INCORPORATING AN ETHIC OF CONTEXT AND PLACE IN MECHANISTIC RESEARCH: A PLACE-BASED WILDFIRE RISK ASSESSMENT IN THE XÁXLI'P SURVIVAL TERRITORY

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Abstract

Wildfires pose a significant economic and social challenge to communities throughout British Columbia. For some Indigenous communities, a large landscape fire has the potential to change their traditional territory and communities permanently. To allocate limited resources to the costly effort of wildfire mitigation, communities need a baseline for the spatial distribution of risk. For the Xáxli'p and their community forest, the wildfire risk is an urgent concern, locally effected by forest fuels, human ignition, and wind. Local knowledge of community members gathered through workshops were used to validate existing forest, wind, and access data. Using existing data and community data, areas of higher risk and other landscape considerations were identified and mapped to support planning by the Xáxli'p Community Forest to create a fire-resilient landscape.

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I am also grateful for the autonomy provided and encouraged by my supervisor Scott Green and committee members Herb Hammond and Agnes Pawlowska-Mainville to learn, explore and create my own experience. The learning this allowed (and pushed me towards) has no substitute.

Chapter 1: Introduction to the Xáxli'p Community Forest, the Research Collaboration and Wildfire

Research Introduction

This research is a partnership with the Xáxli'p Community Forest (XCF), created by and for the Xaxli'pmec of Fountain Valley in what they refer to as their "Survival Territory." The relationships between Indigenous communities and researchers have a history of imbalance (L. Smith, 1999), with many researchers misrepresenting these communities and claiming expertise through the "objective" scientific method that often removes relationships in deference to statistics and classifications (L. Smith, 1999). Guided by Indigenist philosophy and community-directed methods, this research explores how western science can support Indigenous knowledge and self-determination – specifically supporting Xáxli'p eco-cultural restoration and wildfire mitigation by providing specific technical expertise and resources.

Throughout colonial history in Canada, Indigenous peoples have been forced to make considerable cultural compromise and adaptations when differences arose, subjecting them to government and institutional authority and practice (King, 2012). The Xáxli'p Survival Territory was claimed by the crown and sold, their language and traditional livelihoods were suppressed, and their children were sent to residential school (Drake-Terry, 1989; T. Smith, 1998). With such legacies, the burden should now be on researchers to put in the work and reach across this cultural gap to help create solutions that are suitable for the individual culture and unique setting of the community.

Research Grounded in People and Place

Xáxli'p is an Indigenous community located in the mountains of southwestern British Columbia in the Pavilion Ranges eco-section (Ministry of Environment and Climate Change Strategy - Knowledge Management, 2019) 10 km east of Lillooet looking over the Fraser River from Fountain Valley (Figure 1). They are a member of the Lillooet Tribal Council and the second-largest community of the St'át'imc Nation with around 1059 members, about 263 who live on their reserves (Indigenous and Northern Affairs Canada, 2019).

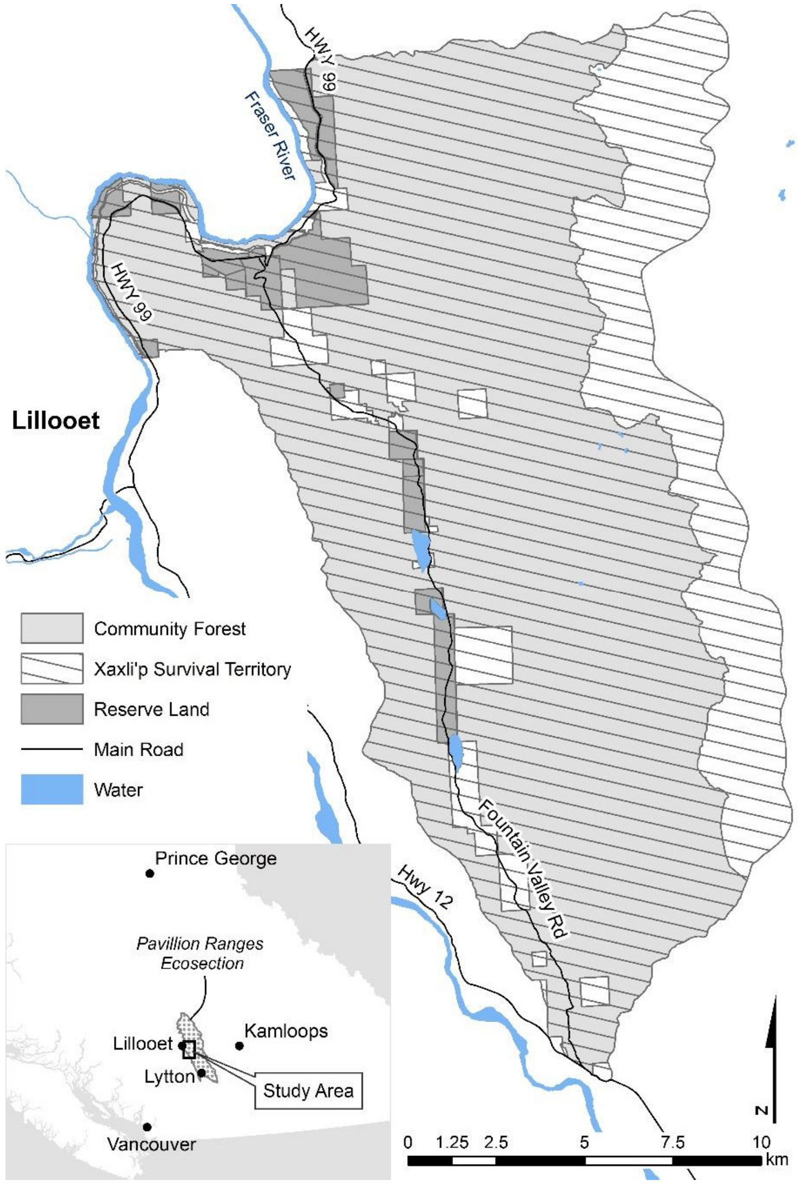


Figure 1: Boundaries of the Xáxli'p Survival Territory and Community Forest.

The Xáxli'p traditional territory covers about 31,419 ha from the height of land on the western side of Fountain Valley to past the height of land east of the valley (Diver, 2016). Xáxli'p community members started referring to this area as the "Xáxli'p Survival Territory" after a Xáxli'p Elder coined the phrase at a community meeting because txhough their traditional territory covers a small area it provided for their livelihood for thousands of years (Diver, 2016). The core of the Survival Territory is Fountain Valley, where the local topography transitions from the Fraser River Valley at about 200 m above sea level (asl) to a valley which connects back to the Fraser River Valley at the south end surrounded by steep and rugged mountains reaching over 2000 m asl. Xáxli'p means "brow of the hill" reflecting the location of their main village at the north end of the valley on a terrace above the Fraser River (Xáxli'p, 2017).

The Xáxli'p connection with this land goes back millennia, with evidence that the region was occupied 8000 years ago, with nearby archaeological sites of villages dating back 1,600 – 2,600 years (Diver, 2016). The Survival Territory provided for the Xáxli'p (and continues to in a reduced scope today); "from a birds-eye view of looking down in Fountain Valley, it's like an oasis within an arid area" (Diver, 2016, p. 31), creating habitat for deer for hunting, berries and plants for food and medicines, and annual salmon runs in the Fraser River which still brings Xáxli'p families to their fishing holes in August to catch and dry salmon in the winds off the Fraser (Diver, 2016; Xáxli'p Community Forest, 2017). A network of historic trails traces the territory connecting different ecosystems and elevations and are an essential part of Xáxli'p culture used today by hunters and the community to bring youth up into the mountains (Diver, 2016; Xáxli'p Community Forest, 2017). The Traditional Ecological Knowledge (TEK) of Xáxli'p Elders is rooted in the wisdom of many generations of ancestors that lived in the Survival Territory, and their way of life depends on relationships with the land and passing that on to future generations.

The last century has brought ranching, recreational development and high grade-logging in the Survival Territory. However, with the valley's small size, the community recognizes that resource extraction cannot be hidden away without impacting them. Due to the ecological importance of water in the arid climate, maintaining the local hydrology is a priority for community members (Weinstein, 1995), which led to the XCF gradually ending grazing and clear-cut logging in the valley by 2008 (Diver, 2016).

Xáxli'p Pursuit of Self-determination.

The Xáxli'p "Mission Statement" to guide their strategic planning is characterized by several key goals: "to be proud, independent, self-sufficient Xáxli'pemc and continue to pursue a land settlement with the Canadian Government; to work with the best interest of Xáxl'ipmec with support, trust and respect of one another; and for all to be open-minded" (Xáxli'p, 2017). In accordance with the goals, the Xáxli'p have a long history of resistance against the loss of control of their Survival Territory and strategically working to regain self-determination starting with the Declaration of the Lillooet Tribe, logging blockades, and treaty negotiations (Figure 2) through to the recent procurement of a Community Forest Agreement in 2011.

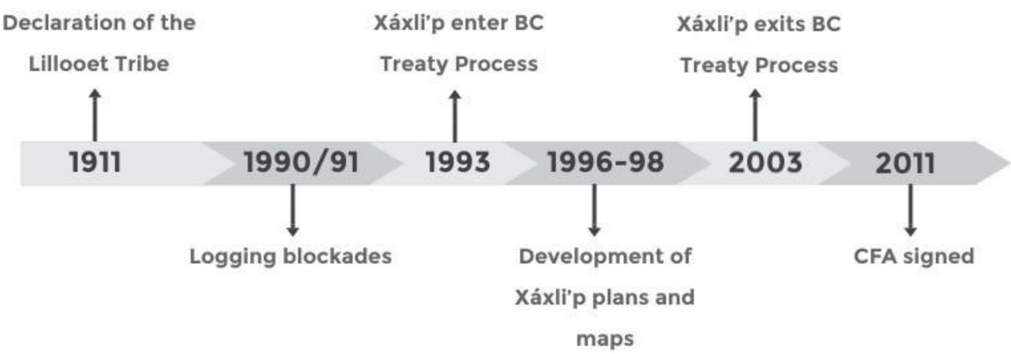


Figure 2: Timeline of some key Xáxli'p events towards achieving self-determination (Diver, 2016).

The changes on the landscape observed by Xáxli'p community members have been a significant consequence of the appropriation of Xáxli'p authority under colonialism. Having a Community Forest Agreement in place affords the Xáxli'p community greater autonomy towards ensuring that the integral social, cultural and land relationships can continue for future generations. The Community Forest Agreement with the provincial government covers 23,265 ha, of the 31,419 ha Xáxli'p Survival Territory and excludes private land and reserves in the valley bottom, as well as the eastern edge of the territory (Figure 1). It is managed under the Xáxli'p Community Forest (XCF), and this arrangement is viewed by the Xáxli'p community as an interim measure to protect the land until they regain title (Diver, 2016). From the XCF mission statement, "considering the needs of present and future generations, the XCF carries out ecologically and culturally sustainable land use for the benefit of Xaxli'pmec and other beings in our Survival Territory" (Xáxli'p

Community Forest, 2013). The XCF team consists of a board of directors that guide the mandate of the XCF, a forest crew that implements the eco-cultural restoration work, a forester and office staff that manage the implementation (Figure 3) as well as the Range Riders who travel around the territory maintaining a physical presence on the land. The focus of the XCF eco-cultural restoration is to "restore degraded ecosystems, to restore cultural resources and activities, and to create a sustainable community economy based on high quality, value-added timber and non-timber forest products" (Xáxli'p Community Forest, 2017).

Figure 3: XCF forest crew and staff spring/summer 2017 (Green, S. 2017).

Collaboration for Localized Solutions

In past land-management work, the Xáxli'p community has emphasized that creativity and flexibility were necessary for negotiations between cultures; they are deliberately trying not to emulate existing systems of land management but are looking to create locally suitable plans that support their cultural values (Diver, 2016; Weinstein, 1995). This approach aligns well with the Indigenist research methodology (described in the next section), placing importance on the research team working closely with the XCF team to ensure culturally appropriate, place-based research and solutions.

To create localized, useful information for community-directed research, the limitations of existing data and processes must be acknowledged, and place-based solutions such as Traditional Ecological Knowledge (TEK) should be implemented. TEK is qualitative, observational, long-term and highly localized knowledge that should not be generalized to other environments or locations (Kimmerer, 2000). Likewise, for this partnership with the XCF, it is a long-term project that will generate site-specific information, not assume to be transferrable beyond its borders.

A major concern of the Xáxli'p community is keeping their TEK relevant in the wake of changes wrought by resource extraction, wildfire suppression and climate change. The potential erosion of their TEK will have consequences on inter-generational relationships when youth no longer see value in the obsolete knowledge of their Elders that rely on intricate landscape relationships (Weinstein, 1995), creating a barrier to cultural continuance. A large wildfire that could significantly change the ecosystem poses an existential threat to Xáxli'p traditions and culture, and in response to this, the XCF team is interested in obtaining a clearer understanding of the forest fuels and their spatial dispersal in order to manage them to reduce this risk.

Research Objective.

