SCIENCE-BASED GUIDELINES FOR MANAGEMENT OF THINHORN SHEEP IN YUKON

Yukon

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Yukon Department of Environment
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Summary

The following guidelines provide an overview of the scientific information used by Environment Yukon and other parties, as appropriate, to make monitoring and harvest management decisions specific to thinhorn sheep populations (*Ovis dalli* spp.) in Yukon, including Dall's (*O. d. dalli*) and Stone's (*O. d. stonei*) sub-species. They are not meant to replace management planning but are a resource that will help promote consistent science-based input and responses to management plans, programs, and regulation proposals. They are a working document that will be reviewed periodically and updated based on new information. Future iterations of the guidelines are intended to include a section on mitigating impacts of land use on sheep.

For clarity, the information in these guidelines is only part of what is needed to make wildlife management decisions. It complements other sources of information used to manage wildlife in Yukon, including traditional and local knowledge, as well as wildlife management processes undertaken by the Yukon Fish and Wildlife Management Board (YFWMB), Wildlife Management Advisory Council-North Slope [WMAC-(NS)], renewable resources councils (RRCs), and others.

Decisions based on these guidelines will help ensure the long term sustainability of Yukon's sheep populations.

Overview of sheep management guidelines

Two of the primary tools used to manage thinhorn sheep populations in Yukon are population monitoring (Section 3.1) and harvest management (Section 3.3).

Population monitoring (Section 3.1)

1. *Sheep within a discrete mountain block (described by a Game Management Subzone (GMS) or group of subzones) represent a management unit (Section 2.1).*
    - GMSs were first drawn with sheep management in mind: rivers, valleys, and terrain typically defined the boundaries of a GMS and readily contain the alpine areas inhabited by sheep.
    - Current and future research will help improve our ability to designate sheep populations (i.e., genetics and survey work).
    - Harvest management is specific to a GMS or group of GMSs.
2. *There is less information on sheep populations than other ungulate populations. Management actions are more conservative to help ensure a population is not overharvested.*
    - Sheep are challenging and expensive to monitor because they live in remote areas that are logistically difficult to survey. Consequently, many thinhorn sheep populations in Yukon have not been surveyed or survey information is dated.

- Population surveys are prioritized based on management concerns. The criteria used to decide on which populations to survey includes:
    - Knowledge of a population's size, distribution, and status.
    - Accessibility of the population.
    - Current and historical harvest rates and availability of harvest information from all users.
    - Current and anticipated land use activities within a range.
    - Social, financial, and political considerations.

3. *Minimum count surveys are conducted via aircraft.*
    - Survey information is used to estimate "total minimum counts", not population size or density. Minimum counts are based on the actual number of animals observed during the survey. Population size cannot typically be estimated as it is not known how many sheep are missed during surveys. Where that information exists, a correction factor may be applied to the minimum count to address missed animals.
    - Animals are classified as lambs, rams and nursery sheep during minimum count surveys.
        - "Nursery sheep" include ewes, yearlings, and 2-year-old rams that have not yet joined the ram bands. It is difficult to distinguish yearlings and 2-year-old rams from ewes during aerial surveys without greatly increasing disturbance and risk of injury.
4. *The status of sheep populations is based on the total minimum count, productivity (lambs per 100 nursery sheep), sex ratio (rams per 100 nursery sheep), and the proportion of rams in each horn curl category (1/2, 3/4, or full curl) (Section 2.6).*
    - On average, a June/July productivity ratio of 25 lambs per 100 nursery sheep is needed for a stable population.
    - On average, a minimum of 50 rams per 100 nursery sheep are observed in unharvested or lightly harvested populations.
        - Low ram to nursery sheep ratios (e.g., 40 rams per 100 nursery sheep or less) suggests there are too few rams in the population, meaning harvest rates may need to be adjusted.
    - Other useful supplemental information includes weather patterns, which can affect lamb survival, and ages of harvested rams, which can be used to determine if too many older rams are being removed from the population (see Section 3.3).
5. *Survey details are sensitive; only summary information is released to the public.*
    - Sheep are very predictable in their seasonal range use and are very visible in the alpine. Release of specific survey information (e.g., location, sex, and age) may make populations more vulnerable to overharvest.

Harvest management (Section 3.3)

Harvest rate recommendations are guidelines and may be adjusted based on specific and objective knowledge of a population, including its status, trend, distribution, accessibility, disturbance within its range, harvest pressure on adjacent populations, and other sources of mortality. Guidelines must also be considered in light of meeting obligations under the *Umbrella Final Agreement* (1993) and *Inuvialuit Final Agreement as Amended* (2005) related to conservation and long term optimum productivity.

The following guidelines should be used to evaluate harvest rate recommendations for specific sheep populations:

6. *There should be no harvest of populations that are very small or are believed to be in serious decline.*
7. *Ewe harvest should be avoided.*
    - The harvest of 1 ewe is equal to the harvest of 5 rams in terms of its effect on population change.
    - Even a small ewe harvest is associated with a high risk of population decline.
        - Ewe harvest has a bigger impact on populations than ram harvest. The loss of an ewe means a loss of all the lambs she could have produced during the rest of her lifetime
    - Pregnancy rates typically exceed 75% so it is unusual for a ewe not to produce a lamb.
8. *Harvest of full curl rams is the lowest risk strategy for long-term maintenance of sheep populations.*
    - Full curl rams are typically older rams (although a full curl can be attained anywhere between 4 and 11 years). Old rams are more likely to die of natural mortality than young rams so removing some of them from the population is less likely to affect natural population size and structure.
    - Limiting harvest to "full curl" rams helps ensure harvest is sustainable as population information is often non-existent, limited, or dated.
    - Full curl rams can be identified in the field, allowing the use of this physical feature as a harvest management tool. Expanding harvest to include partial curl rams may bias the male age structure of the population towards younger males, potentially resulting in lower rates of productivity and lower rates of young ram survival. It may also increase the risk of harvesting ewes as it may be difficult to distinguish between younger rams and ewes.
9. *A full curl ram harvest rate of no more than 4% of the non-lamb population is considered sustainable for populations that have been surveyed.*
    - A maximum 4% harvest rate helps ensure that the natural age structure of the male population is maintained (a mix of older and younger age rams).
    - Similar to harvest of partial curl rams, overharvesting of full curl rams can have consequences for sheep population dynamics and genetic diversity.

- Differential harvest rates based on population size and trend may be incorporated into future recommendations as techniques used to monitor sheep improve and allow for more precise estimates of population metrics.

