The Interaction Between Thinhorn Sheep and Wildland Fire in the Yukon:

A Summarized Literature Review

Prepared for Yukon Wild Sheep Foundation

Shifting Mosaics Corporation
August 26, 2025
Fort Nelson, British Columbia, Canada

TABLE OF CONTENTS

Citation
Shifting Mosaics Corporation. 2025. The Interaction Between Thinhorn Sheep and Wildland Fire in the Yukon: A Summarized Literature Review. Shifting Mosaics Publication 25.25. Fort Nelson, BC, Canada.

Shifting Mosaics Team
Alexis Jorgensen MSc, Dr. Mitchell Greer PhD, Anna-James Thompson BSc, Dr. Marie-Pierre Rogeau PhD, Dr. Gillian Leverkus PhD, and Dr. Sonja Leverkus PhD RPBio RPF PAg

Introduction

Thinhorn sheep (*Ovis dalli*; including subspecies *dalli* and *stonei*) are herbivores located in mountainous regions of the Yukon, Northwest Territories, Alaska, and northern British Columbia (Jex et al. 2016). There are two subspecies of thinhorn sheep: Dall sheep (*Ovis dalli dalli*) and Stone's sheep (*Ovis dalli stonei,* northern British Columbia) (Geist 1971, Jex et al. 2016). Thinhorn sheep live in habitats ranging from rugged mountain slopes to grasslands (Sittler et al. 2015). They are a culturally important species to both Indigenous and non-indigenous communities in the Yukon and British Columbia and are hunted for food and hides (Shifting Mosaics Consulting 2024).

Thinhorn sheep may roam individually, but commonly form small groups varying by season (Geist 1971). Geist (1971) noted an average group size from 1.9 to 5.1 Stone's sheep in British Columbia, with a maximum group size of 21 during rutting season (November-December). In the Yukon, he recorded up to 100 Dall sheep in a group, but noted that the number of lambs and yearlings was much smaller than in British Columbia (Geist 1971). Thinhorn sheep range varies throughout the year because of migration between winter and summer ranges (Bowyer and Leslie 1992). Range for both male and female sheep may also vary by season and reproductive stage (Geist 1971).

The availability of forage, escape terrain, and sufficient sightlines to detect predators are important habitat features. Walker and Parker (2007) found that thinhorn sheep selected for escape terrain throughout the year in northern BC and that ewes generally avoided alpine spruce communities, most likely due to limited grass availability and restricted sightlines due to dense trees. Mineral licks may be seasonally important to sheep (Bowyer and Leslie 1992). Leverkus et al. (2017) presented a resource selection of habitat preference for the priority wildlife species of the Muskwa-Kechika Management Area which includes Stone's sheep highlighting the importance of heterogeneity and landscape mosaics (Figure 1).

Thinhorn sheep rely on high elevation herbaceous plants for food (Luckhurst 1973). Graminoids generally make up the majority of their diet, however; forbs and browse (shrubs) can also be important food sources (Seip and Bunnell 1985c, Bowyer and Leslie 1992). High quality forage habitat is especially important in winter, when sheep are often nutritionally challenged (Jex et al. 2016). Grasslands are valuable habitat as they provide forage and the opportunity to easily move to escape terrain if predators are encountered (Jex et al. 2016). Across northern Canada wildland fire is a disturbance which drives habitat composition and vegetation type resulting most often in higher quality, easier access, and increased abundance of important forbs and browse (Figure 2). The shifting mosaic resulting from time since fire creates differences in vegetation structure and composition which not only supports heterogeneity but also increased available resources for multiple species across a landscape (Leverkus et al. 2017).

		Resource Selection of Habitat Preference				
Species	Provincial Listing	Bare rock	Open range-land / alpine / sub-alpine	Open forest	Dense forest	Water / riparian
Humans	yellow					
Horse	yellow					
Wood bison	red					
Plains bison	red					
Moose	yellow					
Elk	yellow					
Woodland caribou	red & blue					
Mountain goat	yellow					
Thinhorn stone sheep	yellow					
Grizzly bear	blue					
Gray wolf	yellow					
Wolverine	blue					
Fisher	blue					
Northern myotis	blue					
Lesser sandhill crane	yellow					
Short-eared owl	blue					
Peregrine falcon	red					
Bay-breasted warbler	red					
Cape may warbler	red					
Black-throated green warbler	blue					
Connecticut warbler	red					
Bull trout	blue					
Lake trout	yellow					
Arctic grayling	yellow					
Rainbow trout	yellow					
Northern pike	yellow					
Western toad	yellow					

Figure 1. Resource section of habitat preference of priority species in northeast British Columbia from Leverkus et al. (2017).

Species	Habitat/Vegetation Type Resource Selection	Citation
Woodland caribou, *Rangifer tarandus caribou*	alpine: summer use and winter use	Seip & Bunnell 1985; Pojar & Stewart 1991b; Gustine et al. 2006a; Gustine & Parker 2008; BC Ministry of Environment 2009a
	subalpine	BC Ministry of Environment 2009a
	open rangeland	Pojar & Stewart 1991b
	open forest	DeLong et al. 1991; Pojar & Stewart 1991a, Fisher & Wilkinson 2005; Dalerum et al. 2007; BC Ministry of Environment 2009a
	dense forest: winter use	DeLong et al. 1991; Fisher & Wilkinson 2005; Gustine et al. 2006a; Dalerum et al. 2007; Gustine & Parker 2008, BC Ministry of Environment 2009a
	muskeg/riparian	Pojar & Stewart 1991a; BC Ministry of Environment 2009a
Mountain goat, *Oreamnos americanus*	rock: escape terrain	Pojar & Stewart 1991b; Hamel & Côté 2007; BC Ministry of Environment 2009a
	alpine	Meidinger & Lewis 1983; Pojar & Stewart 1991b; Hamel & Côté 2007; BC Ministry of Environment 2009a
	open rangeland	DeLong et al. 1991; Pojar & Stewart 1991b; Peck & Currie 1992; Goddard 2011
Stone's sheep, *Ovis dalli stonei*	rock: escape terrain and mineral licks	Pojar & Stewart 1991a; Walker et al. 2006; BC Ministry of Environment 2009a; Sittler 2013
	alpine: winter range, yearly	Meidinger & Lewis 1983; Seip & Bunnell 1984; Seip & Bunnell 1985; Pojar & Stewart 1991b; Walker et al. 2006; BC Ministry of Environment 2009a
	open rangeland/ burned sub-alpine: foraging	Meidinger & Lewis 1983; Seip & Bunnell 1984; Seip & Bunnell 1985; DeLong et al. 1991; Pojar & Stewart 1991a; Pojar & Stewart 1991b; Gustine et al. 2006b; Walker et al. 2007; BC Ministry of Environment 2009a; Goddard 2011; Wince 2011
	dense forest: escape terrain	BC Ministry of Environment 2009a

Figure 2. A mosaic of habitat and vegetation type supports multiple species across northern Canada (Leverkus et al. 2017).

Trends and Threats
Thinhorn sheep are classed as S4 in the Yukon and G5T4 globally meaning that populations are considered secure or apparently secure (Government of Yukon 2024). However, there is concern about the potential impact of factors such as climate change, adverse weather events, predation and disease on this species. Changing climate may threaten wild sheep populations by increased growth of woody vegetation resulting in the reduced availability of high quality open habitat (Jex et al. 2016). Shrubification or shrub encroachment into sheep habitat may restrict movement corridors, reduce forage quality and quantity, decrease the availability of functional escape terrain, and increase challenges in predator detection. Adverse weather events linked to climate conditions pose immediate threats to populations and have been linked to recent population declines in the Yukon and elsewhere (Government of Yukon 2023a, 2023b, Shifting Mosaics Consulting 2024). Disease poses a serious threat to sheep. Sheep can suffer from a variety of pathogens and the risk of pneumonia transmission from domestic to wild populations is of particular concern in the Yukon (Shifting Mosaics Consulting 2024).

The Interaction of Wildland Fire and Wild Sheep

Wildland Fire
Fire is natural disturbance that alters and renews ecosystems. Fire drives landscape heterogeneity, creating a patchwork of ecosystems of different ages which may serve as habitat for a variety of wildlife species (Sittler et al. 2015, Leverkus et al. 2017). Fire increases the productivity and digestibility of regenerating vegetation and improves sight lines for detecting predators (Seip and Bunnell 1985a, Sittler 2014, Jex et al. 2016). Wildfire and prescribed fire provide many benefits for ungulates. Prescribed fire is incorporated globally to achieve multiple land management goals including fuel reduction to decrease the risk of uncontrollable wildfires and restoration and enhancement wildlife habitat (Weir and Scasta (eds.) 2022).