This research was initiated by and designed closely with the XCF to follow their direction and priorities that emerged over the research period and to provide culturally appropriate and localized research. In conversations with Sybil Diver (Diver, 2016), community member Roger Adolf highlights those priorities:

> "We knew that we had to do something up here in Fountain Valley. We really needed (tree) spacing. Because the other thing that we were afraid of was forest fires. Because if we didn't do anything about the land, the land might be endangered. Spacing was really important – which we have done a lot of… but at the same time, we always wanted to do our own logging, and protect the water mainly." (Diver, 2016, p. 42).

The goal of this research is to provide the XCF team with information and resources to support their eco-cultural restoration objectives, primarily related to wildfire risk that threatens their cultural continuance. One definition for wildfire risk is the probability that a fire will change the net value of the forest resources (Thompson & Calkin, 2011); for the Xáxli'p community, the 'net value' is not limited to infrastructure or focused on loss of future income from the trees, but includes all relationships with the land that supports their cultural continuance.

As the first stage of research laying the groundwork of what will hopefully be a long-term partnership between UNBC and the Xáxli'p Community Forest, the objective of the research is to address the following questions: 1) What is the wildfire risk in the Xáxli'p Survival Territory? 2) What data and data quality gaps exist to answer this question? And 3) What can we do with the existing data for XCF land management until we have more locally suitable data?

The existing datasets and systems for fuel classification used by the British Columbia government and many other practitioners are not necessarily the best resources for local use because they are created using extrapolated assumptions and measurements to service the whole range of ecosystems in Canada with a particular focus on boreal forests (Forestry Canada, 1992; Perrakis & Eade, 2016). With these systemic limitations, it is useful to bring in TEK to build suitable solutions for Indigenous land management where "disagreements between TEK and resource management policies do not prevent collaboration, but rather indicate places where national narratives may not fit local environments, making traditional ecological knowledge and regional science essential to sustainable management" (Ray, Kolden, & Chapin III, 2012). Following this collaborative understanding, this project seeks to improve local classifications building on the detailed data collected by the XCF forest crew and Xáxli'p knowledge of their territory to start developing the datasets required for wildfire modelling.

Applying Indigenist Philosophy

For some, Indigenist research is meant to be undertaken exclusively by Indigenous people in their own communities (Coghlan & Brydon-Miller, 2014). For this research, we take a philosophy more aligned with Rix, Wilson, Sheehan and Tujague (2018) in which the view is that "Indigenist research respects and honors Indigenous ways of knowing, being, and doing through using methods that are informed by, resonate with, and are driven and supported by Indigenous peoples" and allows space for non-Indigenous people to apply this way of thinking (Wilson, 2013). Indigenist philosophy is not about claiming ideas, but about the relationship with the ideas, how they shape you and you shape them, and the complex relationships between different ideas and people (Wilson, 2013). For non-Indigenous researchers like myself, an important starting point is acknowledging that I have a non-Xáxli'p worldview, and an exploration of the differences (Rix et al., 2018). Therefore everything I observe and learn about the Xáxli'p Survival Territory and community is interpreted through my worldview or "epistemological lens" (Absolon & Willett, 2005), which does not capture the entire story.

Relationality captures the approach of being mindful of the interconnectedness between everything; people, landscapes, and ideas are all in relation to one another, and we are our relationships (Wilson, 2013). For Xáxli'p people, their land ethic focuses on relationships and responsibilities, highlighting the importance of thinking of future generations and the dynamics and learning between generations (Weinstein, 1995).

> "It all falls into the same dish, if you will. If you don't have trees, you don't have life. And it just keeps going right down the chain. If you don't have trees you don't have water, and water is our survival." - David Adolf (Diver, 2016, p. 159).

From an institutional perspective, the land is a pool of resources we manage, rather than us being intimately part of the landscape with complex relationships tying us to all parts (Leopold, 1949). By seeing it exclusively for its resources, the exploitation of the land compartmentalizes and simplifies those relationships. Xáxli'p member Arthur Adolf interviewed by Sybil Diver (2016) highlighted the limitations that institutional views introduce:

> "It's especially hard for some community leaders to see the vision when they've been trained or educated thorough a system like contemporary forestry, where the only element that they envision for an economy is exploiting the resource." - Arthur Adolf (Diver, 2016, p. 160)

Indigenist researchers must help illuminate a path to success for Indigenous communities (Wilson, 2013); therefore, it is paramount that this research supports a self-determined future for the Xáxli'p community. Researchers are accountable for creating and maintaining healthy relationships (Wilson, 2013), which in this context means sustaining essential relationships within the landscape (between the fire ecology, wildlife, hydrology, etc.) and with the people in and around it. Context is vital to Indigenist research and applying theories from other ecosystems assumes that the relationships are the same for both, which is very unlikely.

Community-Directed Research.

In community-directed projects, outsiders should support and not impose a process; the aim is for communities to define the priorities and objectives supported by scientific expertise, innovation, and research (Minkler, 2004). In the history of many Indigenous communities throughout the world and Canada, there is a colonial legacy of outside agents (NGO's, governments, industry, funders, academics, professionals) dictating research priorities and objectives through various mechanisms, including funding, expertise and colonial power and control. This has undermined the authority and wisdom of Indigenous cultures and often failed to produce meaningful benefits to local communities and ecosystems compared to the community time and money invested (Castellano, 2004; Government of Canada, 2016; L. Smith, 1999).

With the Indigenist and community-directed approach, the methodology and outcomes are not fixed; instead, they are adaptive to the emerging processes and relationships that arise during the research. The focus on community priorities that guides community-directed research aligns with the trend of measuring research success for their social, economic and environmental impact rather than through institutional indicators such as peer-reviewed publications (Proctor, 2010).

The Position of the Researcher.

Claiming objectivity is counter to Indigenist methodology where the idea of 'putting yourself forward' allows the readers to understand your relationships and bias, and holds the researcher accountable (Absolon & Willett, 2005). I grew up in the Rocky Mountain Trench in southeastern BC, between the spine of the Rockies and the wetlands of the Columbia River. My parents immigrated to Canada from Switzerland a decade before I was born, which created a family space of exploring new aspects of culture, without many entrenched rules about 'this is what culture is.' They built a space where curiosity was encouraged, and there was a keen knowledge that we are only ever understanding part of what people are communicating with us. In contrast, my background as a Western-trained scientist has been a barrier in my comprehension of Indigenist methodology and Indigenous ways of knowing because of my skill honed to classify, measure, compare and explain – stripping away the relationships and nuance. This thesis is part of my exploration and learning process so that I can be another strand supporting reconciliation. It is my sincere hope that I have respected the voice and ethic of the Xáxli'pmec in this work.

Research for Reconciliation

Given the historic power imbalance between Indigenous peoples and Canada's institutions, reconciliation must be woven into the research design, paying particular attention to decolonizing the research process (L. Smith, 1999). As outlined by the guidelines of the Truth and Reconciliation Commission of Canada (2015), research in support of reconciliation should be "supporting Aboriginal peoples' cultural revitalization and integrating Indigenous knowledge systems, oral histories, laws, protocols, and connections to the land." Reconciliation is consistent with the goals and principles of Indigenist research, which provides a framework to support the mandate for reconciliation. Non-Indigenous professionals in the natural resource sector can support reconciliation by creating, supporting and enabling the capacity within communities for self-determination through ensuring access to land and the autonomy to manage it with a set of cultural values (Wilson, 2013; Wyatt, 2008). From the beginning, it has been the intent that this research collaborates closely with the Xáxli'p Community Forest and follows their guidance to produce outcomes they can apply.

Cultural Understanding of Wildfire and Ecosystem Health

Fire is an important landscape driver throughout the Survival Territory with wide-spread evidence of fire-scarring on old trees (Figure 4) and remnant stands of widely spaced old trees that have now filled in with thickets of dense young trees since fires have been actively suppressed (Figure 5). Fire is not isolated from culture; many Indigenous cultures across North America and the world actively used fire to manage their landscapes, including the Xáxli'p (Cape York Elders, 2013; Carroll, Cohn, Paveglio, Drader, & Jakes, 2010; Mistry, Bilbao, & Berardi, 2016; Ray et al., 2012).

Figure 4: Fire scarring on old Douglas fir tree (Green, S. 2017).

Figure 5: Dense regeneration associated with wildfire suppression (Green, S. 2017).

Anthropogenic Fires

With the process of colonization, European perceptions of the wastefulness and danger of fire increased wildfire suppression efforts and increasingly discouraged and then criminalized cultural fire until many Indigenous groups had lost their traditional knowledge of fire management (Kimmerer & Lake, 2001; Pyne, 2008). Without fires on the landscape, forests became increasingly dense, which supported less frequent but larger and more intense fires (Williams, 2013), as has been observed in the Xáxli'p Survival Territory. The landscape around Lillooet has a history of anthropogenic fire like many other forests in BC (Boyd, 1999; Gray, Andrew, Blackwell, Needoba, & Steele, 2002; Lewis, Christianson, & Spinks, 2018) and has a history of low-intensity cultural burning used by the Xáxli'p to thin the underbrush and maintain a patchwork landscape of high-quality habitat for wildlife and community food and medicines (Xáxli'p Community Forest, 2017). Forest densification and ground-level fuel loading associated with fire suppression have been observed by the nearby Lytton First Nation (Lewis et al., 2018), and some community members there continue to use fires to reduce ground fuels with reduced extent and purpose compared to historic traditional use.

The difference between anthropogenic versus natural fires lies in the seasonal timing, frequency, location and extent of the fire, resulting in different outcomes on the ecosystems (Kimmerer & Lake, 2001). The seasonal timing varies by the location, the type of ecosystem, and what was to be achieved by burning. Similarly, the frequency of historic burn applications depended on what was the desired fire-outcome; grass forage could be burned every year, berry-picking areas every 3 to 5 years. The spatial extent of the fire was controlled by the timing of fire applications, natural fuel breaks, and regular burning that reduced fuel (Kimmerer & Lake, 2001). To help growing conditions and reduce the summer fire hazard in Lytton, fires were lit in spring and fall at low elevations, which burned themselves out as they travelled upslope into the forest (Lewis et al., 2018).

Fire Regime

Ecosystems that are adapted to a specific fire regime rely on certain intensities or frequencies of wildfire to endure (Alexander, Cruz, Vaillant, & L. Peterson, 2013; BC Wildfire Service, 2015). The fire regime is defined by the fire frequency, area burned, season, intensity and severity (Stephens, North, & Collins, 2015) and is determined by historical wildfire records, fire evidence in the forest, or stand composition (Gray et al., 2002; Rogeau, Parisien, & Flannigan, 2016). Fire regimes vary with forest type, geography, climate, and land management practices and is a critical influence on forest ecology.

Understanding the local fire regime is important for land management in order to avoid the oversimplification of applying national or regional narratives about the role of fire on a different ecosystem (Ray et al., 2012). The landscape around Lillooet has been shaped by fire, both natural and anthropogenic, for hundreds of years (Gray et al., 2002; Province of British Columbia, 2011); it has one of the shortest fire intervals in the province, with high variability of burn intensity (Gray et al., 2002). Though not much of the Survival Territory has burned in the last 20 years (Figure 6), sites studied nearby had a historic mean fire interval ranging from 6.6 to 11.6 years over the last 500 years (Gray et al., 2002) leaving most of the Survival Territory overdue for fire.

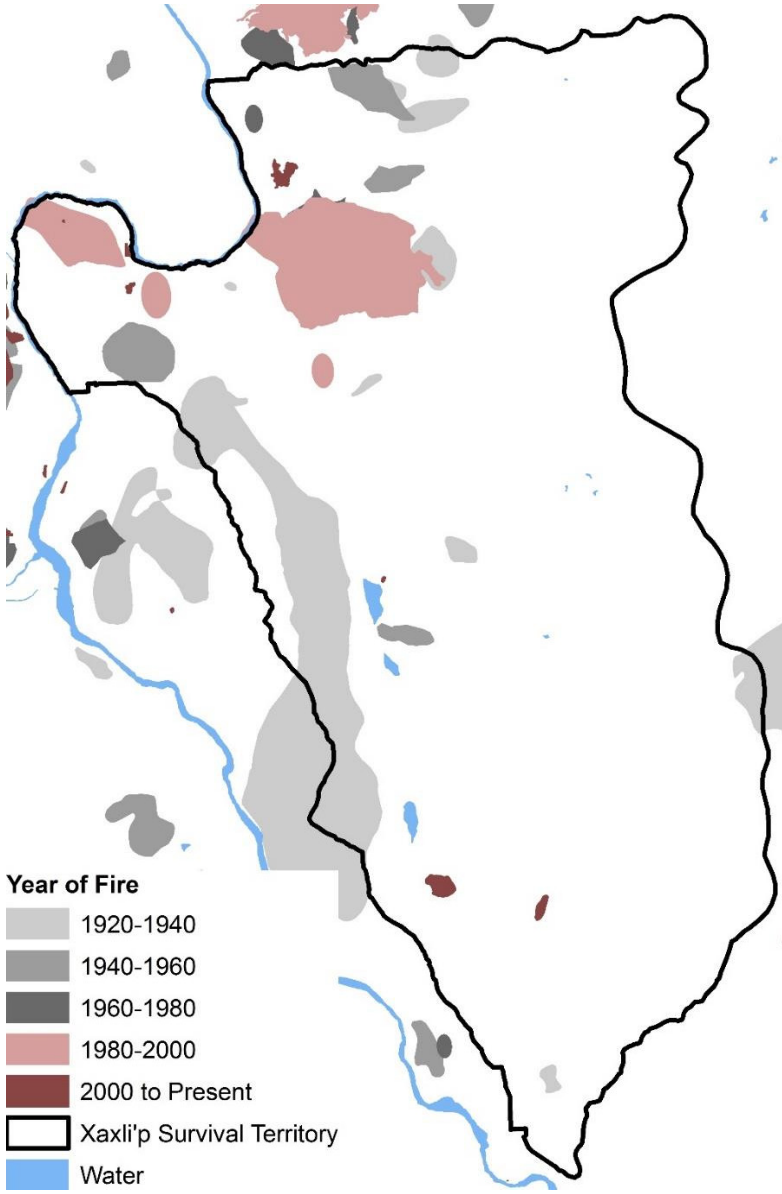


Figure 6: History of fires recorded in the Xáxli'p Survival Territory by the Provincial Government (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - BC Wildfire Service, 2019).