10. *For populations with no or outdated survey information, recommendations on sustainable harvest numbers are based on a number of indictors used to assess risk:*
    - The proportion of older rams in the harvest:
        - Maintaining some older rams in the population is important for lamb productivity, and genetic diversity. As required under Yukon's Wildlife Act, all thinhorn sheep harvested by licensed hunters must submit the head for aging. Based on these submissions, additional monitoring and harvest management actions may be required if:
            - The proportion of rams age 8 or older represents less than 60% of the harvest over the last 5 years.
            - There are few or no rams 10 years or older in the harvest over the last 5 years.
            - These proportions will be interpreted in light of the sample size of harvested rams.
    - Availability of harvest information from all user groups.
    - Number of ewes removed from the population.
    - Sources and extent of other mortality or risk of mortality.
    - Degree of population isolation.
    - Changes in sheep demographics based on local knowledge, including reports of limited recruitment in the past few years and changes in sheep distribution and density.
    - Continuous years of bad weather, which may affect lamb production.
    - Amount of existing and proposed disturbance within the population's range.
11. *Harvest rate should be adjusted based on the number of ewes removed from the population, in which the harvest of 1 ewe is equal to harvest of 5 rams.*

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Introduction

1.1 Purpose

The following guidelines provide an overview of the scientific and technical information used by Environment Yukon and other parties, as appropriate, to make monitoring and harvest management decisions specific to Thinhorn Sheep (*Ovis dalli spp.*) populations in Yukon. The intent of the guidelines is to help users provide consistent science-based input and responses to management plans, programs, and proposals based on the most up to date scientific information.

Guidelines are not the same as a management plan. They will be used to provide science-based direction for managing wildlife populations and assessing population status and trend. Monitoring and management recommendations depend in part on this assessment; for example, survey work may be prioritized for a population deemed to be at increased risk of decline because of high harvest pressure. Environment Yukon uses as many lines of evidence as possible to make inferences about a population to ensure management actions are sound.

These guidelines are a starting point for discussion and may be adjusted pending more specific, objective knowledge of a population. They are one part of what is needed to make wildlife management decisions (Figure 1). Processes exist in Yukon to integrate scientific, local, and traditional knowledge and ensure that this knowledge is used to inform wildlife management. Public participation in wildlife management processes is facilitated by public bodies such as the Yukon Fish and Wildlife Management Board (YFWMB), Wildlife Management Advisory Council-North Slope [WMAC (NS)], renewable resources councils (RRCs), and others. For more information on the role of the YFWMB and RRCs in wildlife management, please see Chapter 16 of the *Umbrella Final Agreement* (1993). For more information on the role of WMAC (NS) in fish and wildlife management, please see the *Inuvialuit Final Agreement as Amended* (2005).

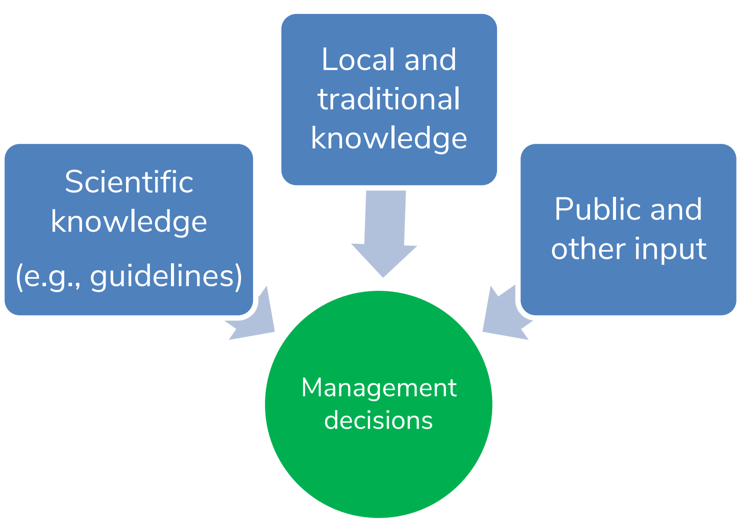

Figure 1. Role of guidelines in wildlife management in Yukon.

1.2 Management and regulatory context

Stewardship of natural resources in Yukon is mandated through the Wildlife Act, Environment Act and constitutionally entrenched Land Claim agreements. Within Yukon land claim agreements, the principles of conservation[1,2], long term optimum productivity, and sustainability guide management programs while actions are guided through related legislation, policy, guidelines, or formal agreements.

1.3 Management principles for Yukon's wildlife

Management of Yukon's wildlife is guided by the following principles. These principles are derived from fundamental practices within the fields of wildlife management and conservation biology.

1. Naturally self-sustaining wildlife populations are the principal management objective.
2. Wildlife populations will be, to the best extent possible, managed within their natural range of variation.
3. Management of human activity, including harvest, disturbance, and land use are the primary tools available for recovering or maintaining wildlife and wildlife habitat.
4. Management will be adaptive.
5. The interests of all consumptive and non-consumptive users will be recognized and considered in the management of wildlife populations.
6. Management will be guided by the precautionary principle.
7. Management will, to the best extent possible, be ecosystem based.

1.4 Review process

These guidelines are a living document that may be revised as new information becomes available. For example, future iterations of this document are intended to include a section on mitigating impacts of land use, as our knowledge of the specific responses of Yukon's sheep to human activity increases. Currently, Environment Yukon reviews and provides advice on a variety of land use and development applications, most commonly under the Yukon Environmental and Socio-Economic Assessment Act (YESAA). Other legislation, in addition to the Wildlife Act, Environment Act, and land claim agreements, is in place to ensure responsible resource development in sheep habitat. These include the Forest Resources Act, Quartz Mining Act, and Placer Mining Act.

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[1] Conservation as defined in the *Umbrella Final Agreement* (UFA; 1993): the management of Fish and Wildlife populations and habitats and the regulation of users to ensure the quality, diversity and Long Term Optimum Productivity of Fish and Wildlife populations, with the primary goal of ensuring a sustainable harvest and its proper utilization. In the UFA, Long Term Optimum Productivity is defined as productivity required to ensure the long term continuation of a species or population while providing for the needs of Yukon Indian People and other harvesters and non-consumptive users of Fish and Wildlife in the short term.

[2] Conservation as defined in the *Inuvialuit Final Agreement* as Amended (IFA; 2005): the management of the wildlife populations and habitat to ensure the maintenance of the quality, including the long term optimum productivity, of these resources and to ensure the efficient utilization of the available harvest.