Research on the interaction between fire and thinhorn sheep in the Yukon is limited. However, there is evidence that fire enhances Stone's sheep habitat in northern BC. Seip and Bunnell (1985a, 1985b) found that both the abundance and digestibility of forage were greater in burned than unburned areas and that parasite load may be reduced where fire had occurred. Similarly, Sittler et al. (2014), found that burned areas (one year post fire) had greater abundance and digestibility of forage than unburned sites. Walker and Parker (2007) state that burned slopes, shrubs, and subalpine communities had the greatest plant biomass of all community types sampled. Hoefs (1979) discusses a 1978 study by Dr. J. P. Elliot entitled, *Range Enhancement and trophy production in Stone Sheep* (original not found) which noted improved range quality and quantity, sheep density, reproductive rates, and horn growth on areas treated by prescribed fire. However, Hoefs (1979) suggests that sheep may not have been monitored for enough time to indicate long term trends.

Increased forage quality and availability is valuable to sheep during winter when food may be scarce (Sittler et al. 2015). Walker et al. (2007) observed that BC Stone's sheep selected burned areas most commonly during winter and spring and suggest that spring burning may assist to maintain winter habitat. Stone's sheep have been noted to select for burned grass communities during fall, winter, and lambing (Walker and Parker 2007). Early plant senescence at higher elevations may drive use of burned areas in the fall (Walker and Parker 2007). In addition, fire results in earlier vegetation growth and availability in the spring when many resources are limited elsewhere (Walker and Parker 2007).

Wildland fire improves sight lines in sheep habitat by reducing woody plant encroachment which allows local populations to detect and avoid predators (Sittler et al. 2015, Jex et al. 2016). Shrub encroachment, shrubification, has been detected in alpine areas in the Yukon where there is potential for the treeline to transition to higher elevations over time (Reid et al. 2022). Conway (2012) found that trees on south facing slopes and flat terrain in the Kluane region have invaded 30m into grasslands in the last 60 to 80 years.

In 1983, the Government of Yukon completed a prescribed fire near Kluane Lake with the goal of reducing shrub encroachment into sheep habitat (Manfred Hoefs 2009). Hoefs (2009) stated that the fire created good habitat for sheep and moose but he did not provide further detail. A study of herbicide and fire use to reduce shrub encroachment into sheep winter range on Sheep Mountain near Faro was planned in the early 1990s (R.E. Schweinsburg 1991), but the results of this project could not be found. Hand clearing of brush and downed wood was also attempted to improve sheep habitat near Faro (Schweinsburg 1990). Sheep did not appear to increase use of the treated habitat; however, this was likely a result of clearing activities occurring when sheep were in the area, leading to avoidance of workers (Schweinsburg 1990).

Thinhorn Forage Species and Fire

There is limited available research about the influence of fire on specific thinhorn sheep forage and browse. To address this knowledge gap, we compiled known forage species for thinhorn sheep, their general response to fire, methods of regeneration, palatability, root depth and other relevant information using the USDA Fire Effects information System (Appendix 1). This work ought to be built upon as knowledge is shared and gathered through the Yukon Wild Sheep Foundation Prescribed Fire Program. We strongly recommend considering the role that fire plays in the successful propagation, maintenance and conservation of important forage and browse species for thinhorn sheep.

Related Species: The Influence of Fire on Bighorn Sheep
Though bighorn sheep (*Ovis canadensis*) occur at lower latitudes, they are closely related to thinhorn sheep and occupy similar mountainous habitats. Bighorn sheep have been found to favour fire-maintained habitat as fire exclusion can negatively alter plant presence, decrease forage availability, and reduce security through obscuring sight lines (Chapman and Feldhamer 1982). In Colorado, vegetation change due to fire suppression between 1962 and 1977 led to increased forest and shrub cover and a decreased rock land cover (Wakelyn 1987). This reduced the availability of both high and moderate visibility habitat, escape terrain, and potential high use habitat for bighorn sheep. Sheep were crowded into remaining high visibility areas and their traditional migration routes were altered (Wakelyn 1987). Bentz and Woodward (1988) found that bighorn sheep in the Rocky Mountains of Alberta used burned areas more than adjacent unburned areas, even up to 61 years post fire. They suggested that this was due to improved sight lines, rather than changes in forage quality or quantity (Bentz and Woodard 1988).

Prescribed fire emulates historical fire regimes to aid sheep migration, improve sight lines and maneuverability (BC Ministry of Forests 2022). Most prescribed fire practitioners and Indigenous Fire Stewards consider prescribed fire as an ecological process occurring across the land. Others may recognize prescribed fire as a tool to increase the availability and quality of bighorn sheep forage (BC Ministry of Forests 2022, Whiting et al. 2023). Low-intensity wildfires or prescribed fires maintain productive understory plant communities in winter range (Northern Wild Sheep and Goat Council 2022). Prescribed fire in Colorado was found to improve the winter diet quality of both bighorn sheep and mule deer, likely by increasing the amount of green grass available (Hobbs and Spowart 1984). Early green-up of burned soils may lead to multiple flushes of young, high quality forage across landscapes where there is a patchwork of burned and unburned areas (Hobbs and Spowart 1984). Forage from recently disturbed plant communities produced by fire was preferred to forage from older grasslands in early and mid winter in Montana, likely due to recently burned vegetation remaining partially green throughout the winter (Riggs and Peek 1980). However, the availability of recently burned vegetation dropped by approximately two thirds during midwinter due to heavy snow cover, whereas climax grasslands tended to be on convex topography so remained largely available (Riggs and Peek 1980).

Prescribed fire creates favourable open habitat and restores habitat connectivity for sheep. Ostovar (1998) noted frequent use of recently burned areas near summer range in Yellowstone National Park, likely due to the removal of large stands of coniferous trees. Allen et al. (2016) suggested that prescribed fire or tree removal could be used to restore connectivity between isolated populations of bighorn sheep in the Okanagan Valley. Smith et al. (1999) noted a 148% increase in bighorn sheep use of burned sagebrush after prescribed fire in Utah, including expansion of sheep into previously unused locations. Rams, ewes, and yearlings all used burned and logged areas and group sizes increased after these treatments (Smith et al. 1999). However, the authors emphasized that repeat treatments would likely be required in both logged and burned areas to maintain sight lines over time (Smith et al. 1999). This consideration remains valid for current day prescribed fire programs globally and specifically in Canada.

Schirokauer (1996) suggested that replacement of naturally occurring wildfire with prescribed fire is important in the maintenance of bighorn sheep habitat. However, the presence of private structures and other concerns limit the effectiveness of a policy which allows wildfires to burn. Therefore, it is increasingly important to maintain local, state, and federal prescribed fire programs (Schirokauer 1996). Schirokauer (1996) suggests that the top priority for the application of prescribed should be areas of bighorn sheep habitat experiencing conifer encroachment (Schirokauer 1996). They highlight that the value of a burned site depends on factors such as proximity to escape terrain (Schirokauer 1996).

Prescribed fire positively influences bighorn sheep, however, adverse climatic conditions or competition may curtail its benefits. Clapp and Beck (2016) found increased bighorn use of areas treated with prescribed fire in Wyoming. However, a late season wildfire, which occurred in drought conditions, was associated with increased sheep mortality the following spring (Clapp and Beck 2016). They recommend caution when burning in drought conditions as other factors may influence forage availability (Clapp and Beck 2016).

Fire may increase dietary overlap between bighorn sheep and mule deer leading to competition for resources in winter or early spring (Spowart and Hobbs 1985). Spowart and Hobbs (1985) found increased overlap in the diets of domestic bighorn sheep and mule deer after fire, largely due to increased grass and decreased browse consumption by deer (Spowart and Hobbs 1985). However, dietary overlap appeared to be greatest in spring when forage was abundant, reducing the probability of significant competitive stress (Spowart and Hobbs 1985). A consideration for the Yukon is that multiple species will likely be attracted to recently burned areas through the process known as pyric herbivory, the fire-grazing interaction. To ensure that concentrated grazing lawns do not create an increase in competition for forage and browse resources, strategic application of fire across multiple prescribed fire units nested within landscape or watershed boundaries will be the best option moving forward.

Beyond North America: The Influence of Fire on Argali Sheep (*Ovis ammon*)

Bragin et al. (2017) used habitat suitability models to identify preferred habitat of Argali sheep (*Ovis ammon*) and Siberian ibex (*Capra siberia*) in Mongolia. Sheep and ibex presence was correlated to low-density shrub and short grass areas. Though fire was not mentioned, their results indicate habitat preference similar to North American wild sheep, preferring open, short grass/shrub environments. Bragin et al. (2017) suggest that their model could assist park managers make informed decisions about how to improve habitat conditions in protected areas. This study, combined with similar information from North America may also help guide prescribed fire or other habitat enhancement practices for Dall sheep.