Land Management Effects on Wildfire Ecosystems

Fire suppression, along with high-grade logging, has been impacting Xáxli'p ecosystems since the mid-1900s, increasing forest densities. This has resulted in a lower abundance of wildlife, reduction in food and medicine plants, and caused many areas to become more arid (Xáxli'p Community Forest, 2017) because forest densification increases competition for water and has been shown to result in stressed forests in water-limited landscapes (Cáceres et al., 2015).

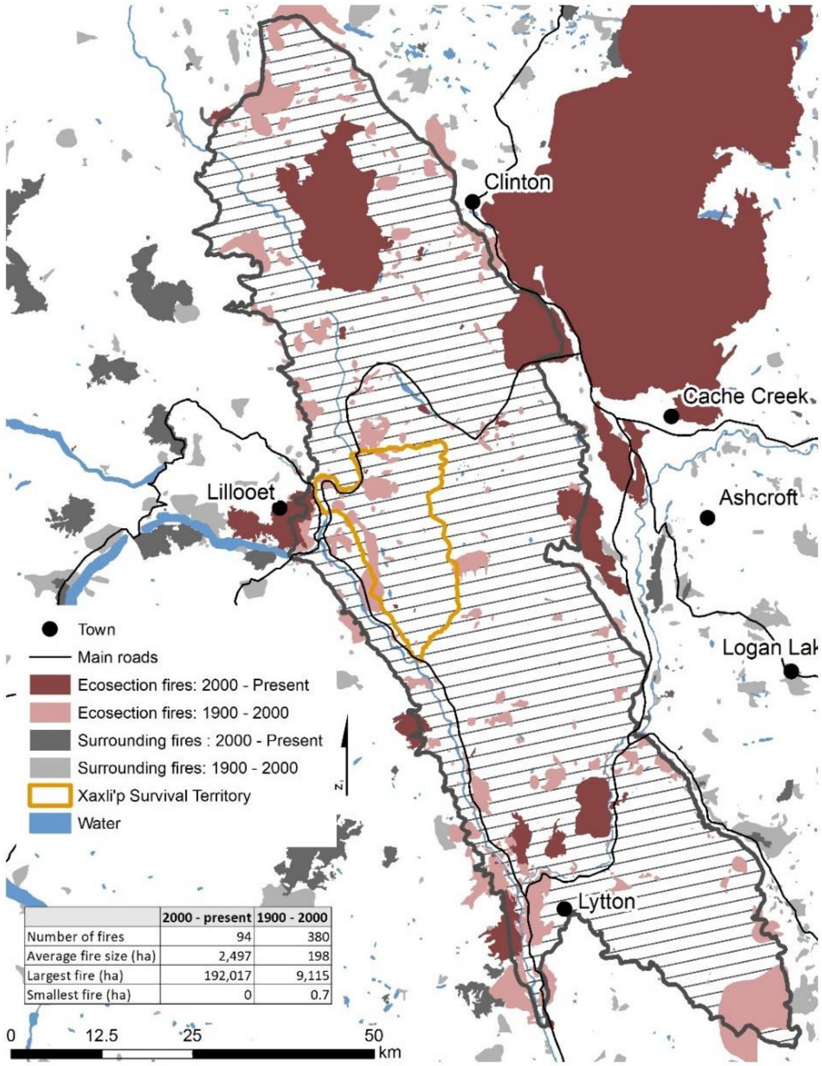
Institutional Culture of Wildfire Suppression.

In southern BC, forestry practices in the early 1900's focused on the extraction of Ponderosa Pine (Pinus ponderosa) until it became scarce, then switching to Douglas fir (Pseudotsuga menziesii). During this time, the practice was to primarily extract the largest trees, creating a considerable change in the forest structure, with smaller trees (Klenner, Walton, Arsenault, & Kremsater, 2008). There was also increased wildfire suppression throughout southern British Columbia to protect timber resources (Klenner et al., 2008).

Application of institutional forestry practices and a single wildfire narrative to diverse landscapes with different fire regimes led to a century of dramatic ecosystem changes across North America. Colonialists brought a culture of fire-suppression with them and imposed it in their new environment, curtailing the traditional use of fire by First Nations people and increasing fire-fighting efforts (Carroll et al., 2010; Kimmerer & Lake, 2001). Many Indigenous cultures around the world are still limited in their fire use by land ownership, regulations, and the ecological legacy of wildfire suppression (Carroll et al., 2010). The imposition of these European land management practices over the past 150 years have changed forests across North America, resulting in more homogenized forests that are denser with smaller, less fire-resistant trees, and often less shrub understory (Gray et al., 2002; Hessburg et al., 2016; Kimmerer & Lake, 2001)

Fire Regime Changes on the Landscape.

Ecosystems with historic frequent, low-intensity wildfires have shown a shift to less frequent, higher intensity wildfires since the 1800s (Gray et al., 2002; Williams, 2013). In the Pavilion Ranges eco-section, the area surrounding the Xáxli'p Survival Territory including Lillooet and Lytton, 94 wildfires have overlapped the eco-section since 2000 (Figure 7), burning a total of 75,052 ha (Data BC & Ministry of Forests, Lands, Natural Resource Operations and Rural Development - BC Wildfire Service, 2019). After a century of fuel accumulation associated with wildfire suppression and climate change, wildfires in the eco-section over the last 20 years are larger than before. Low to moderate severity fire regimes like this may have missed 4 to 10 wildfire cycles in the last 150 years due to wildfire suppression in North America compared to high-severity regimes that may have only missed 1 to 2 wildfire cycles during the same period (Stephens et al., 2015). The earlier recorded fires in the Pavilion Ranges eco-section (1919-1999) had a modest average size of 198 ha, but the average wildfire size since 2000 has increased to 2,497 ha. The largest of these fires burned 192,017 ha in the 2017 Clinton/Cache Creek fire, over six times the area of the Survival Territory, highlighting the risk of a large wildfire burning through their entire territory.



	2000 - present	1900 - 2000
Number of fires	94	380
Average fire size (ha)	2,497	198
Largest fire (ha)	192,017	9,115
Smallest fire (ha)	0	0.7

Figure 7: Wildfire history in Pavilion Ranges eco-section (Ministry of Environment and Climate Change Strategy - Knowledge Management, 2019; Ministry of Forests, Lands, Natural Resource Operations and Rural Development - BC Wildfire Service, 2019).

Fuel Accumulation in Wildfire Suppressed Landscapes.

Understory fires, where the fire runs low along the ground, correspond to low wildfire severity and tend to have a short return period. These forest areas that burn frequently have more open tree spacing and less dense fuels (Figure 8), with lighter (but highly flammable) grasses and herbs resulting in lower-intensity burns. Dense coniferous forests with connected tree canopies support severe fires and burn infrequently. Mixed fire regimes like the area around Lillooet fall in between, with moderate wildfire severity over a patchwork of low and high severity areas where tree mortality is between 20 to 70 percent (Hessburg et al., 2016).

Figure 8: Open ponderosa pine stands at the south end of the Survival Territory illustrates an ecosystem characteristic of a low-intensity fire regime that is non-fatal to mature Douglas fir and ponderosa pine (Green, S. 2017).

With longer wildfire intervals (due to the natural fire regime, or because of wildfire suppression), fuel accumulation is greater, and there is denser tree spacing, thicker branches and trunks, and more dead woody debris in the forest litter (Figure 9). This increase in fuel leads to stand-replacing fire regimes where fires burn with higher severity and burn into the canopy with enough intensity to kill off mature trees (Gray et al., 2002). When the landscape connectivity of dangerous fuels increases, the area that burns in a single event may also increase, reducing the consequent forest patchiness (Gray et al., 2002). The increased wildfire intensity and area burned associated with increased fuel loading can have adverse effects on the soil, water regime, wildlife habitat, and carbon storage (Stephens et al., 2015; United Nations University, 2009). Permanent ecosystem changes have been attributed to high-intensity fires due to increased soil erosion caused by the missing organic materials resulting in trees being unable to re-establish from the lack of soil (Stephens et al., 2015).

Figure 9: Examples of forests in the Survival Territory with an accumulation of fuels from closely spaced trees and dead woody debris, increasing wildfire risk (Green 2017).

Facilitating Wildfire Risk Mitigation

More recent recognition of the adverse effects of wildfire suppression on ecosystems has led policymakers to encourage land managers to focus on returning forests to pre-settlement characteristics, which is supported by the re-integration of wildfire in land management (Kimmerer & Lake, 2001). Differences in landscapes and land-use priorities mean effective mitigation plans are unique to a location in order to balance the different physical and social factors at play. For the Xáxli'p community, managing the eco-cultural landscape and community safety is a key priority over managing for forest productivity. Their eco-cultural restoration plan prioritizes a landscape network that is healthy, resilient and supports cultural continuance (Xáxli'p Community Forest, 2017) while using standard western approaches with thinning and prescribed burns and increasingly more Indigenous management methods.

Managing the wildfire risk in wildfire suppressed landscapes is necessary to maintain ecological and cultural values due to potential consequences for ecology, health, safety and economics (Thompson & Calkin, 2011). Strategic planning requires an analysis of the risk of wildfire and its effect on the landscape in order to mitigate these effects (Thompson & Calkin, 2011). Additionally, conflicting land-use values require land managers to set landscape priorities regarding how they will manage for wildfire risk. For example, the use of wide swaths of logged and/or burned areas as fuel breaks around communities is an efficient, cost-effective method of reducing fuels. However, the public may be opposed to the resulting visual, ecological or hydrological impacts. Identifying threats on the landscape such as fuels, ignition points, weather and uncertainty around them is a critical first step for land managers trying to adjust management practices to mitigate the risk of potentially devastating wildfires (Thompson & Calkin, 2011). Addressing wildfire risk requires balancing community safety, ecosystem, cultural, timber, and health values; each is met with different mitigation measures (Ohlson, Berry, Gray, Blackwell, & Hawkes, 2006).

Landscapes adapted to frequent ecosystem fires with high variability and patchiness dominated by fire-maintained species are considered fire-absorbent landscapes (Leverkus et al., 2017) (Figure 10). These patches provide fuel breaks on the broader landscape because they burn more frequently and, therefore, have reduced fuel loads and can absorb wildfire without becoming stand-replacing fires (Leverkus et al., 2017). The presence of fire absorbent areas within a greater landscape matrix is essential for resilience in withstanding wildfire disturbances and avoiding large-scale, high-intensity fires (Leverkus et al., 2017).

Figure 10: Open patches visible in the foreground as well as on the opposite side of the valley build a fire absorbent landscape in parts of the Xáxli'p Survival Territory (XCF Forest Crew, 2017).

Variations in topography, weather, forest structure, and fuels can dramatically affect the behaviour of a wildfire moving across a landscape, resulting in variable tree and shrub mortality (Gray et al., 2002). With time, this variable mortality creates a heterogenous ecosystem with pockets of older fire-resistant forests, open shrubs, and young regeneration (Stephens et al., 2015). Steep, complex terrain, like what is in the Survival Territory, creates highly localized fire regimes (Klenner et al., 2008; Parisien, Walker, Little, Simpson, & Wang, 2012). Research on these localized fire regimes suggests that historically the low-severity fires did not likely spread far, resulting in occasional higher severity fires despite forest and climate conditions consistent with frequent low-severity burns (Klenner et al., 2008).

With the high risk that large area crown-fires pose to people and resources, forest managers seek to reduce the area of forest that supports high-severity fire, breaking it up and increasing heterogeneity and pyrodiversity by creating a landscape mosaic with both older forest stands (Hessburg et al., 2016) and younger and/or less dense forests to provide fuel breaks. Landscapes with high connectivity between dangerous fuels have greater spread and severity of fires. Restoring fire-adapted landscapes focuses on increasing heterogeneity with more forest openings and lower tree densities (Stephens et al., 2015), and focusing on creating more fire-absorbent and climate change resilient forests. To support this, land managers can prioritize restoration on ecosystems that historically had frequent wildfire activity such as valley bottoms and south-facing slopes, and use cooler, high elevations to identify fire refugia where old-growth forest patches can be maintained and created (Rogeau & Armstrong, 2017).

