in the province. Will reduce hunting pressure;
Challenges: Will reduce hunting opportunity. Must be implemented provincially).

k. Establish a time interval of eligibility to harvest a ram, i.e., introduce a 3 or 5 year "wait-out" period between successful harvest of a sheep within Region 4. This would require a species-specific tag for each species of sheep in BC (bighorn and thinhorn). About 55% of sheep harvested are taken by resident sheep hunters who have never harvested a ram before;
(Benefits: Hunters may be more selective in what is harvested. Hunting pressure and harvest numbers should decline by about 10% with a 3-year or up to 15–18% with a 5-year period;
Challenges: Some resident hunting opportunity will be lost, proportionate to the wait-out time. More costly for government to administer. Must be implemented provincially).

l. Increase license fees;
(Benefits: Will likely reduce the number of hunters, with the degree of reduction relative to the fee increase;
Challenges: Loss of recreational opportunity that may target lower income earners. Must be implemented provincially).

8. Standardize hunting regulations within region (e.g., GOS or LEH).
(Benefits: Ease of enforcement;
Challenges: Some areas require unique regulations for management and to sustain herd viability).
9. Do not allow GOS ram harvest of any PMU with ≤75 observed sheep ***or*** ≤100 estimated sheep.
(Benefits: Protects breeding rams and reduces hunter disturbance;
Challenges: May restrict harvest opportunity where some level of harvest is sustainable).
10. Consider allowing a *limited and closely regulated* ram harvest in PMUs of ≤75 observed sheep *or* ≤100 estimated sheep when historical data indicate that a population is unlikely to reach a population of this size and/or ≥30 rams:100 ewes and ≥30 lambs:100 ewes are observed during mid- to late winter surveys. In this case, use of LEH regulations could be used to restrict the

number of rams harvested from the PMU.
(Benefits: Protects a sufficient proportion of breeding rams while allowing for hunting opportunity;
Challenges: Must be monitored carefully to ensure harvest is not supressing the population. Will increase resident hunting pressure in remaining PMUs with GOS).

11. When a population is high, to maintain population health, to reduce potential for contact with domestic animals causing disease outbreaks, or to aid in reduction of agriculture-related conflicts, up to about 10% of the population could be removed annually as "non-trophy sheep" (a female sheep or a male sheep under one year of age) or ewe hunt.
(Benefits: Can result in reduced density and higher productivity.
Challenges: Must be monitored carefully to ensure population objective is maintained. Removes pressure on agriculture to support efforts to minimize risk of contact with domestic sheep and goats).

Habitat management

The interim **habitat management objective** is to maintain >80% of all native sheep range in each PMU as high quality, defined as large patches of source habitats with low risk of mortality and good productivity (after AESRD 2015). Succession, forest encroachment, spread of invasive plants and overgrazing by livestock and other ungulates have degraded bighorn sheep ranges in many areas of the region. Human disturbance – roads, motorized and non-motorized forms of transportation and recreation trails – can displace sheep and render some habitats less functional.

12. Conduct regular habitat assessments to identify areas to conduct and guide adaptive habitat management. Assess all sheep seasonal ranges and migration corridors for health and ecosystem function, including forage quality. Follow an adaptive management approach so that habitat enhancement projects are monitored for effectiveness to support bighorn sheep, and successful enhancement efforts are repeated. Collars should be used in the 2–3 highest risk PMUs to obtain better resolution seasonal use and movement data to refine assessments and to confirm the degree of utilization of newly enhanced areas.
(*Benefits: Provides tracking of ecosystem health and targeting of management, especially for high-elevation grasslands and low-elevation winter ranges;*
Challenges: Costly, requires coordinated system for archiving reports and data to inform habitat enhancement projects. Collaring studies can also be costly)
13. Identify, maintain and enhance habitat connectivity and sheep movement corridors within and among PMUs. These could include mid-elevation and low-elevation corridors (e.g., Dibb et al. 2008), involve private land securement (e.g., NTBC, NCC) and promotion of wildlife-friendly fencing designs that provide for movement across private lands but with lower entanglement hazards.
(*Benefits: Improves functional landscape connectivity;*
Challenges: Costly – collaring studies may be required to identify high priority areas for management, and ecosystem restoration is labour-intensive)

14. Where succession and forest encroachment have significantly affected the quantity or quality of bighorn sheep habitats, conduct ecosystem restoration operations such as implementation of fire and habitat management practices to benefit bighorn sheep (e.g., prescribed burning, slashing, limbing, revegetation and reseeding). Any ecosystem restoration should limit the spread of invasive plants; only conduct burning where invasive plants are functionally minimized or absent.
    (*Benefits: Can restore open grasslands in sheep range to increase habitat quality and carrying capacity;*
    Challenges: Costly and often labour-intensive. May encourage invasive plants. More open forests/grasslands may increase use by recreational users)
15. FLNRORD staff to work closely with land managers to identify infestations of invasive plants and develop strategies for removing from and preventing the spread of invasive plants within bighorn sheep habitat, especially in alpine habitats and winter ranges. Where the use of chemical herbicides will prove the most effective means, incorporate a public education and outreach strategy to inform the public and First Nations communities about the need for the approach and selected tools.
    (Benefits: Can restore sheep range habitat quality and carrying capacity;
    Challenges: Costly, long-term, often labour-intensive, and requires ongoing monitoring)
16. Develop and update regional winter, summer and transitional range mapping. Collars should be used in the 2–3 highest risk PMUs to obtain better resolution seasonal use data to refine mapping. Archive range boundaries in the provincially managed Wild Mountain Sheep Registry spatial database.
    (Benefits: Provides clarity for land use planning;
    Challenges: May be challenging to accomplish using modelling; summer and transitional ranges especially challenging. Collaring studies can be costly)
17. Secure habitat protection for native bighorn sheep winter ranges in the form of government legislation and regulations, as well as private land conservation (e.g., NTBC, NCC). Create UWR Orders for all sheep winter ranges currently not covered by existing Orders under the *Forest and Range Practices Act* (FRPA). Sheep winter ranges should also be covered by either a Section 16 or 17 of the *Land Act*[7] for core and high capability habitat, respectively. Avoid development in high quality sheep winter range such that there is no net loss of winter range. Significant summer ranges, rutting areas, transitional pre-winter ranges, lambing grounds and mineral licks should be identified and protected under government legislation.
    (Benefits: Would ensure protection of critical winter ranges, under FRPA and Lands Act, which are limited on the landscape, and other key habitats/features. Will facilitate assessment of proposed industrial development projects;
    Challenges: Legislation is a time-intensive process and may not offer protection in the time

[7] Section 16 precludes or prevents the acceptance of Crown land applications in a defined area, while areas covered under a Section 17 are attached to conditions that must be met before a Crown land application is accepted. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/land-water-use/crown-land/reserves.pdf

required. Winter range would not be protected from mining. May be opposition to assigning Section 16 and 17 notices to a large portion of the high elevation land base)

18. All mineral licks should be reported to the Wildlife Habitat Features (WHF) database[8] and managed as per the WHF field guide[9]: no road construction within 200 m (if practical), avoid construction, layout, cruising, etc. during sensitive timing window (April 1 – October 1), reclaim all roads within 200 m of lick, maintain visual screens on roads/trails leading to and from the lick, maintain a minimum of 100 m intact forest surrounding the lick and connect adjacent forest to provide wind-firm travel corridor(s).
    (Benefits: Would enhance protection of seasonally important mineral licks which are limited on the landscape. Will facilitate assessment of proposed industrial development projects;
    Challenges: Requires identification of mineral licks within the WHF database)
19. Road development for industrial use and timber harvest within a 5 km buffer of sheep winter range should be deactivated and/or completely rehabilitated immediately following completion of the associated activity and obligations.
    (Benefits: Would reduce access to and disturbance of seasonally important winter ranges. May reduce predator access to winter ranges;
    Challenges: Costs involved and requires cooperation from industry)
20. Where overgrazing on sheep ranges, especially winter ranges, is suspected and competition with elk or domestic cattle is shown to be a factor, develop strategies to reduce overall grazing pressure to enable restoration of range quality and sufficient forage carry-over for sheep. These strategies may include increasing the forage allocation for sheep (above the current 50% allocation for all ungulates) where they overlap with cattle, monitoring range tenure holders to ensure compliance with Range Management Plans that retain a specified percentage of natural forage units for wildlife, and population reduction/removal of one or all species involved.
    (Benefits: Will likely result in increased range quality and carrying capacity;
    Challenges: May result in difficult decisions on species priorities, and potential conflict with cattle ranchers)
21. Ensure new and existing motorized access into sheep range is carefully managed to reduce negative impacts to sheep populations (e.g., regional Access Management Plans, Access Management Areas [AMA], Motor Vehicle Hunting Closed Areas [MVHCA], or shorter-term options under *Forest and Range Practices Act* that can prohibit public access on industrial roads). Conduct a values assessment to verify that the current AMAs are spatially capturing the current values on the landscape sufficiently, especially as they relate to identifying the need for additional access measures in high value sheep habitats. Work collaboratively with the Conservation Officer Service to develop an enforcement plan to enhance compliance within AMAs in the East Kootenays and enhance public understanding through signage and outreach. If required, roads should be deactivated, access should be closed or alternative routes developed

[8] https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/legislation-regulation/forest-range-practices-act/government-actions-regulation/wildlife-habitat-features/kootenay-boundary-wildlife-habitat-features-order

[9] https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/legislation-regulation/frpa-pac/wildlife-habitat-features/whf_field_cards_kootenay_boundary_minerallick.pdf

for hiking, trail riding, or vehicular access where such activities may disrupt normal sheep use of seasonal ranges or increase sheep vulnerability to harvest.
(*Benefits: Motorized access management can reduce "visual vulnerability" and sheep vulnerability to harvest and contribute to the quality of ram harvest by reducing disturbance. Can lead to more even distribution of hunters;*
Challenges: Increased enforcement costs and implications to non-hunting users. Opposition from some stakeholders. Need to consider other effects of opening an AMA on winter range)

22. In areas where recreation is considered a factor contributing to disturbance of a bighorn sheep population, FLNRORD to work with land users and the public to mitigate the effects of disturbance associated with recreation. These include ATVs, snowmobiling, hiking, mountain biking, alpine touring, and horse-back riding. These efforts should be considered as part of a regional recreation management planning process (e.g., a Recreation Access Management Plan). Ensure that all proposed trail network expansions authorized by Rec Sites and Trails as well as all recreational events (e.g., commercial recreation tenures, and dirt bike and mountain bike competitions) in bighorn sheep habitat go through the referral process and requires input from Ministry habitat biologists. A cumulative effects assessment of existing commercial recreational tenures should be conducted prior to approval of additional tenures.
(*Benefits: Can lead to diminished disturbance to sheep populations;*
Challenges: Requires monitoring of recreational tenures and possible implementation of restrictions to activities)
23. Use cumulative effects framework to guide land use decisions on sheep summer and winter ranges.
(*Benefits: May limit negative cumulative development and activities within sheep ranges;*
Challenges: Restrictions on development and activities may affect other land users)
24. Conduct continual assessment of changes to the Agriculture Land Reserve (ALR) that subdivide larger acreages that have the potential to lead to hobby farms with domestic sheep and goats near sheep winter range. Work with regional districts to determine appropriate recommendations to subdivide land near sheep winter range.
(*Benefits: May limit potential disease transmissions;*
Challenges: Restrictions on development and activities may affect other land users)

Health assessment and management

The **health management objective** is to reduce risk of respiratory disease outbreaks due to contact with domestic sheep and goats. The primary challenge for management of bighorn sheep health is to minimize the risk that bighorn sheep will contact *Mycoplasma ovipneumoniae* (Movi) positive domestic sheep and goats, which often results in catastrophic die-offs across interconnected bighorn populations. In the absence of Movi, the risk of pneumoniae when domestic sheep are comingled with bighorn sheep is reduced by over 90%.

25. Provincial policy and regulations are required to prohibit new domestic sheep and goat farms within areas of high risk of contact with wild sheep, and to mandate Movi testing and treatment protocols on existing sheep and goat farms within high-risk areas. The prohibition against

domestic sheep and goat grazing on Crown land should be maintained for areas used by wild sheep and mountain goats. Continued outreach and education through the BC Sheep Separation Program is essential to improve awareness of the disease risk to wild sheep, and promote a consensus approach to management with all stakeholder groups.
(Benefits: Reduces the likelihood of pneumonia outbreaks, catastrophic die-offs, followed by years of low lamb recruitment. Removing Movi from domestic flocks also increases productivity. Avoiding the "bad press" of high-profile die-offs is also good for domestic sheep industry
Challenges: Creates complexity and restrictions for domestic sheep/goat producers in high-risk areas. New regulation/legislation is complex and requires significant political will within Ministry of Agriculture. The effectiveness of provincial agricultural policy, as well as compliance and enforcement options, are unknown at this time)

26. Baseline herd health data are required for all bighorn sheep herds in the Kootenay Region, especially those with low lamb recruitment (<20 lambs:100 ewes) and high risk of contact with domestic sheep and goats, or are connected with herds that are. Develop comprehensive herd health assessment and monitoring projects in conjunction with the provincial wildlife veterinarian for any bighorn sheep project in the Kootenay Region where there is an opportunity for biological sample collection, especially where there are known domestic sheep farms within bighorn sheep range. Obtain biological samples and test for Movi detection (nasal swabs and blood serum) opportunistically when handling all bighorn sheep. Develop hunter harvest sampling programs (nasal swabs from skulls) and ensure proper sample handling and submission to laboratory; hunter harvest sampling should be made a component of Compulsory Inspection for all harvested rams.
(Benefits: Provides ability for early detection during new outbreaks. Enables monitoring of persistence of disease in bighorn herds;
Challenges: Analytical costs. Requires coordination among regional biologists, provincial wildlife vet, Compulsory Inspectors, and laboratories. Currently the majority of sheep heads have hide removed when CIs are conducted, which may increase the chance of false negative results)
27. For bighorn sheep populations with potential to interact with domestic sheep or goats, increase knowledge of wild sheep movement patterns, habitat use, survival, etc. using GPS collaring together with local knowledge.
(Benefits: Provides additional understanding of wild sheep movements and potential for interaction with domestic stock. Provides valuable location data to support effective habitat enhancement projects. Provides opportunity to integrate local knowledge into decision-making.
Challenges: Costly. Potential for capture-related mortality. Public opinion generally against visible collars on bighorn sheep)
28. Continue to support purchase/securement of private land (including restricted covenant) and creation of bighorn sheep-specific Conservation Areas in areas where there has been a history of domestic sheep and goat farming overlapping with bighorn sheep range. Investigate potential to create conservation covenants on private land that would prohibit farming domestic sheep and goats in high risk areas. Where domestic sheep farms exist within bighorn sheep range, work with BC Sheep Separation Program to support test-and-treatment techniques that reduce the prevalence of respiratory pathogens (Movi) carried by domestic sheep in areas with high risk of

contact with wild sheep.
(Benefits: Effective at creating separation between domestic sheep/goats and bighorn sheep. Removing Movi from domestic flocks also increases productivity;
Challenges: Expensive to purchase private land as well as to offset costs of encumbering private land with restrictive covenants. Uncertainty related to whether Agricultural Land Commission would support Conservation Covenants, as well as enforcement and compliance options).

Predation management

The **predator management objectives** are to consider temporary, targeted management, directed at PMUs or subpopulations with <125 estimated sheep or at sub-populations that have observed declines >40% below peak numbers. Where evidence of predator (e.g., cougar) specialization on bighorn sheep exists, targeted actions employed when sheep are on vulnerable winter and spring ranges could result in population recovery. Although several species of predators occur in the Kootenays that prey on bighorn sheep, in many areas cougars – often only a few individual cougars – are likely the primary proximate cause of mortality and are known to generate overall population declines in small populations of bighorn sheep through direct killing and reduced reproductive effort and calf recruitment (Knopff and Boyce 2007, Bourbeau-Lemieux et al. 2011, Rominger 2018). Before considering a predator management program, managers should carefully evaluate the current herd status, habitat condition, herd health problems, and predator-prey issues. Predation should be identified as a factor in bighorn sheep population performance (e.g., assessment of predator levels or trend, low adult sheep survival and high proportion of losses to predation) prior to initiation of increased predator management. Recommendations for cougar management align with the 2015 Kootenay Region Cougar Harvest Strategy (FLNRORD, unpubl. data), which recommends increasing female harvest to up to 40% of total harvest on bighorn sheep winter ranges, consideration of targeted removal of cougars specializing on bighorn sheep, limiting male harvest to meet age objectives (to retain older males), and increasing season length if desired female harvest is not achieved. Enhanced predator management should be used as a short-term solution, as habitat enhancement projects that improve forage quality and quantity and that reduce cougar stalking cover will likely increase sheep population resilience and provide the best long-term benefit (Rominger 2018).

29. Consider liberalizing cougar hunting regulations, including increase in bag limit, season extension and quotas on male cougars in management units having sheep populations of <125 estimated individuals or that have declined >40% below peak numbers with evidence of cougar specialization on bighorn sheep. Retain the existing regulation that hunters may not hunt a cougar kitten or any cougar in its company.
(Benefits: Encourages hunters to harvest more cougars and more females, which may stop declining sheep numbers and reduce vulnerability to extirpation. Restricting quota on males would promote older cougar age structure
Challenges: Requires regional regulation change. If not applied across the region will result in different regulations among management units. Controversial among some stakeholders)
30. Consider temporary cougar management programs to focus on specific areas for targeted removals to ensure the long-term persistence and viability of bighorn sheep herds. These

programs will only be applied to sheep populations or major herd components of a PMU with <125 estimated individuals or that have declined >40% below peak numbers with evidence of cougar specialization on bighorn sheep.
(Benefits: Provides additional options to target individual cougars that may be specializing on sheep; Will likely reduce sheep mortality rates and reduce vulnerability to extirpation; Challenges: Requires change in policy. Controversial among some stakeholders)

31. Consider educating predator hunters on the management benefit of removing female cougars near bighorn sheep populations, especially on winter range.
(Benefits: Provides increased knowledge to and opportunities for engagement with stakeholders. If hunter opinions changed should result in reduced cougar predation on sheep; Challenges: Many houndsmen oppose population reductions and do not typically target females. May disrupt social structure and exacerbate predation if large males primarily hunted, as large male cougars tend to prey on larger ungulates such as elk and moose instead of sheep. May require changes to cougar quotas)

Evaluation of Trade-offs

The likely effects of various bighorn sheep harvest, habitat and predation management options on selected management objectives were evaluated in consequence tables (Tables 4, 5). The current GOS regulations were most effective at maximizing annual harvest (at least in the short term) and hunter opportunity, while region-wide LEH regulations could produce the highest escapement of older rams, and higher hunter success and quality of hunt (Table 4). Habitat protection and access management has high potential to increase overall population stability and sub-population resiliency, while targeted cougar management can increase population resiliency and size (or at least stabilize a decline) and lamb ratios (Table 5). The consequence tables were presented to governments and stakeholders to facilitate discussion on trade-offs among management options. The consequence tables were used to inform decisions but were not used to select any specific recommended option.

Table 4. Consequence table showing the likely effect of bighorn sheep harvest management options for the Kootenay Region for selected management objectives (darker colour = better; blank is not applicable). First Nations harvest needs are unknown.

Population Management	What is Better	Units	Region-wide GOS – full curl	Region-wide GOS – mature curl	Region-wide LEH	LEH in specific PMUs	LEH with ≥½ or ¾ curl	GOS with quota to close	Shorten GOS by 5 days	Shorten GOS by 10 days	Limit lifetime ram harvest	3–5-year wait-out period	Increase license fees	Non-trophy harvest
Population resiliency	↑	% of ewes												
Population size	↑	Median pop. size												
Appropriate sex/age ratios	↑	Lamb:ewe ratio												
Appropriate sex/age ratios	↑	Ram:ewe ratio												
Escapement of mature rams	↑	% mature rams												
Disease outbreaks	↓	Potential for contact												
Harvest Management														
Annual harvest	↑	# of rams												
Hunter success	↑	Kills/hunter												
Hunting opportunity	↑	# of days												
Quality of hunt experience	↑	Hunter satisfaction												
Enforcement														
Enforcement effort	↓	Reduced enforcement												
Regulation complexity	↓	# of seasons, regs.												

Table 5. Consequence table showing the likely effect of bighorn sheep habitat and predation management options for the Kootenay Region for selected management objectives (darker colour = better; blank is not applicable). First Nations harvest needs are unknown.