Yukon Fire Regime

Mountain Fires

Information on the modern-day Yukon fire regimes was gained by examining the Yukon Government fire occurrence dataset. Fire perimeters dating from 1946 to 2021 can be visualized by decade using an open version of ArcGIS on-line (Government of Yukon 2016). A defunct Fire Atlas Project, also available on-line (Government of Yukon n.d.), provides statistical fire occurrence analysis on fire distribution by cause (lightning vs human) and region for the period from 1950 to 2001.

The frequency and size of fires in the Yukon varies notably by location. There is an unequal spatial distribution of large-size fires (≥ 200 ha), both lightning- and human-caused, over the Yukon Territory (Figure 3). This is likely partially due to lightning strike shadows (locations where lighting is uncommon) in areas that are less commonly burned. Lightning shadows are most often associated with high mountain ranges, as is the case in Kluane National Park and Reserve where lightning fire ignitions are very rarely recorded (Hawkes 1983). They have also been identified in the southern Canadian Rockies (Wierzchowski et al. 2002).

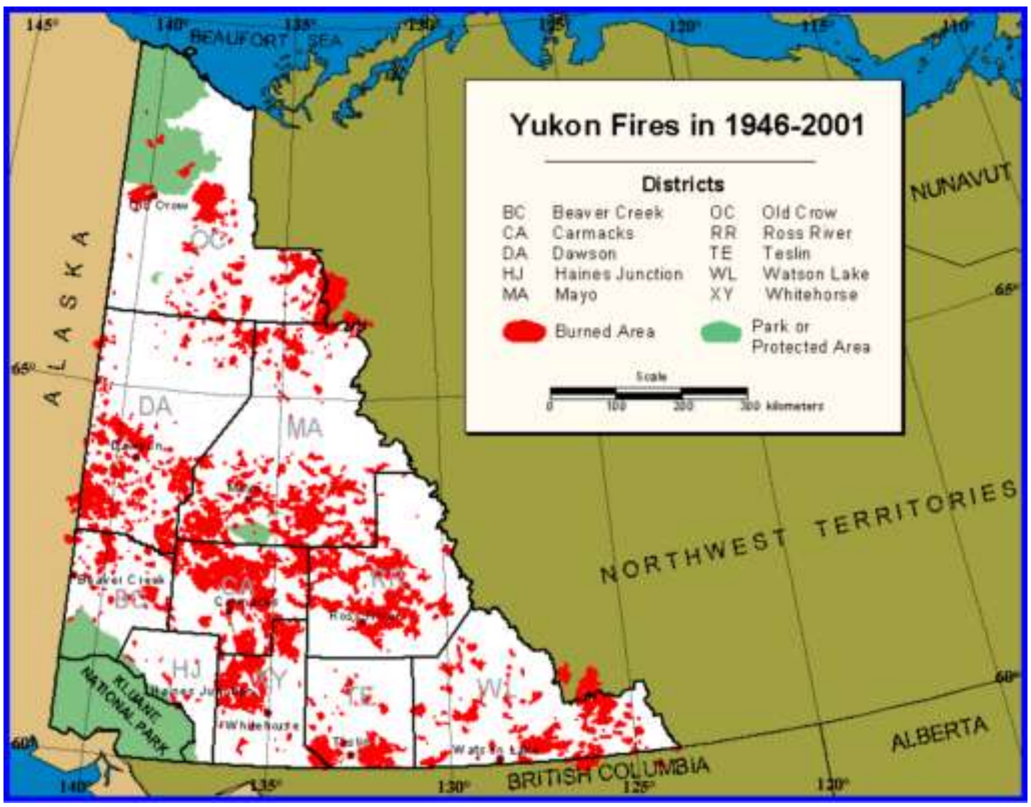

Figure 3. Distribution of large size fires (≥ 200 ha) between 1946 and 2001. Source: Yukon Fire Atlas.

Rugged mountainous ecosystems, dissected by rocky ridges, appear to be subject to far fewer fires than regions with uninterrupted forest cover (Figure 4). In such regions, fires tend to be smaller as burning is bound by rocky ridges which restrict spread to forested valley bottoms (Rogeau et al. 2016).

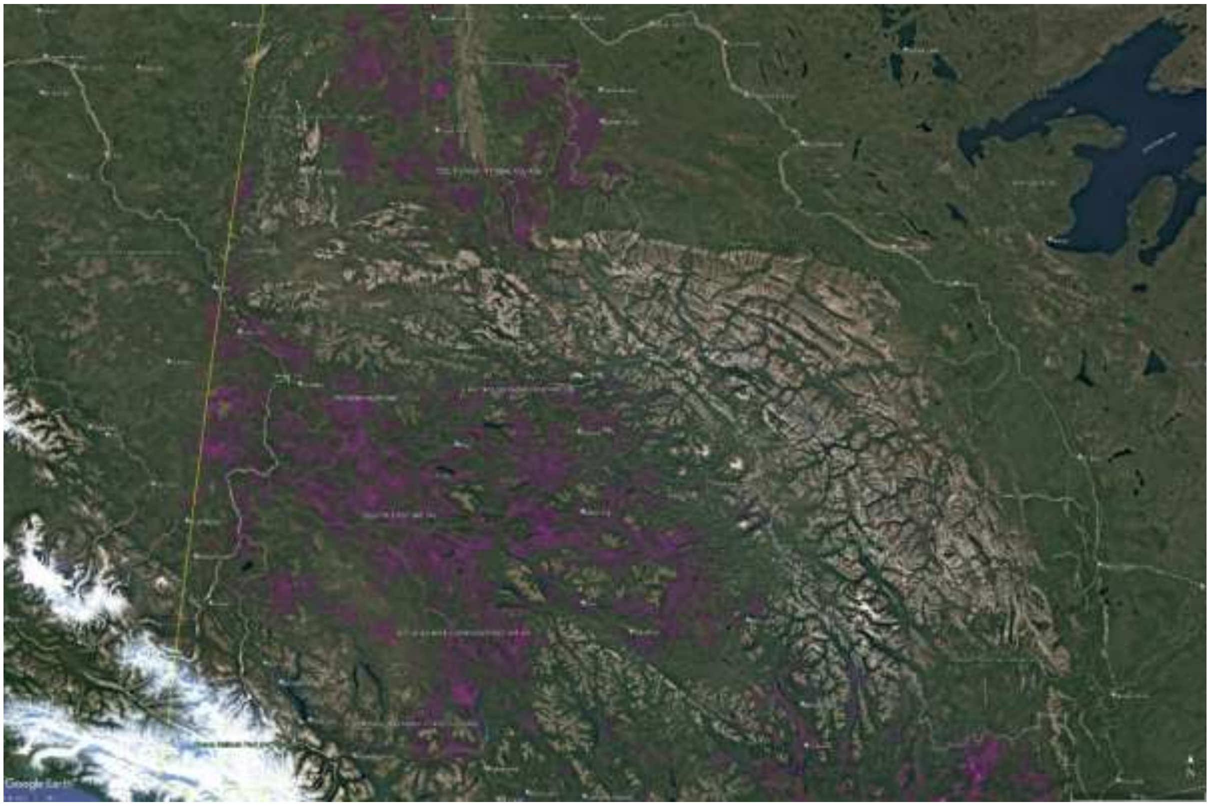

Figure 4. Burned areas from 1946 to 2021 (purple areas) overlaid on Google Earth imagery. The darker tones of purple indicate an overlap in fires.

Topographic features, such as aspect and elevation, also play a significant role on fire spread patterns, notably during spring and fall. A study from the Southern Canadian Rockies, which has similar topography as mountainous parts of the east and central Yukon, found that south-facing aspects at lower elevations burned twice as often as cool and high-elevation slopes during the pre-industrial era (Rogeau and Armstrong 2017). A similar pattern was observed in the foothills, but to a lesser degree. A study from another region of the Canadian Rockies found that survival of forest patches through multiple fires was closely tied to topographic features including high elevations near the treeline, cool aspects, small creek basins running perpendicular to main valleys, and the amount of non-vegetation coverage (i.e. fuel breaks) present in the area (Rogeau et al. 2018).

Parts of the Yukon with continuous fuel and gentler terrain may experience larger and more frequent fires than mountainous regions. *Regional Ecosystems of West-Central Yukon* (Grods et al. 2012) state that the Yukon and Klondike Plateau ecoregions have some of the highest levels of fire activity in the territory, with an average fire cycle of 100 years. They suggest that this is due to summer thunderstorms bringing a high density of lightning strikes combined with the rolling, forested terrain with few topographic fuel breaks. In extreme fire years, up to 20% of the Klondike Plateau can burn in a single season. This may lead to large areas of shrub and deciduous forest being present in the region over time.