Xáxli'p Eco-cultural Restoration

What was likely a fire absorbent landscape before institutionalization, the Survival Territory has become quite homogenous over the past few decades. The suspension of Xáxli'p fire management has put the ecosystem in a state that will now take considerable effort, cost, and time to restore historic, pre-suppression fuel conditions. In response to such ecosystem changes, the XCF team developed an Ecosystem Based Conservation Plan (EBCP) to protect and restore areas necessary for healthy water, forests, wildlife and Xáxli'p cultural continuity (Xáxli'p Community Forest, 2019). This landscape-level plan defines a network of connected areas of protection that supports forest functions and varied land-uses while sustaining biodiversity (Hammond, 2009) and provides a project framework that integrates well with creating a fire absorbent landscape in the Xáxli'p Survival Territory. The strategic execution of the EBCP plan is vital to maximizing the efficacy of the treatments with limited community resources. A primary mechanism for rebuilding a fire-absorbent landscape has been restoration treatments undertaken by the forest crew (Figures 11 and 12) to thin the forest and reduce ladder fuels.

Figure 11: Example of an XCF restoration area with thinned trees and low branches removed (Green, S. 2017)

Figure 12: Edge of restoration area – thick regrowth associated with fire suppression (back trees) compared to restoration ecosystem (foreground) (Green, S. 2017)

Further steps will likely include larger-scale mitigation measures (such as large burns) to return the landscape to a state where incremental, multi-scale measures can be used, such as small patches of annual low-intensity burns to maintain a more traditional fire absorbent landscape. Other mitigation measures suggested by outside government reports for Fountain Valley include controlled burns of forest understory, surface fuel reduction in areas of wider tree spacing, strategic fuel treatment placement to prevent north-south fire spread, buffers around the local campground in the middle of Fountain Valley to reduce the risk of run-away campfires, fuel reduction around private properties to protect dwellings, and annual burning, irrigating or grazing of fields (Province of British Columbia, 2011).

The Components of Wildfire Risk and their Mitigation Strategies

Understanding fire behaviour is necessary to implement effective risk-mitigation measures. "Assessing wildfire risk requires an understanding of the likelihood of wildfire interacting with valued resources, and the magnitude of potentially beneficial and negative effects to resources from fire" (Thompson & Calkin, 2011). Fire behaviour is defined as "the manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather and topography" (Canadian Interagency Forest Fire Center, 2002). The three commonly recognized types of wildfires are ground fires burning the organic layer on or below the ground, surface fires burning fuels above the soil layer, and crown fires that burn in the forest canopy (Scott & Reinhardt, 2001). Fires may burn as ground or surface fires and may fizzle out on their own because of low temperatures or high moisture/relative humidity, or they may take off and spread to the forest canopy, starting a crown fire (Alexander et al., 2013). Crown fires can exhibit extreme fire behaviour with the potential to burn at high temperatures and move very quickly (Alexander et al., 2013) and as a result can pose significant risks impacting ecosystems that are not adapted to high-intensity fires and the nearby human activities (Stephens et al., 2015).

Understanding the dynamics between fuel, wind and topography informs planning and executing fuel mitigation (BC Wildfire Service, 2015) to get the best results for resource investment. As mentioned previously, efforts to reduce the threat in high-risk areas may include thinning trees, removing ladder fuels, and incorporating prescribed burns (BC Wildfire Service, 2015), which may prioritize Wildland Urban Interface's (WUI) (Province of British Columbia, 2012).

Fuel Risk Mitigation.

The trio of fuel, weather and topography determine actual fire conditions, but land managers can only directly change the fuel component, while the risks introduced by weather and topography can only be managed indirectly. As a result of decades of wildfire suppression in the Xáxli'p Survival Territory, the forest fuel loads have increased, and Xáxli'p traditional knowledge used to manage the landscape with fire has been mostly lost.

Fuels for wildfires include dead and living organic material, including standing, fallen and decomposing in the duff layer. The structure, chemistry, volume, state of decomposition of forest fuels is highly variable throughout a landscape (Gray et al., 2002), but can be roughly classified into categories that translate to their effect on fire behaviour. Coniferous forests with more small and medium-sized trees have been found to have greater wildfire severity due to the increased vertical continuity in the forest structure (ladder fuels), leading to crown fires (Alvarez, Gracia, Castellnou, & Retana, 2013). The Fire Behaviour Prediction (FBP) system is a classification system that is widely used in Canada to classify fuels

(Forestry Canada, 1992), though other systems exist and take a different approach to quantifying fuels using measured values. The categories of the FBP system can be used to identify areas with high-risk fuels to inform mitigation measures.

Research in south-central BC found that fuels had the greatest effect on wildfire behaviour, followed by weather and ignition sources (Wang et al., 2016), though fuels have been found to be less significant in other infrequent high and mixed-severity fire regimes (Alvarez et al., 2013). Methods for reducing the fuel risk include prescribed burning, forest thinning, and irrigation and grazing of fields (BC Forest Service, 2018; Province of British Columbia, 2011). The spatial pattern of fuel reduction treatments on the landscape is also key, creating fuel breaks, targeting high-risk areas, and reducing the fuel continuity by creating a patchwork of low and high-risk fuel types (Hessburg et al., 2016; Province of British Columbia, 2011). Fuel reduction and other mitigation measures are not a one-time fix; they will require ongoing work to ensure efficacy, and in many cases, require subsidies because of high resource demands and limited value of the extracted materials (Hessburg et al., 2016).

Prescribed Burning.

Traditional burning practices were (and to some extent still are) used by many Indigenous communities throughout the world to modify the environment to improve survival; it fulfilled many needs, from cleaning up village sites, creating habitat for flora and fauna that could be harvested, to destroying pests (Kimmerer & Lake, 2001). In wildfire adapted ecosystems, many species thrive with frequent low burning fires and become scarce with few fires, so the reintroduction of wildfire can restore ecosystem health as well as act as a risk management strategy. Recognizing the long term use of wildfire by Indigenous groups in many ecosystems, more institutional forest managers have come to appreciate the value of wildfire on the landscape, both economically and for the ecosystem health (Taylor & Alexander, 2006; Williams, 2013) which has encouraged the use of fire in landscape management.

Contemporary use of prescribed burning includes hazard reduction, silviculture, wildlife habitat enhancement, range burning, insect and disease control, conservation of natural ecosystems (Weber & Taylor, 1992). The management of mixed-severity forest regimes is more complex than low and high severity regimes because a patchwork and balancing of ecosystems is necessary. The use of fire for restoration requires frequently burning open forests but ensuring it is controlled and localized in order to retain adjacent areas of older, denser growth (Hessburg et al., 2016). To reduce the severity and maximize ecological benefits, applications of managed fire are restricted to moderate fire weather rather than extreme fire weather (Hessburg et al., 2016).

Thinning and Biomass Removal.

The forest crew's restoration treatments have focused primarily on reducing ladder fuels and thinning the forest density in plots around the territory (Figure 13). The location of this work was guided by the EBCP and dialogue with Elders to prioritize areas of higher value to the community for berry picking, wildlife, sensitive ecosystems and sacred areas (Diver, 2016). Thinned trees and branches are left on the ground to support water retention in these forests stands and support healthy soils; suitable sized logs are removed for firewood for the community. Thinning is a more flexible option for land managers because it can be undertaken at any time while prescribed burns have a limited season of use. Even though thinning reduces ladder fuels and stand density, it may not reduce crown fires because there is often an increase in surface fuels if they are not removed from the stand entirely, or vegetation grows up (Raymond & Peterson, 2005). The removal of trees to reduce the stand density and the removal of biomass such as dead woody debris and ladder fuels such as the lower branches of trees is recommended by the BC Forest Service (BC Forest Service, 2018).

Figure 13: Examples of forest thinning undertaken for eco-cultural restoration in the Survival Territory with debris left on the ground for ecological benefits (Green, S. 2017).

Comparison.

Highly altered landscapes may have too much fuel loading to safely and effectively consider using prescribed burns and may require initial fuel reduction before returning fire to the landscape (Hessburg et al., 2016). A combination of treatments or a phased approach over many years can be used to achieve the lowest risk and most cost-effective treatments to restore landscapes to a more fire-absorbent state. Fuel reduction through forest thinning is costly and slow while controlled burns can be applied to larger areas, but have associated issues with public perception, air quality and liability (Stephens et al., 2015).

Mechanical thinning alone does not sufficiently mimic wildfire as a disturbance, but thinning followed by prescribed burning is an effective fuel and wildfire risk management strategy that reduces more of the overall fuel load and provides ecological conditions for fire-adapted species (Hessburg et al., 2016;

Prichard, L. Peterson, & Jacobson, 2010). Using thinning to reduce young regrowth and ladder fuels associated with forest densification allows wildfires to burn through older-aged stands without high mortality (Hessburg et al., 2016). In a review of studies looking at the effect of fuel treatments on reducing wildfire severity Kalies and Yocom Kent (2016) reported that "all studies found a positive effect of at least one treatment. Several studies found that thin + burn treatments had the greatest positive effects while burning or thinning alone had either less of an effect or none at all" (Kalies & Yocom Kent, 2016).

Fire Weather Risk Factors.

Under moderate weather conditions, reducing fuel is an effective strategy to manage the wildfire risk, but in regions with high fire weather severity and during extreme fire weather conditions, the efficacy is still scrutinized (Moritz, Moody, Krawchuk, Hughes, & Hall, 2010). Weather conditions that contribute to higher wildfire risk and can cause fires to spread quickly are hot temperatures, high winds, and low moisture (BC Wildfire Service, 2015). The Fire Weather Index (FWI) System is used in Canada using temperature, relative humidity, wind speed, wind direction and precipitation (Turner & Lawson, 1978). Fire weather varies throughout the year, creating the conditions for wildfire seasons that can start in April and extend into September in the Lillooet area.

Wind.

Fuels and terrain show a greater effect on wildfire risk in low wind areas, but severe wind conditions cause fires to become extremely large and unstoppable (Moritz et al., 2010). Wind has been shown to have a significant impact in the initiation of crown fires in areas with high wind (Alvarez et al., 2013) with an increase in the relative importance of wind as a risk factor in these areas; mountain passes and other terrain features that funnel wind are correlated to high wildfire danger and the quick spread of fires in California (Moritz et al., 2010). In the Survival Territory, the narrow valley with steep slopes funnels the north-south wind of the Fraser Canyon, allowing for the possibility that a wildfire could sweep the whole valley.

Climate Change.

The concern about higher fuel loads and unhealthy forests resulting from fires suppression may be compounded by the effects of climate change with longer wildfire seasons and more extreme fire weather (BC Wildfire Service, 2015). Climate change is expected to increase fire-weather and ignitions in many areas in BC, increasing the number of fires (Nitschke & Innes, 2008; Wang et al., 2016). The fire weather season is also expected to lengthen by nearly 30% by 2070, with most of that gain in the spring (Nitschke & Innes, 2008).

The ecosystem composition changes predicted because of climate change are expected to impact wildfire risk, though studies have produced conflicting projections for the province. Some studies suggest that areas currently displaying a mixed-surface fire to intermittent crown fire regime are expected to become mixed intermittent crown fires to full crown fire regime (Nitschke & Innes, 2008). Other studies suggest fuel categories will shift to lower-risk categories as areas expected to get less precipitation have reduced forest productivity and areas of higher precipitation have more fuel (Meyn et al., 2013; Wang et al., 2016). These contradictions are likely due to the complex topography in BC, causing temperature-precipitation-vegetation relationships to vary with different ecosystems (Meyn et al., 2013) and confounding generalizations. The shift in ecosystem composition expected as a result of climate change will likely be slow because of long-lived tree species, but recruitment after disturbances will provide opportunities for more rapid ecosystem shifts capitalizing on the change in climate (Wang et al., 2016).

Geography and Wildfire Risk.

The physical and human geography of the Xáxli'p Survival Territory plays a pivotal role in the local wildfire risk and shape the options for mitigation. The steep mountainous side hills (Figure 14) and flat valley bottom affect how fires might move. The concentration of habitation and land-use along the valley bottom concentrates ignition risk and human safety concern while the limited road access restricts where mitigation can be undertaken on a restricted budget.

Figure 14: The complex terrain of the Xáxli'p Survival Territory that supports varied ecosystems and fire behaviour (XCF Forest Crew, 2017).

Variable Terrain Creates Highly Variable Burn Conditions.

Topography is linked to both weather and fuel, by providing the surface for both factors to develop, leading to covariant effects on fire-behaviour. Topography in mountainous terrain including slope steepness, slope aspect, elevation and landforms can slow or speed up fires, or funnel and divert the path, creating pockets of forest with longer wildfire return intervals and creating heterogeneous burn patterns (Rogeau & Armstrong, 2017).