In addition to the as-needed revisions, these guidelines will be reviewed and updated, in full, every 10 years. This periodic review process will ensure the document remains current with scientific understanding, and relevant to the Yukon.

2 Species background

2.1 Distribution and status

Thinhorn sheep are found in Alaska, northern British Columbia, Yukon, and the Northwest Territories. In Yukon, thinhorn sheep distribution is generally restricted to specific mountain ranges, on the dry sides of mountains (Figure 2). Sheep within a discrete mountain block (described by a Game Management Subzone (GMS) or group of subzones) are considered to represent a management unit as it is assumed there is little movement of sheep between mountain ranges. GMS were originally drawn with sheep management in mind: rivers, valleys, and terrain typically define GMS boundaries and contain the alpine areas inhabited by sheep. However, recent surveys have documented sheep occupying non-typical habitats along river corridors, notably the Yukon River (Environment Yukon, *unpublished results*). Genetics and survey work is currently underway to help Environment Yukon better delineate thinhorn sheep populations.

The scarcity of sheep in certain areas such as Englishman's Range (part of the Big Salmon Range) and the Cassiar and Logan Mountains may be explained by the considerable snowfall and lack of winter range in these regions. There are also a few areas where human activities such as historical commercial meat hunting or mining and exploration activities have resulted in range abandonment, population declines or local extirpation. Examples are the Montana, Nares, and Caribou Mountains near Carcross (Barichello and Carey 1991) and Keno Hill near Mayo (Environment Yukon, *unpublished data*). However, there is evidence that some of these areas are slowly being recolonized (Environment Yukon, *unpublished data*).

Thinhorn sheep are listed as "big game" under Yukon's Wildlife Act. They are not considered a species at risk in Yukon or any other jurisdiction. The species has traditionally been separated into 2 subspecies: Dall's sheep (*Ovis dalli dalli*) and Stone's sheep (*O. d. stonei*) (Bowyer and Leslie 1992; Appendix 1). "Fannin" sheep occurring in south–central Yukon *may* be a result of interbreeding between the 2 subspecies (Worley *et al.* 2004), but genetically are Dall's sheep (Loehr *et al.* 2006) and are managed as such.

In 1984, Yukon government biologists estimated that there were about 22,000 thinhorn sheep in the territory, with roughly 85% being white Dall's sheep and 15% being coloured (including Stone's and Fannin sheep). This territory-wide estimate has not been updated. Some populations have declined in recent years, but the extent of these declines is not known because sheep are not monitored comprehensively or regularly across Yukon.

A substantial portion of the Canadian and international thinhorn sheep population is in Yukon. The total population in Canada is approximately 41,500 animals (Festa-Bianchet 2008), of which 27,000 are Dall's sheep and 14,500 are Stone's sheep. The global population is estimated to be approximately 111,500 sheep (Festa-Bianchet 2008). Thinhorn sheep are considered one of the most abundant types of wild sheep in the world today.

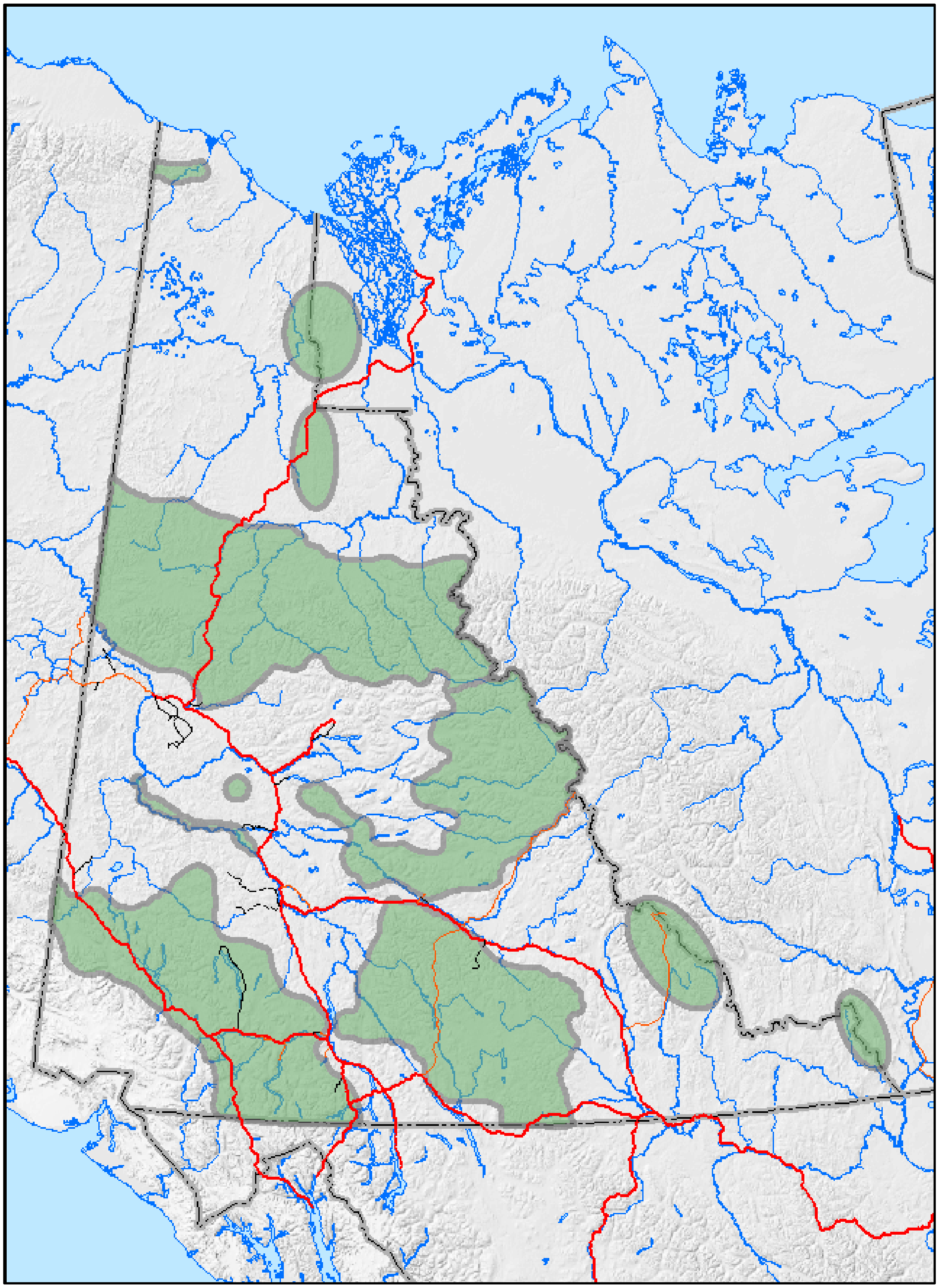

Figure 2. Generalized thinhorn sheep distribution across Yukon. This map captures the major areas of sheep occurrence in Yukon.