Population Management	What is Better	Units	Ecosystem restoration	Invasive plant mgmt.	Habitat protection	Access management	Liberalize cougar regs.	Targeted cougar mgmt.	Regulating domestic sheep on private land
Population resiliency	↑	% of ewes							
Population size	↑	Median pop. size							
Appropriate sex/age ratios	↑	Lamb:ewe ratio							
Appropriate sex/age ratios	↑	Ram:ewe ratio							
Escapement of mature rams	↑	% mature rams							
Disease outbreaks	↓	Potential for contact							
Harvest Management									
Annual harvest	↑	# of rams							
Hunter success	↑	Kills/hunter							
Hunting opportunity	↑	# of days							
Quality of hunt experience	↑	Hunter satisfaction							
Enforcement									
Enforcement effort	↓	Reduced enforcement							
Regulation complexity	↓	# of seasons, regs.							

Management Recommendations by Population Management Unit

Following are PMU-specific assessments of population trend, harvest, land ownership, strengths/resiliency and threats/concerns followed by management recommendations specific for each PMU. Note that management recommendations that apply across the region and within most PMUs are provided under Management Issues, Tools and Recommendations, above. Region-wide changes to harvest regulations (e.g., implementation of a shortened GOS season) and many recommendations for habitat management and disease management policies would impact all PMUs. The actions below represent priorities for the short term (1-3 years) and long term (>3 years). Many of the recommendations are the responsibility of FLNRORD, but other groups and organizations can drive and facilitate management of bighorn sheep in the Kootenay region.

Population or habitat trends at the PMU level may mask differing trends within herds that comprise each PMU. While most of the management recommendations are directed at the PMU level, specific management recommendations may be made to address an issue or concern with an individual herd within a PMU. Management recommendations at the PMU level are provided in approximate order of recommended priority.

Management objectives for the Elk Valley East PMU are not finalized as Ministry staff are currently working with Ktunaxa Nation Council to develop objectives that incorporate Ktunaxa values. These objectives will be presented in a separate document.

1 Flathead-Waterton

There is currently no target population size for this PMU. There is poor knowledge of population trend and numbers occurring within BC during fall hunting season because the majority of wintering occurs within Alberta.

Population trend

This PMU is shared with Alberta and Waterton Lakes National Park (WLNP) with sheep occurring during summer and fall in high-elevation habitat along the Continental Divide and wintering occurs primarily east of the Divide. Herds in this PMU winter at high elevation, with very few sheep wintering within BC, thus the population estimate for the Flathead-Waterton PMU is largely derived from winter surveys conducted by Alberta and WLNP. Approximately 40 sheep were estimated in 1986–2001, increasing to 85 sheep by 2014. The most recent estimate is 148 sheep in 2019, calculated from the total estimated within the PMU in Alberta (Alberta survey in 2018 and WLNP survey in 2019) split in two between jurisdictions.

Harvest

Harvest: An average of approximately 1 sheep was harvested annually from the BC side of this population from the early 1980s to early 2000s (Fig. 9). From the early 2000s to 2016 the harvest increased to about 5 sheep annually then declined to 1–2 annually.

Following the harvest trend the **harvest rate** (as determined for the BC half of the PMU estimate) increased from 2.2% through the 1990s to 3.1% in 2005 and 4.2% in the late 2000s, before declining to 2.8% during 2012-15 and 1.6% in 2016-17.

Hunter numbers: Number of resident hunters within MU 4-01 averaged 27 from 2008–17 with an increasing trend to 2014 and low hunter numbers in 2017.

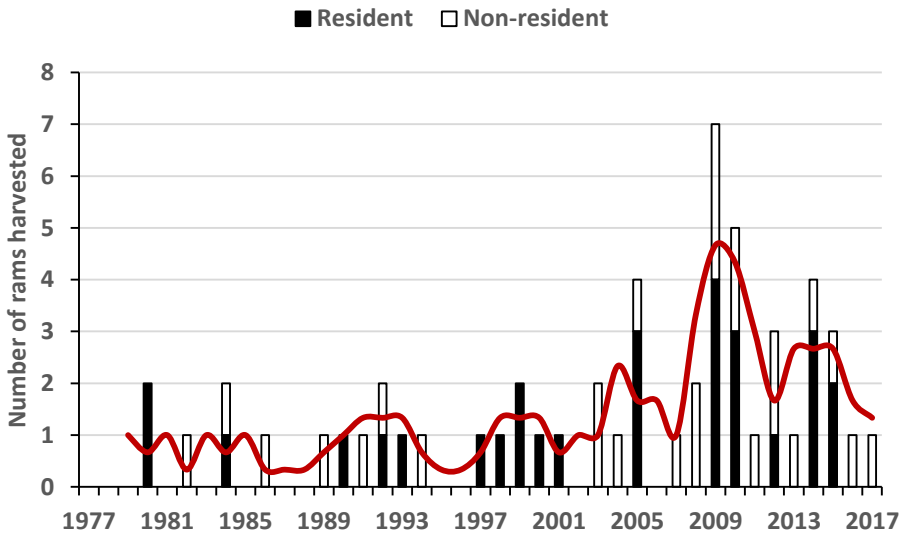

Figure 9. Number of rams harvested in the BC side of the Flathead-Waterton PMU by resident and non-resident hunters, 1977–2017. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- Population trend appears stable but surveys conducted by Alberta and WLNP.
- Small amount of private land (0.1%) limits concerns with domestic sheep/goat disease.
- 5.6% of PMU is park/protected area (Fig. 10).
- WLNP is a hunting refugium.
- BC-Alberta border may act as a form of hunting refugia as sheep can escape hunters from one side of the Divide (acknowledging there is hunting in many areas on both sides of the Divide).
- Limited access to much of the high-elevation habitat.
- East Flathead AMA in place.
- BC-Alberta transboundary planning occurred prior to Alberta recently finalizing a recreation plan (South Saskatchewan Regional Plan 2014-2024, Amended May 2018). Most lands within adjacent Alberta are within the Castle Wildland Provincial Park, except for lands at the end of Alberta Highway 774 which abuts BC north of Middle Kootenay Pass. Wildland parks manage for conservation while providing low-impact backcountry outdoor recreation opportunities and nature-based tourism products and services.
- Nearly 40% of the WLNP affected by the Kenow wildfire in 2017. Wildfires within the PMU in 2017 and 2018 occurred with mixed severity with fire effects from valley bottom to mountain

top with the majority of fire above forest harvest operability which will remain un-roaded and left to revegetate naturally.

Threats/concerns

- Poor knowledge of population trend and numbers occurring within BC during fall hunting season.

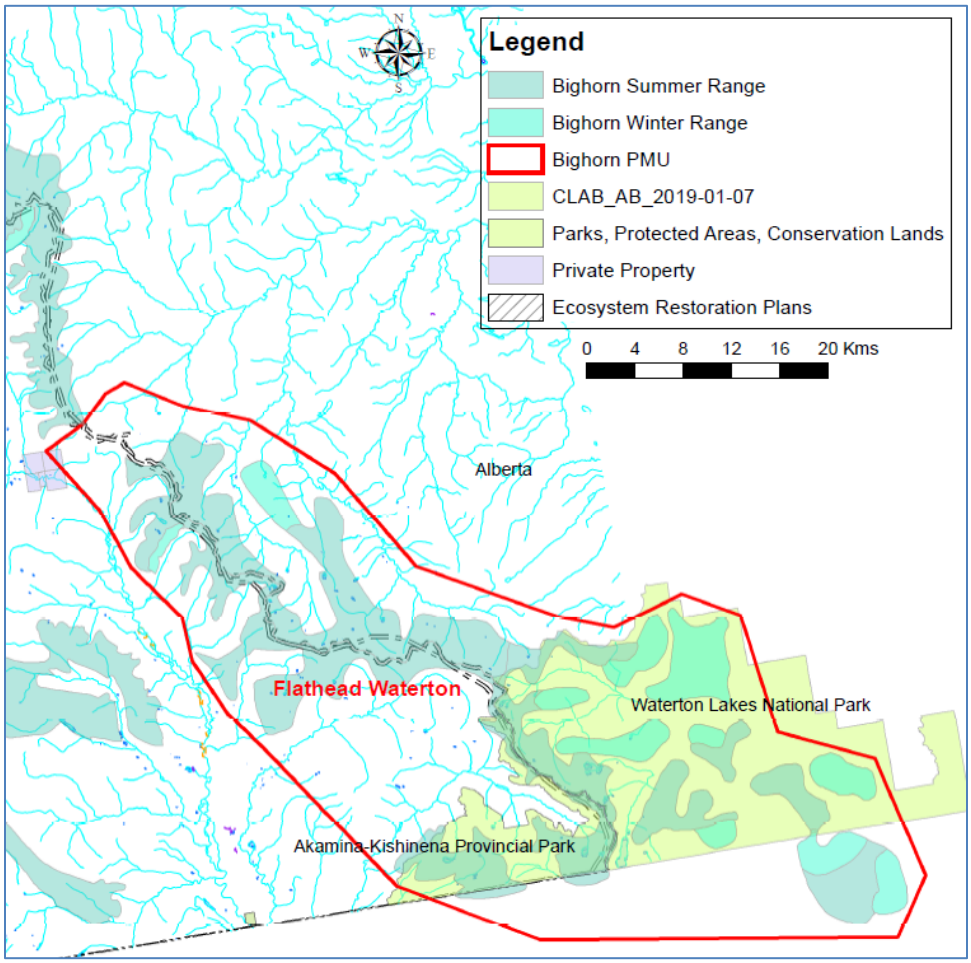

Figure 10. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the BC portion of the Flathead-Waterton PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- Harvest rate was high during the mid to late 2000s (noting that population numbers are poorly understood).
- Much of PMU shared with Alberta, which manages to full curl regulations.
- BC has little control over disturbance and threats on winter range outside of BC.
- High recreational disturbance on summer and fall range; access from Alberta primarily north of Middle Kootenay Pass. Recently finalized Alberta South Saskatchewan Regional Plan may push more backcountry users into BC.

Management recommendations

1. To better quantify fall sheep numbers within BC, conduct a September (pre-hunt) survey combining aerial and ground methods. Harvest data and local knowledge can help focus the flight, which could also be used to examine seasonal road use and AMA compliance.
2. Increased access management and road deactivation in areas of high recreation use.
3. Monitor the effects of the Kenow wildfire with WLNP staff.

2 Wigwam Flats-Elko-Phillips

The target population size is 370 sheep (range 300–450). A major concern is that many of the winter habitats are in deteriorated health primarily due to invasive plant infestations.

Population trend

Bighorn sheep estimates for PMU 2 have fluctuated over time but have generally remained within 20% of the median (Fig. 11). Currently, most herds within the PMU are within target with the exception of the Galtons/Phillips herd. Peak numbers were observed in the early 1990s and late 2000s. Lamb ratios have averaged at or just above population objective since 2001, and ram ratios were generally at or above objective (Fig. 12). Herds in this PMU winter primarily at low elevation.

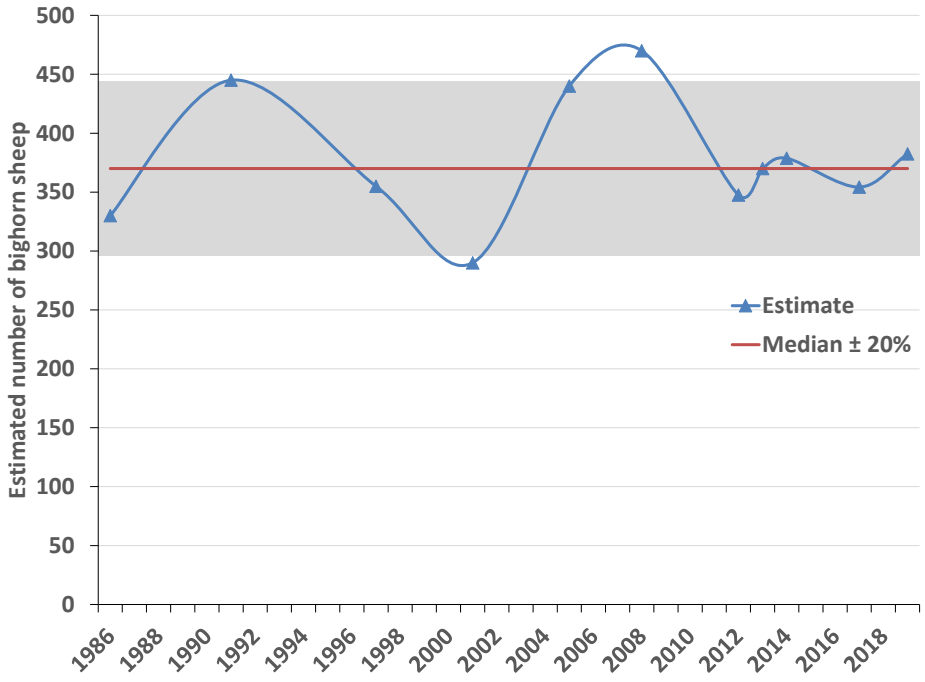

Figure 11. Bighorn sheep population estimate trend for Wigwam Flats-Elko-Phillips PMU with the median estimate (± 20%) of the last 5 surveys.

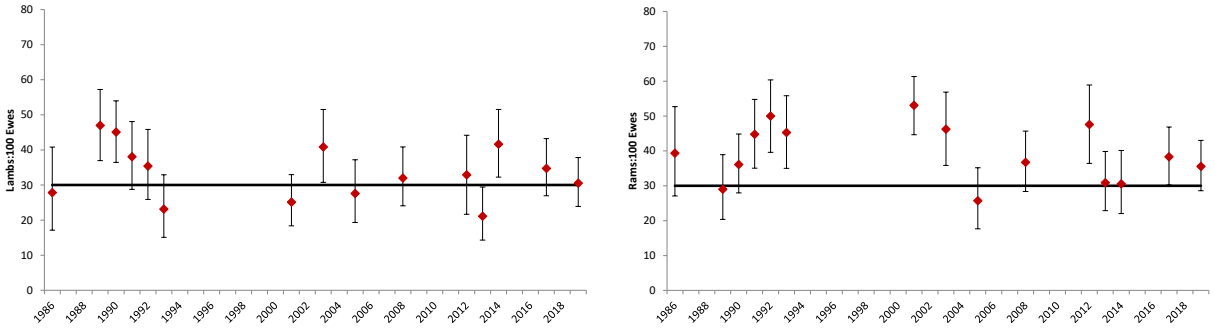

Figure 12. Trends in lamb (left) and ram (right) ratios over time in Wigwam Flats-Elko-Phillips PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

Harvest

Harvest: Roughly 4–10 rams were harvested annually from the PMU 2 over the past 15 years, with the most recent peak in harvest occurring during the mid- to late 2000s with a declining trend since the late 2000s (Fig. 13).

The **harvest rate** varied from 1.4–1.9% through the 1990s to mid-2000s, peaking at about 2.0% in the mid to late 2000s, declining to about 1.3–1.4% % during 2012–17.

Hunter numbers within MU 4-02 (the management unit encompassing most of the Wigwam Flats-Elko-Phillips PMU) averaged 50 annually during 2008-17 with a slight increasing trend over time except for 2017, when hunter numbers dropped by half.

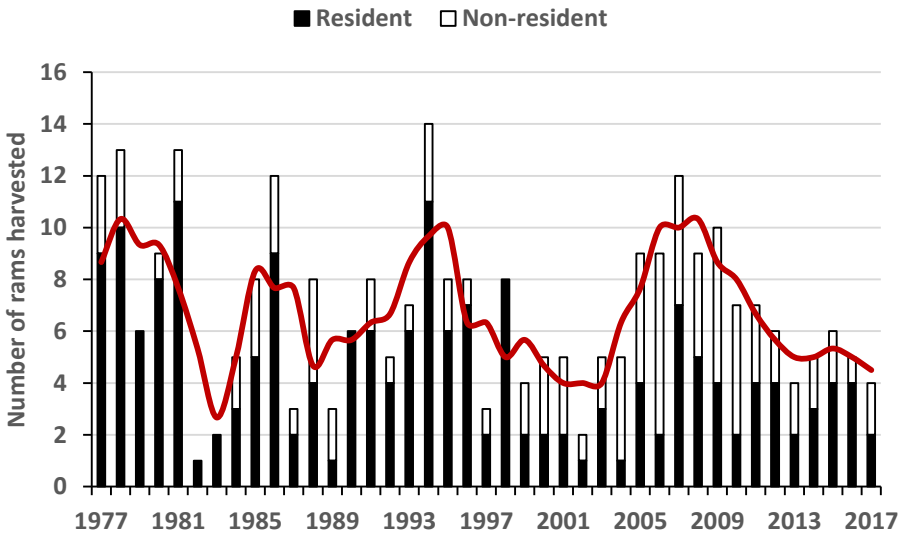

Figure 13. Number of rams harvested in the Wigwam Flats-Elko-Phillips PMU by resident and non-resident hunters, 1977–2017. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- Estimate is within population objectives, although some decline in Galtons/Phillips herd.
- 4.4% of PMU is protected as Conservation Land (Fig. 14).
- Galton Range, Sheep Mountain, Upper Wigwam and Wigwam Flats-Mt. Broadwood/Sportsman Ridge AMAs in place.
- 18.7% of PMU is within FWCP ecosystem enhancement (ER) planning areas (Galton ER Plan, White Bull Elk ER Plan; Fig. 14). Treatment for invasive plants being conducted by FLNRORD (with funding from Habitat Conservation Trust Foundation and FWCP) and The Nature Trust of BC (NTBC) in Wigwam Flats and invasive plant management and prescribed burns conducted by FWCP in Lizard Range and Galtons. Additional invasive plant management is being conducted by Nature Conservancy Canada (NCC).

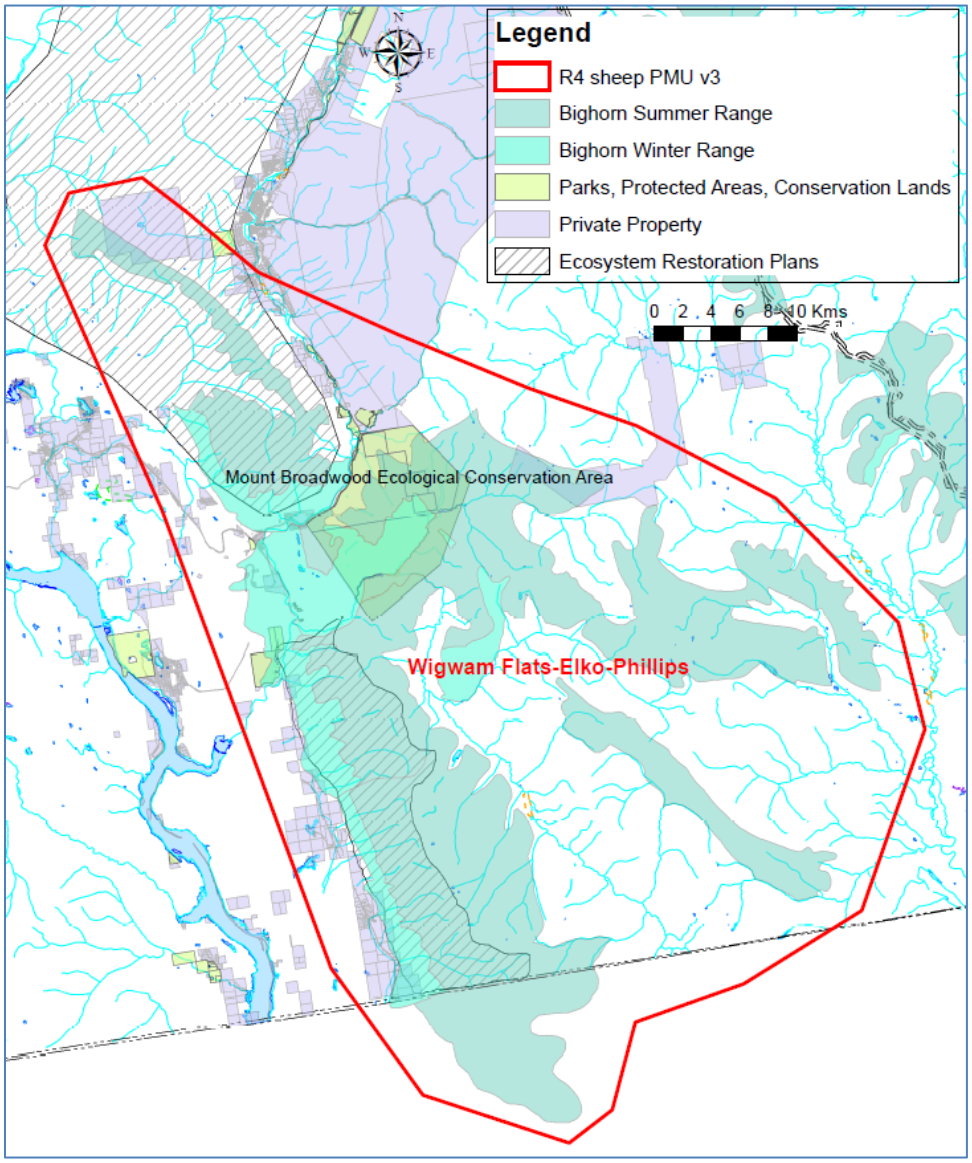

Figure 14. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the BC portion of the Wigwam Flats-Elko-Phillips PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- Diversionary salting conducted to reduce highway mortality from the Elko herd.
- FLNRORD has been working with the Tobacco Plains Indian Band to keep domestic goats (used for grazing invasive plants) outside of bighorn sheep habitat.