Fires managers in the rugged mountain landscapes associated with thinhorn sheep habitat will need to consider the wide spatial variability of fire frequency (notably influenced by aspect and elevation) and be mindful of potential fire impacts in ecosystems that are regulated by long fire-free intervals.

Naturally drier conditions on south-facing slopes may be ideal for the application of prescribed fire and in such locations, combined with increased summer drought or higher temperature due to changing climate, may contribute to burning that increases desired fire effects of as well as to test forest resilience. These fires could aim to change ecosystems to benefit or create open sheep habitat. A dry environment may favour the regeneration of hardy vegetation such as grasses above that of trees or shrubs, to the potential benefit of local sheep populations.

Indigenous Fire in the Yukon

Prescribed fire was historically implemented by Yukon Indigenous groups. There is evidence that Kluane First Nation practiced intentional burning to enhance habitat for game and improve hunting practices (Kluane First Nation 2022). In 2023, Kluane First Nation and the Government of Yukon completed a prescribed fire in Duke Meadows with the purpose of reducing shrub and tree encroachment into the area (Government of Yukon n.d.). The final results of this project are pending, but field crews noted that burned plots appeared to have greener, lusher vegetation than unburned areas (Government of Yukon n.d.).

Members of Teslin Tlingit First Nations also had an interaction with fire historically. Interviewees from Teslin in 2013 stated that they had heard of fire being used to improve moose habitat in the past (Timko et al. 2015). Several interviewees also stated that fires were needed to maintain the environment and fire suppression was leading the forests to become overgrown (Timko et al. 2015).

Fire History in the Yukon

Dr. Stephen Pyne (2007) eloquently scripted a brief fire history of the Yukon which is relevant to consider as we move forward with the Yukon Wild Sheep Foundation’s vision of a prescribed fire program for the Territory:

> *“… The Yukon Valley sucked in thunderstorms that occasionally sparked fire bursts, and by remaining unglaciated it had known anthropogenic fire for longer than anywhere else in Canada. If its geography made fire urgent, its history made fire unique.*

Those facts combined into a land of two fire geographies, one hard and one soft. There is a hard matrix of deep structure and long rhythms, a tough template of terrain and climate that extends back into the Pleistocene by which lightning concentrates in the central valley where summer moisture plies up the long reach of the Yukon River, with a particularly heavy focus around the Klondike River. Fires clump like placers with the difference between sites varying as much as hundredfold. Big fires rage and vanish with the peculiar lumpiness of boreal burning. The second geography is a soft pattern shaped by people. It is a mobile matrix of sudden shakings and abrupt restructurings, a land of tight fire corridors and sprawling fire rushes as people change how and why they come and go and how they release and hold fire. Both the hard and the soft matrices are regimes of boom and bust; they can co-exist, each in its own realm, but they can also clash with explosive violence. By the end of the twentieth century, fires were equally divided in their cause between people and lightning, which is to say the two geographies enjoyed a rough balance.

…The dual geography of fire in the Yukon had a startling clarity. Compared with most provinces, the Yukon faced a simpler task in principle and a harder one in practice. The principle was to keep each fire to its assigned place, to let the long rhythm of the hard matrix beat as it would and to contain the fires of the soft matrix within the fire suppression levees thrown around the corridors of human traffic and habitation. The crunch came in practice, for no institution could hold big fires to a predestined place any more than it could hold a thunderstorm to a single hill. Boreal fires could not be turned up and down like the flames of a gas stove by twisting a bureaucratic dial. What mattered most were the bad seasons and the big fires that could conceivably obliterate small communities nestled like nuggets amid the flammable placers of the boreal forest. Those fires continued, often, as in 1982, after policy reform and reorganization.

What mattered was their larger setting, and that was the problem on the horizon, the glowing spark in the deep duff. With each year, it became harder to separate the two realms. The deep matrix was regrowing its coniferous coating and so recovering its ancient capacity for expansive boreal fire, even as the soft matrix matrix of roads and settlements proliferated, forcing proportionally more of the land into higher protection status, gerrymandering the landscape into more borders and less bulk, developing exurban burls and sending out new branches. Each border crowded against the other, and each pushed back. The two geographies blurred and, if unchecked, would require near-blanket coverage of the backcountry to protect the fractal borders thrown up by a new-character colonization.

…The future depended on whether the soft matrix could hold, for if its borders blurred too deeply, no fire agency could contain wildfire except by a forward strategy that would prove ruinously expensive and hopelessly insufficient when the Big One came. No Canadian agency could face down such a fire, and no other had such need to hope it would not have to."

Considerations

Limited Research
The full extensive literature review explores a range of subjects relating to thinhorn sheep, bighorn sheep and fire. However, it is important to note that research specifically examining the interaction between thinhorn sheep and fire is limited. In addition, most of the publications found relating thinhorn sheep and fire discuss Stone's sheep in northern BC, rather than Dall sheep in the Yukon.

Winter Availability of Forage
Increased forage abundance due to fire may not be available to sheep in winter. Seip and Bunnel (1985b, 1985a) noted that, though there were greater levels of forage in subalpine areas cleared by fire than by processes such as landslides or avalanches in the Northern Rockies, most burne areas were inaccessible to sheep in winter due to deep snow. This is significant as winter is when sheep are most likely to be nutritionally stressed. Seip and Bunnel (1985b) suggest targeting windswept ridges or other areas with limited snow cover for prescribed fire.

Stone's Sheep Versus Dall Sheep: Habitat and Shrub Encroachment
Hoefs (1979) raised the concern that the influence of fire on thinhorn sheep in the Yukon may differ from northeast BC due to differing habitat use. Yukon Dall sheep appear to have a more defined vertical distribution across the year, meaning that they may use burned areas at different times than sheep in BC (Hoefs 1979). In addition, subalpine sheep habitat in the Yukon is commonly dominated by deciduous shrubs (Hoefs 1979). Waterreus and Alexander (1996) found that prescribed fires in Talbot Arm (1983) and Red Ridge (1993-1994) in the Yukon did not reduce shrub encroachment. In fact, the Red Ridge area had increased biomass of woody plants one-year post-fire.

Competition and Predation
There is potential for fire to increase competition between thinhorn sheep and other northern ungulates. Of particular concern is whether fire will attract elk into thinhorn sheep habitat, leading to increased competition for resources in burned areas (Walker and Parker 2007, Sittler et al. 2014). However, research by Sittler et al. (2014) found that elk tended to remain at lower elevations and less rugged terrain than Stone's sheep in BC, reducing competition risk. Similarly, Jung et al. (2015) noted significant dietary overlap between wood bison and thinhorn sheep in southwest Yukon, raising the potential for competition between these species. However, they state that differing habitat use between sheep and bison may mitigate potential competitive impacts (Jung et al. 2015). Jung et al. (2015) concluded that further research is required to assess interactions between these species. They did not find high dietary overlap between sheep and elk, moose, mule deer, woodland caribou in their study area region (Jung et al. 2015).

The potential for fire to attract competing ungulate species into sheep range has also raised concerns about predator-prey dynamics. If ungulate populations increase on a burned landscape, predators may likely move to the area (Milakovic 2008). This may increase predation risk to local thinhorn sheep. Concerns about competition and predation emphasize the need for monitoring of burned sheep habitat to determine the influence of fire on species dynamics.

Public Reticence
In the past, there was much less interest in using fire to enhance sheep habitat after the attempted prescribed fire near Kluane Lake in 1985 (Manfred Hoefs 2009). This fire, planned by the Yukon Wildlife Branch, was intended to reduce shrub encroachment and increase grass production on local sheep range. The burn site was abandoned when it appeared that ignitions were not successful. However, small smouldering fires were burning in the soil in hidden locations. These fires later developed into an uncontrolled wildfire during hot, windy weather (Manfred Hoefs 2009). Though modern thermal imaging allows easier detection of hot spots, events such as this can lead to public and government reticence to allow prescribed fire on the land.

Current Work and Future Research

Further research may assist the discussion and interpretation of the role that wildland fire in conserving and maintaining thinhorn sheep habitat in the Yukon. The Wild Sheep Engagement Program, administered by the BC Wild Sheep Council and Wild Sheep Foundation aims to use prescribed fire to improve Stone's sheep habitat in BC (Wild Sheep Foundation 2024, Wild Sheep Society of British Columbia 2024). Blueberry River First Nation presented the Landscape Disturbance Matrix as the pathway to manage wildland fire throughout northeast BC and the Muskwa-Kechika Management Area (Leverkus et al. 2018). The US Fish and Wildlife Service is currently undertaking the *Dall Sheep Response to Fire Project* at Kenai National Wildlife Refuge in Alaska (US Fish and Wildlife Service 2024). Though results are pending, these projects will help to build knowledge on the influence of fire on thinhorn sheep.