In the Lillooet area, dry, upland sites have more frequent, lower severity wildfire regimes, whereas northerly aspects and drainage bottoms have older forests with high severity fires (Gray et al., 2002). This has also been found in other mixed-severity fire regimes similar to the Survival Territory, where wildfire frequency is lower and wildfire intensities higher on north-facing aspects (Gray et al., 2002; Lecina-Diaz, Alvarez, & Retana, 2014). Higher elevations display more frequent fires resulting in higher stand densities of older trees lower on the slopes and stand density decreasing as elevation and snowpack increases (Gray et al., 2002). Steeper slopes show signs of higher flames, indicating a greater wildfire intensity as slopes steepen, and increasing tree mortality (Lecina-Diaz et al., 2014). This causes steeper slopes to have lower tree densities and have species compositions that favour fire-resistant species (Gray et al., 2002). The downward slope displays an effect in the cessation of crown fires, but the effects of slope are greatest at low wind speeds where the dominant effects of wind were not affecting wildfire spread (Alvarez et al., 2013).

Human Driven Ignition Patterns.

In the Xáxli'p Survival Territory, the majority of modern recorded fires are ignited by people (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - BC Wildfire Service, 2018). The areas around recreation sites, as well as near private dwellings and along the network of back roads, have been identified as higher risk features for human ignitions (Province of British Columbia, 2011). Research suggests human ignitions may be reduced by higher policing, and limiting access to high-risk areas during severe fire weather (BC Forest Service, 2018;

Collins, Penman, & Price, 2016; Province of British Columbia, 2011). This can be supported by education for backcountry users and people living in the wildland-urban interface as well as focusing mitigation on areas where human ignition is more likely to occur.

Limitations Created by The Road Network.

All the inhabitants in the Survival Territory live near the valley bottom, coinciding with the areas of high ignition. With only one narrow road providing access through Fountain Valley, emergency egress in case of a wildfire is a concern (Province of British Columbia, 2011). In addition to the higher ignition risk near roads, fuel mitigation efforts are also restricted to the forest area accessible by the existing road network and must be taken into account in planning (Hessburg et al., 2016).

Conclusion

In the Xáxli'p Survival Territory, the increased fuels from decades of wildfire suppression, the steep mountainous terrain with complex wind patterns from the nearby Fraser River valley and the increasingly extreme fire weather create a wildfire risk that has become a growing concern for community members. The eco-cultural restoration program for the Survival Territory provides a mechanism to work toward restoring ecosystem resilience while reducing the wildfire risk. The restoration of the ecosystem is critical to Xáxli'p cultural relevance for future generations, and the return of anthropogenic fire to the landscape has significant implications for their cultural and ecological health. The cultural implications of this Indigenist research approach necessitates the incorporation of traditional knowledge and creating locally adapted solutions.

Chapter 2: Exploration of Existing Datasets for Wildfire Risk Assessment Guided by Community

Connecting Research Purpose to Data

Following the Indigenist and community-based model, this research is undertaken as a fluid and dynamic process to adapt to the operational needs of the Xáxli'p Community Forest (XCF) as their objectives develop and information gaps or needs are identified. The foundation for this thesis rests on the relationships created between the XCF and the University of Northern British Columbia (UNBC) research team. Ongoing meetings and conversations with the XCF board and employees throughout the first two years identified their top concerns and the research direction and were used to share information and substantiate and verify the data products produced. At each stage, the data and conversations informed the next steps, all while trying to uphold the ethic of context and place to honour Xáxli'p objectives.

Developing the Research Question with the XCF

The partnership started in November 2016 through conversations with Herb Hammond, a forester and consultant for the XCF for many years, who suggested that the XCF might have projects that could use external resources. An introductory letter sent to the XCF board proposed a partnership where UNBC research could support the work of the XCF employees with technical expertise and resources. In early 2017, after an introductory meeting with the XCF board and employees to discuss the knowledge of the research team and critical issues for the XCF, the board approved the research partnership and prioritized wildfire risk as the key issue to focus initial research on. Throughout the research process, the board acted as an advisory committee along with the XCF employees to guide the research.

Discussions with Herb identified the existing Ecosystem Based Conservation Plan (EBCP) ecosystem classifications developed for the XCF as a potential data source that could be adapted for location-specific fuel-classification. In April, three days were spent in the Xáxli'p Survival Territory, in the field and the office, building relationships with the XCF board and employees and visiting a range of ecosystems and restoration sites the XCF forest crew has treated with various methods to reduce the forest fuels. The forest crew explained their restoration work along with the associated forest surveys and EBCP ecosystem data. The XCF board and employees expressed that the creation of a wildfire risk assessment showing areas of high-risk would be a useful focus of the research to prioritize fuel treatments and offered the use of data and fieldwork undertaken up to that point.

Xáxli'p Ecosystem Based Conservation Plan Dataset.

As part of the Xáxli'p Ecosystem Based Conservation Plan, a spatial layer categorizing the ecosystems in the valley was developed (Silva Forest Foundation, 2011). It was generated from aerial and satellite interpretation, site visits and local knowledge and is used by the XCF team in their current eco-cultural restoration work. The dataset covers the full Xáxli'p Survival Territory even though the XCF agreement does not cover the full extent. The footprint of this dataset was used for all further analysis to support the full Survival Territory and Xáxli'p self-determination goals.

This dataset identifies landcover type (ex. alpine, cliff, forest, urban, shrub, talus slope) and additional details for vegetated areas. All vegetated areas are classified by dominant vegetation type (forbs, shrubs, trees), ground cover of vegetation (very sparse, sparse, open, dense), slope (flat, moderate, steep, very steep), moisture regime (very dry, dry, sub-mesic, mesic, wet) (Table 1). There are additional modifiers that may also be applied (ex. complex terrain, exposed rock, wetland, snow-dominated ecosystem).

Table 1: Ecosystem descriptors used in the Ecosystem Based Conservation Plan dataset

Attribute	Description	Data Code
Dominant Vegetation Type	Forbs	F
	Shrubs	S
	Trees	T
Groundcover of Vegetation (crown cover in the forest)	Very Sparse: 1-10%	VSP
	Sparse: 11-25%	SP
	Open: 26-60%	OP
	Dense: >60%	DE
Moisture Regime	Very Dry	VD
	Dry	D
	Sub-Mesic (slightly dry)	SM
	Mesic (average to moist)	M
	Wet	W
Slope Gradient	Flat: 0-20%	F
	Moderate: 21-40%	M
	Steep: 41-60%	S

	Very Steep: >60%	VS
Modifiers	Complex terrain	CT
	Shallow soil over rock	SR
	Exposed rock	ER
	Talus/scree	TA
	Wetland	WL
	Large riparian ecosystem	RZ
	Snow dominated	SD
Landscape Descriptors	Alkali flats beside water	ALKALI
	Alpine shrubs or meadow ecosystems	ALPINE
	Industrial clear-cuts	CCUT
	Avalanche chute	CHUTE
	Cliff	CLIFF
	Dry, open ponderosa pine forest	DRY_PY
	Dry ravel - steep slope	D_RAV
	Very Dry site with sparse vegetation	D_SPAR
	Earthflow	EARTHFLOW
	Exposed rock	ER
	Agricultural field	FIELD
	Forest	FOR
	Meadow	MDW
	Sagebrush	SAGE
	Other Shrubs	SHRUB
	Talus slope/rock scree	TALUS
	Settled area	URB
	Utility or road clearing	UTIL

The different attributes separately observe a single variant or are combined to provide a generalized sense of the ecosystem conditions at the site. Throughout the Survival Territory, the dominant vegetation is trees with a mixed range of density (Figure 15). At the same time, site moisture and slope show similar patterns that vary with the terrain: where the slope is steeper, the moisture tends to be lower. When the attributes are combined, each ecosystem type gets a code that describes the site follow the order of vegetation, density, moisture and slope. For example, a site coded F OP D M is forested with open stand structure, dry, and a moderate slope.

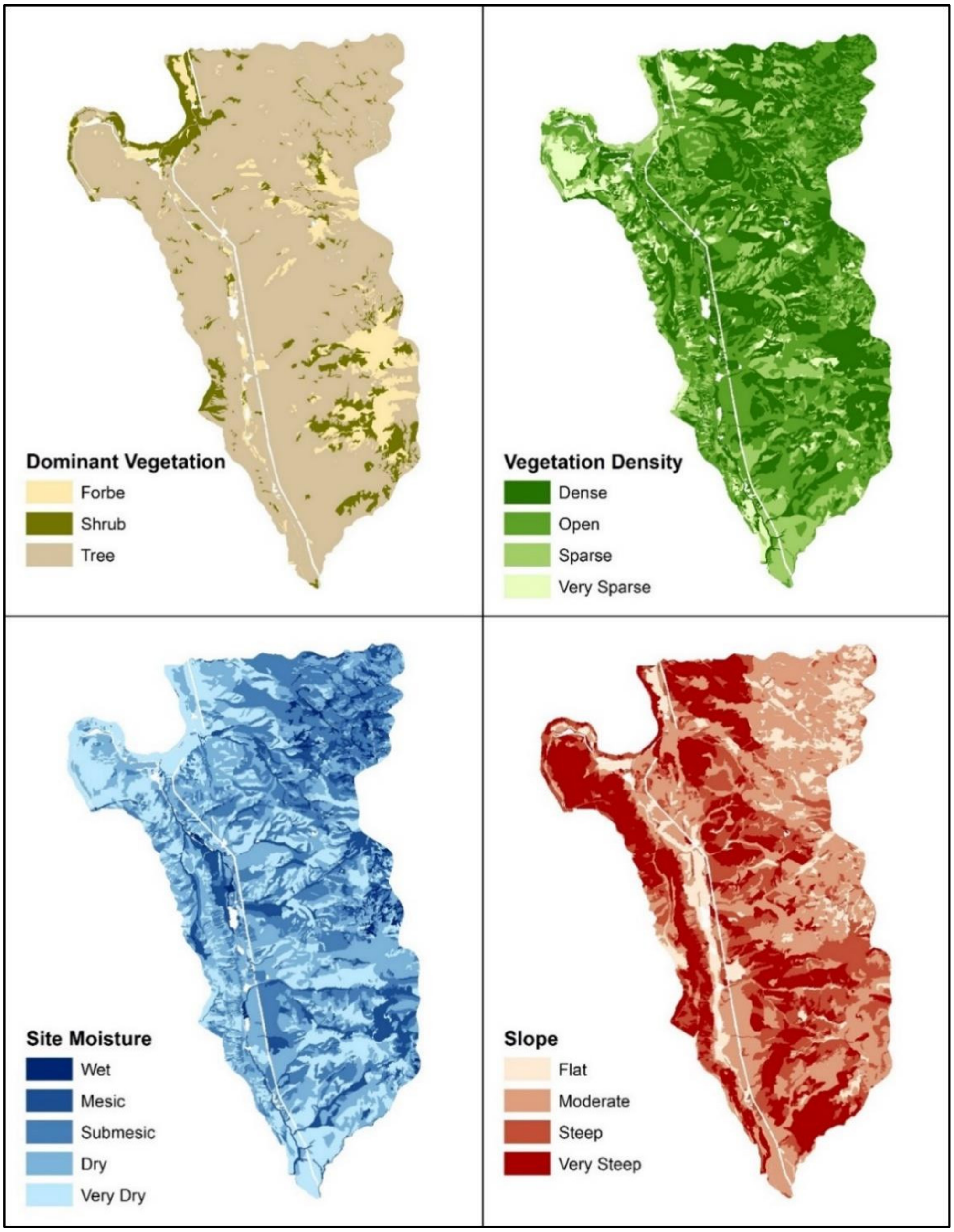


Figure 15: The variation of Ecosystem Based Conservation Plan ecosystem descriptors in the Survival Territory.

Leveraging the accuracy and local suitability of the EBCP ecosystem data is vital for the local scale of the project and the work of the XCF team. However, for it to have maximum usefulness and opportunity for assessing and mitigating wildfire risk modelling, the way it is adapted to fuel risk should still interface or translate to existing wildfire risk assessments and models to make the most of existing research and application.

Fuel Classification in Canada

The standard method for provincial and federal wildfire risk assessment uses the Canadian Forest Fire Danger Rating System (CFFDRS) and associated fuel classifications to run models such as Burn-P3 (Parisien et al., 2005) to understand wildfire behaviour on the landscape. The CFFDRS was developed in Canada to support decision-making by fire management agencies to allocate resources based on fire danger levels (Taylor & Alexander, 2006). The fire danger rating system incorporates ignition, weather, topography and fuels and has two primary sub-systems, the Canadian Fire Weather Index (FWI) and the Canadian Forest Fire Behaviour Prediction (FBP) system (Taylor & Alexander, 2006).