Threats/concerns

- Apparent increase in cougar numbers coupled with recent decline in white-tailed deer may have amplified predation pressure on sheep.
- Of two mortalities detected from four collared Galton herd sheep, one was wolf predation and one was unknown (Ayotte 2019).
- Many of the winter habitats are in deteriorated health:
    - Range quality may be reduced;
    - Invasive plants are prevalent throughout the PMU at lower elevations;
    - Forest ingrowth has occurred on some ranges;
    - Lack of escape terrain within the Galton Range and portions of Wigwam Flats, concentrated winter range.
- 7.8% of PMU is private property, with many areas from Elko south to the US border at high risk of disease from contact with domestic sheep/goats (Fig. 14).
- Mining exploration and development (Flathead Ridge migration corridor).
- Salt brine used by Ministry of Transportation and Infrastructure (MOTI) on highways puddles within highway rumble strips near wintering sheep, increasing risk of sheep-vehicle collisions.
- Human disturbance: hunting/recreation/dogs.
- Increasing use of mountain bikes within sheep spring range may cause increased disturbance.
- Galtons/Phillips herd shared with Montana (Johnsen 1993).
- Domestic sheep producers occur adjacent to the border in Montana, producing a high risk threat of disease transmission.
- The Tobacco Plains Indian Band uses domestic goats for controlling infestations of invasive plants on Reserve lands.

Management recommendations

1. Evaluate sheep range habitat condition and forage quality (especially in the Galtons to explore why numbers have declined) and conduct habitat enhancement for continued restoration. Continue monitoring of ecosystem restoration initiatives.
2. Conduct invasive plant management in areas of high priority.
3. Conduct selective habitat restoration projects (prescribed burns not recommended in all portions of this PMU due to invasive plants but it is a suitable treatment on appropriate sites).
4. Work with MOTI to reduce highway mortality along Highway 3, including addressing road salt brine puddling and attracting sheep into high risk situations and speed reductions.

5. Maintain movement corridors through linear transportation corridors to ensure bighorn sheep can safely move north to south through Highway 3 near Elko.
6. Explore revision to current AMA legislation to manage use of mechanized transportation (primarily mountain bikes) and maintain dogs on leash in areas of high sheep use, primarily during the sensitive winter and spring seasons.
7. Initiate a collaring study to examine seasonal range use within the Wigwam Flats portion of the PMU. Data could be compared with collaring study from the late 1990s (Kinley 1997).
8. Review the Phillips Creek (Galtons) LEH season which occurs in November and discuss with Montana their any-sheep permit and season length (extends to end of November).
9. For herds within the PMU with <125 estimated sheep where predation is shown to be limiting population growth, consider enabling special predator/cougar management programs.
10. FLNRORD to continue to work with the Tobacco Plains Indian Band to manage use of domestic goats on reserve lands.
11. Work with the Regional District of the East Kootenay to conduct education and outreach to inform private land owners about disease risk from domestic sheep/goats to wild sheep.

3 Elk Valley East

The target population size for this PMU is about 640 sheep (range 515–770). The major concern is that habitat loss from coal mining operations will displace sheep from critical winter ranges, resulting in overcrowding on existing winter ranges and eventual habitat deterioration and population declines.

Population trend

Population size increased during the 2000s to peak in 2010, dip during the early to mid-2010s and increase in 2019 (Fig. 15). This PMU contains the greatest number of bighorn sheep in the Kootenay Region. Herds in this PMU winter at high elevation; Ewin Ridge is considered the most important alpine bighorn sheep winter range in BC (Demarchi 1968). Lamb ratios have generally averaged about 35 lambs:100 ewes since the mid-2000s, and ram ratios have been well above objectives (Fig. 16). For more information regarding this herd refer to Poole (2013), Poole et al. (2016) and Poole et al. (2018).

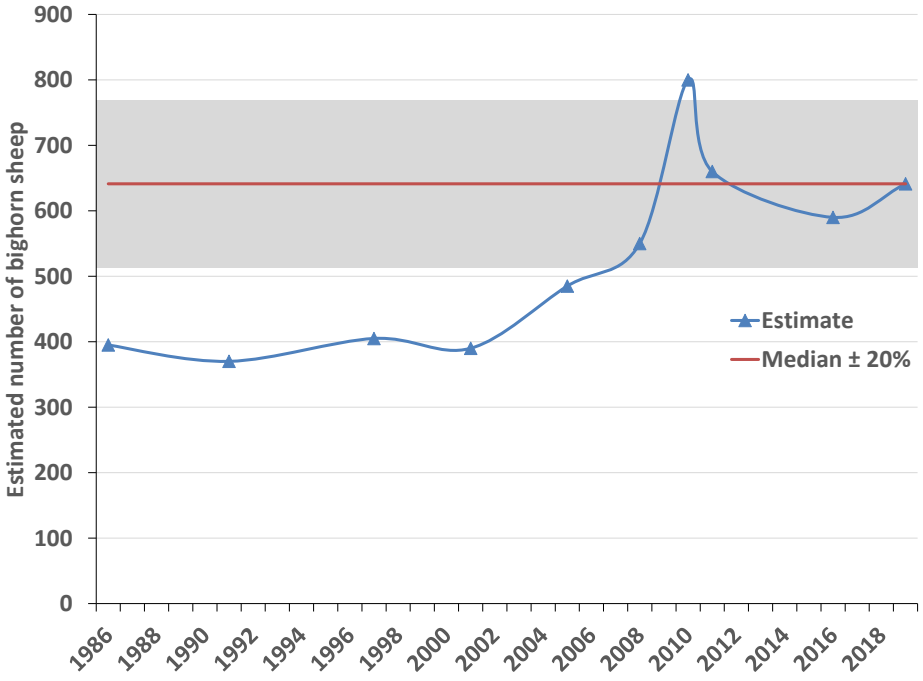

Figure 15. Bighorn sheep population estimate trend for Elk Valley East PMU with the median estimate (± 20%) of the last 5 surveys.

Harvest

Harvest: The harvest in the Elk Valley East PMU has varied over time from 4 to 13 rams annually. This PMU has produced the highest ram harvest, averaging 9 rams annually from 2008-17 with a stable trend. The harvest is largely by resident hunters as much of the PMU is unallocated to guide outfitters (Fig. 17).

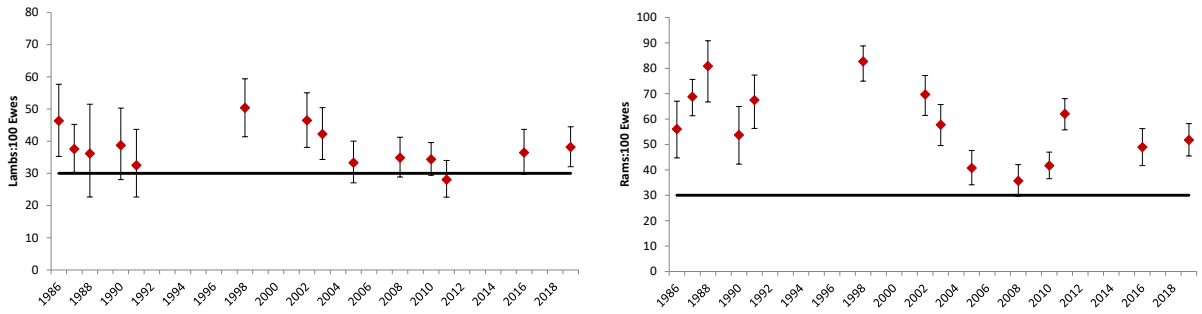

Figure 16. Trends in lamb (left) and ram (right) ratios over time in Elk Valley East PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

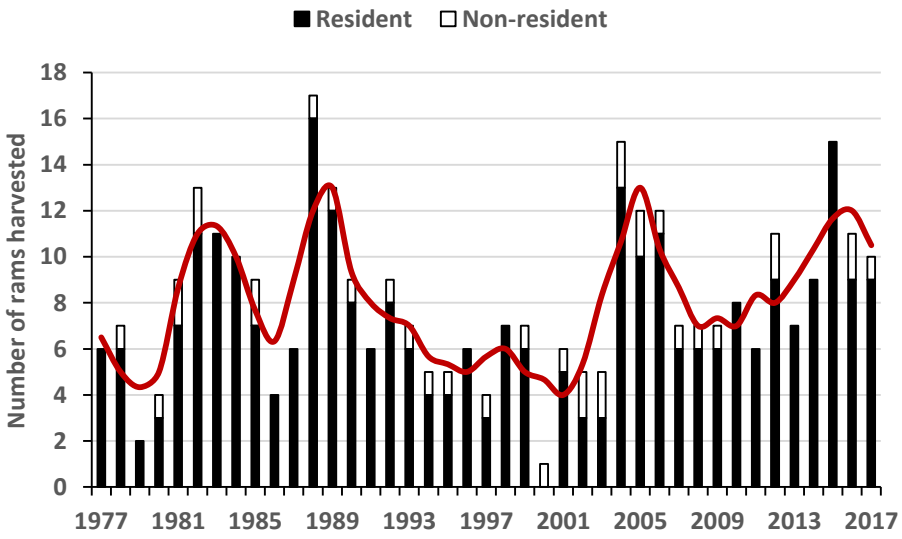

Figure 17. Number of rams harvested in the Elk Valley East PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

The **harvest rate** for this PMU has remained below 2% except during the mid-2000s when the rate was approximately 2.3%.

Hunter numbers: MU 4-23 (which encompasses both the Elk Valley East and Elk Valley West PMUs) hosts over one-third of all resident hunters in the Kootenay Region, averaging about 160 hunters annually with no trend over the past decade among years.

Strengths/resiliency

- The Elk Valley Cumulative Effects Management Framework (CEMF) was recently completed, which provides recommendations for decision-making related to the development of natural resources (Elk Valley Cumulative Effects Management Framework Working Group 2018, Poole et al. 2018).
- Refugia provided by no-hunting areas surrounding Teck Coal operations (Fig. 18).

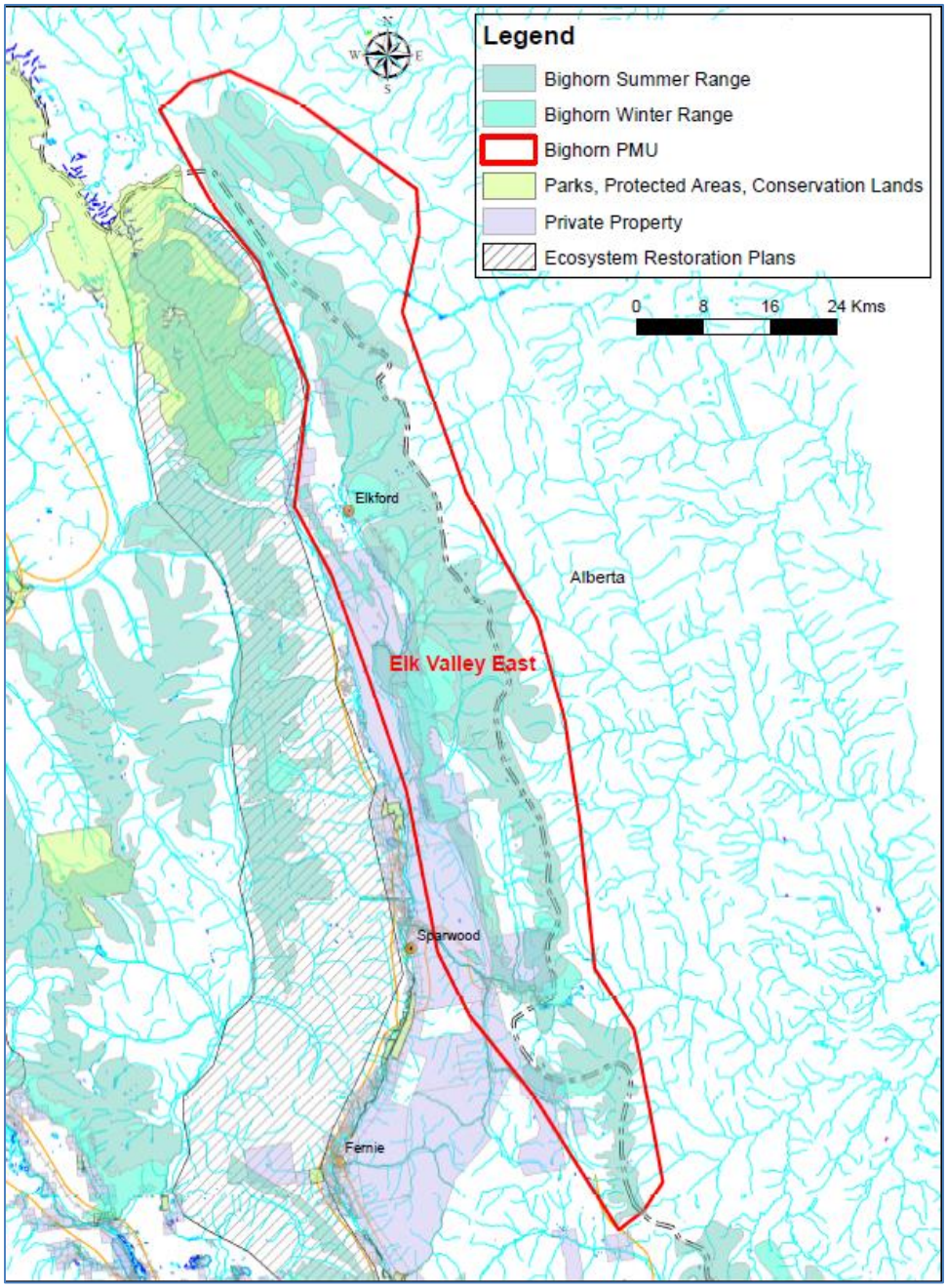

Figure 18. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the BC portion of the Elk Valley East PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- AMAs in place in Alexander Creek, Corbin Creek, Chauncey-Todhunter and Upper Elk Valley/Fording River.
- Population levels appear higher than historical numbers, however size of area inventoried prior to 1998 is unknown. Lamb and ram ratios above population objectives.

Threats/concerns

- Habitat loss from coal mining operations will displace sheep, including from winter ranges critical for population persistence, and likely result in population declines. Mining activity in Castle Mountain/Chauncey Ridge and well as Greenhills Ridge North and Turnbull West appear to be in the early conceptual stage of design.
- High elevation, red-listed rough fescue and Idaho fescue communities are highly threatened by mining and associated road construction. Within the Elk Valley East, <5 km^2 of the rough fescue community exists.
- High elevation winter range and grasslands once removed cannot be replaced; recovery and remediation of factors that drive these high elevation grasslands are not possible after conversion to open-pit mines.
- There is currently no mechanism in place to protect these high-elevation grasslands.
- Declining forage quality on some ranges, in part due to high elk numbers (which appear to be declining), as well as the spread of invasive plants.
- Sheep range habitat quality north of the mines unknown (the Tobermory-Aldridge area).
- Disturbance of sheep because of extensive access to high-elevations, especially within Alexander Creek and access from Alberta. Summer access increases sheep vulnerability during the harvest.
- High access from mining and logging roads has increased vulnerability to harvest.
- Winter snowmobiling in Aldridge Creek.
- Portions of PMU shared with Alberta, which manages to 4/5 curl regulation.
- PMU with the highest proportion of private property (19%), which has the potential to increase risk of contact and disease transmission from domestic sheep/goats (although no history of disease).
- No parks/protected areas, no conservation lands within sheep range within this PMU.

Management recommendations

1. Avoid impacts to and loss of high quality bighorn sheep winter range and critical habitat as guided by the Cumulative Effects Management Framework (CEMF) assessment and recommendations (Elk Valley Cumulative Effects Management Framework Working Group 2018).
2. Assess winter range condition/health every 3–4 years using the Uplands Function Checklist (UFC) Assessment Method (Fraser 2007), with more infrequent full ecological range assessments (such as Smyth 2014) conducted at longer intervals (8-10 years).
3. Restore/improve and enhance range condition in impacted winter ranges.
4. Manage invasive species and control their spread and impacts on winter ranges.
5. Develop a mechanism to protect rare, red-listed and important high elevation grasslands and bighorn sheep winter range from habitat disturbance.
6. Limit further road development in PMU aligning with the CEMF assessment and recommendations (Elk Valley Cumulative Effects Management Framework Working Group 2018) combined with delivery of road deactivation.
7. Prevent expansion of current motorized and mechanical use of Weary Ridge.

8. North of the mines (Aldridge Creek to Tobermory), evaluate sheep range habitat condition and, where appropriate, conduct habitat enhancement. Monitor ecosystem restoration initiatives.
9. Identify and map inter-mountain migratory routes and seasonal corridors; and prescribe management actions within a regulatory framework to protect routes and corridors.
10. For additional discussion and recommendations please see Elk Valley Cumulative Effects Management Framework Working Group (2018) and Poole et al. (2018).

4 Elk Valley West

The target population size for the Elk Valley West PMU is about 150 sheep (range 120–180). Numbers have significantly declined and there is little known about seasonal range use and movements.

Population trend

Sheep abundance in this PMU was higher from the late 1980s to early 2000s, an estimated 150–180 sheep (Fig. 19). Since the mid-2000s the estimate has decreased, and in 2019 was the lowest recorded (roughly 75 sheep). The current estimate is about 60% lower than the peak in 2002. Lamb ratios were high during the 2000s to early 2010s, declined to close to population objective in 2016 and 2019 (Fig. 20). Ram ratios have generally remained above objective. Herds in this PMU winter at high elevation.

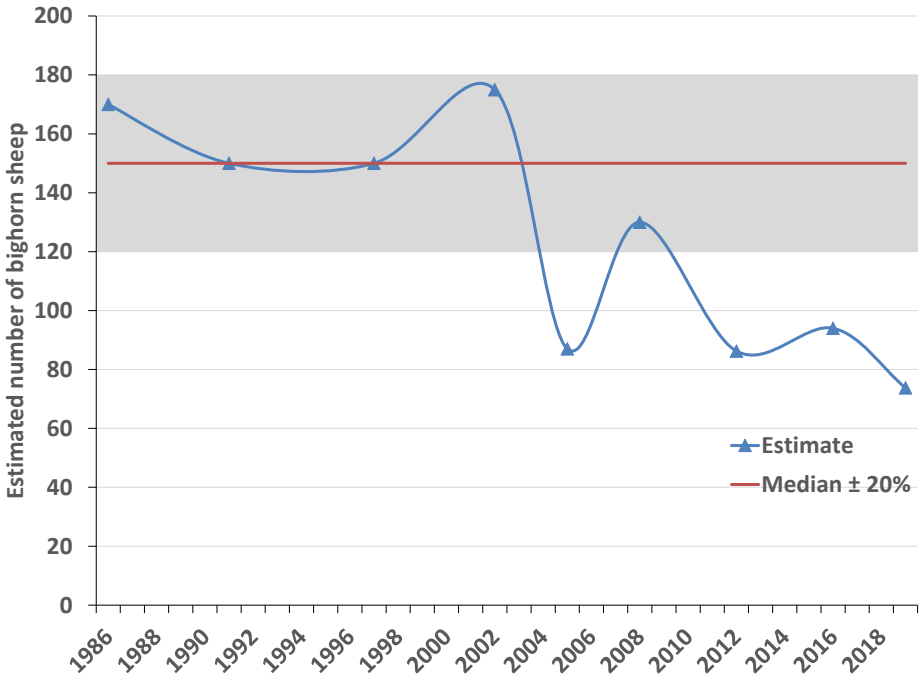

Figure 19. Bighorn sheep population estimate trend for Elk Valley West PMU with the median estimate (± 20%) of the last 5 surveys prior to the lowest survey in 2019.