Prescribed fire in the Yukon will be foundational in expanding knowledge for decision makers, wildlife and habitat managers, wildland fire professionals, and others keen on putting good fire out on the land. Increasing the capacity to safely implement, monitor, contain, and complete prescribed fire burn plans across spatiotemporal scales in the Yukon is fundamental for the conservation of thinhorn sheep habitat in a changing climate.

Future research questions for consideration include:

- What are the differences between wildland fire in BC compared to the Yukon and how do they relate to thinhorn sheep in both locations?
- What is the influence of wildland fire in the reduction of shrubification in the Yukon? What indices are required to reduce vertical structure of deciduous shrub encroachment into Dall sheep habitat and what is the response of forage under these indices?
- What is the interaction between wildland fire and competition between ungulates?
- Does fire influence the nutrition and digestibility of forage in specific Dall sheep ranges?
- Is there an interaction between wildland fire and health of thinhorn sheep?

Conclusion

There is evidence that fire benefits thinhorn sheep by increasing forage quantity and digestibility, reducing woody plant encroachment thereby increasing migration routes and sight lines for predator detection. Prescribed fire is known to reduce parasite loads and to positively influence habitat for multiple species across the globe. At lower elevations, prescribed fire enhances bighorn sheep habitat and studies suggests that it can provide similar benefits to thinhorn sheep in the Yukon.

While research on the relationship between thinhorn sheep and fire, particularly Dall's sheep, is limited, implementing prescribed fire and strategically incorporating wildfire can still occur in a safe and efficient manner. The strategic application of fire over time and across multiple prescribed fire units nested within landscape or watershed bounds is greatly recommended to move the Yukon Wild Sheep Foundation Prescribed Fire Program forward.

Literature Cited

Allen, C. H., L. Parrott, and C. Kyle. 2016. An individual-based modelling approach to estimate landscape connectivity for bighorn sheep (*Ovis canadensis*). PeerJ 4:e2001.

BC Ministry of Forests. 2022. Habitat enhancement for *Ovis canadensis* at Bull Mountain through prescribed fire.

Bentz, J. A., and P. M. Woodard. 1988. Vegetation characteristics and bighorn sheep use on burned and unburned areas in Alberta. Wildlife Society Bulletin (1973-2006) 16:186–193.

Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis dalli*. Mammalian Species 393:1–7.

Bragin, N., S. Amgalanbaatar, G. Wingard, and R. P. Reading. 2017. Creating a model of habitat suitability using vegetation and ruggedness for *Ovis ammon* and *Capra sibirica* (Artiodactyla: Bovidae) in Mongolia. Journal of Asia-Pacific Biodiversity 10:390–395.

Chapman, J. A., and G. A. Feldhamer. 1982. Wild mammals of North America: Biology, management and economics. Johns Hopkins University Press., Baltimore, Maryland.

Clapp, J. G., and J. L. Beck. 2016. Short-term impacts of fire-mediated habitat alterations on an isolated bighorn sheep population. Fire Ecology 12:80–98.

Conway, A. J. 2012. An investigation of forest-grassland dynamics in Southwest Yukon, Canada. Queen's University, Kingston, Ontario.

Geist, V. 1971. Mountain sheep: A study in behaviour and evolution. University of Chicago Press, Chicago and London.

Government of Yukon. 2016. Fire perimeters by decade – 1950s to 2020s.

Government of Yukon. 2023a. Brooks Arm, Ruby Range & Killermun sheep population surveys – 2022: Summary of 2022 survey report. Government of Yukon.

Government of Yukon. 2023b. Kluane region sheep population surveys – 2023: Summary of 2023 survey results. Government of Yukon.

Government of Yukon. 2024, July 5. Thinhorn Sheep. https://yukon.ca/en/outdoor-recreation-and-wildlife/yukon-wildlife/dalls-sheep.

Government of Yukon. (n.d.). Yukon Fire History Atlas.

Government of Yukon. (n.d.). Duke Meadows prescribed fire vegetation monitoring: Poster.

Grods, J., S. R. Francis, J. C. Meikle, and S. Lapointe. 2012. Regional Ecosystems of West-Central Yukon. Part 1: Ecosystem Descriptions. Environment, Government of Yukon by Makonis Consulting Ltd. and Associates., West Kelowna, BC.

Hawkes, B. C. 1983. Fire history and ecology of forest ecosystems in Kluane National Park: Fire management implications. Page Resource Dynamics of the Boreal Zone. Canadian Forestry Service, Thunder Bay, Ontario.

Hobbs, N. T., and R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. The Journal of Wildlife Management 48:551–560.

Hoefs, M. 1979. The use of prescribed burning to improve Dall sheep habitat in the Yukon. Pages 183–189 Proceedings of Workshop - "Wildlife and Wildfire." Yukon Wildlife Branch in Whitehorse, Whitehorse, Yukon, Canada.

Jex, B. A., J. B. Ayotte, V. C. Bleich, C. E. Brewer, D. L. Bruning, T. M. Hegel, N. C. Larter, R. A. Schwanke, H. M. Schwantje, and M. W. Wagner. 2016. Thinhorn sheep: Conservation challenges and management strategies for the 21st century. Wild Sheep Working Group, Western Association of Fish and Wildlife Agencies.

Jung, T. S., S. A. Stotyn, and S. M. Czetwertynski. 2015. Dietary overlap and potential competition in a dynamic ungulate community in northwestern Canada. The Journal of Wildlife Management 79:1277–1285.

Kluane First Nation. 2022. Kluane First Nation Forest Resources Management Plan. Kluane First Nation.

Leverkus, S.E.R., S.D. Fuhlendorf, M. Geertsema, R.D. Elmore, D.M. Engle, and K.A. Baum. 2017. A landscape disturbance matrix for conserving biodiversity. Journal of Ecosystems and Management 17(1):1-26.

Leverkus, S.E.R., J.D. Scasta, R.L. Concepcion, M. Lavallée, and K. White. 2018. Peace-Liard Prescribed Fire Program: Part A – Rationale. Shifting Mosaics Consulting, Fort Nelson, British Columbia, Canada in partial fulfillment of contract # GS18FSJ0006 for the BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, Fort St. John, British Columbia, Canada.

Luckhurst, A. J. 1973. Stone sheep and their habitat in the northern Rocky Mountain foothills of British Columbia. University of British Columbia, Vancouver, British Columbia.

Manfred Hoefs. 2009. Highlights of wildlife management in the Yukon during the seventies and early eighties with emphasis on sheep.

Milakovic, B. 2008. Defining the Predator Landscape of Northeastern British Columbia. University of Northern British Columbia, Prince George, BC.

Northern Wild Sheep and Goat Council. 2022. Position statement - Impacts of climate change on mountain goats and their habitats: Considerations for conservation, management and mitigation. Northern Wild Sheep and Goat Council.

Ostovar, K. 1998, December. Impacts of human activity on bighorn sheep in Yellowstone National Park. Montana State University, Bozeman, Montana.

Pyne, S. 2007. Awful Splendour: A Fire History of Canada. UBC Press.

R.E. Schweinsburg. 1991. Habitat improvement through brush control on sheep winter range, Faro, Yukon. Technical Report, Government of Yukon, Whitehorse, Yukon.

Reid, K. A., D. G. Reid, and C. D. Brown. 2022. Patterns of vegetation change in Yukon: recent findings and future research in dynamic subarctic ecosystems. Environmental Reviews 30:380–401.

Riggs, R. A., and J. M. Peek. 1980. Mountain sheep habitat-use patterns related to post-fire succession. The Journal of Wildlife Management 44:933–938.

Rogeau, M.-P., and G. W. Armstrong. 2017. Quantifying the effect of elevation and aspect on fire return intervals in the Canadian Rocky Mountains. Forest Ecology and Management 384:248–261.

Rogeau, M.-P., Q. E. Barber, and M.-A. Parisien. 2018. Effect of topography on persistent fire refugia of the Canadian Rocky Mountains. Forests 9:285.

Rogeau, M.-P., M. D. Flannigan, B. C. Hawkes, M.-A. Parisien, and R. Arthur. 2016. Spatial and temporal variations of fire regimes in the Canadian Rocky Mountains and foothills of southern Alberta. International Journal of Wildland Fire 25:1117–1130.

Schirokauer, D. 1996, April. The effects of 55 years of vegetative change on bighorn sheep habitat in the Sun River area of Montana. University of Montana, Missoula, Montana.

Schweinsburg, R. 1990. Report on habitat clearing project for Fannin sheep in Faro, Yukon. Government of Yukon.