The FBP system "provides quantitative estimates of head fire spread rate, fuel consumption, fire intensity, and fire description"(Forestry Canada, 1992) based on experimental, wild and prescribed burns across Canada, leaning heavily on boreal forests. The model uses fuels, weather, topography, foliar moisture content and time since ignition. It relies on fuel categories characterized on a mixture of dominant tree species, tree spacing, and stand age, which relates to the fuel loading that these conditions display (Perrakis & Eade, 2016). Canada's wide range of forest types is a challenge for the development and implementation of a national system, and the domination of boreal forests in the CFFDRS and FBP reflects this challenge (Taylor & Alexander, 2006). Because of the issues that arise when trying to categorize fuel types outside of the specific ecosystems forming the base of these systems (primarily boreal and sub-boreal forests) (BC Wildfire Service, 2015), some ecosystems in BC require adaptations of the FBP categories using local expertise on fire behaviour (Parisien et al., 2012)

While an in-person assessment by a wildfire professional provides the best estimation of the fuel category beyond using the FBP categories, over large scales, this is impractical. Additionally, most areas do not have localized datasets like the EBCP in the Xáxli'p Survival Territory. To address this issue in British Columbia, the Vegetation Resource Inventory (VRI) has been used to classify the entire province into adapted FBP fuel types. VRI is a BC Government forest resource inventory dataset with detailed site descriptions for forested areas throughout the region based on photo interpretation and some ground sampling (Ministry of Forests Lands and Natural Resource Operations, 2018). By using this system, it allows for the unique ecosystems in the province that are not represented in the national system to get a fire behaviour characterization (BC Wildfire Service, 2015). For example, an ecosystem type not represented in the Canadian FBP system may use a category from the other side of the country that has a similar fuel structure to achieve a realistic fire behaviour when modelled (Parisien et al., 2012). Many wildfire models in BC use the BC VRI dataset because it provides standardized and continuous coverage for the province and can easily convert to fuel categories following standardized methods (Parisien et al., 2005; Perrakis & Eade, 2016). However, the appropriate application of this is partial to landscapes with uniform and continuous fuels and simple, homogenous topography with constant and unidirectional wind (Taylor, Pike, & Alexander, 1996), limiting its suitability in the highly variable terrain of the Xáxli'p Survival Territory. In addition to this, the spatial and temporal accuracy of the VRI dataset is variable across the province. Within the Survival Territory, assessments are from between 1977 and 2012 and all projected values are only valid up to 2015 (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Forest Analysis and Inventory, 2017).

Description of the FBP Fuel Categories.

There are 16 benchmark fuel categories in the FBP system (Table 2), qualitatively described by their stand structure and composition, surface and ladder fuels, and forest floor cover and organic layer (Forestry Canada, 1992). "A fuel type is a fuel complex of sufficient homogeneity and extending over an area of sufficient size that equilibrium fire behaviour can be maintained over a considerable time period" (Forestry Canada, 1992). This qualitative description requires practitioners to make subjective decisions about forest stand characteristics such as "well-stocked" or "moderate density" (Perrakis & Eade, 2016).

Stand structure includes the crown closure, species, stand and crown height of a given forest. Composition, distribution, and height describe the three classes of fuels - surface, ladder, or litter fuels. Surface and ladder fuels compose the layer that sits on top of the forest litter, which includes the herb, shrub, and young conifer understory as well as flaky bark, dead woody debris, low tree crowns. On the forest floor are the litter fuels consisting of the low ground cover (such as dead grass, lichen, and moss) and the duff layer.

Table 2: Canadian Forest Fire Behaviour Prediction (FBP) system fuel categories (Taylor, Pike, & Alexander, 2000).

Coniferous

C-1	Spruce-lichen woodland
C-2	Boreal spruce
C-3	Mature jack or lodgepole pine
C-4	Immature jack or lodgepole pine
C-5	Red and white pine
C-6	Conifer plantation
C-7	Ponderosa pine – Douglas fir

Mixed wood

M-1	Boreal mixed-wood – leafless
M-2	Boreal mixed-wood – green
M-3	Dead balsam fir mixed-wood – leafless
M-4	Dead balsam fir mixed-wood – green

Deciduous

D-1	Leafless aspen

Open

O-1	Grass

Slash

S-1	Jack or lodgepole pine slash
S-2	White spruce-balsam slash
S-3	Coastal cedar-hemlock – Douglas fir slash

When modelled, each fuel type has associated equations for fire spread (Perrakis & Eade, 2016; Wang et al., 2016); "the C-2 (boreal spruce) and C-4 (immature lodgepole pine) fuel types are highly conducive to spread, whereas the C-5 (red and white pine) and C-7 (ponderosa pine) fuel types have slower spread potential. The deciduous (D-1) and mixed-wood (M-1/2) fuel types have faster fire spread rates in the spring, before leaf flush than later in the season. Fire spread potential in the grass (O-1) fuel type also varies seasonally with the curing percentage "(Wang et al., 2016).

Converting Ecosystem Data to Fuel Categories

As discussed in Chapter 1, there is a significant relationship between forest composition and wildfire severity. Ensuring functional fuel categories that are usable for future research into wildfire modelling requires having forest data with appropriate metrics and spatial resolution. As a preliminary stage of an ongoing relationship between the XCF and researchers, a necessary foundation was exploring the usability of existing datasets and determining whether the accuracy and precision are appropriate for the scale of the Survival Territory or whether at this scale and application better forest composition information is required.

Combining EBCP and VRI Datasets

The EBCP and VRI datasets were used together as an initial attempt to classify forest fuels and get the strengths of each by combining the higher confidence and accuracy of the EBCP forest density data with the critical fuel structure variable of stand age from the VRI dataset. The spatial features of the EBCP formed the framework and the attributes of the VRI dataset were merged to this dataset using the VRI record that covers the largest area of each given EBCP polygon when there were significant boundary discrepancies. This dataset was classified into ecosystem categories using density from the EBCP and forest age from VRI (Table 3). Ecosystems dominated by forbs and shrubs were kept as individual fuel types, while the forest densities were used for further categorization (dense, sparse & open, and very sparse). The dense stands were then further classified by stand age from the VRI attributes into young forests (less than 60 years old), middle-aged forests (60-99), and old forests (100+).

Table 3: VRI and EBCP - V1 and V2 classification categories.

Stand Density (Restoration Ecotype Dataset)	Stand Age (VRI Dataset)	FBPS/Severity Rating (Taylor et al., 2000)	V1	V2
Dense	60-99 years	C2 / Very High	x	x
Dense	>100 years	C3 / High	x	x
Dense	<60 years	C4 / Very High	x	x
Open	All ages	M1 (75% conifer) / Moderate	Combined into one Open/Sparse category	x
Sparse	All ages	M1 (25% conifer) / Moderate		x
Very Sparse	All ages	C7 / Low	x	x
Grasslands, non-forested vegetation	n/a	O1 / Very Low	x	x

The EBCP/VRI ecosystem categories were classified into fuel risk categories (Table 3) according to the fuel type descriptions from the Field Guide to the Canadian FBP System (Taylor et al., 1996) and BC specific work by Perrakis and Eade (2016). The result was a heterogeneous landscape dominated by the mixed coniferous, deciduous M1/2 fuel category, with large patches of dense mature C3 fuels (Figure 16, A). The fire behaviour of the M1/2 category has significant variation depending on the ratio of coniferous to deciduous trees – higher coniferous composition can support higher risk wildfires. Such a large area categorized as sparse (M1/2 – 25% coniferous, 75% deciduous) and open (M1/2 – 75% coniferous, 25% deciduous) prompted another iteration to separate the sparse and open categories into different fuel categories (Table 3) to represent the different levels of risk better and provide more nuance (Figure 16, B).

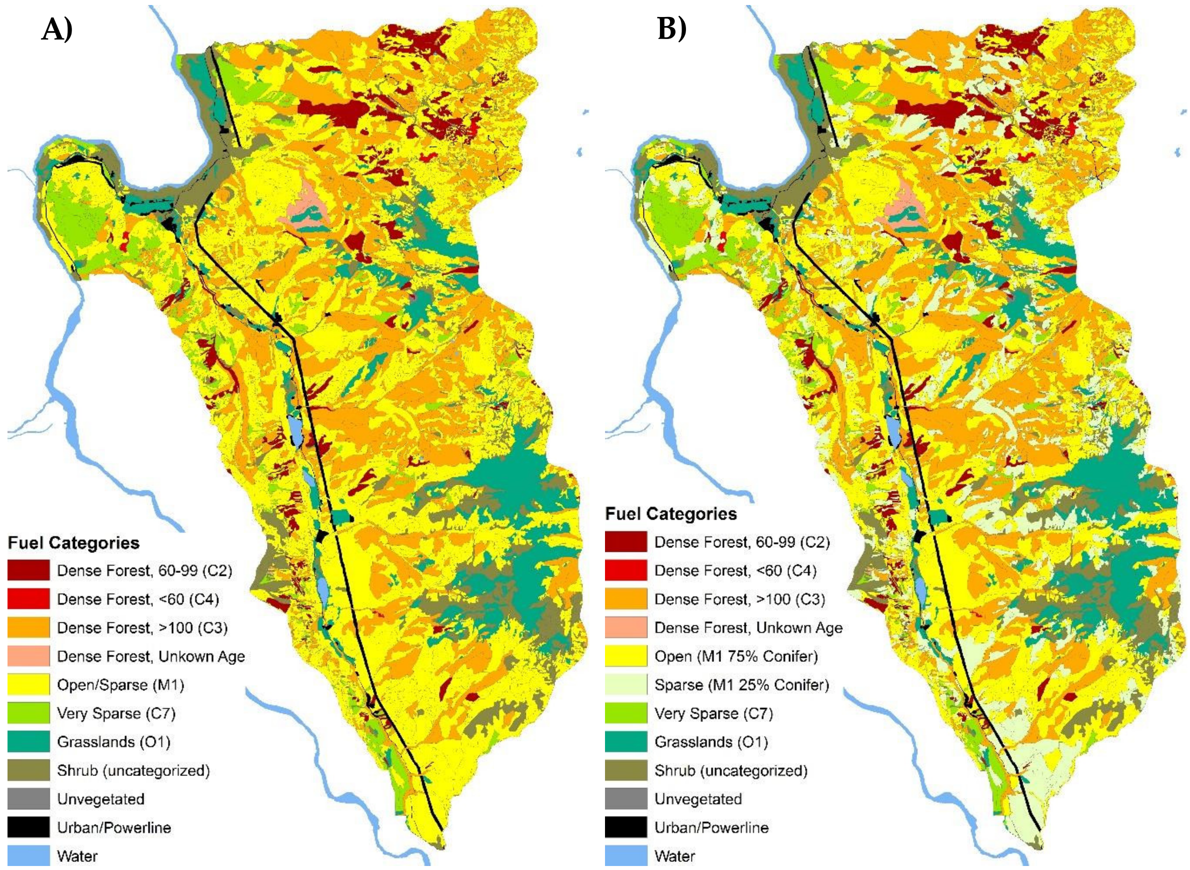


Figure 16: VRI and EBCP combined data, A) first iteration Open and Sparse combined, B) Open and Sparse categories separated.

From visiting the Xáxli'p Survival Territory, exploring the datasets and conversations with the XCF board and employees as well as other wildfire experts, it was determined that the VRI data is too outdated to add accurate information about fuel loading. Substantial regeneration (and therefore densification) of the forest in the last 40 years has resulted in many stands being 2-aged. There is a widely spaced older forest demographic (likely due to frequent historic fires) and a very dense young forest growing up around this (without fires, young seedlings were not thinned out). The VRI stand ages do not reflect this pattern because of the assessment year and dataset attributes. Relying on an age classification generated decades earlier may not provide enough sensitivity for fuel classifications, particularly for the oldest age category (covering over 80% of the landscape, Figure 17) because the 2-aged nature of the stands changes the fuel structure significantly for both canopy density and ladder fuels.

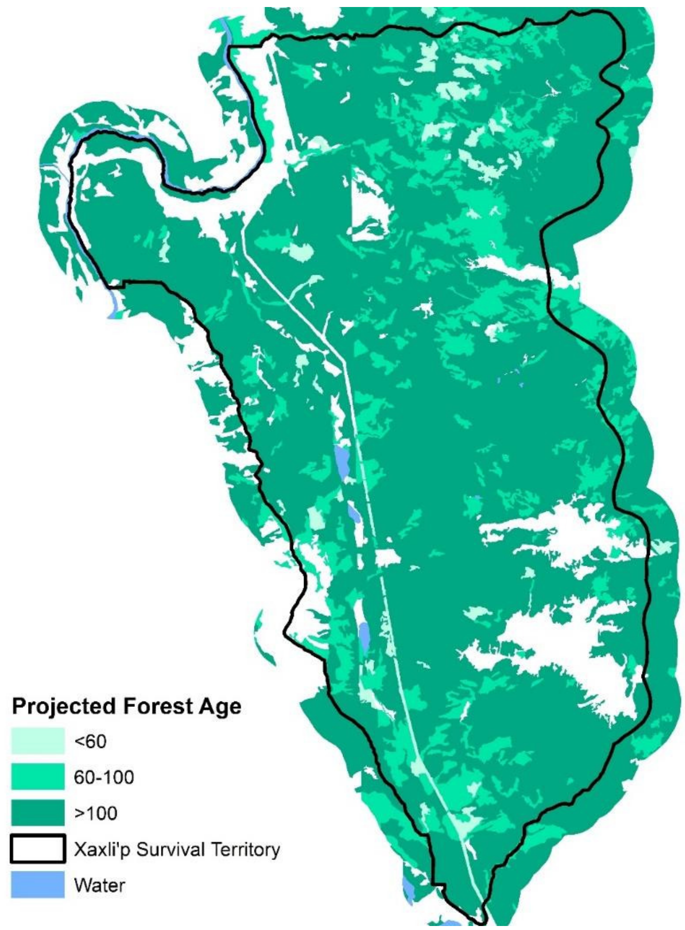


Figure 17: Projected forest age from the BC VRI dataset (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Forest Analysis and Inventory, 2017).