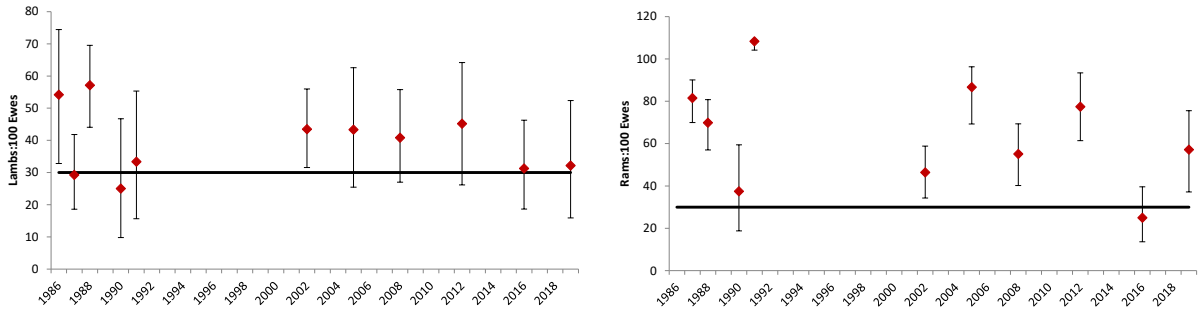

Figure 20. Trends in lamb (left) and ram (right) ratios over time in Elk Valley West PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

Harvest

Harvest: Approximately 2–5 rams have been harvested annually from the Elk Valley West PMU (Fig. 21).

The **harvest rate** has fluctuated among years, peaking at 3.2% in the mid-2000s, 3.6% during 2012-15 and 2.9% during 2016-17.

Hunter numbers: As noted above for the Elk Valley East PMU, hunter numbers within MU 4-23 have been high and stable, but there is no way to assign hunter effort to east or west of the Elk River.

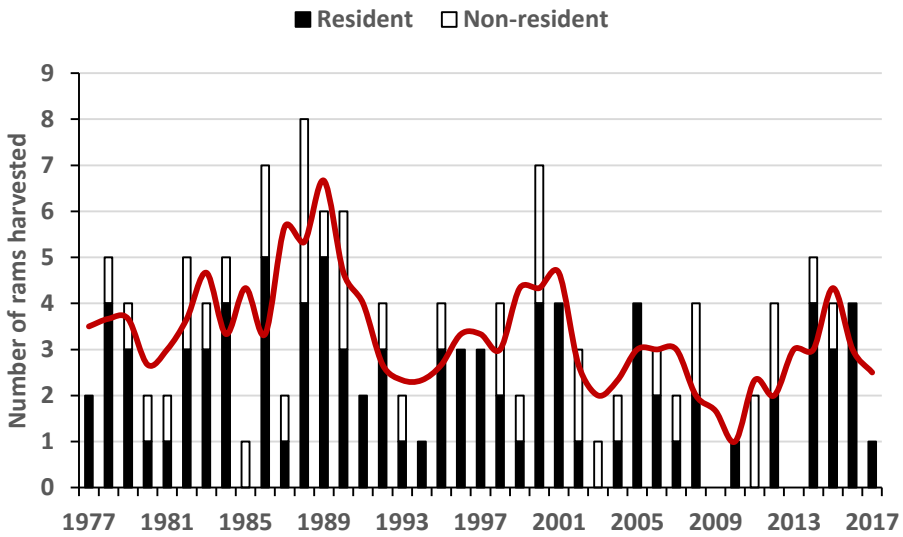

Figure 21. Number of rams harvested in the Elk Valley West PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- The Elk Valley Cumulative Effects Management Framework (CEMF) was recently completed, which provides recommendations for decision-making related to the development of natural resources (Elk Valley Cumulative Effects Management Framework Working Group 2018.).

- Provincial parks/protected areas cover 30% of the PMU in the north, protecting habitat but not restricting hunting (Fig. 22).
- Some access restricted through AMAs (Upper Elk Valley, Weigert Creek) and provincial parks.
- 90% of this PMU is within FWCP ecosystem enhancement planning area (White Bull Elk ER Plan).
- Very little private land within this PMU (0.4%).

Threats/concerns

- Low density population in an area of higher snow loads and lower quality winter range.
- Seasonal movement corridors unknown.

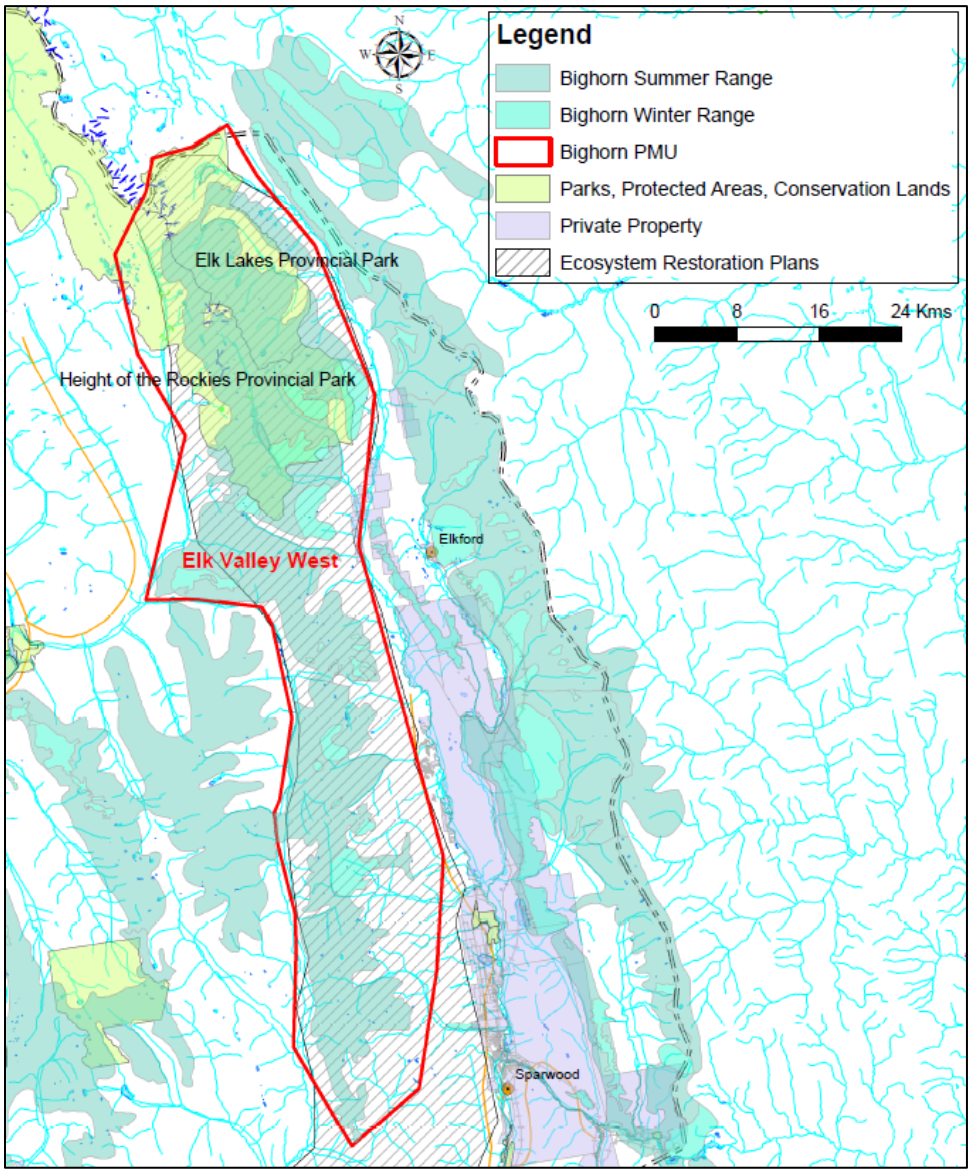

Figure 22. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Elk Valley West PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- Estimated harvest rate at or above 3% during the 2010s.
- Some sheep habitat is shared with large and increasing numbers of mountain goats; the implications to sheep populations are unknown.
- Cougar/wolf predation and avalanches may be factors causing declines (S. Medcalf, Elk Valley Bighorn Outfitters, pers. comm.).
- Winter and summer motorized recreation has potential to affect Crossing Creek and Hornaday sub-populations.
- Future logging may increase visual vulnerability.
- Possible future mining may result in the loss of important habitats.

Management recommendations

1. Evaluate habitat condition of sheep range and conduct habitat assessment to revise population target based on habitat capability.
2. Resurvey the PMU during winter 2020 to verify the low sheep numbers observed during the winter 2019 survey.
3. Where appropriate, conduct habitat enhancement to restore alpine habitat and forage quality, and reduce forest ingrowth, which may include prescribed burns.
4. Conduct a collaring study to determine sheep seasonal habitat use and movement corridors.
5. Re-evaluate harvest and hunting pressure from existing seasons and adjust accordingly.
6. Limit further road development in PMU aligning with the CEMF assessment and recommendations (Elk Valley Cumulative Effects Management Framework Working Group 2018) combined with delivery of road deactivation.
7. Through a values assessment approach determine the need to place restrictions on motorized access which may include snowmobile access (i..e., AMA) on the north side of Crossing Creek and other areas of high snowmobile activity to reduce disturbance to sheep winter ranges.
8. Assess impacts of recreation on sheep and sheep habitat in high use areas and evaluate management options, including development of a recreation management plan.
9. Augment sheep numbers with transplant from Elk Valley East PMU, using sheep in mine areas that are threatened by habitat removal.

5 Bull River

The target population size is about 125 sheep (range 100–150) although this may not be attainable due to deteriorated habitat condition. Major issues are that many of the winter habitats are in deteriorated health and there may be amplified cougar predation pressure.

Population trend

The Bull River population experienced near complete die-offs in the early 1940s and mid-1960s due to pneumonia (Bandy 1966). After peaking in the late 2000s, the estimate for the Bull River population declined during winter 2014-15 and 2015-16 to about 75 sheep in 2017, below the lower median value for the herd (Fig. 23). Lamb ratios were below population objectives for most of the late 2000s through

2010s with a recent increase starting in 2018, and ram ratios were generally at or above objectives, increasing steadily since the mid-2010s (Fig. 24). Herds in this PMU winter at low elevation.

Harvest

Harvest: Between 0 and 8 rams were harvested annually from the Bull River PMU, with the 3-year running average between 2–5 rams annually over the past 15 years (Fig. 25).

The **harvest rate** varied from 1.9–2.2% through the 1990s and early 2000s, peaking at about 3.2–3.5% in the mid to late 2000s, declining to about 2.4% during 2012–15, and was approximately 2.7% during 2016–17.

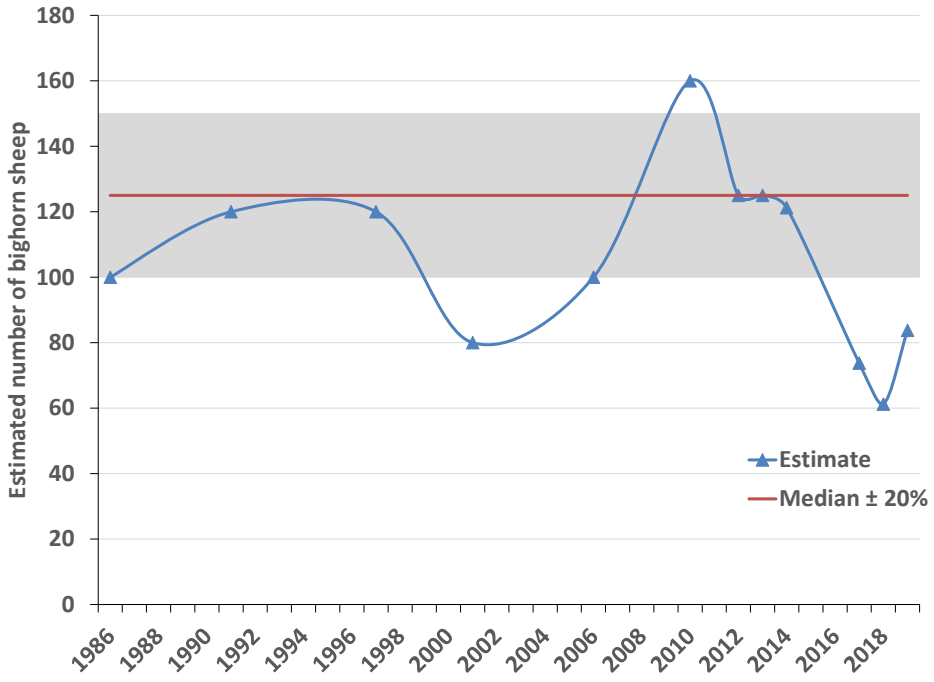

Figure 23. Bighorn sheep population estimate trend for the Bull River PMU with the median estimate (± 20%) of the last 5 surveys prior to the lowest survey in 2018.

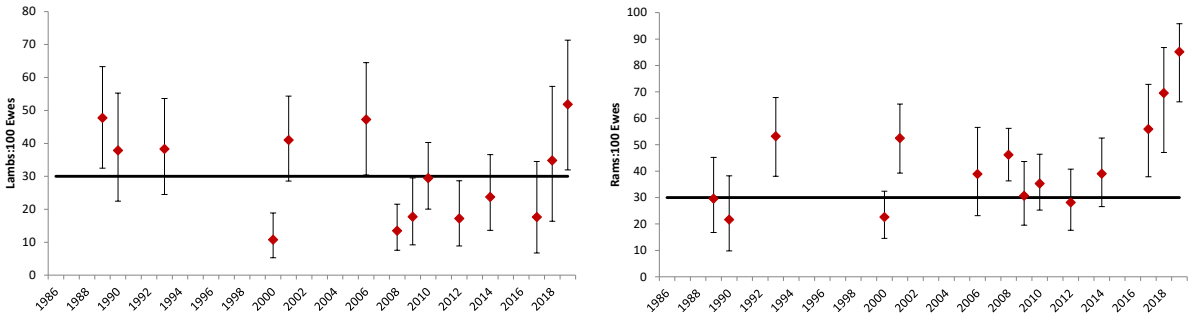

Figure 24. Trends in lamb (left) and ram (right) ratios over time in the Bull River PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

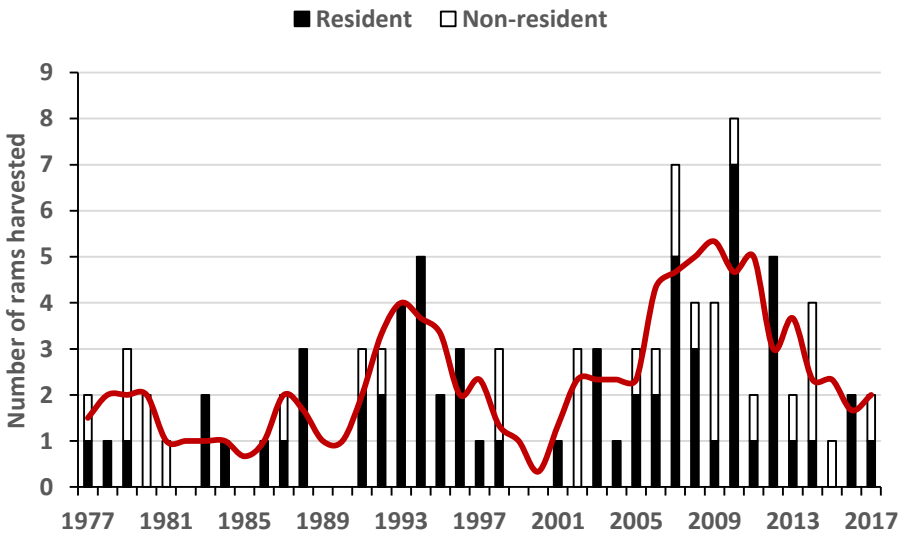

Figure 25. Number of rams harvested in the Bull River PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Hunter numbers within MU 4-22 (the management unit encompassing most of the Bull River PMU) are the second highest in the region, and averaged 89 annually during 2008-17 with a slight declining trend over time.

Strengths/resiliency

- Conservation Lands exist in low-elevation winter range of this PMU which restrict motorized access and cattle grazing (e.g., NTBC and Red Barn properties; Fig. 26).
- Existing AMAs in the Pickering Hills, Sheep Mountain and Power Plant (majority of Bull Mountain range).
- 5% of this PMU is within a FWCP ecosystem enhancement planning area (White Bull Elk ER Plan). Treatments for invasive plants have occurred and are ongoing, and slashing has recently occurred on Hatchery Ridge. More intensive invasive plant management is occurring and will occur within the PMU from 2017-21 (I. Teske, FLNRORD, pers. comm.).
- Much of Hatchery Ridge is an active woodlot belonging to NTBC where timber harvest and management is being conducted in consideration of sheep values.
- Prescribed burning is planned in areas with reduced invasive plant coverage to enhance summer and transitional bighorn sheep habitats to enhance forage quality and improve habitat connectivity.
- Diversionary salting conducted to reduce highway mortality.
- Nine male and female sheep from the herd currently GPS radio-collared (Ayotte 2019).

Threats/concerns

- Apparent increase in cougar numbers coupled with recent decline in white-tailed deer may have amplified predation pressure on sheep.

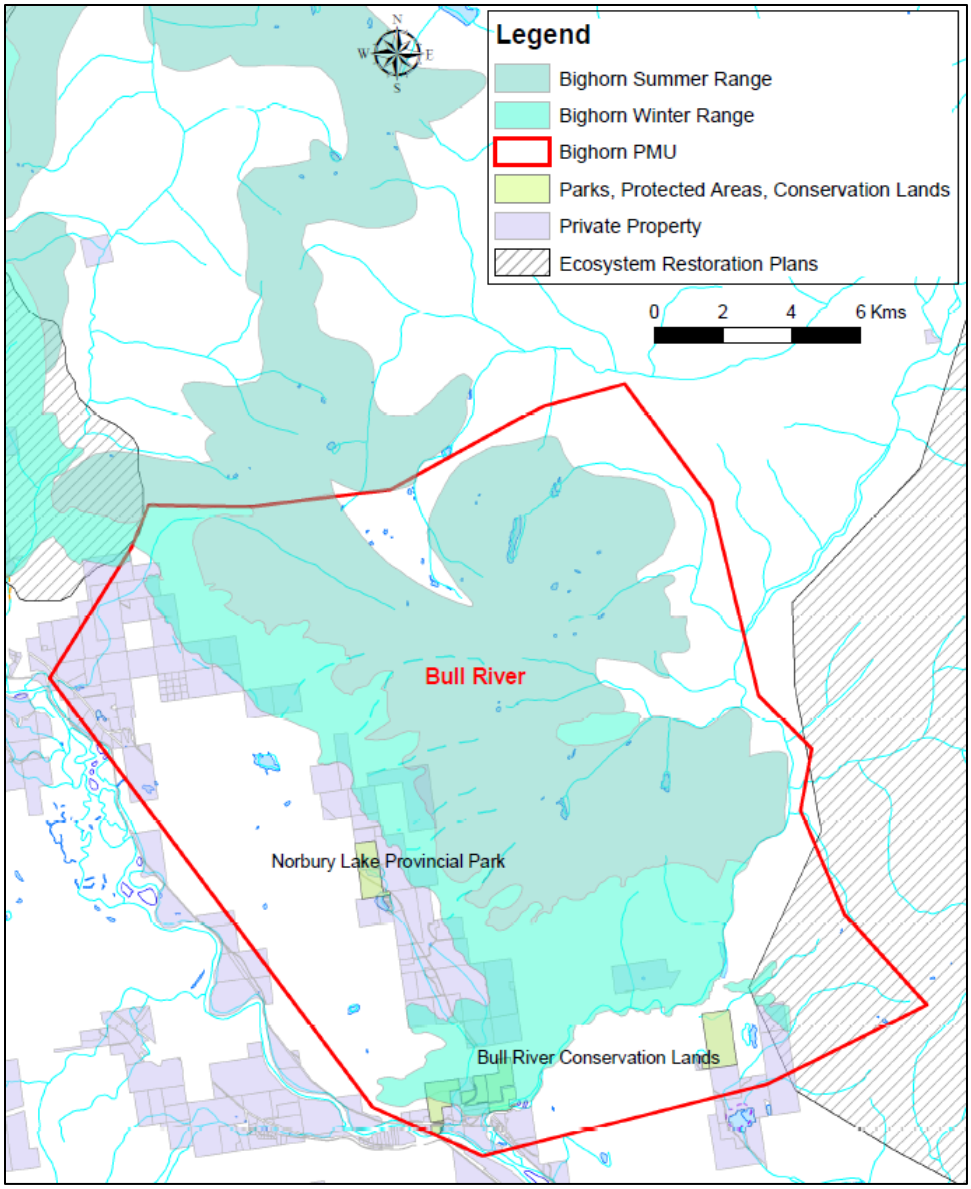

Figure 26. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Bull River PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- Cougar numbers on winter range have been shown to be high. A peak in cougar harvest in MU 4-22 during 1994–2000 coincided with decreasing sheep population trend (Compulsory Inspection data). A second peak in cougar harvest from 2009 to present also coincided with a decreasing sheep population trend. Wolf harvest in MU 4-22 increased in 2013-14 (Compulsory Reporting data) and remained at a moderate level (Compulsory Inspection data), indicating a likely increased wolf population.
- Cause of one of two mortalities from collared Bull River sheep suspected as predation (Ayotte 2019).
- Many of the winter habitats are in deteriorated health:

  - Overgrazing, possibly resulting from wildlife and/or cattle;
  - Invasive plants;
  - Forest ingrowth reducing sightlines and facilitating cougar predation;
  - Lack of escape terrain, concentrated winter range.
- 11% of this PMU is private land, much of it with high risk of contact and disease transmission from domestic sheep/goats (Fig. 26).
- Human disturbance: hunting/recreation/dogs, especially during sensitive time periods – spring and winter.
- Increasing use of mountain bikes within sheep spring range may be causing increased disturbance.