Seip, D. R., and F. L. Bunnell. 1985a. Nutrition of Stone's sheep on burned and unburned ranges. The Journal of Wildlife Management 49:397–405.

Seip, D. R., and F. L. Bunnell. 1985b. Range burning, Stone's sheep, and the leaky bucket. Pages 44–47 Fire's Effects on Wildlife Habitat - Symposium Proceedings. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Seip, D. R., and F. L. Bunnell. 1985c. Foraging behaviour and food habits of Stone's sheep. Canadian Journal of Zoology 63:1638–1646.

Shifting Mosaics Consulting. 2024. Risk assessment of respiratory pathogen transmission from domestic small ruminants to thinhorn sheep and mountain goats in the Yukon and northern British Columbia. Shifting Mosiacs Report 24.03, Fort Nelson, British Columbia.

Sittler, K. L. 2014. Influence of prescribed fire on Stone's sheep and Rocky Mountain elk: Forage characteristics and resource separation. University of Northern British Columbia, Prince George, British Columbia.

Sittler, K. L., K. L. Parker, and M. P. Gillingham. 2015. Resource separation by mountain ungulates on a landscape modified by fire. The Journal of Wildlife Management 79:591–604.

Sittler, K. L., K. L. Parker, M. Gillingham, R. Wheate, and D. C. Heard. 2014. Burning for northern mountain ungulates: Effects of prescribed fire. Research Extension Note, Natural Resources and Environmental Studies Institute, University of Northern British Columbia, Prince George, British Columbia.

Smith, T. S., P. J. Hardin, and J. T. Flinders. 1999. Response of bighorn sheep to clear-cut logging and prescribed burning. Wildlife Society Bulletin 27:840–845.

Spowart, R. A., and N. T. Hobbs. 1985. Effects of fire on diet overlap between mule deer and mountain sheep. The Journal of Wildlife Management 49:942–946.

Timko, J., S. Green, R. Sharples, and A. Grinde. 2015. Using a community-driven approach to identify local forest and climate change priorities in Teslin, Yukon. Cogent Social Sciences 1.

US Fish and Wildlife Service. 2024. Dall's sheep response to fire: Fecal sample raw collection data. https://catalog.data.gov/dataset/dalls-sheep-response-to-fire-fecal-sample-raw-collection-data.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51:904–912.

Walker, A. B. D., and K. L. Parker. 2007. Habitat selection and behavioural strategies of Stone's sheep in the Besa-Prophet. Part 2 of project "An ecosystem approach to habitat capability modelling and cumulative effects management. University of British Columbia, Prince George, British Columbia, Canada.

Walker, A. B. D., K. L. Parker, M. P. Gillingham, D. D. Gustine, and R. J. Lay. 2007. Habitat selection by female Stone's sheep in relation to vegetation, topography, and risk of predation. Écoscience 14:55–70.

Waterreus, M., and S. A. Alexander. 1996. The effects of prescribed fire on vegetation on the south slope of Red Ridge, southwest Yukon. Progress Report, Government of Yukon.

Weir, J., and D. Scasta (eds.). 2022. Global Application of Prescribed Fire. CSIRO Publishing, Clayton South, Victoria.

Whiting, J. C., V. C. Bleich, R. T. Bowyer, and C. W. Epps. 2023. Restoration of bighorn sheep: History, successes, and remaining conservation issues. Frontiers in Ecology and Evolution 11.

Wierzchowski, J., M. Heathcott, and M. D. Flannigan. 2002. Lightning and lightning fire, central cordillera, Canada. International Journal of Wildland Fire 11:41–51.

Wild Sheep Foundation. 2024. Stone's sheep habitat enhancement in B.C.: 600 hectares of habitat enhanced in 2024. http://wildsheepfoundation.org.

Wild Sheep Society of British Columbia. 2024. All Projects. https://www.wildsheepsociety.com/all-projects.

Appendix 1: Thinhorn Sheep Forage and Fire

Table 1. Summary of thinhorn sheep forage species and their response to fire. Citations identifying forage species are included in the table. Citations relating to fire response are in the reference table below and are sourced in the USDA Fire Effects Information System. Many of the graminoid species are agronomic (agriculturally grown) and they are not recommended to be incorporated in a genetically native seed mix on native rangelands. However, future research could investigate the response to fire by native grasses, forbs, and shrubs selected by thinhorn sheep.

Common Name	Latin Name	Study Location	Citation (Forage Species)	Response to Fire	Fire Citation
Bluegrass	*Poa* spp.	Toad River, BC (Muskwa and Stone Range)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia. Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	(Specifically, Kentucky bluegrass/*Poa pratensis*) **Rhizomatous** **Palatability:** Very palatable (spring for ungulates when green/succulent). **Nutritional Value:** Extremely nutritious early on, once plant begins to flower, nutrition decreases. **Roots:** Shallow root system. **Regeneration:** Produces many seeds. **Fire Effects:** Timing of fire, and growth stage of the plant is key for fire response. *Season and severity*: Low severity fires conducted when the plants are dormant have little effect. High severity, late spring fires usually reduce cover, while early spring, summer, and fall fires of low to moderate severity have less impact or may promote growth. *Frequency*: A fire may reduce Kentucky bluegrass abundance temporarily, but it usually recovers within 1-3 years if it is not burned multiple times. *Moisture:* This species is more susceptible to fire damage in drier conditions.	1

Brome	*Bromus* spp.	General (lit. review)	Bowyer, R., and David M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	(Specifically fringed brome/*Bromus ciliatus*) **Non-rhizomatous** **Palatability:** Highly palatable. **Roots:** Well-developed root system. **Reproduction:** Reproduces from seed. Wind pollinated. **Fire Effects:** Top killed in most fires. Low tolerance to fires of moderate to high severity (likely due to being non-rhizomatous). Regeneration on burned areas is generally from seeds migrating in from off-site.	2
Reedgrass	*Calamagrostis canadensis*	SW Yukon	Bowyer, R. T., Leslie, D. M. Jr. and J. L. Rachlow. 2000. Dall's and Stone's sheep. Pages 491-544 in S. Demarais. and P. R. Krausman. Ecology and Management of Large Mammals in North America. Prentice Hall, Upper Saddle River, New Jersey	**Rhizomatous** **Palatability:** Palatable when young. **Roots:** Generally shallow. **Sexual reproduction:** Wind pollinated, seeds remain viable in soil for up to five years. **Vegetative reproduction:** Growth from rhizomes, creates network during growing season. **Fire Effects:** Rhizomes may survive fire. Wind dispersed seeds may colonize burned areas. *Drought*: During drought shoots have low moisture content—making regeneration difficult. *Severity*: *C. canadensis* typically sprouts from surviving rhizomes after low severity fires. Light surface burning has been shown to increase abundance. Moderate severity fires are also likely to only kill aboveground vegetation leaving rhizomes intact. High severity fires can kill below ground rhizomes. *C. canadensis* may sprout from wind-dispersed seeds whether or not rhizomes are destroyed during fire.	3

Wild rye	*Elymus* spp.	Toad River, BC (Muskwa and Stone Range)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia.	**Rhizomatous** **Roots:** Within the 1st 2.5 feet (0.76 m) of soil. **Regeneration:** Highly germinable plant. Seedlings are robust and can establish rapidly. **Fire Effects:** Can re-establish after fire through surviving rhizomes or seeds. Heat transfer to buds below the surface is often not substantial. *Season:* Responds poorly to early spring fire. Best response comes from summer fires. A study in Iowa showed growth began earlier in February burned areas compared to unburned. Broadcast seeding led to a high yield of plants when done on a forested area after a late summer fire in Idaho.	4
Fescue	*Festuca* spp.	Toad River, BC (Muskwa and Stone Range)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia. Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	(Specifically Red fescue/*Festuca rubra*) **Rhizomatous** **Palatability:** Moderate during summer, fair for livestock **Reproduction**: Reproduces by seeds or spreads vegetatively. Can spread via rhizomes **Fire Effects:** NOTE: Limited information on USDA Fire Effects Information System. No information available on short-term response to fire. Culms and leaves likely killed by fire. A study in northern BC/Yukon notes that the species existed in spotty distribution in lower elevations after fire. ***Festuca rubra* is introduced and not native**. Red fescue was able to establish fair to excellent stands in Idaho. **CAUTION: May outcompete native species in areas it is introduced to.** *For successful burning*: Soil should be dry, with enough wind to produce quick, thorough fire. Fires regulates how fescue grows in an area.	5