2.2 Habitat requirements

Thinhorn sheep are adapted to living in relatively dry areas with little snow. They feed on ground vegetation like grasses and herbs. They are generally associated with steep and rocky alpine/subalpine terrain interspersed with patches of vegetation. The rugged terrain provides refuge from predators and is exposed to wind, which helps reduce snow accumulation (Simmons 1982, Walker *et al*. 2006, Walker *et al*. 2007).

Wild sheep are more sensitive to range impacts than most other northern ungulate species (Miller *et al*. 1991, Papouchis *et al*. 2001). Thinhorn sheep demonstrate high levels of range fidelity (Hoefs and Cowan 1979) and use their range in very traditional and predictable manners. Seasonal ranges, such as winter ranges and rutting or lambing areas, are used by the same animals and their offspring at the same time every year. Damage to these traditional ranges (particularly to key or limiting habitat components) can result in displacement and even range abandonment.

2.3 Mineral licks

All Yukon ungulates use mineral licks, which are areas where dissolved elements or clays have been naturally deposited. Mineral licks, which are scattered throughout Yukon, provide animals with essential minerals such as sodium, magnesium and trace elements that are necessary for dietary and health reasons (Jones and Hanson 1985; Ayotte *et al*. 2006). Mineral licks affect the distribution of many ungulates (Jones and Hanson 1985), including sheep (Tankersley 1984; Ayotte *et al*. 2006; Gerberding 2006; Ayotte *et al*. 2008). For example, Simmons (1982) described mineral licks as the “foci of the activities of ‘ewe groups’ (ewes and juvenile rams) in the summer months.” Walker *et al*. (2007) reported that Stone’s sheep travel to non-preferred habitats such as riparian zones to access licks. Sheep have high levels of fidelity to specific licks and will travel substantial distances (up to 20 km) to access them, even though closer licks are available (Heimer 1973, Tankersley 1984).

In general, mineral licks are used as soon as possible in spring and use remains active through July (and, in some studies, into August; Simmons 1982, Tankersley 1984, Ayotte *et al*. 2008). However; timing of use can vary. In Faro, sheep monitored with motion sensor cameras predominantly used the Blind Creek lick in late winter and not at all during the summer (Environment Yukon, *unpublished data*). Heimer (1973) reported greatest use of licks during June. In a study of mineral lick use by Stone sheep in northern British Columbia, Ayotte *et al*. (2008) found that sheep use of dry licks was highly variable during the summer with peaks occurring through the season. There may be some sexual segregation in the use of licks with rams tending to use licks earlier (mid-May) than females (June) (Tankersley 1984).

2.4 Habitat use and selection

A combination of factors including vegetation, predation risk, and topography best explain sheep habitat use, although there is considerable variation among different groups of sheep. Much of the recent work on habitat use and selection was completed for Stone’s sheep in British Columbia (Walker *et al*. 2007) and for Dall’s sheep in the Richardson’s Mountains (Lambert Koizumi 2012).

Sexual segregation – The sexes are spatially segregated through much of the year,

most likely due to differences in reproductive strategies, access to forage, activity budgets, and predation risk (Main *et al*. 1996, Ruckstuhl and Nehaus 2000; Corti and Shackleton 2002). Most association between the sexes occurs during the breeding season and most segregation occurs during the lambing season.

Winter (1 January – 30 April) – Winter ranges are often a limiting factor for sheep and may consist of only 5% to 10% of the total year-round range available to a population. Winter range is essential for population maintenance. Typical sheep winter ranges are south or west-facing, steep, grassy slopes that do not receive much snow, or where wind, sun, and gravity redistribute snow and create snow-free areas. In British Columbia, adult Stone's ewes select steep slopes and higher elevations along ridges with south- and west-facing slopes and avoid subalpine spruce stands and north or east aspects (Walker *et al*. 2007). In the Richardson's mountains, Dall's rams select for rugged terrain, steep slopes, and barren lands whereas Dall's ewes select for east- and west- facing slopes (Lambert Koizumi 2012).

Late winter (March/April) – Stone's sheep selection for steep slopes and south-facing slopes is more pronounced in late winter, probably due to increased solar radiation and decreased snowpack due to wind exposure. Burned areas are also selected in late winter (Walker *et al*. 2007), although selection may be tempered by wind exposure and annual variation in snow depth (Seip and Bunnell 1985). Similarly, Dall's ewes select steep habitat and rams avoid north-facing slopes in later winter (Lambert Koizumi 2012).

Lambing (1 May – 15 June) – Stone's sheep ewes select habitat with mid-elevations, steep slopes, dry alpine, burned grass, shrub, areas with high vegetation quality, and rocky areas (Walker *et al*. 2007). Likewise, rugged and steep terrain is selected by Dall's ewes, which also avoid north slopes (Lambert Koizumi 2012). In contrast, Dall's rams' habitat choices reflect mostly their foraging needs, with a selection for southern slopes, barrens, forests, herbs, shrubs, and water access. Ewes' habitat selection reflects a trade-off between selecting for forage quality and minimizing predation risk if with young. For example, females with lambs typically seek areas with more protective cover from predators (rocky escape areas) and spend less time in shrubby areas than females without young (Hoefs and Cowan 1979; Rachlow and Bowyer 1998; Corti and Shackleton 2002, Walker *et al*. 2006).

Summer (mid-June through August) – Stone's ewes are generally less selective in summer than during other seasons (Walker *et al*. 2007), although they may increasingly select for higher elevations, possibly because they are tracking forage growth (Seip 1983). Both Dall's ewes and rams increased their use of higher elevations, rugged and steep terrain in summer (Lambert Koizumi 2012). Dall's ewes also select for eastern slopes but avoid south- and west-oriented slopes, barrens, forests, herbs, shrubs, snow and water land cover (Lambert Koizumi 2012). Rams avoid northern slopes and select for southeast slopes, barrens, bryoids, and water (Lambert Koizumi 2012).

Fall (1 September – 31 October) – Stone's sheep show variable habitat selection and use of topographic features. There is a general avoidance of subalpine coniferous areas and areas with large frost-broken boulders with lichen coverage, but sheep use lower elevation burn areas when available (Walker *et al*. 2007). Dall's ewes show no particular pattern of habitat use and selection, but rams select for lower elevations, southeast oriented slopes, as

well as barrens, bryoids, forests, herbs, shrubs, snow, and water land covers (Lambert Koizumi 2012).