Management recommendations

1. Increase habitat restoration projects where appropriate to improve ecosystem health and discourage invasive plant spread.
2. Evaluate sheep winter habitat condition and forage quality and if cattle are shown to contribute to deteriorated range condition, reduce cattle stocking rates where appropriate.
3. Control and manage invasive plants.
4. Retain LEH regulations until population trend increases and there is sufficient escapement of mature rams (e.g., annual harvest of <40% of legal rams or <10% of the estimated number of rams).
5. Evaluate and reassess sheep values to explore the need for a boundary change to the Power Plant AMA to add Hatchery Ridge.
6. Explore revision to current AMA legislation to manage use of mechanized transportation (primarily mountain bikes) in areas of high sheep use, primarily during the sensitive spring season.
7. Monitor predators/cougars and if numbers are high or where individual specialization by cougars on sheep is suspected, consider enabling special predator/cougar management programs (population is <125 estimated sheep and is well below target population objective).
8. Consider reduction in harvest rate and assess impacts of current hunting pressure on sheep movements.
9. Continue education and outreach to inform private land owners about disease risk from domestic sheep/goats to wild sheep.

6 Premier-Wildhorse

The target population size is about 75 sheep (range 60–90). Predation may be a factor limiting sheep numbers.

Population trend

The estimate for this PMU was much higher in the late 1980s to mid-1990s (150–250 sheep), but the population declined and has remained relatively stable since the early 2000s (Fig. 27). High numbers

coincided with a larger population on Premier Ridge when likely low predator numbers allowed for sheep use of Premier Ridge. Premier Ridge is no longer suitable (higher predator numbers and very little escape terrain is available) and currently unlikely to maintain a large sheep population. Current sheep habitat is east of Premier Ridge along west facing slopes (historical winter range). Lamb ratios since 2000 have largely been below objective, while rams ratios have fluctuated 30–50 rams:100 ewes (Fig. 28). Herds in this PMU winter at low elevation.

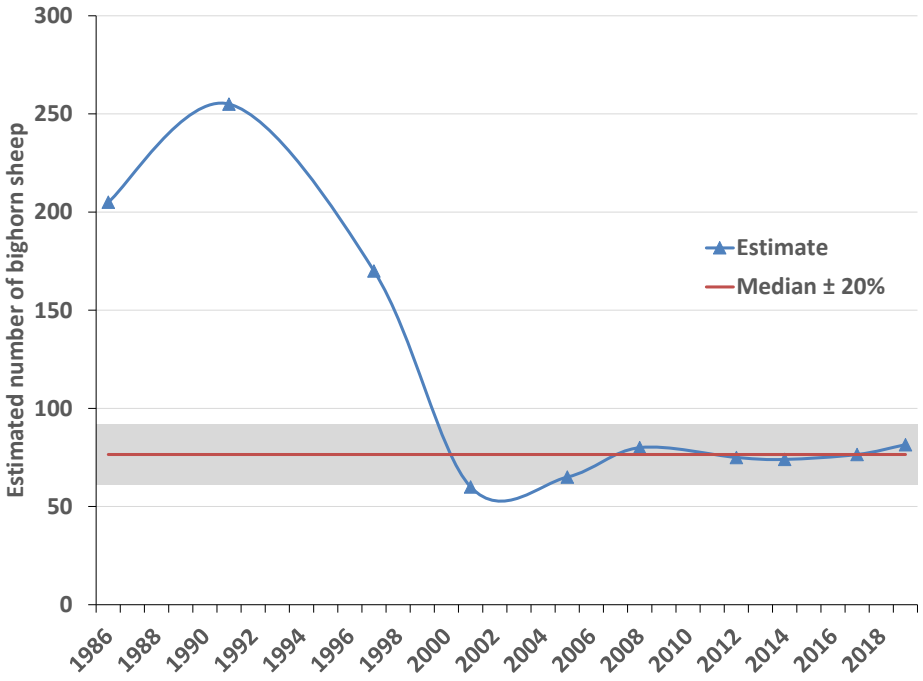

Figure 27. Bighorn sheep population estimate trend for the Premier-Wildhorse PMU with the median estimate (± 20%) of the last 5 surveys.

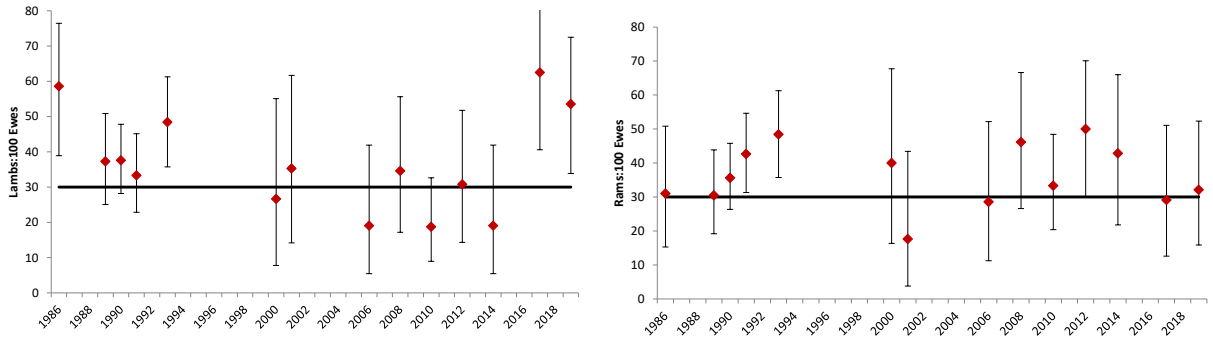

Figure 28. Trends in lamb (left) and ram (right) ratios over time in Premier-Wildhorse PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

Harvest

Harvest: The harvest generally ranged from 2–5 rams annually during the 1980s to mid-1990s, and subsequently declined to less than 1 ram annually (Fig. 29).

The **harvest rate** has remained low at <2% during the 1990s and late 2010s and <1% during other times, and dropped to <0.5% since 2012.

Hunter numbers: The Premier-Wildhorse PMU shares MU 4-21 with PMU 8 and a small portion of MU 4-22 with PMU 5. Considering MU 4-21, the number of hunters declined from a peak of 60 in 2009 to roughly 30–40 annually since 2011.

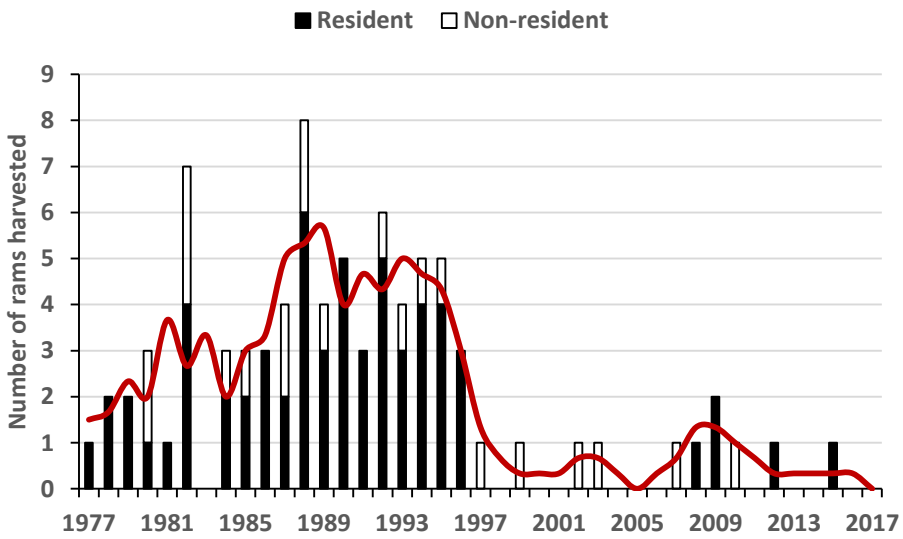

Figure 29. Number of rams harvested in the Premier-Wildhorse PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- 11% of this PMU is park/protected area (Fig. 30).
- There are Conservation Lands within this PMU.
- 28% of this PMU is within FWCP ecosystem enhancement planning area (Bighorn Sheep Premier to Wildhorse ER Plan) where considerable work has occurred (primarily slashing and burning).
- AMAs exists in Galbraith Creek and on Premier Ridge.

Threats/concerns

- Lack of escape terrain, forest ingrowth and increased predators on Premier Ridge appear to have effectively removed functional sheep habitat.
- Predation may be a factor limiting sheep numbers; predator hunting is challenging due to difficult access and terrain.
- Private property exists within bighorn sheep range which could lead to high risk of interaction with domestic sheep.

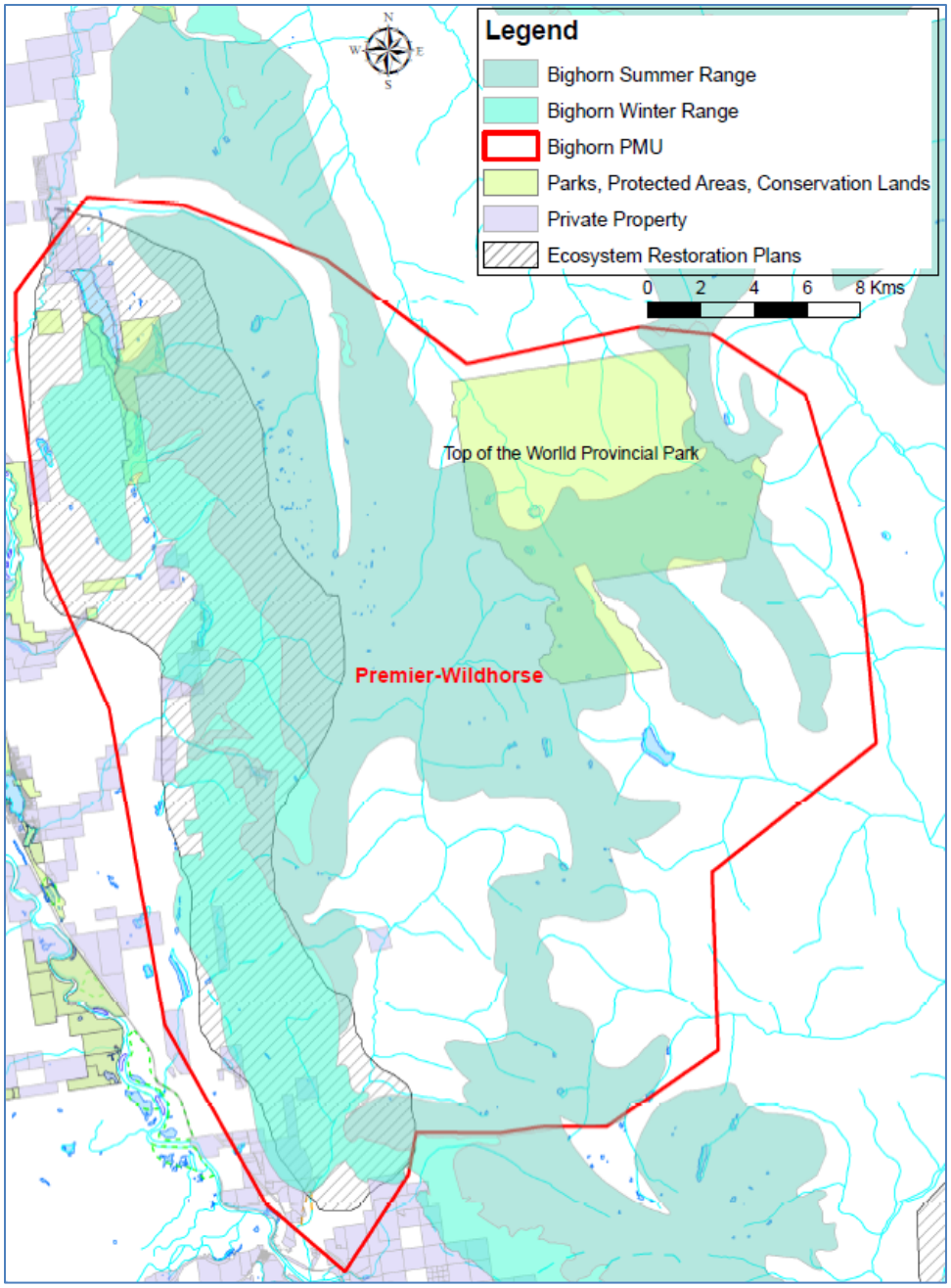

Figure 30. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Premier-Wildhorse PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

Management recommendations

1. Evaluate condition of sheep winter and transitional range and conduct habitat enhancement and restoration. Continue monitoring of ecosystem restoration initiatives.
2. Assess whether key migratory routes have been interrupted by conflicting land uses.

3. Monitor predators/cougars and if numbers are high consider enabling special predator/cougar management programs (population is <125 estimated sheep and >40% below peak numbers).
4. Encourage landowners to not place wildlife exclusion fencing on properties within low elevation winter range and not allow domestic sheep or goats.

7 Whiteswan-Sharktooth

The target population size for PMU 7 is about 190 sheep (range 150–225). Motorized access is a concern in some areas of the PMU.

Population trend

The estimated number of sheep in this PMU has fluctuated considerably over time, which may be partially a result of incomplete survey coverage (Fig. 31). The most recent estimate (250 sheep) is above population target. Lamb ratios have generally remained above 30 lambs:100 ewes, and ram ratios have been well above management objective (Fig. 32). Herds in this PMU winter at high elevation.

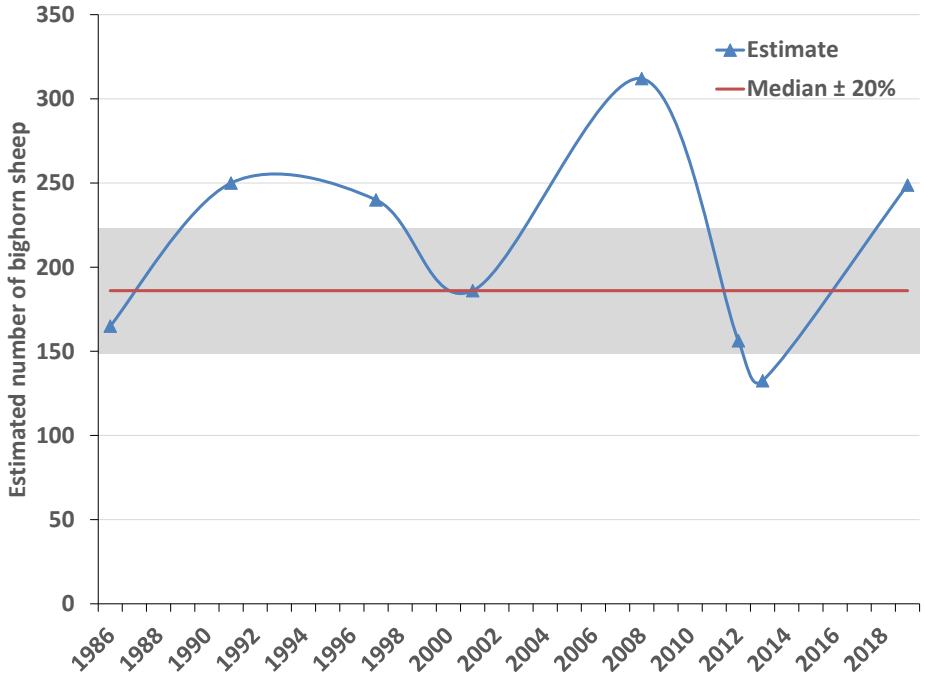

Figure 31. Bighorn sheep population estimate trend for the Whiteswan-Sharktooth PMU with the median estimate (± 20%) of the last 5 surveys.

Harvest

Harvest: Prior to the late 1990s the annual harvest generally ranged from 4–8 rams, but subsequently decreased to 2–4 rams (Fig. 33).

The **harvest rate** during the 1990s was around 2.6%, and has since decreased to <2%.

Hunter numbers: This PMU encompasses portion of MUs 4-21 and 4-24. Between these two management units roughly 60–80 residents hunt sheep annually, with a slight declining trend over time. The actual number of hunters within the Whiteswan-Sharktooth PMU would likely be about two-thirds of these values.

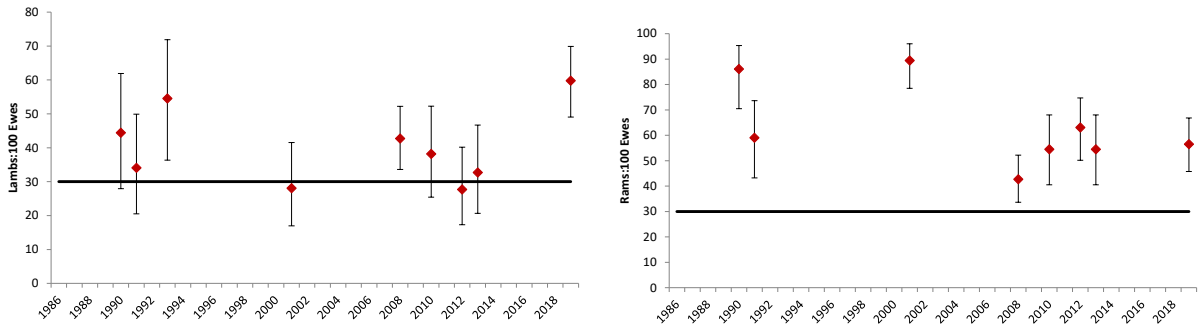

Figure 32. Trends in lamb (left) and ram (right) ratios over time in Whiteswan-Sharktooth PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

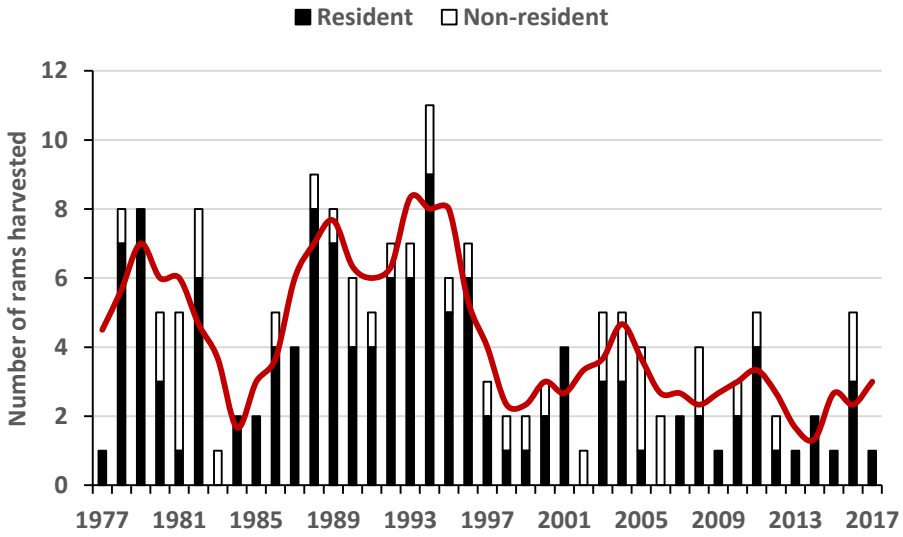

Figure 33. Number of rams harvested in the Whiteswan-Sharktooth PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- Current population estimate and composition ratios appear good.
- There is very little private land within this PMU (0.8%; Fig. 34), thus little threat from potential interaction with domestic sheep and goats.
- Relatively remote; difficult access.
- Mutton Creek AMA in place.