Sedges	*Carex* spp.	Toad River, BC (Muskwa and Stone Range)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia. Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	Fire may increase the *Carex* spp. growth in some incidences to the point where it suppresses regeneration of other species. May require moderate fires and ample seed sources of various alternate species nearby to create a diverse community that will not be immediately encroached on by *Carex* spp.	6
Yarrow	*Achillea* spp.	Toad River, BC (Muskwa and Stone Range)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia.	**Rhizomatous** **Fire Effects:** Can regenerate rapidly on burned areas through rhizomes or wind dispersed seeds. Research has suggested that yarrow frequency may exceed pre- fire levels by the 3rd year post-burn. Rhizomes often only sustain minor damage from fire but may be destroyed by severe burns. *Achillea* spp. have low ignitability.	7
Willows	*Salix* sp.	Toad River, BC General (lit review)	Seip, D. R., and F. L. Bunnell. 1985c. Foraging behaviour and food habits of Stone's sheep. Canadian Journal of Zoology 63:1638–1646. Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	*Salix* spp. tend to regenerate well after fire. A high proportion of *Salix* spp. existing on site may resprout following a burn.	8

Birds eye berries/ bearberry/ kinnikinnick	*Arctostaphylos uva-ursi*	NWT and Yukon	Benson, K. 2023. Gwich'in knowledge of Divii (Dall's sheep): Community-based monitoring and traditional knowledge of the Richardson Mountains Divii (Dall's Sheep) population. Gwich'in Tribal Council Department of Culture and Heritage.	**Rhizomatous** **Palatability:** Extremely palatable for wildlife. **Roots:** Fairly deep root system. **Reproduction:** Primarily asexual. **Habitat:** Usually found in well-drained soils that have low levels of clay and silt. **Fire Effects:** Response depends on factors such as fire severity and soil conditions. Seeds in the soil often survive and may be stimulated to germinate by fire. However, cover may be reduced. *Severity: A. uva-ursi* can survive moderate severity fires if its roots are in mineral soil. However, it may be killed if its roots are in organic soil. Severe fires tend to lead to *A. uva-ursi* being shorter and having fewer sprouts. *Example of* A. uva-ursi *cover 3 Years post-fire in across various burn severities in Montana* - Unburned areas: 3.27% - Low severity: 1.80% - Moderate severity: 0.89% - High severity: None	9
Blueberry	*Vaccinium* spp.	Toad River, BC (Muskwa and Stone Range) General (lit review)	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia. Bowyer, R., and D. M. Jr. Leslie. 1992. *Ovis Dalli*. Mammalian Species 393: 1–7.	(Specifically, bog blueberry/*Vaccinium uliginosum*) **Rhizomatous** **Palatability**: Fair to moderate **Regeneration:** Vegetative and sexual reproduction, can colonize exposed mineral soil, seeds often dispersed by birds or other animals **Soils**: Grow in acidic soils **Fire Effects:** *Severity:* Fire typically top kills *V. uliginosum.* It may sprout from surviving rhizomes after low severity fires, but moderate to high severity fire can destroy these underground structures. It may only survive fire areas where the organic layer is not fully consumed.	10

				Seeds, leaves, and berries: Fire destroys *V. uliginosum* seeds. Seeds must be dispersed into a burned area from other locations for regeneration. *V. uliginosum* leaves may be larger in burned areas. Berry production may be delayed for a few years post-fire but flower production is greater on burned than unburned sites.	
Fringed sage	*Artemiesia frigida*	Southwest Yukon	Jung, T. S., S. A. Stotyn, and S. M. Czetwertynski. 2015. Dietary overlap and potential competition in a dynamic ungulate community in northwestern Canada. The Journal of Wildlife Management 79:1277–1285.	**Rhizomatous** **Palatability**: Low for livestock, fair for wildlife, eaten when other food sources are scarce. **Regeneration:** Reproduces by seed from both ray and disc flowers, wind pollinated, no seeds are produced in dry years. **Fire Effects:** Typically to-killed by fire. May resprout from the stem base after burning. *A. frigida* seedlings may re-establish quickly after fire, However, it may only be able to re-establish immediately after fire if competition is reduced. Density may return to pre-burn levels by the third year after fire. However density has been reduced by spring and fall burns in mixed grass areas of the Canada Great Plains.	11
Lichen	*Cladonia sp.*	Toad River, BC (Muskwa and Stone Range) Southwest Yukon	Seip, D. R. 1983. Foraging ecology and nutrition of Stone's sheep. Fish and Wildlife Report, BC Ministry of Environment, Victora, British Columbia. Jung, T. S., S. A. Stotyn, and S. M. Czetwertynski. 2015. Dietary overlap and potential competition in a dynamic ungulate community in northwestern Canada. The Journal of Wildlife Management 79:1277–1285.	NOTE: There is limited information in the USDA Fire Effects Information System about lichens. Fire may improve habitat for various lichen species through altering tree height, canopy opening or other factors.	12

Table 2. Citations relating to fire effects for each species from the USDA Fire Effects Information System.

Number	Plant	Citations
1	Bluegrass (*Poa* spp.)	Abrams, M.D. 1988. Effects of burning regime on buried seed banks and canopy coverage in a Kansas tallgrass prairie. Southwestern Naturalist 33(1): 65-70. Bushey, C.L. 1985. Summary of results from the Galena Gulch 1982 spring burns (Units 1b). Missoula, MT: Systems for Environmental Management. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana. Daubenmire, R. 1968. Ecology of fire in grasslands. Pages 209-266 in J.B. Cragg, ed. Advances in ecological research: Vol. 5. New York: Academic Press. Fulbright, T.E., Redente, E.F. and Hargis, N.E. 1982. Growing Colorado plants from seed: A state of the art: Volume II: Grasses and grasslike plants. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. Hansen, P.L., Chadde, S.W. and R.D. Pfister. 1988. Riparian dominance types of Montana. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, Montana. Hill, G.R. and Platt, W.J. 1975. Some effects of fire upon a tall grass prairie plant community in northwestern Iowa. Pages 103-114 in M.K. Wali, ed. 1975. Prairie: A multiple view. University of North Dakota Press, Grand Forks, North Dakota. McEwen, L.C. and D.R. Dietz. 1965. Shade effects on chemical composition of herbage in the Black Hills. Journal of Range Management18: 184-190. Olson, W.W. 1975. Effects of controlled burning on grassland within the Tewaukon National Wildlife Refuge. Thesis, North Dakota University of Agriculture and Applied Science, Fargo, North Dakota. Steuter, A.A., 1986. Fire behavior and standing crop characteristics on repeated seasonal burns--northern mixed prairie. Pages 54-59 in A.L. Koonce, ed. Prescribed burning in the Midwest: state-of-the-art: Proceedings of a symposium, 3-6 March 1986, Stevens Point, WI. Stevens Point, WI. Fire Science Center, College of Natural Resources, University of Wisconsin.

2	Brome (*Bromus* spp.)	Bartos, D.L. and W.F. Mueggler. 1981. Early succession in aspen communities following fire in western Wyoming. Journal of Range Management 34(4): 315-318. Boggs, K., Hansen, P., Pfister, R. and J. Joy. 1990. Classification and management of riparian and wetland sites in northwestern Montana (Draft Version). Montana Riparian Association, Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana. Harper, K.T., Sanderson, S.C. and E. D. McArthur. 1992. Riparian ecology in Zion National Park, Utah. Pages 32-42 in Clary, W.P., McArthur, E.D., Bedunah, D., Wambolt, C.L. eds. Proceedings--symposium on ecology and management of riparian shrub communities, 1991 May 29-31, Sun Valley, ID. Intermountain Research Station, Forest Service, U. S. Department of Agriculture, Ogden, Utah. Wright, H.A., and A.W. Bailey. 1980. Fire ecology and prescribed burning in the Great Plains--a research review. Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah.
3	Reedgrass (*Calamagrostis canadensis*)	Conn, J.S. and M.L. Farris. 1987. Seed viability and dormancy of 17 weed species after 21 months in Alaska. Weed Science 35: 524–529. Crane, M.F. and W. C. Fischer. 1986. Fire ecology of the forest habitat types of central Idaho. Intermountain Research Station, Forst Service, U.S. Department of Agriculture, Ogden, Utah. Hardy BBT Limited. 1989. Manual of plant species suitability for reclamation in Alberta. 2nd Edition. Alberta Land Conservation and Reclamation Council, Edmonton, Alberta. Herzman, C.W., Everson, A.C., Mickey, M.H. & others. 1959. Handbook of Colorado native grasses. Colorado State University Extension Service, Fort Collins, Colorado. Hogg, E.H. and V.J. Lieffers. 1991. The relationship between seasonal changes in rhizome carbohydrate reserves and recovery following disturbance in *Calamagrostis canadensis*. Canadian Journal of Botany 69: 641–646. MacDonald, S.E. and V.J. Lieffers. 1991. Population variation, outcrossing, and colonization of disturbed areas by *Calamagrostis canadensis*: Evidence from allozyme analysis. American Journal of Botany 78(8): 1123–1129. Smith, D.W. and T.D.W. James. 1978. Changes in the shrub and herb layers of vegetation after prescribed burning in *Populus tremuloides* woodland in southern Ontario. Canadian Journal of Botany 56: 1792–1797. Sylvester, T.W. and R.W. Wein. 1981. Fuel characteristics of arctic plant species and simulated plant community flammability by Rothermel's model. Canadian Journal of Botany 59: 898–907.