Rut (1 November – 31 December) – Year after year, male and female sheep gather during the rutting season. These are areas that often feature steep, convex, south-facing alpine slopes (Walker *et al.* 2007). However, the location of actual rutting areas can vary year to year based on factors such as snow conditions, which if deep enough, can result in sheep using lower elevation sites to breed.

2.5 Climate change

Scientists predict increased average global temperatures and changes in precipitation regimes as a result of anthropogenic contributions of greenhouse gases to the atmosphere (Post *et al.* 2009). The most rapid and severe changes associated with this trend are expected for northern regions like Yukon and Alaska (ACIA 2005; IPCC 2007). Because of associated shifts in climate envelopes, scientists predict distributional shifts for many species and changes in habitat composition (Walther *et al.* 2002).

Such ecological changes have already been observed in the north, including the upward migration of the treeline observed in southwestern Yukon (Danby and Hik 2007) and the increase in shrub density in Alaska (Sturm *et al.* 2001, Tape *et al.* 2006). Changing climatic regimes may also lead to increased winter precipitation (i.e., snow; Environment Yukon 2009), more icing events, changes in the timing of spring green-up, changes in sheep-parasite/disease dynamics (including the emergence of new diseases and parasites; Kutz *et al.* 2004, Kutz *et al.* 2005, Kutz *et al.* 2009; Altizer *et al.* 2013) and increased forest fire frequency due to increasing temperatures (Gustine *et al.* 2014). These changes may alter sheep behaviour, migration/movement patterns, and seasonal distribution across the landscape as they attempt to cope with changing forage distribution and availability.

Predicting the magnitude and direction of climate change impacts on sheep distribution and abundance in Yukon is difficult, but is still an important consideration when developing long term management and monitoring actions for sheep.

2.6 Population biology

2.6.1 Density

The density of sheep in Yukon, where they occur, ranges from less than 2 sheep/100 km^2 to more than 30 sheep/100 km^2. The impact of density dependence on thinhorn sheep population dynamics is unclear (i.e., the impact that increasing density has on forage competition, disease transfer, etc.), although in a study in the southwest Yukon, populations with higher density had reduced productivity (i.e., there were fewer lambs surviving to join the breeding population; Burles *et al.* 1984). Hoefs (1984) suggested sheep on Sheep Mountain in southwest Yukon were at their ecological carrying capacity. This trend has also been observed in Alaska (Murphy and Whitten 1976).

Changing age structure may confound the ability to detect density dependence. Festa-Bianchet *et al.* (2003) noted that changes in age structure may be the cause of apparent density dependence in adult bighorn sheep survival. That is, it is known that the age structure of sheep populations fluctuates over time, meaning the numbers of animals in different age classes will change. This may make it appear that animals were lost due to density dependence, when in fact it may be the fluctuating nature of sheep populations. Management considerations are typically based on minimum counts and other demographic factors rather than density.

2.6.2 Reproduction

Ewes become sexually mature at approximately 2½ years and typically have one lamb per year. Bunnell and Olsen (1981) found that on Sheep Mountain in southwest Yukon, reproduction typically did not occur until 4 years of age. Pregnancy rates typically exceed 75% (Simmons *et al.* 1984). Twinning is rare (Hoefs 1978). Female age structure biased towards young or old animals may affect population dynamics. For example, reproductive performance of young (2 - 4 years old) and senescent (13 or older) ewes is reduced (Festa-Bianchet and King 2007).

2.6.3 Lamb survival and recruitment

Observed summer lamb to nursery sheep ratios range from roughly 10 to 40 lambs per 100 nursery sheep but vary greatly from year to year and geographically within a year (e.g., Russell and Hegel 2011). This is typical for most large herbivores (Gaillard *et al.* 2000) and can drive most of the variability in sheep population dynamics. In other words, the number of lambs recruited into the breeding population has a larger impact on sheep populations than the number of animals leaving the population through predation or hunting. Variation in lamb production and survival rates means the age structure of any sheep population will shift from time to time. This can have consequences for harvest rates. For example, the average number of full-curl rams entering the population is dependent on the average number and survival of lambs born seven to eight years before (see Section 2.6.4). On average, a productivity ratio of 25 lambs per 100 nursery sheep is needed for a stable population (Hegel 2015).

Winter weather—particularly snowfall—is one of the largest factors affecting lamb recruitment prior to birth (i.e., during gestation), which can affect birth rates (Murphy and Whitten 1976, Burles *et al.* 1984). Spring weather at lambing can also influence recruitment, but the relationship between spring weather, forage availability (and quality) and lamb growth and subsequent survival is complex. Wet springs can lead to larger lamb size and increased over-winter survival if it leads to greater forage availability shortly after lambing (Portier *et al.* 1998). However, if the rapid flush of new growth occurs too quickly or too early, it may mean nutritious forage is not available throughout the summer. This can affect lactation and consequently lamb survival (Pettorelli *et al.* 2007).

Time series analysis indicates summer lamb abundance on Sheep Mountain, Yukon, may be inversely correlated to snowshoe hare abundance as a result of sharing common predators like coyotes, lynx, and eagles (i.e., lamb abundance decreases as snowshoe hare abundance increases; Wilmshurst *et al.* 2006). Experimental studies in the Yukon involving wolf removal suggest thinhorn sheep recruitment rates and population abundance are not strongly correlated to wolf abundance (Barichello *et al.* 1989b, Hayes *et al.* 2003). This conclusion is similar to reports from Alaskan studies (Mech *et al.* 1998, Mitchell *et al.* 2015). Prugh and Arthur (2015) reported that the primary sources of lamb mortality in the Alaska Range, Alaska, were coyotes and golden eagles. They speculated that if the removal of wolves resulted in a “release” (i.e., increase) in the number of meso-predators such as coyotes, sheep population growth rates would actually be reduced following wolf removal efforts.

2.6.4 Age at which rams reach full curl

Yukon data indicates that roughly 55% of rams attain full curl in their 7th or 8th years, with 85% of all rams attaining full curl status before their 9th year (Environment Yukon, *unpublished data*). However, the age at which full curl is attained is variable and ranges from 4 to 11 years depending on rate of horn growth. Research on sheep in Yukon has shown that horn growth follows a roughly 10 year cycle that may be driven largely by climatic conditions from the Pacific Ocean (Hik and Carey 2000).