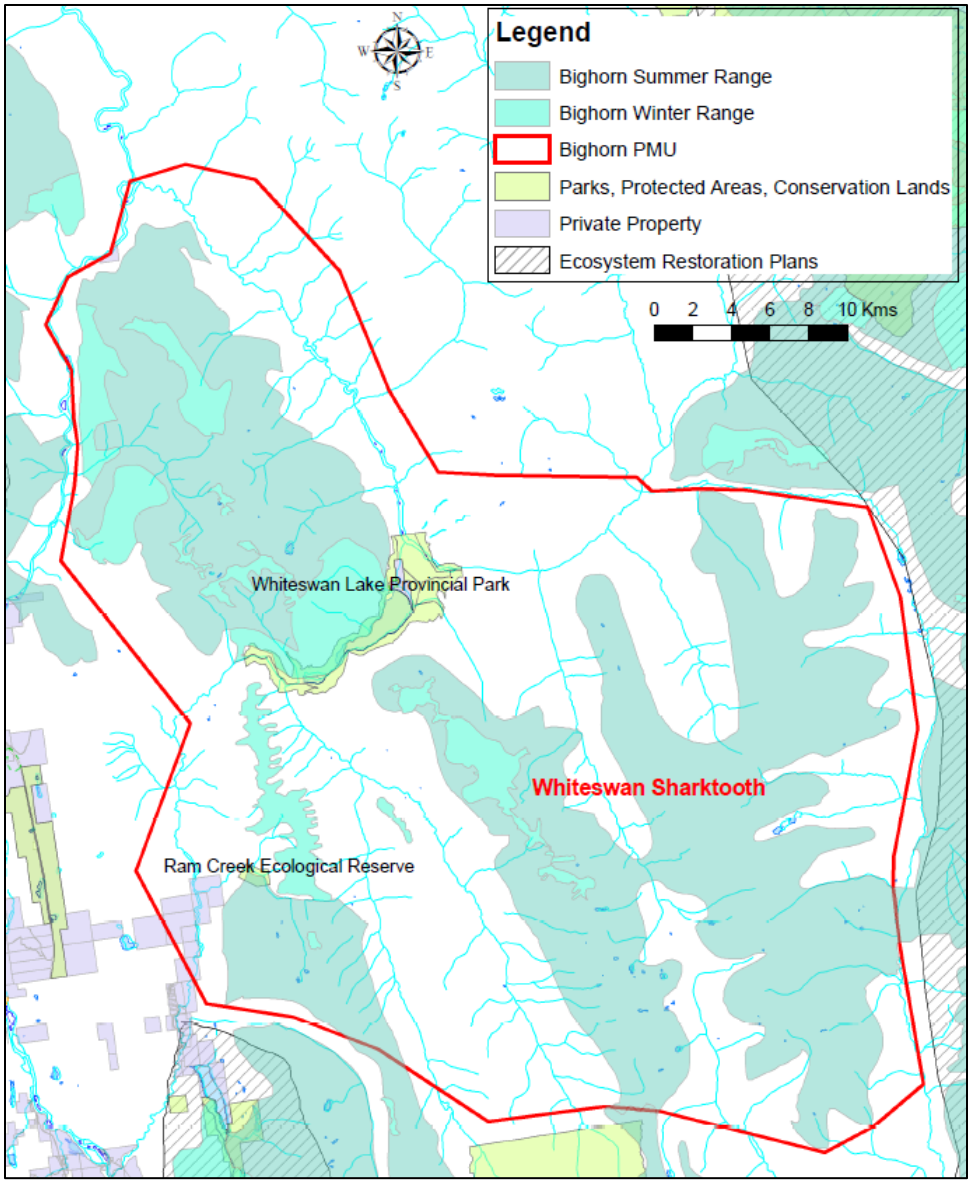

Figure 34. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Whiteswan-Sharktooth PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

Threats/concerns

- Cougar numbers appear to be high; wolves may be a secondary concern (D. Sword, Whiteswan Lake Outfitters, pers. comm.).
- Access for predator hunting difficult.
- Recent logging has increased motorized access to Mount Glen.

Management recommendations

1. Through a values assessment approach determine the need to place restrictions on motorized access, including the need for an AMA on Mount Glen to restrict easy access to bighorn sheep (and mule deer).
2. Continue to explore priority habitat restoration projects.
3. Assess whether key migratory routes have been interrupted by conflicting land uses.
4. Assess impacts of recreation on sheep and sheep habitat in high use areas and evaluate management options, including development of a recreation management plan.

8 Columbia-Radium

The target population size for PMU 8 is about 255 sheep (~140 for Radium and ~120 for Columbia Lake; range 205–305). Major issues with this PMU include wintering areas and highway mortality in and near Radium, increased housing developments near winter range, cougar predation, and conifer ingrowth.

Population trend

Since peaking in the early 1990s the population estimate has steadily declined, down about 35% (Fig. 35), with both main components of the PMU showing reduced numbers. Population targets of herds in part based on social limits within Radium and to a lesser extent Canal Flats. Lamb ratios have hovered around the management objective for many surveys with a reduction in 2019, while the ram ratio has generally been above objective except for the late 2000s and early 2010s (Fig. 36). Anecdotal evidence

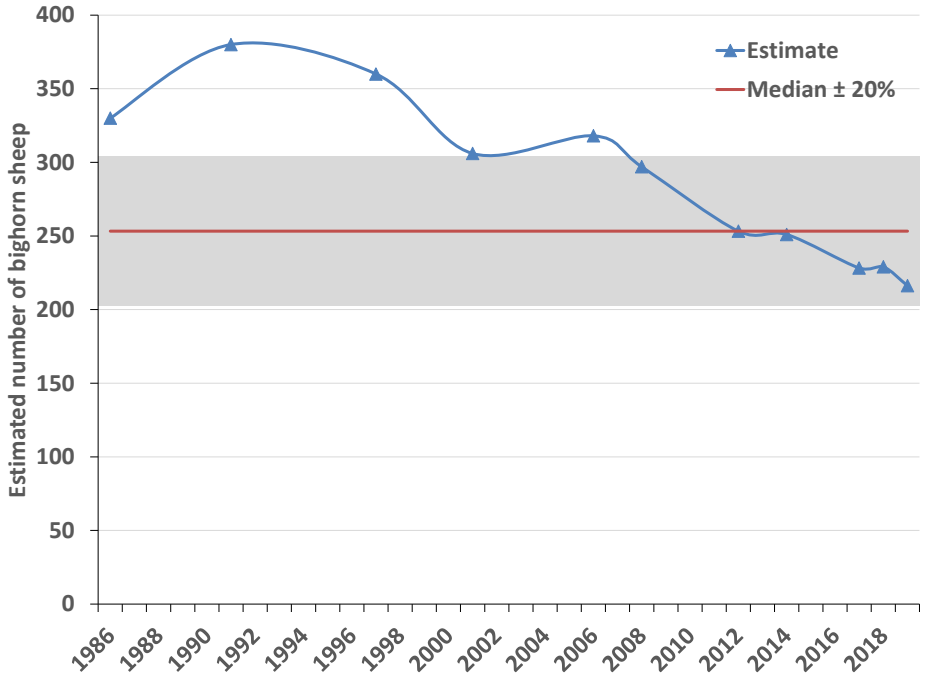

Figure 35. Bighorn sheep population estimate trend for the Columbia-Radium PMU with the median estimate (± 20%) of the 5 surveys from 2006–2017.

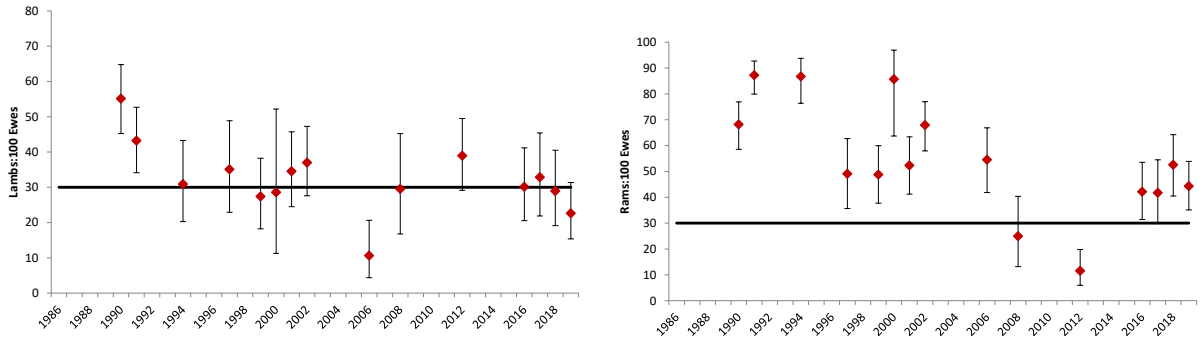

Figure 36. Trends in lamb (left) and ram (right) ratios over time in Columbia-Radium PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

and one collared ewe suggest very occasional occurrence of sheep in the Purcell Mountains (A. Dibb, Parks Canada (retired), pers. comm.). Herds in this PMU winter at low elevation.

Harvest

Harvest: Harvest within the Columbia-Radium PMU peaked in the late 1980s and early 1990s at a high of about 14 rams annually, declined, increased again through the 2000s to peak at 8 rams annually, and subsequently decreased to about 4 rams annually (Fig. 37).

The **harvest rate** was upwards of 2.4% during the early to mid-1990s and late 2010s, but has remained <2% during other periods.

Hunter numbers: The Columbia-Radium PMU covers MU 4-25 (shared with PMU 9) and MU 4-35. The combined number of hunters is roughly 50–65 annually with a declining trend over time.

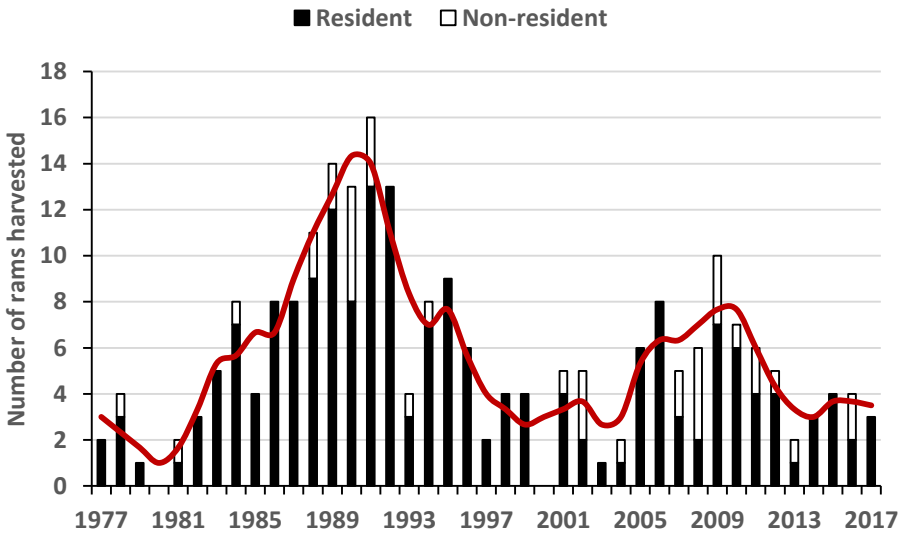

Figure 37. Number of rams harvested in the Columbia-Radium PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- 19% of this PMU is within park/protected areas. Protected from harvest in the town of Radium and Kootenay National Park (Fig. 38).
- 5% of PMU is within East Side Columbia Lake Wildlife Management Area providing winter range for bighorn sheep.

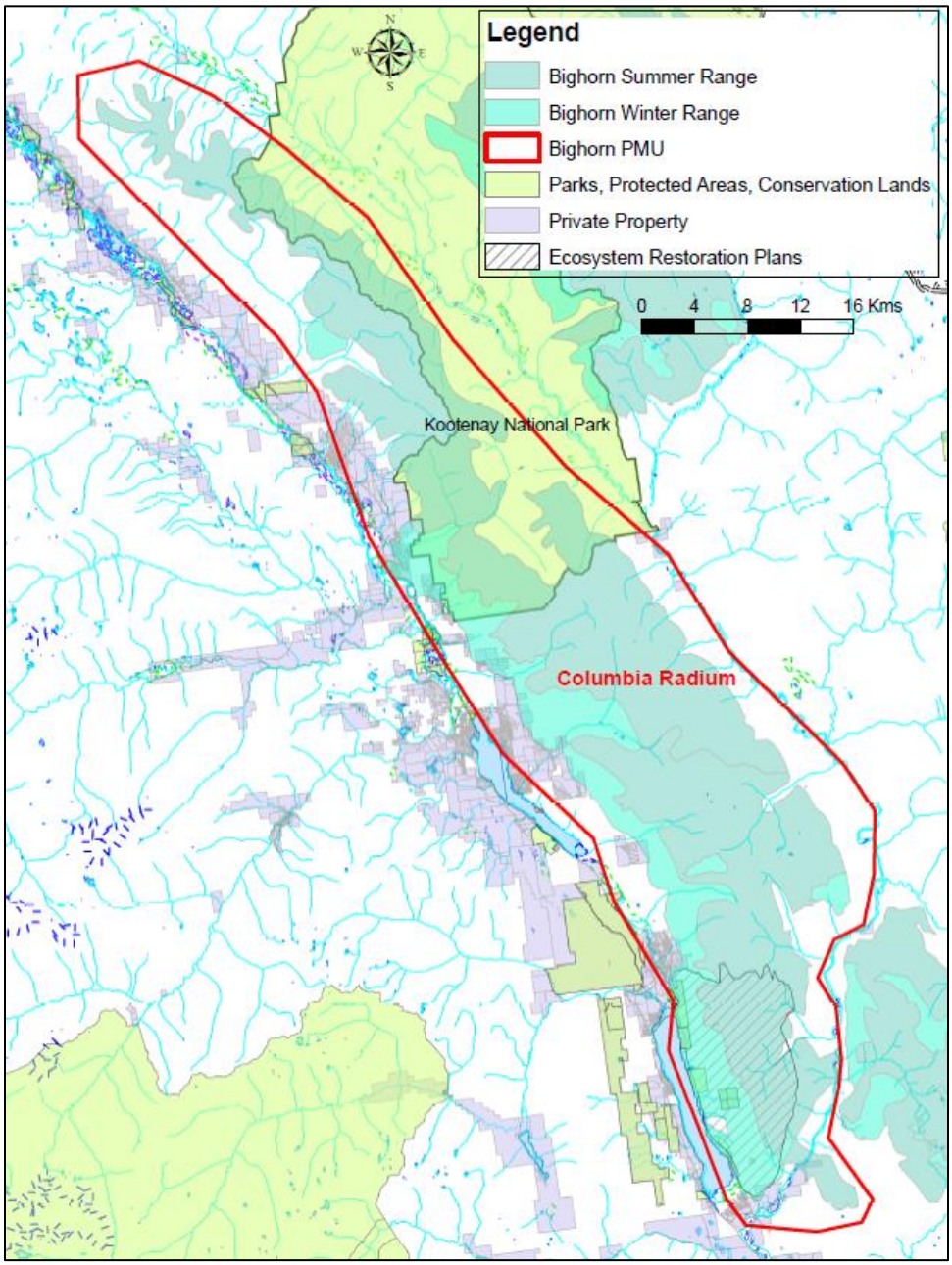

Figure 38. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Columbia-Radium PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

- NCC has Lot 48 and NTBC has several parcels of conservation lands within the Columbia Lake Eastside Conservation Property Complex.
- Highly viewable within Radium and one of the best locations in Region to observed bighorn sheep.
- 8% of the PMU is within FWCP ecosystem enhancement planning area (Columbia Lake East ER Plan) where primarily slashing has occurred
- Ecosystem restoration – primarily prescribed burns with some thinning– was conducted in Sinclair Canyon and Redstreak area above Radium in the 2000s, primarily in winter/spring ranges.
- AMAs in place near Columbia Lake winter range and Stoddard Creek.
- Extensive GPS telemetry dataset available from both ewes and rams from a Kootenay National Park study conducted 2002-08 (A. Dibb, Parks Canada (retired), unpubl. data).

Threats/concerns

- 7% of this PMU is private property (Fig. 38), with the potential for high risk of contact and disease transmission from domestic sheep/goats.
- Housing developments close to Columbia Lake and Radium affecting winter range.
- Road from a new mine may be affecting sheep migration route (Upper Kootenay).
- Invasive plants in alpine areas, largely a result of motorized users in the alpine.
- Little respect for AMA – offroad ATV and snowmobile use on grasslands winter range.
- Increasing use of mountain bikes within sheep spring range may be causing increased disturbance.
- Radium sheep winter range heavily concentrated on the Springs golf course, Village of Radium Hot Springs, Mile Hill, and lower Sinclair Canyon. Large numbers of sheep are concentrated in a small area of mostly artificial habitat, far from escape terrain, with potential for conflicts with dogs and humans, collisions with motor vehicles, and spread of disease.
- Highway mortalities in Radium averaging about 10 sheep/year, most occurring on Mile Hill within the first 2–3 km south of the 4-way stop where sheep cross extensively. Salt may be attracting sheep to highway surface. Additional signage installed by MOTI in 2018, but MOTI does not support reduced speed limits.
- Cougar predation along Columbia Lake and in town of Radium, with predation specialization by individual cougars apparent in several areas. Management of cougars in national parks unlikely to occur.

Management recommendations

1. Maintain quality winter and transitional habitat in areas east of and above Radium. Encourage ecosystem restoration within national parks to improve migration routes for sheep.
2. Work with MOTI to reduce sheep-vehicle collisions, with potential options including reduced highway speed and fencing coupled with animal crossing structures, especially on Mile Hill (Dibb 2006).

3. Initiate a collaring study to examine seasonal range use within the Columbia Lake portion of the PMU. Data could be compared with collaring study from the late 1990s to early 2000s (Kinley 1997, Dibb 2006).
4. Monitor predators/cougars and if numbers are high or where individual specialization on sheep is suspected, consider enabling special predator/cougar management programs within herd ranges within the PMU that have high cougar numbers (some herds are <125 estimated sheep and below target population objective).
5. Assess impacts of recreation on sheep and sheep habitat in high use areas and evaluate management options, including development of a recreation management plan.
6. Through a values assessment approach determine the need to place and enforce restrictions on motorized access. Work with the Conservation Officer Service to enforce compliance of AMAs.
7. Explore revision to current AMA legislation to manage use of mechanized transportation (primarily mountain bikes) in areas of high sheep use, primarily during the sensitive spring season.
8. Monitor and maintain migration corridors.

9 Assiniboine

The target population size for the Assiniboine PMU is about 65 sheep (range 50–80). This is a shared population with Banff National Park with poor knowledge of winter distribution.

Population trend

The population estimate has fluctuated over time, which could be related to sheep wintering elsewhere during inventories of the traditional BC winter range. Sheep were more wide-spread in the late 1960s including in the Mt. Wardle area within Kootenay National Park and along the Cross River and off the Mitchell River (Stelfox 1978), but current numbers and distribution are well reduced or absent (S. Wrazej, Parks Canada, pers. comm.). The population estimate peaked in the mid- to late 2000s at about 85 sheep, but the subsequent survey in 2019 (after a 10-year gap) estimated only 45 sheep (Fig. 39). Lamb ratios have been at or above objective, with equal numbers of lambs and ewes detected in 2019 (Fig. 40). Ram ratios have been generally well above objective. Herds in this PMU winter at high elevation.

Harvest

Harvest: Upwards of 3–5 rams were harvested annually during the late 1970s and 1980s, but the harvest declined to 1–2 annually since the early 1990s (Fig. 41). Much of the recent harvest is from non-residents.

The **harvest rate** was estimated to be about 3.8% during the 1990s, declined to 2.0–2.4% during the 2000s, and up to 2017 was <1.5%. The lack of inventory between 2009 and 2019 hampered accurate assessment of harvest rate.

Hunter numbers: The Assiniboine PMU is within MU 4-25, which also covers PMU 8. Likely only about one-quarter of the 50–60 hunters within MU 4-25 hunt the Assiniboine PMU.