4	Wild Rye (*Elymus* spp.)	Arno, S.F. 2000. Fire in western forest ecosystems. Pages 97-120 in J.K. Brown and J.K. Smith, eds. Wildland fire in ecosystems: Effects of fire on flora. Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah. Blake, A.K. 1935. Viability and germination of seeds and early life history of prairie plants. Ecological Monographs 5(4): 405-460. Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, Kansas. Weaver, J.E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecological Monographs 28(1): 55-78. Robocker, W.C. and B. J. Miller. 1955. Effects of clipping, burning and competition on establishment and survival of some native grasses in Wisconsin. Journal of Range Management 8: 117-120. Howe, H.F. 1994. Response of early- and late-flowering plants to fire season in experimental prairies. Ecological Applications 4(1): 121-133. Wheeler, W.A. and D.D. Hill. 1957. Grassland seeds. D. Van Nostrand Company, Princeton, New Jersey. Ehrenreich, J.H. and J.M. Aikman. 1963. An ecological study of the effect on certain management practices on native prairie in Iowa. Ecological Monographs 33(2): 113-130. Slinkard, A.E., Nurmi, E.O. and J.L. Schwendiman. 1970. Seeding burned-over lands in northern Idaho. Agricultural Experiment Station, Cooperative Extension Service, College of Agriculture, University of Idaho, Moscow, Idaho.
5	Fescue (*Festuca* spp.)	Densmore, R.V. 1992. Succession on an Alaskan tundra disturbance with and without assisted revegetation with grass. Arctic and Alpine Research 24(3): 238-243. Dittberner, P.L. and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC. Eriksson, O. 1989. Seedling dynamics and life histories in clonal plants. Oikos 55: 231-238. Hardison, J.R. 1980. Role of fire for disease control in grass seed production. Plant Disease July: 641-645. Oswald, E.T., and B.N. Brown. 1990. Vegetation establishment during 5 years following wildfire in northern British Columbia and southern Yukon Territory. Pacific Forestry Centre, Pacific and Yukon Region, Forestry Canada, Victoria, British Columbia.

		Slinkard, A.E., Nurmi, E.O. and J.L. Schwendiman. 1970. Seeding burned-over lands in northern Idaho. Agricultural Experiment Station, Cooperative Extension Service, College of Agriculture, University of Idaho, Moscow, Idaho. Wilson, S.D. 1989. The suppression of native prairie by alien species introduced for revegetation. Landscape and Urban Planning 17: 113-119.
6	Sedges (*Carex* spp.)	Halpern, C.B., Antos, J.A., McKenzie, D., and A.M. Olson. 2016. Past tree influence and prescribed fire mediate biotic interactions and community reassembly in a grassland-restoration experiment. Journal of Applied Ecology 53(1): 264–73.
7	Yarrow (*Achillea* spp.)	Hamilton, E.H. 2006. Fire effects and post-burn vegetation development in the Sub-Boreal Spruce Zone: Mackenzie (Windy Point) Site. Forest Science Program, British Columbia Ministry of Forests and Range, Victoria, British Columbia. Bourdŏt, G.W., Field R.J., and J.G.H. White. 1985. Growth analysis of *Achillea millefolium* L. (yarrow) in the presence and absence of a Competitor – *Hordem vulgare* L. (Barely). New Phytologist 101(3): 507–19. Antos, J.A., McCune, B. and C. Bara. 1983. The Effect of Fire on an Ungrazed Western Montana Grassland. American Midland Naturalist 110(2): 354. Aleksoff, K.C. 1999. *Achillea Millefolium.* In: Fire Effects Information System. Fire Sciences Laboratory, Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture. https://www.fs.usda.gov/database/feis/plants/forb/achmil/all.html. Hogenbirk, J.C. and C.L. Sarrazin-Delay. 1995. Using fuel characteristics to estimate plant ignitability for fire hazard reduction. Water, Air, & Soil Pollution 82(1–2): 161–70.
8	Willows (*Salix* spp.)	Stein, S.J., Price, P.W., Abrahamson, W.G. and C.F. Sacchi. 1992. The Effect of fire on stimulating willow regrowth and subsequent attack by grasshoppers and elk. Oikos 65: 190–96.
9	Birds eye berries (*Arctostaphylos uva-ursi)*	Arno, S.F. Simmerman, D.G. and R.E. Keane. 1985. Forest succession on four habitat types in western Montana. Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah. Bradley, A.F. 1984. Rhizome morphology, soil distribution, and the potential fire survival of eight woody understory species in western Montana. Thesis, University of Montana, Missoula, Montana. Klinka, K., Krajina, V.J., Ceska, A. and A.M. Scagel. 1989. Indicator plants of coastal British Columbia. University of British Columbia Press, Vancouver, British Columbia.

		Mallik, A.U. and C.H. Gimingham.1985. Ecological effects of heather burning. II. Effects on seed germination and vegetative regeneration. Journal of Ecology 73: 633-644. Nimlos, T.J. Van Meter, W.P. and L.A Daniels. 1968. Rooting patterns of forest understory species as determined by radioiodine absorption. Ecology 49(6): 1145-1151. Rowe, J.S. 1983. Concepts of fire effects on plant individuals and species. Paged 135-154 in Wein, R.W. and D.A. MacLean eds. SCOPE 18: The role of fire in northern circumpolar ecosystems. John Wiley & Sons, Chichester; New York. Stark, N. and R. Steele. 1977. Nutrient content of forest shrubs following burning. American Journal of Botany 64(10): 1218-1224.
10	Blueberry (*Vaccinium* spp.)	Chapin, F.S.III and K. Van Cleve. 1981. Plant nutrient absorption and retention under differing fire regimes. Pages 301-321 in Mooney, H. A.; Bonnicksen, T.M.; Christensen, N.L. Lotan, J.E. and W.A. Reinsers. Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Forest Service, U.S. Department of Agriculture, Washington, DC. Dayton, W.A. 1931. Important western browse plants. U.S. Department of Agriculture., Washington, DC. Kershaw, G.P. 1988. The use of controlled surface disturbances in the testing of reclamation treatments in the subarctic. Pages 59-70 in Kershaw, P. ed. Northern environmental disturbances. Boreal Institute for Northern Studies, University of Alberta, Edmonton, Alberta. Lutz, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. Forest Service, U.S. Department of Agriculture. Washington, DC. Maillette, L. 1988. Apparent commensalism among three *Vaccinium* species on a climatic gradient. Journal of Ecology 76: 877-888. Martin, Patricia A. E. 1979. Productivity and taxonomy of the *Vaccinium globulare*, *V. membranaceum* complex in western Montana. Thesis, University of Montana, Missoula, Montana. Morin, H. and S. Payette. 1988. Buried seed populations in the montane, subalpine, and alpine belts of Mont Jacques-Cartier, Quebec. Canadian Journal of Botany 66: 101-107. Wein, R.W. 1974. Recovery of vegetation in arctic regions after burning. Canadian Task Force on Northern Oil Development, Ottawa, Ontario.

11	Fringed sage (*Artemiesia frigida)*	Bailey, A.W. and M.L. Anderson. 1978. Prescribed burning of a *Festuca-Stipa* grassland. Journal of Range Management 31: 446-449. Cawker, K.B. 1983. Fire history and grassland vegetation change: Three pollen diagrams from southern British Columbia. Canadian Journal of Botany 61: 1126-1139. Coupland, R.T. 1950. Ecology of mixed prairie in Canada. Ecological Monographs 20(4): 271-315. Dittberner, P.L. and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC. Wasser, C.H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC. Whisenant, Steven G.; Uresk, Dan W. [n.d.]. Effects of fire on vital attributes of a South Dakota, mixed prairie. Draft manuscript, Fire Sciences Laboratory, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Missoula, Montana. Wright, H.A. and R. Thompson. 1978. Fire effects. In Prairie prescribed burning symposium and workshop: Proceedings; 1978 April 25-28; Jamestown, ND: V-1 to V-12. ire Sciences Laboratory, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Missoula, Montana.
12	Lichen (*Cladonia* spp.)	Lafleur, B., Zouaoui, S., Fenton, N.J., Drapeau, P., and Y. 2016. Bergeron. Short-Term response of *Cladonia* lichen communities to logging and fire in boreal forests. Forest Ecology and Management 372: 44–52.