2.6.5 Adult mortality

As evident for Dall's sheep rams at Sheep Mountain in southwest Yukon and the Mackenzie Mountains in the Northwest Territories (Hoefs 1981), once rams reach full curl (Section 2.6.4), their average annual mortality rate is approximately 10-15% per year. Rams older than 10 years are more actively involved in the rut and have average annual mortality rates exceeding 50%.

Adult ewe mortality generally shows the same pattern of mortality as rams (mortality increases with age), albeit with lower mortality rates (~40%) at older ages (Prugh and Arthur 2015).

2.6.6 Adult sex ratio

The sex ratio averages approximately 50-55 rams per 100 nursery sheep in unhunted sheep populations (Hoefs and Bayer 1983). If there are fewer than 40 rams per 100 nursery sheep, additional follow up work may be needed, including possible harvest management actions as there may be genetic or reproductive consequences if there are too few rams in the population (Section 3.3.3). Reasons for a low sex ratio may include variable lamb production, overharvest of rams, or other factors resulting in male-biased mortality. Sexual segregation (Section 2.4) may also impact survey results if males and females are using different ranges at the time of the survey or if there is a difference in the ability of observers to detect male (ram) and female (nursery) groups.

2.6.7 Disease and parasites

Disease in wild sheep is mostly caused by parasitic or bacterial infections and often a combination of both (Appendix 2). Thinhorn sheep in Yukon may be exposed to a variety of diseases and pathogens including verminous pneumonia (Jenkins *et al*. 2007), malignant catarrhal fever virus (MCFV; Zarnke *et al*. 2002), lungworm (Kutz *et al*. 2001), and muscleworm (Kutz *et al*. 2001). No evidence of endemic or epidemic disease that may be population limiting has been detected in thinhorn sheep in Yukon (Worley *et al*. 2006).

Bacterial bronchopneumonia is well documented as an important cause of morbidity and mortality in wild bighorn sheep in North America (Besser *et al*. 2013), and the potential for bronchopneumonia outbreaks in thinhorn sheep populations is a significant cause for concern. In some areas, outside Yukon, bronchopneumonia is responsible for greater adult mortality in bighorn sheep populations than predation (Cassirer and Sinclair 2007). Some bighorn sheep populations have essentially been wiped out by bronchopneumonia epizootics (Singer *et al.* 2001), which are caused by highly contagious bacterial infections. *Mycoplasma ovipneumonia* is one of the most important pathogens involved in the disease (Besser *et al.* 2013). Domestic sheep are often asymptomatic carriers of pathogens that cause bronchopneumonia in wild sheep and contact with domestic sheep is the main risk factor for the disease in many bighorn sheep epizootics. **Separating domestic animals from wild sheep is one of the most important management tools for wild sheep conservation (George *et al.* 2008).**

Thinhorn sheep have been reported to carry lungworm (*Protostrongylus stilesi*) in the Mackenzie Mountains, Northwest Territories (Jenkins *et al.* 2006). Infections of this parasite can cause pneumonia in sheep and also increase the susceptibility of wild sheep to bacterial infections in the lungs. The presence of this parasite is unconfirmed in Yukon, but lungworms consistent with *P. stilesi* have been detected in low numbers of Yukon sheep. Parasitic infections in combination with bacterial infections or physical exertion can cause death in thinhorn sheep (Jenkins *et al.* 2007). For example, lambs exposed to lungworm infections in utero through transplacental infections are more likely to die from pneumonia infections soon after birth.

Contagious ecthyma is a viral infection that causes large sores and scabs on the faces (particularly mouths) of sheep. Lambs are most susceptible to infection. Lambs infected with the contagious ecthyma virus may have reduced survival, though the actual consequences of the disease are unclear (L'Heureux *et al.* 1996). Goldstein *et al.* (2005b) suggests that ecthyma might have a bigger impact on lamb survival than lungworm loads.

Evidence of exposure to MCFV and DNA from MCFV was found in blood samples taken from Alaskan Dall's sheep (Zarnke *et al.* 2002). The significance of these findings to the health of Yukon's Dall's sheep is unclear. Neither MCFVs nor antibodies to MCFVs have been detected in Yukon sheep.

3 Management guidelines

3.1 Population monitoring

Yukon-wide monitoring priorities for thinhorn sheep monitoring are established after consideration of a population's size, distribution, and status; accessibility; historic and current harvest levels; availability of harvest information for all users; and current and anticipated land use activities. These factors are weighed together with social, financial, and political considerations to produce annual and multi-year survey schedules for Yukon's sheep. Some of Yukon's populations have not been surveyed or surveyed recently.

The information collected for populations that have been surveyed is coarser (not as precise) than for ungulates like moose and caribou. Aerial surveys are used to estimate the total minimum count for specific management units, not actual population size or density (Murphy and Whitten 1976, Pollock and Kendall 1987, Udevitz *et al.* 2006). Size and density cannot typically be estimated because it is not known how many sheep were missed (not detected) during surveys. Where that information exists, a correction factor may be applied to the minimum count to address missed animals. Distribution patterns are assumed to be traditional

so a change in the minimum number of sheep observed is considered a change in the population size, given equal survey effort and conditions.

Other population indices obtained during summer aerial surveys include the number of rams per 100 nursery sheep (sex ratio) and the number of lambs per 100 nursery sheep (productivity ratio). It is difficult to distinguish yearlings and 2-year-old rams from ewes during aerial surveys without greatly increasing disturbance and risk of injury so sheep are classified into lambs, rams, and nursery sheep. Nursery sheep include ewes, yearlings, and 2-year-old rams that have not yet joined the ram bands. Because young rams and immature (non-reproductive) ewes are present in nursery groups, the ratio of lambs to nursery sheep is not a true estimate of productivity but it can still be used as an indicator of population status and trend.

3.2 Population management

The management of human activities provides the most practical, cost-effective and socially acceptable tools for sheep management. For example, hunting regulations are intended to allow for sustainable harvesting opportunities while ensuring the long-term welfare of sheep populations.

3.3 Harvest

3.3.1 Harvest allocation

Opportunities for sheep harvest are shared by all users. In Yukon outside of the Inuvialuit Settlement Region, the principle of sharing the allowable sheep harvest among all Yukoners is recognized in government policy and in the *Umbrella Final Agreement* (1993). In the Inuvialuit Settlement Region, the Inuvialuit have the preferential right to hunt for food all species of wildlife (except for migratory non-game birds and migratory insectivorous birds) on the North Slope (*Inuvialuit Final Agreement as Amended*, 2005).