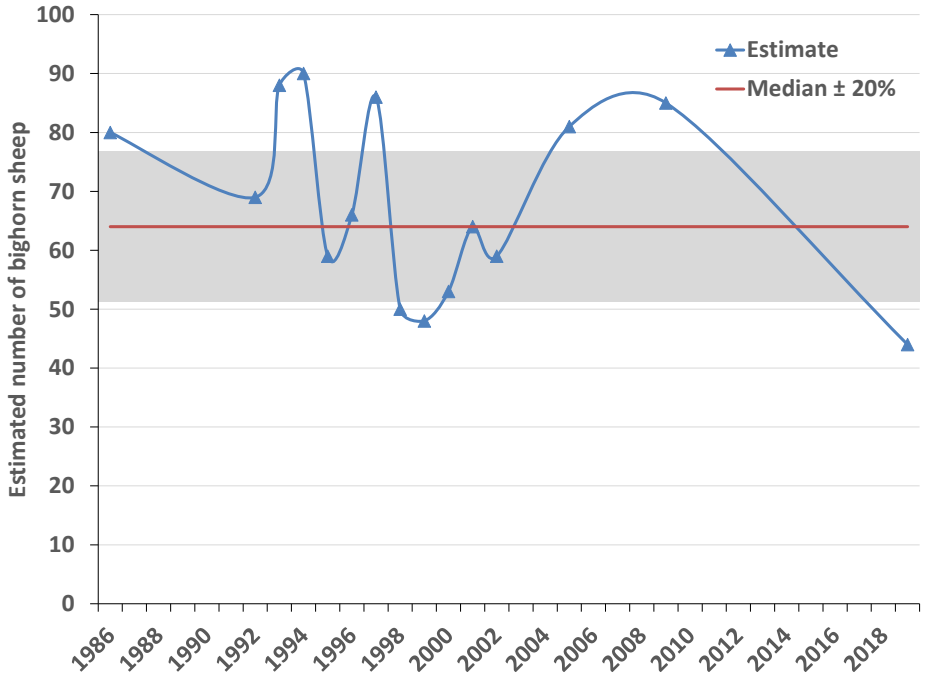

Figure 39. Bighorn sheep population estimate trend for the Assiniboine PMU with the median estimate (± 20%) of the last 5 surveys.

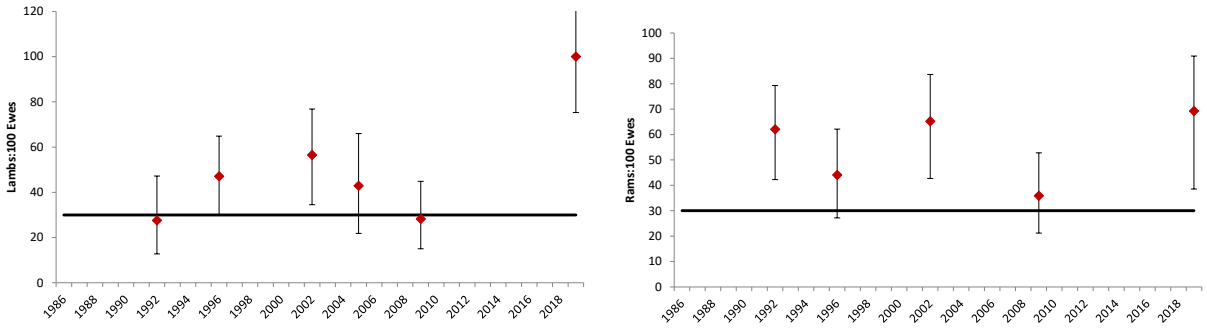

Figure 40. Trends in lamb (left) and ram (right) ratios over time in Assiniboine PMU relative to management objectives (≥30 lambs:100 ewes and ≥30 rams:100 ewes).

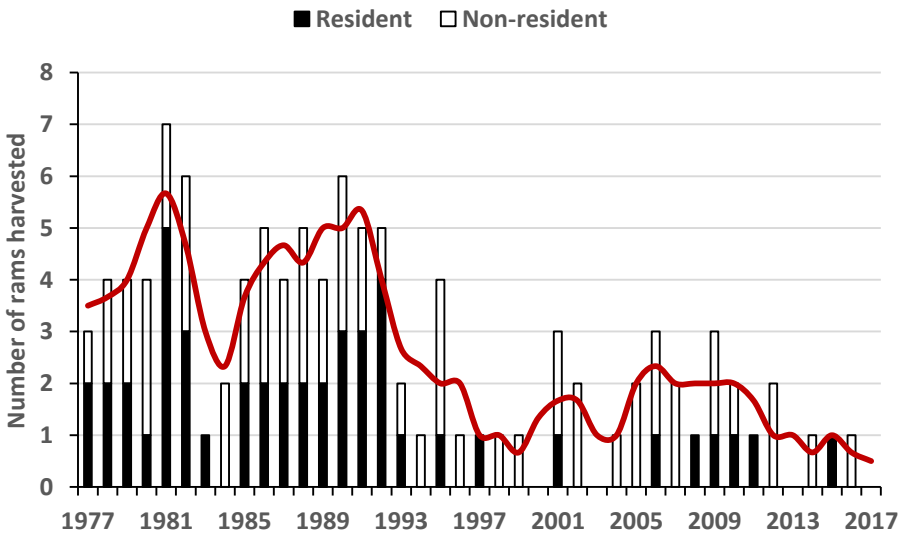

Figure 41. Number of rams harvested in the Assiniboine PMU by resident and non-resident hunters. Trend line (in red) is a 3-year running average. Data obtained from the Compulsory Inspection database plotted in GIS and extracted from within the PMU boundary.

Strengths/resiliency

- 47% of this PMU is within park/protected areas: Mt. Assiniboine Provincial Park (limited development) and Kootenay National Park (no development or hunting; Fig. 42). Alberta range of the herd within Banff National Park (BNP; no development or hunting). There is no private property within this PMU.
- Extensive wildfire in the area in 2017 (Verdant Creek fire) burned most habitat below sheep winter range.
- Historically and currently on LEH harvest, with single authorizations available for either two seasons from 1–31 October prior to 2010 and four 8–9 days seasons spread from 1 October to 3 November post 2010.

Threats/concerns

- Shared population with BNP; status of wintering range of this herd in the park unclear, but may occur within 3-7 km to the east within the Fatigue Creek and Pass areas and within 4 km of the Divide in the Bourgeau Range. Anecdotal observations from the latter range suggest low lamb recruitment and decreased abundance (B. J. Macbeth, Banff National Park, pers. comm.).
- Lodge with helicopter access and helicopter flight-seeing.

Management recommendations

1. Coordinate with BNP in subsequent winter abundance surveys to document sheep numbers and winter ranges used within both Assiniboine Provincial Park and BNP. Ensure that historic winter ranges are surveyed (Stelfox 1978).
2. Re-evaluate harvest and hunting pressure from existing seasons and adjust accordingly.

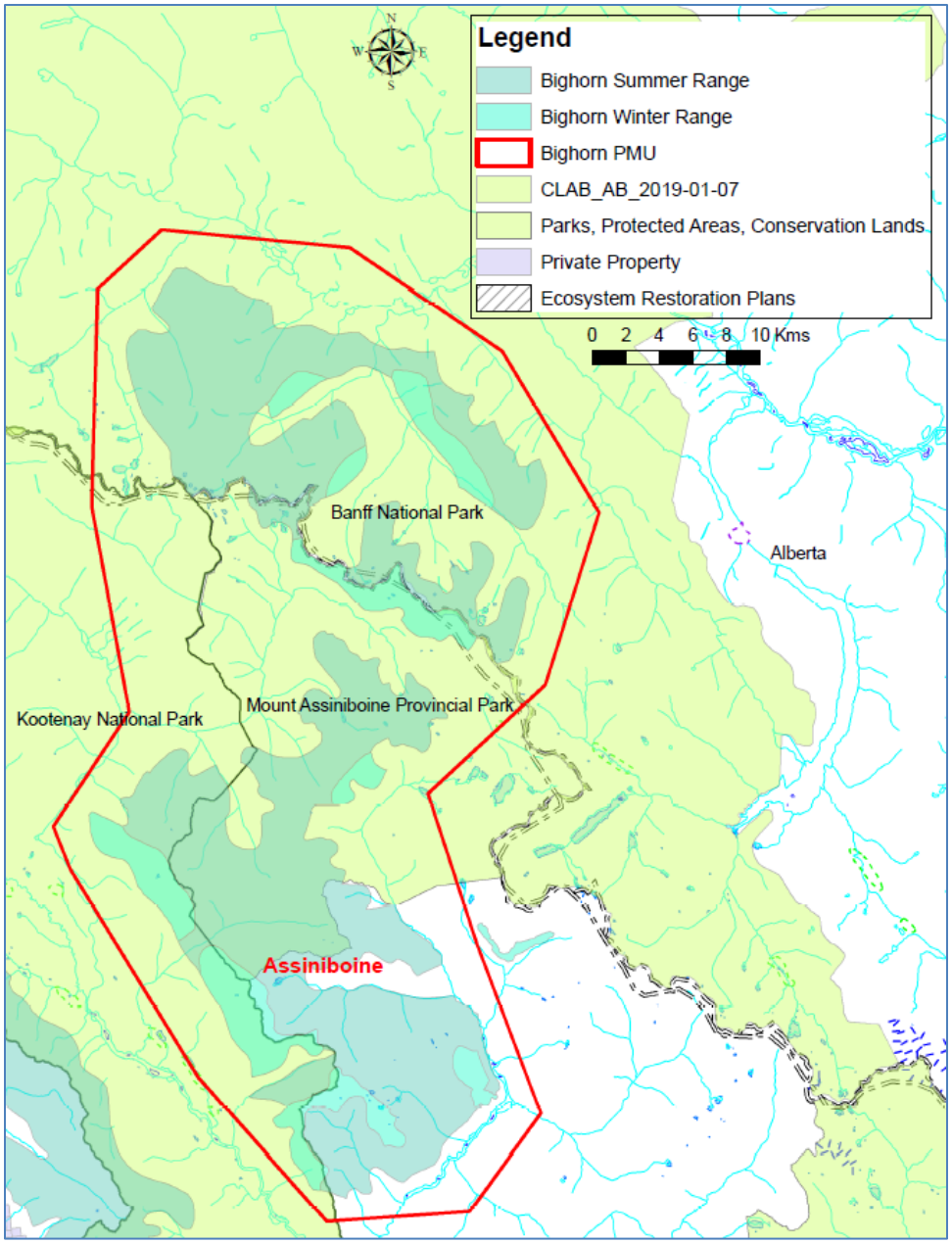

Figure 42. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Assiniboine PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

10 Golden

There is currently no target population size for this PMU. There is a significant 5 year construction project on Highway 1 beginning in 2020 through 4 km of herd range.

Population trend

Local reports of bighorn sheep in the Golden area date back to the 1940s (C. Parent, Golden and District Rod and Gun Club, pers. comm.), with the addition of a band of sheep that dispersed from the Radium herd in the early 1970s (Stelfox 1978). The current target population size for the Golden PMU is about 30 sheep (range 25–35). The estimate for this PMU was as high as 45 in the mid-2000s, dropping to 30 in the late 2000s and continuing lower to 2019 (Fig. 43). As part of a highway expansion project in 2007, 19 sheep were transplanted from this PMU and moved to Whiteswan-Sharktooth. An additional 13 sheep were also moved to the Lazy Lake area in 2009. A long-term feeding program ended in the early 2010s. The feeding program was thought to have inflated the population of bighorn sheep above carrying capacity and increased highway collision concerns. Currently 3 sheep are GPS collared (2 ewes, 1 ram) as part of a project to define seasonal range movements and assess range quality to develop an appropriate estimate of carrying capacity. Few composition data are available. In 2008 observers recorded 7 lambs:12 ewes (58:100) and 14 rams (117:100). Herds in this PMU winter at low elevation.

Harvest

The sheep in this PMU are not hunted. There is only one harvest recorded back in 1990.

Strengths/resiliency

- 12% of this PMU is within park/protected area with no development or hunting (Yoho National Park; Fig. 44).
- A collaring study led by the Golden Rod & Gun Club was initiated in early 2019 to feed into Highway 1 twinning and to assess optimal herd size.

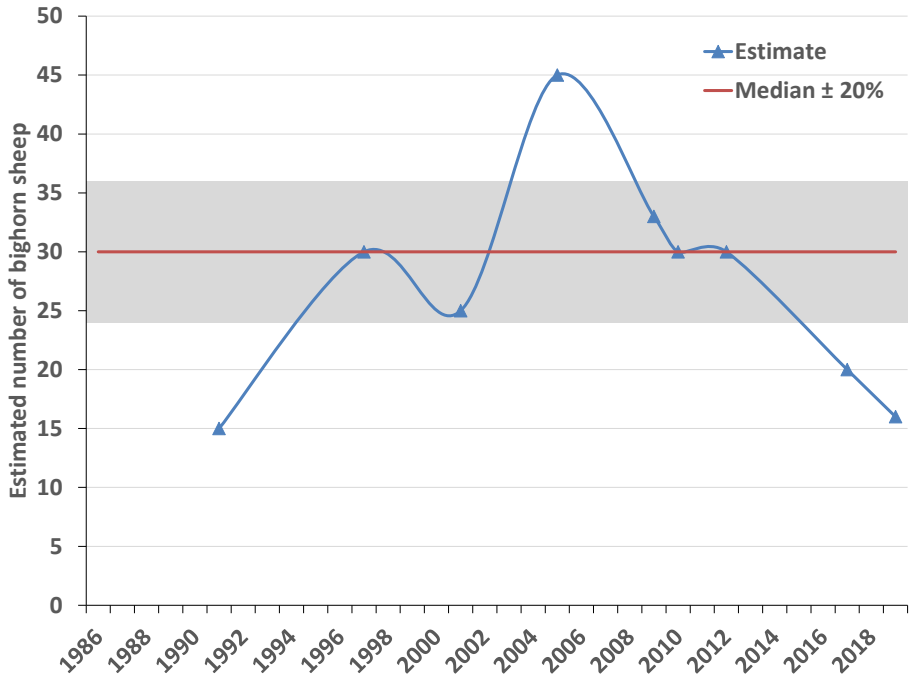

Figure 43. Bighorn sheep population estimate trend for the Golden PMU with the median estimate (± 20%) of the last 5 surveys.

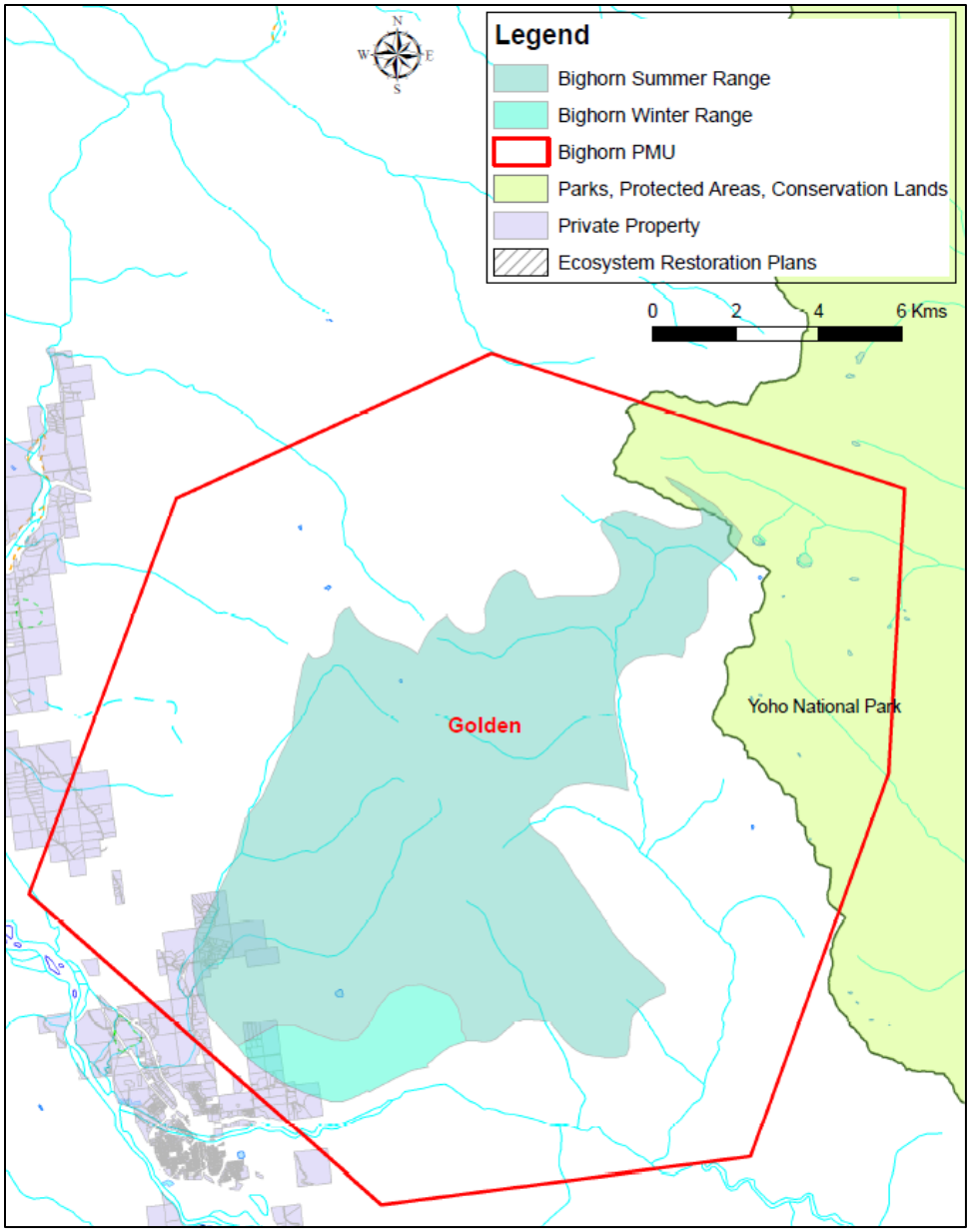

Figure 44. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Golden PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

Threats/concerns

- Traffic mortalities up the Kicking Horse valley.
- Significant 5 year construction project on Highway 1 beginning in 2020 through 4 km of herd range.
- Small and relatively isolated population may lead to inbreeding effects.

Management recommendations

1. Evaluate habitat condition of sheep range and conduct habitat assessment to revise population target based on habitat capability. Sheep numbers in this PMU currently are one-third of the peak numbers and below the population target.
2. Maintain movement corridors to ensure bighorn sheep can safely move north to south through Highway 1.

11 South Salmo

There is currently no target population size for this PMU. This is a small and isolated population shared with Washington.

Population trend

The bighorn sheep in this PMU are a natural northern expansion of a herd from the Hall Mountain area of Washington State, established through introductions in 1972 and 1982. With no adequate natural winter range, feeding in BC sustains this population during winter. Ground counts indicated roughly 40 sheep from 1986–2012, declining to about 22–26 sheep from 2015–18 and about 15 sheep in February 2019 (9 ewes, 2 lambs and 4 rams). Five sheep were collared in March 2018 during a cooperative project with Kalispel Tribe of Indians biologists.

Harvest

Harvest: This PMU is on LEH and has very low harvest, averaging 1.1, 0.7 and 0.9 annually during the 1990s, 2000s, and 2010s, respectively.

The **harvest rate** averaged 2.8, 1.8, 3.0 and 3.3% during the 1990s, 2000s, 2010s and 2014-18, respectively.

Hunter numbers: From 2–10 hunters occur within this PMU annually, regulated by LEH (data from MU 4-08).

Strengths/resiliency

- Under LEH harvest regulation.
- Highly viewable along Highway 3 and one of the best locations in the Region to observed bighorn sheep.
- 8% of PMU protected as Conservation Land (Fig. 45).

Threats/concerns

- Small population and relatively high harvest rate since 2010 (≥3.0%)
- Shared population with Washington.
- Small and isolated population may lead to inbreeding effects.
- Cougar predation may be a factor in the recent decline.
- Vehicle strikes cause some mortality. Salting occurs at feeding station in attempts to reduce highway mortality.