When presented with this update, the XCF board and employees shared site survey data that had been undertaken by the forest crew which included photo-points with GPS locations in various locations in the territory (Figure 18). An expansion of this program would allow the use of these photo-points to validate the ecosystem dataset and get a view on the fuel structure for the ecosystem categories. With the crew travelling around the territory, taking sample pictures in each ecosystem type could increase the reliability of the fuel categorization and provide a photo record of the location. Using these pictures enabled the consultation of outside fuel categorization experts to improve classification skills and verify existing classifications.

Figure 18: Example of a west-facing picture, 1 of 4 taken at a photo-point (XCF Forest Crew, 2017).

Focusing on Locally Created Data to Improve Classification

The forest cover, density, moisture, and slope profiles of the EBCP ecosystem classification was used exclusively in all the subsequent fuel classifications. This provided consistency and locally confident data that could be matched to the fire behaviour that fits the vegetation type, slope, moisture, and density of each ecosystem. Forest ecosystems are represented by their vegetation density, moisture regime, slope gradient. With these attributes, in addition to the shrub and forb ecosystems, there are 51 ecosystem categories covering areas from 4 ha to 3000 ha. To prioritize time and resources, ecosystem types that covered less than 200 ha were not further assessed, resulting in 25 working categories that include 75% of the territory. Existing photo-samples were mapped to ecosystems, and an inventory of the usability and dispersal of the existing photo-points was undertaken to identify gaps. There were 278 existing photo-points sampled in 15 ecosystems; however, they were highly clustered around restoration areas where the crew had done work, some in ecosystem types that covered little area in the Survival Territory. With redundancies and ecosystems not of interest removed, 113 photo-points remained.

With a best-case-scenario target of 10 photo-points per ecosystem type, a sampling procedure was developed with the XCF forest crew (closely following the procedure used for previous site surveys) to take additional photo-points in under-sampled ecosystems. Photo-points were situated in the middle of a polygon (as geographically determined by GPS enabled tablet and map-viewing service) and were taken to capture the forest structure from ground to mid-canopy. Pictures were taken in portrait orientation in the four cardinal directions (north, east, south, west) with the coordinates, compass direction, date, EBCP category, and samplers written on a whiteboard in the picture (Figure 19).

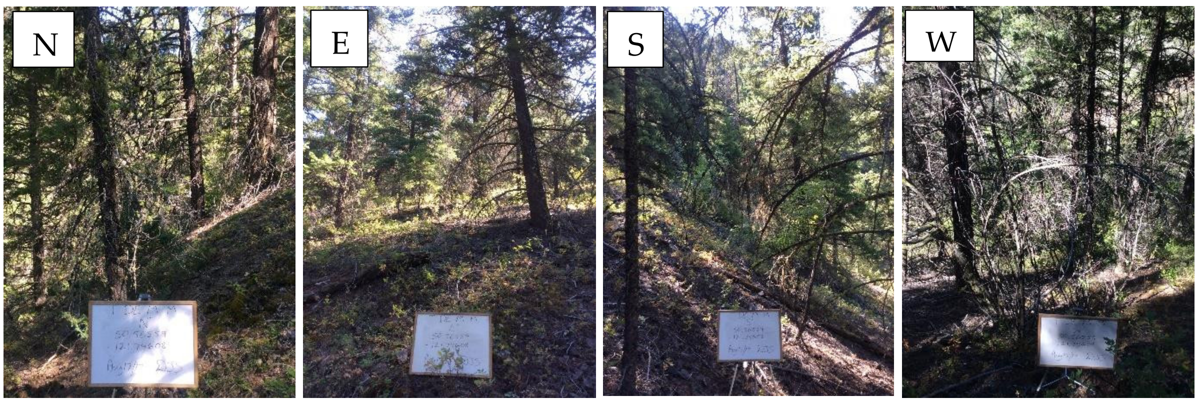


Figure 19: Example of a set of pictures captured at a photo-point in the four cardinal directions (XCF Forest Crew, 2017).

There were 15 categories with existing photo-points leaving 18 ecosystem types needing sampling to reach 10 photo-points. Fortunately, the timing of sampling fit well with the work schedule and staffing numbers of the forest-crew, and they were able to collect over 60 additional photo-points. However, the final samples fell short of the target of 10 samples per EBCP category during the study period because of the many other demands on their time. By the end of sampling, of the 25 ecosystems covering most of the valley, 15 ecosystems got 8 or more samples, 9 got 2 – 5, and there was one unsampled category.

Categorization into fuel types based on the Canadian Forest Service FBP field guide (Taylor et al., 1996) started once the samples were collected. By referencing the manual, the photo-points from each ecosystem category were assessed and assigned a fuel type. Each category was evaluated a second time on a separate date in reverse order to reduce learning-curve errors (Figure 20-A). This assessment was then shared, discussed and re-assessed with supervisor Scott Green to reduce the effects of personal bias (Figure 20-B). The categories were re-visited upon receiving the last 18 points from the XCF forest crew. The categories were further refined following consultation with Mark Parisien (fire research scientist providing context for how to localize FBP) and Dana Hicks (Lillooet fire management specialist), individuals with a practised eye for fuel categorization. These conversations emphasized how the localized nature of fire behaviour would greatly benefit from additional localized fire expertise (Figure 20-C).

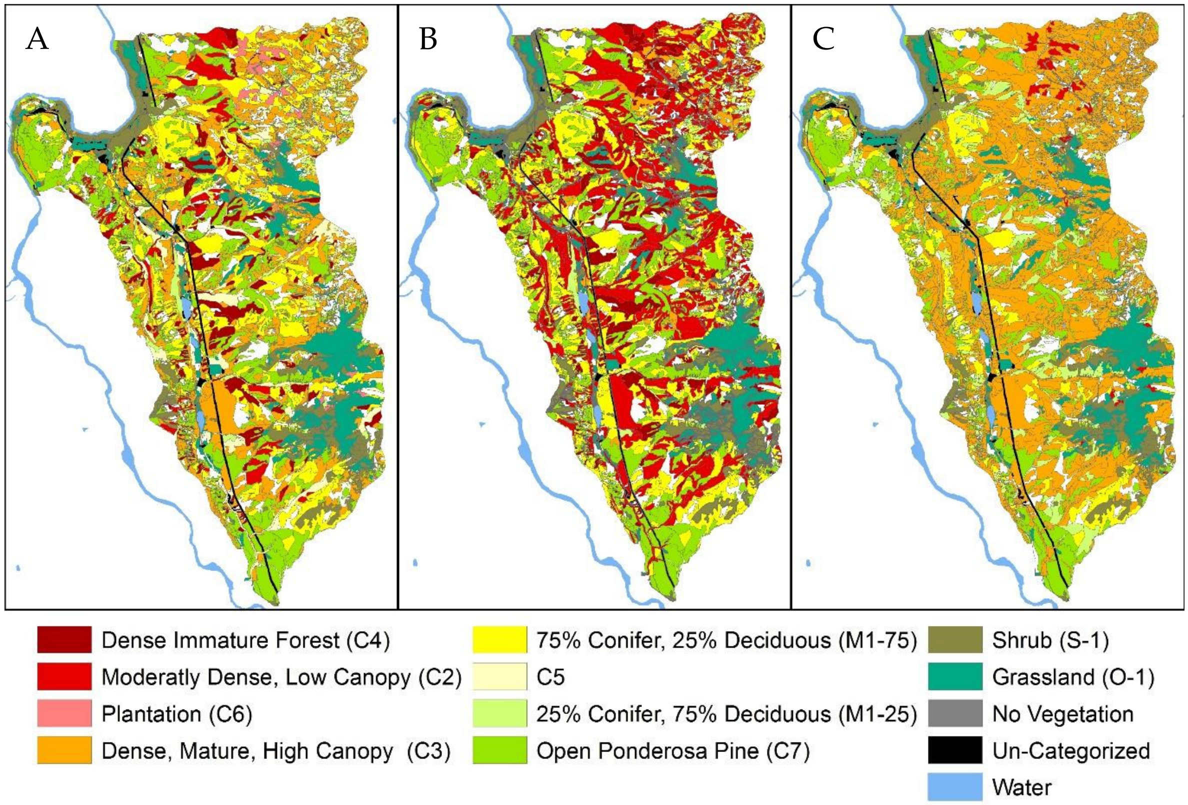


Figure 20: Progression of the EBCP fuel categories through different iterations of information and knowledge.

Improving Iterations of Fuel Classification

There were substantial changes to the mapped fuel risk (Figure 21) as more information was added to the fuel categorization process, and additional expertise was incorporated. Alpine areas, grasslands, and shrubs stayed consistent throughout the iterations because the focus was predominantly on the forested areas. However, in the high-risk categories of C2 and C4, there were considerable shifts where the last iteration has minimal area classified as high-risk and generally a much more homogenous landscape of moderately high-risk fuel types.

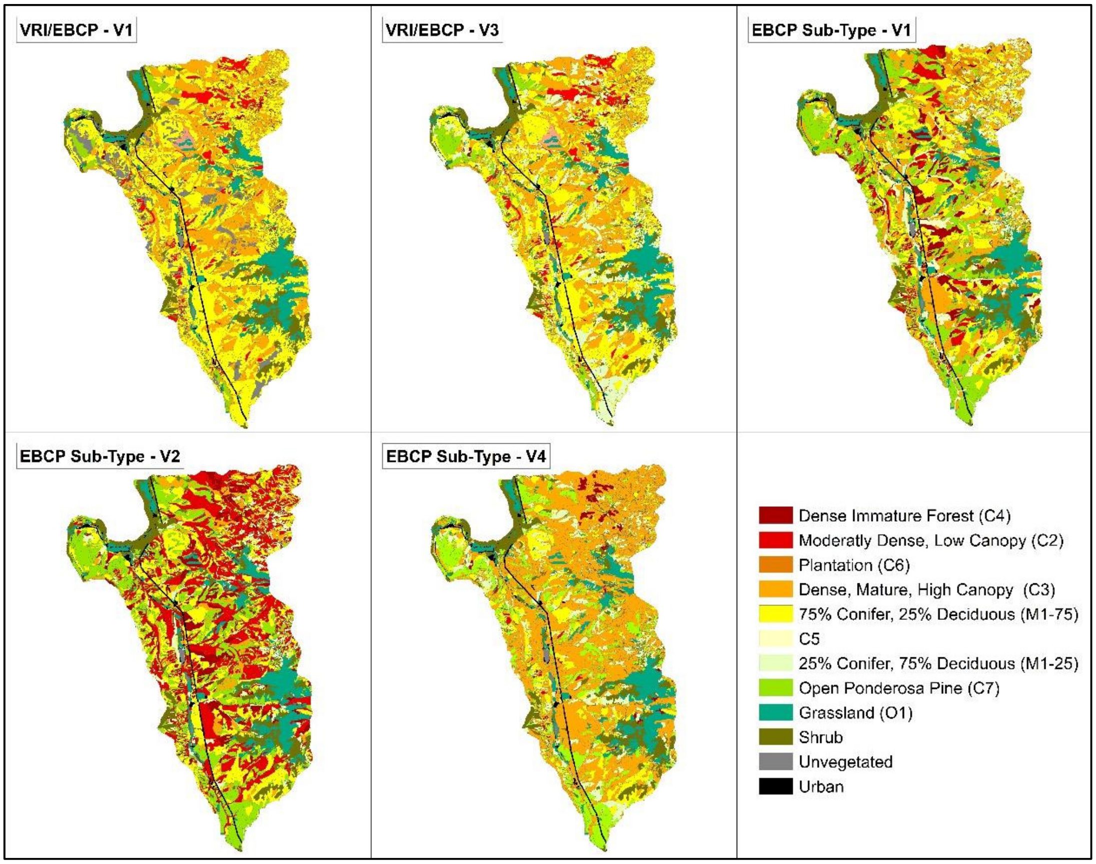


Figure 21: Iterations of fuel classification from VRI/EBCP classification to straight EBCP categories.

Fire Risk Beyond Fuel

Throughout the iterations, the variability within ecosystems and the homogeneity of fuel risk between ecosystems became apparent. The large area covered by C3 fuel categories is a management challenge requiring additional data to separate priority areas for wildfire risk mitigation. In an earlier iteration of fuel categories, Marc Parisien suggested the inclusion of wind information as a risk factor that echoed conversations with the XCF board and employees about how windy the valley gets and how fires from their fishing sites along the Fraser River blow quickly up the hillside with the wind.

The fuel categories produced were first used by the XCF team in November 2017 in a meeting with the Xáxli'p forest manager to select locations for restoration thinning, focusing on locations within 200m or 500m of roads because of the prohibitive cost of building roads. This highlighted the need for bringing in road access as an element of identifying high-risk areas to target. Additionally, because of the homogenous fuel landscape, the capacity of a small crew to reduce risk in high fuel areas is overwhelmed. Focusing the logging projects to enhance low-risk areas to connect them with nearby low-risk areas was proposed as a start to fuel reduction work.