3.3.2 Harvest monitoring and reporting

Reliable information on the annual sheep harvest by all hunters is a cornerstone of effective population management. Sheep are harvested by residents, non-residents, First Nations and the Inuvialuit. Environment Yukon has kept records of the annual sheep harvest reported by licensed hunters in each GMS since 1980. Harvest is assigned to specific subzones based on the location of the kill. All successful licensed sheep hunters must report their harvest to an Environment Yukon office no later than 15 days after the end of the month in which the sheep was killed. Monitoring the harvest for compliance with full curl regulations is done through compulsory measurement and sampling of the horns for sheep harvested by all users.

Yukon First Nation Final Agreements assume all users will report their harvest; this information is needed to manage wildlife effectively. Where First Nation harvest is not available, it is estimated.

3.3.3 Harvest management considerations

Harvest is often a significant source of adult mortality in hunted ungulate populations. A key consideration in managing sheep harvest is to ensure it is sustainable and does not lead to

population declines or significant changes in male age structure. For sheep, this is challenging because of the lack of information on a number of populations and the coarseness of the data collected even when available. Consequently, harvest recommendations are more conservative than for other ungulates to help ensure populations are self-sustaining. Wild sheep are a priority target animal for non-resident hunters so maintaining a long term sustainable sheep harvest is important economically. Of the average annual harvest of about 250 rams, 60% are taken by non-resident hunters (Environment Yukon, *unpublished data*).

The number of legally harvested animals also fluctuates with time and depends in part on previous patterns of lamb recruitment (i.e., if there are a high number of lambs recruited into the population, there will likely be a high number of legal sized rams entering the population 6-7 years later). Other factors must also be considered when assessing harvest sustainability. These include additional mortality sources (e.g., vehicle collisions); current population status, distribution, and trend; accessibility; knowledge of harvest pressure in adjacent populations; the impact of poor weather events on previous years' lamb productivity; and current and predicted levels of human disturbance in a population's range. For vulnerable populations that range in accessible areas or where key habitat is significantly impacted, it may be necessary to completely stop hunting or implement limitations. There should be no harvest of populations that are very small or are believed to be in serious decline.

3.3.4 Harvest rate recommendations

3.3.4.1 Sustainable harvest rates in surveyed populations

Knowledge of what constitutes a sustainable harvest rate is critical; however, harvest rates can only be recommended for those populations where there is some estimate of size (e.g., minimum counts). Computer simulation models can be used to evaluate different harvest management strategies and help guide harvest rate recommendations. For surveyed sheep populations, harvest models were used to *estimate* future population abundance, assuming conditions similar to the recent past, and to *predict* population abundance after altering one (or more) factors that may affect the population (e.g., harvest). Because there is detailed information on male age structure, models were also used to estimate future male age structure, assuming conditions similar to the recent past, and to predict male age structure after altering harvest.

Data from the non-hunted Sheep Mountain Dall's sheep population in southwest Yukon were used to create a "generalized" sheep population that was **initially stable** (Hegel 2015). The effect of different harvest scenarios were assessed as the percent change in the population abundance and age structure over a **10-year period**. Ten years was considered appropriate as it encompasses a full cycle of the Pacific Decadal Oscillation, which is known to influence ecological dynamics of ungulates in Yukon (Hegel *et al*. 2010; Loehr *et al*. 2010), it is slightly longer than the generation time for caribou (~9 years; COSEWIC 2014), which may be an appropriate proxy for thinhorn sheep, and is an appropriate length of time from a management decision-making perspective. Any harvest that resulted in less than a 10% decline in population size over a 10 year period and did not substantially altered male age structure was considered sustainable (i.e., constituted an acceptable level of risk).

The harvest rate recommendations outlined here are generally applicable to all of Yukon's sheep populations where there is information on population size; however, population-specific harvest rate recommendations should be developed where detailed population-specific information is available and where a specific management need exists.

Effects of a ram vs ewe harvest on a stable population

Scenarios investigating the impact of different harvest rates of ewes and rams on population size were assessed and strongly indicate that ewe harvest should be avoided. Harvest of ewes 1 year or older caused the population to decline dramatically over a 10 year period, with a harvest rate of 1% leading to a population decline of over 10%. A 5% harvest rate of ewes resulted in a population decline of nearly 60% in 10 years. Harvest of rams 1 year or older resulted in more gradual long-term population declines. Over 10 years, 1% and 5% harvest rates of any ram resulted in population declines of <1% and 13%, respectively.

Jorgenson *et al*. (1993) also suggests ewe harvest should be avoided because sheep population growth is slow, density-independent and ewe mortality from hunting is likely additive. The loss of an ewe also means a loss of all the lambs she could have produced during her lifetime; typical of large herbivores, adult female survival contributes the most to population growth rate (Gaillard *et al*. 2000). Reduced ewe survival can have significant impacts on a population's ability to remain stable and will certainly limit its ability to increase. Avoiding any ewe harvest helps mitigate this risk.

Understanding the impacts of ram vs ewe harvest on population trends is useful for adjusting overall harvest numbers, given estimated losses of ewes from the population. Ewe harvest results in 10-year population declines that are on average, five times greater than ram harvest of an equivalent rate. In other words, the population impact of harvesting 1 ewe is equivalent to the population impact of harvesting 5 rams. Even if the population is increasing, there is a high risk of decline if ewes are harvested.

Effect of harvesting full curl rams on a stable population

Harvest of full curl rams is the least risky strategy for ensuring harvest does not lead to population declines; moreover, a full curl ram harvest strategy has the lowest impact on male age structure (Hegel 2015). Using a full curl "rule" or strategy as a management tool is made possible because it is relatively easy to identify full curl males in the field (Figure 3).

This assessment is consistent with empirical work: for example, Whitten (2001) suggested that full-curl only harvest in Alaska did not cause population declines, with the caveat that not all full-curl rams are removed annually. Full curl rams are usually older rams, so harvesting them is largely compensatory because natural rates of mortality are higher for older aged rams (i.e., there is a greater chance that an older ram killed during the hunting season would not have survived the winter anyway; Murphy and Whitten 1976; Hoefs and Barichello 1984; also see Section 2.6.4).

Maintaining a natural age structure is important for sheep population dynamics. Expanding harvest to include partial curl rams may bias the male age structure towards younger rams (Hegel 2015), which may affect productivity by prolonging the breeding season because of the relative inexperience of younger rams. A prolonged breeding season can result in lambs being born late the following spring. This will leave them less time to increase their body mass prior to winter, which may result in reduced survival (Mysterud *et al.* 2002, Feder *et al.* 2008).