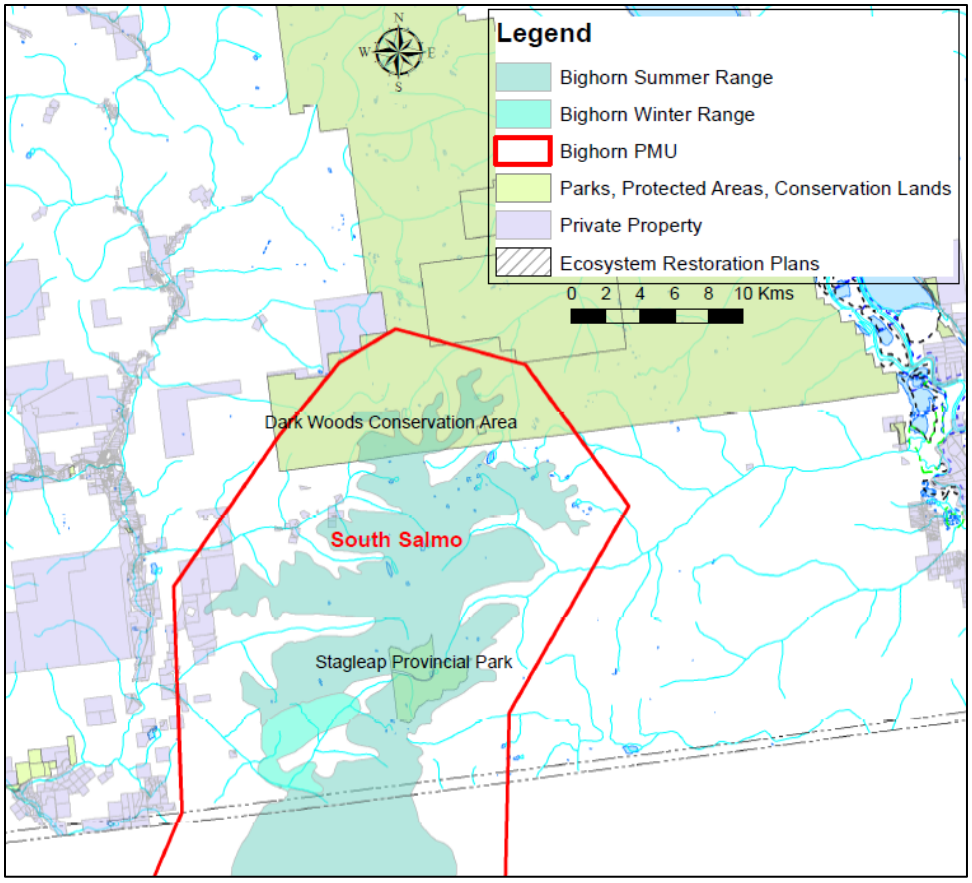

Figure 45. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the BC portion of the South Salmo PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

Management recommendations

1. Close LEH hunt due to low population.
2. Monitor cougars and if numbers are high or where individual specialization on sheep is suspected and cougars appear to be limiting sheep numbers and management is deemed necessary, encourage cougar harvesting including harvest of females.
3. Develop better signage to warn travelers of high impact areas.

12 Lower Arrow

There is currently no target population size for this PMU. This is a small and isolated population that has declined dramatically over the past 10 years.

Population trend

This herd is a result of two groups of sheep moved to Syringa Provincial Park in the 1980s. Aerial and ground counts indicate 50–90 bighorn sheep from 2001 to 2012 (peaking at 91 sheep in 2008; Stent et al. 2013), declining to about 10–11 sheep in 2016-17. The cause of decline was likely related to cougar predation. Composition data from 2008 indicate 4 lambs:38 ewes (11:100) and 6 rams (16:100), both well below objectives. In contrast, in 2011 observers documented 6 lambs:12 ewes (50:100) and 10 rams (83:100), and out of 11 sheep in 2016: 2 lambs, 4 ewes and 5 rams.

Harvest

Harvest: Nine sheep were harvested since 1996, but none have been taken since 2011. No hunting is currently permitted.

Hunter numbers: From 1–3 sheep hunters annually hunted within MU 4-15 up to 2017.

Strengths/resiliency

- 6% of the PMU is protected in Syringa Provincial Park (Fig. 46).
- Ecosystem restoration work for a range of species has been conducted within the last 10 years within the park and is on-going (D. Heagy, BC Parks, pers. comm.).
- There is a small amount of Conservation Land in this PMU.
- Wildfires in 2018 burned much of the higher to mid-elevations in and around sheep habitat.

Threats/concerns

- Cougar predation.
- Invasive plants.
- Small and isolated population may lead to inbreeding effects.

Management recommendations

1. Continue ecosystem restoration and invasive plant management.
2. Assess cougar numbers and if cougars appear to be limiting sheep numbers and management is deemed necessary, encourage cougar harvesting including harvest of females.

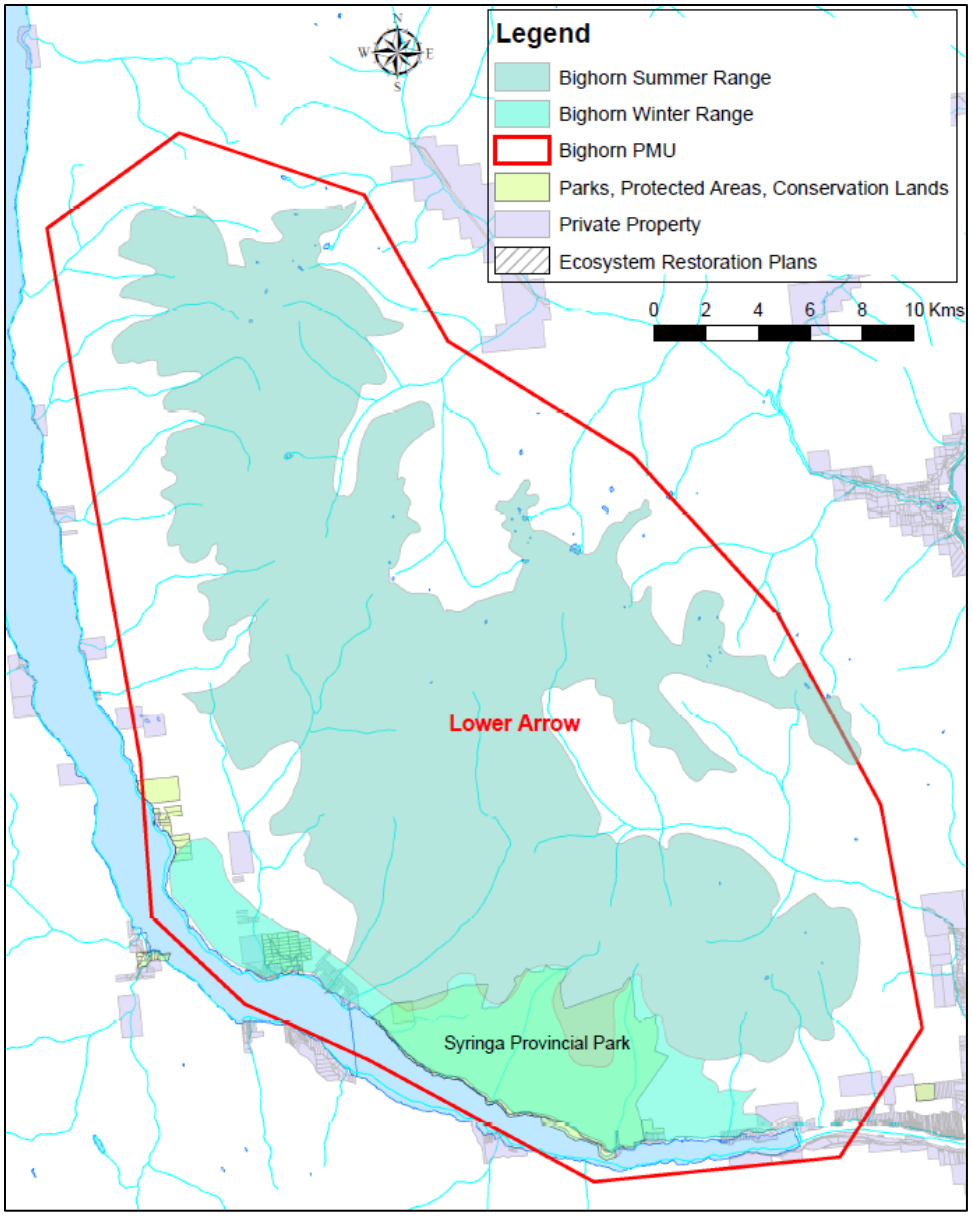

Figure 46. Distribution of parks, protected areas, conservation lands, private lands and areas covered by ecosystem restoration plans in the Lower Arrow PMU. Sheep ranges from the BC Wild Mountain Sheep Registry (https://catalogue.data.gov.bc.ca/dataset/bc-wild-mountain-sheep-registry-distribution).

Monitoring and Indicators

We recommend that regular monitoring and evaluation of all broad and PMU-specific recommendations – at minimum within 3 years of release of this management plan and every 3 years thereafter – be conducted to determine whether management approaches meet objectives stated in the broad management recommendation sections. Monitoring will not only require routine population inventories, but also review of Compulsory Inspection harvest data, habitat assessments, and disease surveillance. If objectives are not met then additional management actions should be considered.

Indicators of successful management include:

- Population and ratio objectives within targets: population within 20% of the median estimate and ≥30 lambs:100 ewes and ≥30 rams:100 ewes as determined from the last 5 aerial surveys;
- Harvest objectives within targets: ram harvest rate ≤3% of the total population estimate and/or <8–10% of the estimated number of rams. Another metric that could be considered is the Idaho (IDFG 2010) target of restricting harvest to <20% of mature (≥¾ curl) rams.
- Habitat objectives within targets: >80% of range within PMU consisting of large patches of source habitats with low risk of mortality and good productivity.

Recommended Priorities

Implementation of this management plan will be subject to capacity and funding availability, which will require prioritizing broad management tools, PMUs and tasks within PMUs. Specific management recommendations within each PMU are provided in approximate order of priority. Combinations of the following criteria should be considered when prioritizing PMUs for management:

- PMUs (or a major herd within a PMU) with a population that has declined below the population target or a population that has declined >40% below peak level, and/or lamb:ewe ratios consistently below 30 lambs:100 ewes, indicating low lamb productivity and survival;
- PMUs with high harvest rate (>2.5% of population estimate), low ram ratios (≤30 rams:100 ewes), low escapement of mature rams, and/or high hunter harvest pressure;
- PMUs having bighorn sheep range with poor or unknown ecological function and would likely benefit from habitat assessment and enhancement and/or access management efforts (e.g., forest ingrowth has increased predation risk and reduced the extent of suitable habitat, winter range is degraded by invasive plants or overgrazing, motorized and mechanized recreation is rampant and unmanaged potentially disturbing sheep on critical ranges or during critical periods of the year);
- PMU's with declining habitat availability and productivity due to development (e.g. mining)
- PMUs with high risk of contact and disease transmission from domestic sheep and goats (e.g., known domestic sheep or goat farms within occupied bighorn sheep range); and
- PMUs with evidence of high predation pressure or specialization by individual predators (usually cougars) on bighorn sheep in vulnerable situations (generally on winter range).

Recommended broad-level management priorities

Recommended PMU priorities

To help determine which PMUs should be the highest priority for management actions we developed a simple matrix table of ranked issues and concerns (Table 6). Ministry staff are currently updating this assessment to include calculated values for the threat categories, adding forward-looking threat categories that can be quantified, and assessing importance of PMUs in meeting broad level management goals. The revised assessment will be included in the regional implementation plan

Based on this initial evaluation, our recommended priority among PMUs and the main reasons for those rankings are:

- PMU 5 Bull River: population below management objective with multiple threats to habitat, domestic sheep risks, and likely high predation pressure.
- PMU 4 Elk Valley West: population 60% below historic levels with low knowledge of movements, range condition and habitat selection, and possible high human disturbance.

Table 6. Evaluation of threats to bighorn sheep Population Management Units (PMUs). Topics were ranked on a scale of 1–5, 1 is the least concern and 5 is the most concern. Habitat function and habitat protection were both ranked 1–3 to provide more even weighting among categories. Ranks were based on known or perceived threats, or lack of data.

PMU	Population trend	Lamb ratios	Harvest/hunter impact	Habitat function	Habitat protection	Human disturbance	Health and disease	Predation	Summed total
1	2	3	2	1	3	3	1	1	16
2	2	3	2	3	2	3	5	3	23
3	1	2	2	2	3	4	1	1	16
4	5	3	4	3	2	4	1	3	25
5	4	4	3	3	3	4	4	4	29
6	4	3	2	1	2	2	2	3	19
7	2	2	2	1	3	1	1	4	16
8	4	4	2	2	2	4	4	3	25
9	5	4	3	1	1	2	1	1	18
10	5	2	-	1	2	4	1	1	16
11	4	2	5	1	1	3	1	3	20
12	5	2	-	1	1	1	1	3	14

- PMU 8 Columbia-Radium: declining population with possible range condition issues and predation concerns for the Columbia Lake herd and high highway mortality and changing use of traditional range for the Radium herd; also domestic sheep risks.
- PMU 2 Wigwam Flats-Elko-Phillips: many winter ranges in deteriorating health, high human disturbance in some herds, vehicle strikes along Highway 3, and some herds at potential high risk of disease from contact with domestic sheep/goats.

Knowledge Gaps

As with many fields of ecological research, there are few empirical studies that provide causal connection between management levers and population response. We will never be able to conduct intensive (collaring) studies to determine movements, habitat selection and population dynamics/survival of sheep in every PMU, thus our knowledge prior to commencing management will generally always be somewhat incomplete. Knowledge gaps can narrow understandings and limit accurate predictions of management outcomes and the effectiveness of management interventions. Some knowledge gaps such as improved understanding of predator distribution and abundance require investigation prior to any decisions related to predator management. Other gaps such as herd baseline health conditions, nutritional fitness, thresholds of habitat quality that result in population-level response, the carrying capacity of a range determined as the number of sheep per available area, or the indirect impacts of human disturbance on population trajectory may be better understood by implementing an adaptive management or monitor-and-modify approach rather than postponing management decisions due to a lack of empirical data.

Population management

- Conduct research to clarify key drivers of population trend.
- Improve knowledge to separate multiple herd and PMU-level limiting factors using GPS collar studies on bighorn sheep to determine survival rates, cause-specific mortality, and reproductive success.
- Conduct research to better quantify proposed bighorn sheep-related hazard benchmarks of habitat loss (*cf* Poole et al. 2018).

Hunting

- Clarify hunter quality of hunting experience with Kootenay Region hunter surveys.
- Quantify the proportion of legal (Class IV) rams in the total ram and overall population from all surveys to document legal ram harvest rate and post-harvest escapement.
- Determine the number of years a ram is legal before it is harvested (from Compulsory Inspections).

Habitat

- Improve range assessments on summer and winter ranges.

- Quantify thresholds of range quality (summer and winter) that are required for long-term support of a stable bighorn sheep herd or to support an increasing herd that has declined [Alberta Plan target is 80% of all range is of "high" quality] although measures of carrying capacity might be a useful metric to monitor over time.
- Review available collar data and include local knowledge to identify "functional" habitat linkages that support genetic connectivity among population units. Apply available tools to protect and enhance these habitat linkages.
- Develop options to control spread of invasive plants following prescribed burns in suitable areas to support burning as a habitat enhancement option.
- Evaluate long-term effectiveness of invasive plant management options.
- Improve broad level recreation planning with input from wildlife managers to minimize backcountry recreation disturbance to bighorn sheep through implementation of best practices.
- Develop and implement techniques to measure backcountry recreation use (e.g., trail counters, cameras) in areas with high likelihood of disturbance to bighorn sheep.

Disease

- Improve understanding and management of the risk of respiratory disease from domestic sheep and goats to bighorn sheep in the Kootenay Region by working with the BC Sheep Separation Program, cross-ministry committees, to identify all domestic sheep and goat farms within a "high risk" (~15 km) buffer around occupied bighorn sheep range, determining the current prevalence of *Mycoplasma ovipneumoniae* (Movi) on domestic sheep and goats farms in high risk areas, applying treatment techniques (e.g., antibiotics), and continuing to test to document any declines in the prevalence of Movi within high risk areas.
- Develop additional measures to reduce transfer of Movi, and promote Bighorn sheep recovery if Movi infections occur.
- Conduct herd health assessments to document baseline health data and facilitate long-term monitoring consistent with the Western Association of Fish and Wildlife Agencies - Wild Sheep Working Group sampling procedures.

Predation

- Develop indices to track cougar abundance on key ranges (especially winter range). Systematic track counts may be one option. Cougar collaring studies, scat, and isotope analyses would also help quantify the limiting role of cougar predation on bighorn sheep in specific areas.
- Develop proactive management options to [address herds with high predation risk due to forest ingrowth; current options are largely limited to prescribed burning and other ecosystem restoration techniques to enhance habitat quality.

Acknowledgements

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) provided funding and support for development of this management plan. Kim Poole and Jeremy Ayotte led the development of the draft management plan, while Patrick Stent and Irene Teske made revisions to the draft prior to approval. We thank I. Teske and P. Stent, FLNRORD, for data, contributions and valuable discussions about bighorn sheep management within the Kootenay Region. We greatly appreciated the knowledgeable input from persons concerned with bighorn sheep in the Kootenays that helped shape this plan. A. Oestreich, M. Crombie, S. Larade and L. Ingham, FLNRORD, assisted with developing the habitat background and management recommendations. M. Festa-Bianchet, Université de Sherbrooke, provided valuable comments on harvesting and horn growth. We thank B. Jex, FLNRORD, for providing excellent comments and suggestions on the penultimate draft.

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Ministry Approval

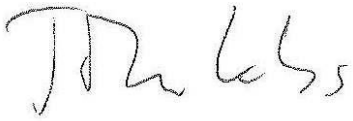
This regional management plan was approved for implementation in April 2021:

Director, Resource Management
Resource Stewardship Division
Kootenay Boundary Region

Reviewed by: John Krebs

Date: 20-April-2021

Signature:

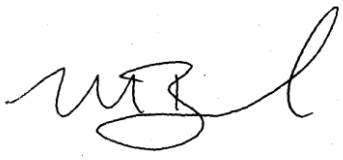


Associate Director, Wildlife
Resource Stewardship Division
Wildlife & Habitat Branch

Reviewed by: Michael Burwash

Date: 31-May-2021

Signature:



Appendix 1: Summary of stakeholder input from engagement sessions.

General Comments

- All groups emphasized the importance of developing a prescriptive plan with clear, measurable indicators connected to specific objectives for each Population Management Unit (PMU).

- Common concerns at a regional level included prioritizing management objectives for viable, healthy, and interconnected bighorn sheep populations before managing for harvest opportunities.

Harvest Management

- Planning and budgeting for more frequent aerial surveys and updated seasonal range maps for each PMU were identified as critical in order to meet the goals and objectives of an effective management plan.

- Several hunting groups also suggested regulation changes designed to reduce over-harvest of bighorn sheep rams in the Kootenays (e.g., species-specific tag for each species of sheep in BC, and regulations to limit the number of rams that could be harvested by an individual hunter in their life-time), as well as regulation changes to reduce the harvest of illegal rams (e.g., reduce time frame between harvest and Compulsory Inspection to avoid "horn bending" – where the horns of slightly below-curl rams are bent after harvest to make them appear full curl).

- Most hunting groups, while acknowledging declining populations coupled with issues of hunter crowding and excessive harvest effort, were opposed to Limited Entry Hunting (LEH) regulations for rams, preferring hunting opportunity but reducing sheep vulnerability and harvest while encouraging selective harvesting or limitations on the number of sheep that an individual could harvest over a period of time.

- Stakeholders noted that application of LEH regulations in a selection of management units will likely displace harvest effort and increase harvest pressure to areas with General Open Season (GOS) regulations.

Habitat Issues

- Threats and concerns identified at the PMU scale included habitat loss and industrial (forestry and mining) road development that facilitates increased public access and visual vulnerability of harvest-aged rams. The steady increase in backcountry recreation (e.g., heli-hiking/biking/skiing, ATV/UTV/motorcycle access) also increases the human disturbance across seasonal ranges and contributes to cumulative effects.

- Invasive plant spread on winter and summer ranges is also a common concern in many PMUs. Stakeholders suggested that enhanced access management prohibitions would help mitigate these negative effects on Kootenay Region bighorn sheep.

- Habitat enhancement projects (e.g., prescribed burns, invasive plant management) and private land acquisition for conservation of bighorn sheep have occurred throughout the Kootenay Region, although gaps need to be assessed across all PMUs.

Predation Management

- Short term options to reduce cougar predation on specific bighorn sheep ranges are warranted in some PMUs where declining alternative prey (white-tailed deer), poor escape terrain (due to conifer ingrowth in native grasslands due to fire suppression), and use of areas such as reclaimed mine sites by sheep have increased the vulnerability of some bighorn sheep herds.