Singer and Zeigenfuss (2002) reported that higher proportions of younger rams in heavily hunted wild sheep populations (Dall's sheep included), resulting in increased levels of ewe harassment during the rut. Increased mating attempts by these younger rams may have reduced their survival because of increased energetic demands.

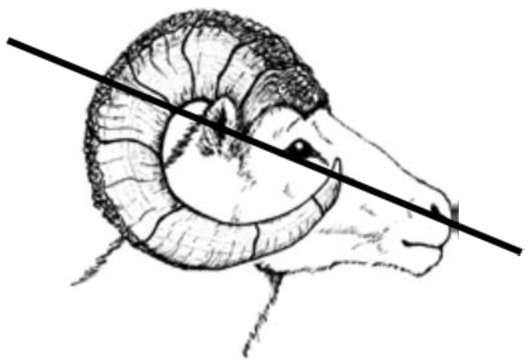

Figure 3. When viewed from the side, with horn bases aligned, a full-curl male has at least one horn that extends beyond a line running from the centre of the nostril through the lowermost edge of the eye.

3.3.4.2 Sustainable harvest rates for surveyed populations

A full curl ram harvest rate of no more than 4% of the non-lamb population size is recommended for populations that have been surveyed. This harvest rate recommendation will help ensure populations don't decline and that a natural age structure is, to the best extent possible, maintained. Removal of all full curl males can have a number of consequences, including reduced lamb productivity (see above), reduced genetic diversity, and reduced quality of the hunt, particularly if there is evolutionary pressures that select against larger horn size (e.g., Coltman *et al.* 2003).

3.3.4.3 Sustainable harvest rates in populations that have not been surveyed

Unsurveyed populations are typically found in remote areas; in most instances, these areas are only harvested by outfitters. A sustainable harvest rate cannot be calculated for these areas because there is no baseline assessment of minimum population size or trend. Instead, an age based threshold approach can be used to gauge if harvest is sustainable and a natural male age structure is being maintained (Hegel 2015). Age based assessments should be based on the previous 5 year age average of harvested rams to account for biases induced by small sample sizes and to avoid making management decisions based on a few years of information.

As required under Yukon's Wildlife Act, all thinhorn sheep harvested by licensed hunters must submit the head for aging. Based on aging results, additional monitoring and harvest management actions may be required if the proportion of rams 8 years or older makes up less than 60% of the harvest over the last 5 years (Hegel 2015). This is a biologically derived threshold based on Hoefs and Bayer (1983), who constructed a life table for rams in an unhunted population in southwest Yukon. Based on this life table, 60% of the non-lamb ram population was age 8 or older, which likely represents the upper limit of this proportion of rams due to the observed recruitment rates in the years prior to their study. While recognizing that the age distribution of rams will fluctuate through time, this threshold of 60% will help maintain a natural distribution of male age classes.

Additional monitoring and harvest management actions may also be required if there are no or very few old rams (10 years or older) harvested over the last 5 years. Assuming rams of a certain age are harvested relative to their availability in the population, the lack of rams age 10 or older harvested during a 5 year period may provide a strong indication that these older males are absent from the population.

Other indicators that can be used to gauge harvest sustainability in unsurveyed areas include:

- Trends in harvest that are not linked to cohort dynamics (e.g., if there is a substantial increase in adults harvested in the last 5-10 years and there is no evidence of high lamb production in previous years).
- Harvest information from all user groups
- The estimated number of ewes removed from the population.
- Other sources of mortality or risk of mortality (e.g., disease risk based on relative proximity to domestic animals).
- Degree of population isolation – more isolated populations are more vulnerable.
- Changes in sheep demographics based on local, unbiased knowledge, including reports of limited recruitment in the past few years and changes in sheep distribution and density.
- Continuous years of bad weather, which may affect future numbers of full curl rams because of poor lamb production 7-8 years prior.
- Amount of existing and proposed disturbance within the population's range.

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APPENDIX 1

Species description

Common Name: Thinhorn sheep
Scientific Name: *Ovis dalli* Nelson
Yukon Subspecies:

Ovis dalli dalli (Dall's sheep)
Ovis dalli stonei (Stone's sheep)

Local Names: Dall's sheep, Dall sheep, Stone's sheep, Stone sheep, Fannin sheep, white sheep, dark sheep

Both thinhorn and bighorn sheep species are derived from a common ancestor that entered North America about 750,000 years ago via the Bering land bridge. Divergence into *O. dalli* and *O. canadensis* was thought to be a result of long-term separation during glaciation events in which *O. dalli* evolved in eastern Beringia and *O. canadensis* evolved in the southern United States (U.S.) (Pielou 1991).

The species has traditionally been separated into 2 subspecies based on pelage colours: Dall's sheep (*O. d. dalli*) are off-white and may have a black tail; and Stone's sheep (*O. d. stonei*) are silver or grey-black with white muzzles, white leg trimmings, white rump patches, and a dark tail (Bowyer and Leslie 1992). There is considerable variation in coat colour within them (Loehr *et al.* 2008a, Loehr *et al.* 2008b). Genetic analysis based on nuclear DNA suggests there is some justification for maintaining the subspecies status of *O. d. dalli* and *O. d. stonei* (Worley *et al.* 2004). Mitochondrial DNA analysis, however, does not support these subspecies designations (Loehr *et al.* 2006). This analysis suggests that both species may have existed in small glacial refugia located between the 2 larger refugia and may have hybridized (Loehr *et al.* 2006).

"Fannin" sheep occurring in south–central Yukon appear to be intermediate in colour between *O. d. dalli* and *O. d. stonei* and may be a result of interbreeding between the 2 subspecies (Worley *et al.* 2004). They have been previously described as a distinct subspecies; however, genetically they are Dall's sheep (Loehr *et al.* 2006).

Worley *et al.* (2004) showed that the geographic range of *O. dalli* can be delineated into at least 8 subpopulations based on mountain range topography. The genetic structure of the population suggests that thinhorns have limited dispersal abilities and mountain ranges represent important barriers to gene flow (Worley *et al.* 2004). These 8 subpopulations are too broad, geographically, to be effectively treated as management units.

APPENDIX 2

Parasites and disease found in wild sheep populations

These parasites and diseases have been detected in wild thinhorn sheep populations in Yukon:

- Verminous pneumonia, caused by *Protostrongylus stilesi* (lungworm)
- Contagious Ecthyma
- Cutaneous papillomas
- Lumpy jaw