Assessing Wind as a Risk Factor

There is no regularly recorded wind data for the Xáxli'p Survival Territory; the closest station with wind data is a BC Wildfire Service operated weather station over the mountains in Lillooet (Station 1830). Wind data obtained from the weather station was downloaded (Pacific Climate Impacts Consortium, 2019) and analyzed to determine the predominant winds in the area in different conditions.

Throughout the day at the Lillooet weather station as temperature rises and relative humidity (RH) falls, the wind speed increases and shifts to predominantly westerlies (Pacific Climate Impacts Consortium, 2019). Throughout the year, the average wind direction is evenly distributed, with a higher frequency of northerly and southerly winds (Figure 22) and an average wind speed of 5.6 m/s. However, this pattern shifts towards predominately west winds during the hot, dry, summer conditions when wildfire risk is at its most significant concern (Figure 22). The average westerly wind speed for hourly recordings with temperatures over 20˚C and relative humidity less than 50% was 9.9 m/s, and it rises to 10.6 m/s at 25˚C and 30% RH.

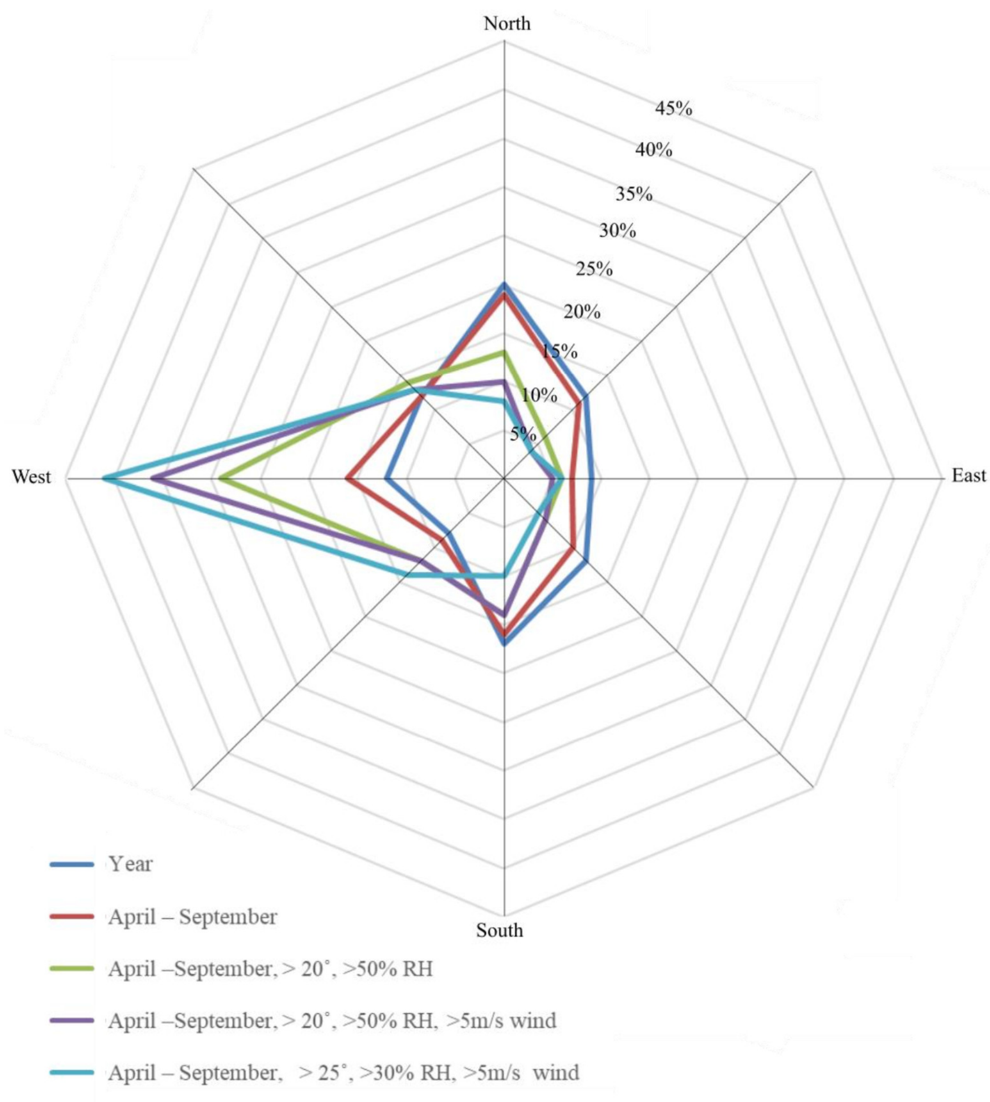


Figure 22: Comparison of predominant winds at the Lillooet weather station (Pacific Climate Impacts Consortium, 2019).

Wind data was modelled using WindNinja V3.3.1 (Forthofer, Butler, & Wagenbrenner, 2018), a software used for modelling the effects of topography on the local wind (Parisien et al., 2012) providing an output that identifies areas of high wind. The model inputs required for WindNinja include a digital elevation model (DEM) and wind speed and direction. An average westerly wind speed of 9.9 m/s were the inputs for the model, which was obtained from wind recordings from April through September for recorded hours over 20˚C and a relative humidity less than 50% to capture summer fire conditions (Pacific Climate Impacts Consortium, 2019). The conservation of mass model was run on a 25m DEM, using the standard 10m Canadian weather station height. The output resolution was 25m and showed a band of high winds at the top of the ridge on the western side of the valley and some smaller high bands in the upper elevations on the east side of the valley (Figure 23, A). The valley bottom had relatively low wind. The average WindNinja windspeed for each EBCP ecosystem unit provides a comparable landscape management unit to compare across the wildfire risk variables (Figure 23, B). This generalized the wind patterns more, with fewer of the high wind pockets showing up in the averages.

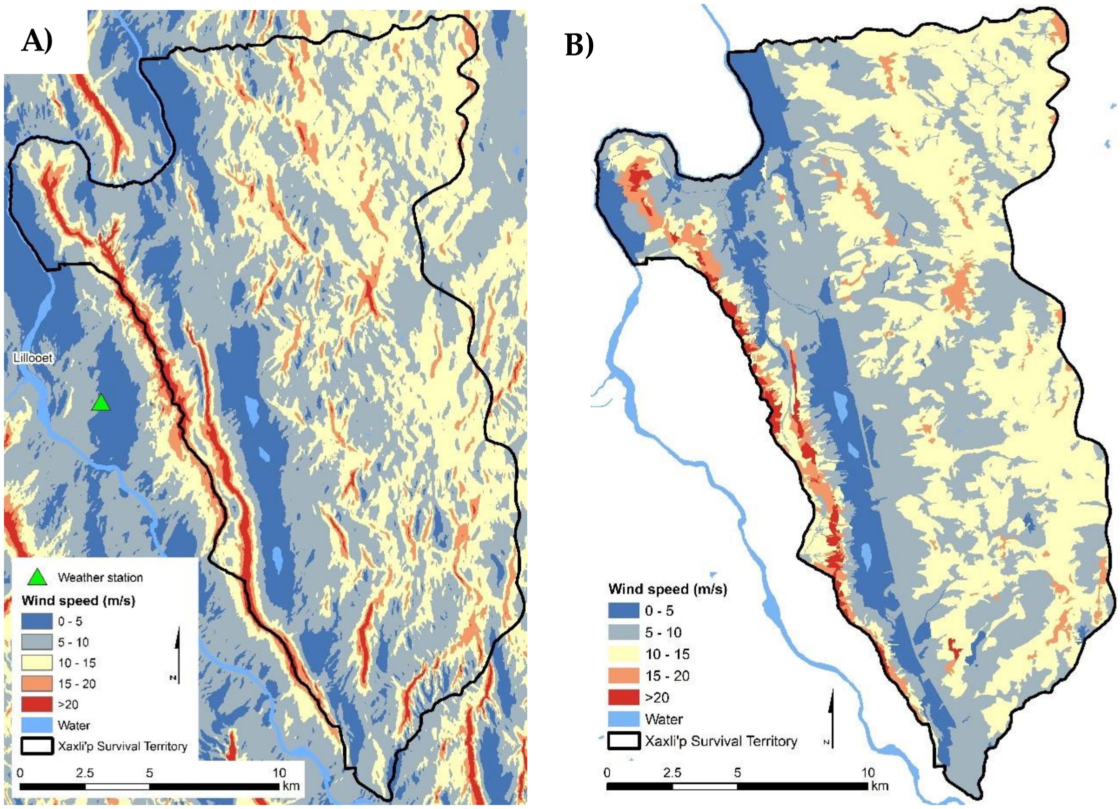


Figure 23: Modelled windspeed across the Survival Territory for the average summer fire weather conditions at the Lillooet Airport; A) the modelled raster output, B) the average wind speed for each EBCP ecosystem unit.

Incorporating Access as an Ignition Proxy

The road layer was included in the wildfire risk assessment for the Survival Territory because of concerns around human wildfire ignitions that are limited to roadways. Additionally, Herb Hammond and XCF forester Robin Strong focused logging planning on areas within 500m of the existing road because it could be easily reached and there is hesitation towards creating new roads for logging (and for other activities) because of concerns over how it opens access and increases the ignition risk and pressure on the ecosystem.

The road network has a few implications to predicting the wildfire risk: 1) road access dictates the distribution of ignition in the predominantly human-caused ignition pattern local to the Survival Territory; 2) the road network limits the ability to undertake eco-cultural restoration treatments without significant road-building costs limiting this work to areas close to the roads and; 3) human habitation is concentrated around these roads.

Table 4: History of ignitions in Fountain Valley comparing natural and human ignitions within buffer distances from the road network.

	200M ROAD BUFFER		500M ROAD BUFFER		ALL
	in	out	in	out	
LIGHTNING	5	31	7	29	36
PERSON	211	52	245	18	263
OTHER	12	6	12	6	18
TOTAL	228	89	264	53	317

There is only 11,205.9 ha in the Survival Territory that is within 500m of access roads. Still, the road network acts as a conduit for ignition risk with over 80% of recorded fires in the area over the last 70 years ignited by people (Table 4), and 93% of those human ignitions occurred within 500m of a road (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - BC Wildfire Service, 2018). The distribution of human ignitions is primarily along the valley bottom and near the camping areas near Kwotlenemo and Chilhil Lakes (Figure 24).

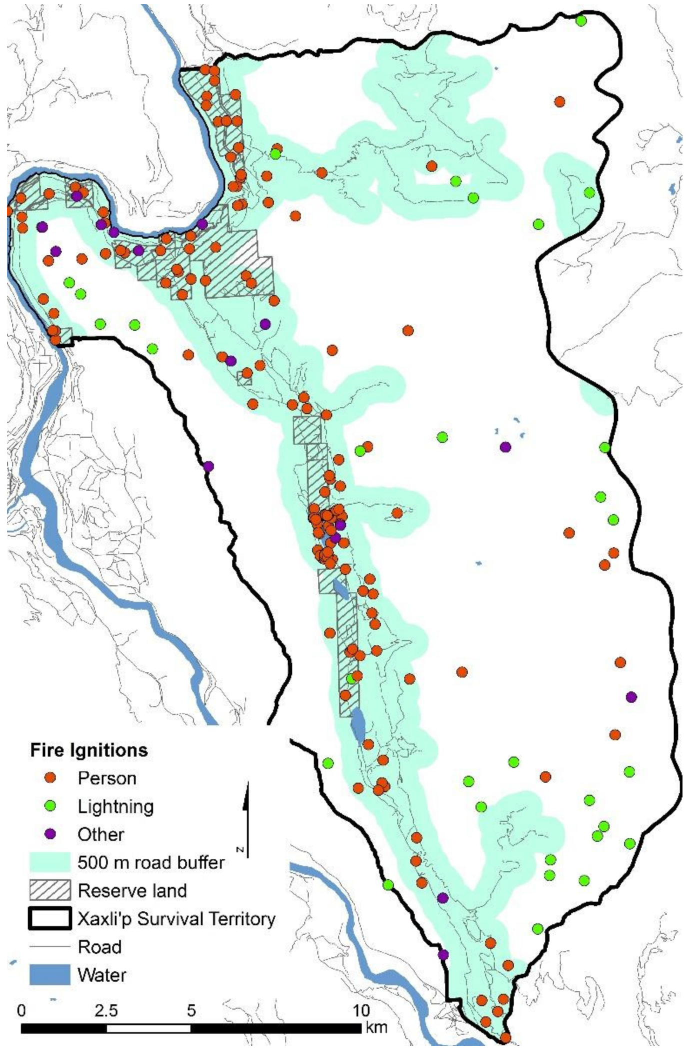


Figure 24: Distribution of fire ignitions relative to access roads.

The data for the road layer was obtained from the XCF and cross-referenced with the Digital Road Atlas layer from DataBC (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - GeoBC, 2017). The road layer was verified by the XCF forest crew to try to obtain the most up to date and accurate representation of the roads in the valley, however, the level of road maintenance and driveability of the roads was not considered for this analysis but would be a future step to refine the ignition risk posed by road access.

A Need for More Context

The level of uncertainty in the quantitative spatial data and processes of assessing wildfire risk as a desk-top exercise does not produce the level of confidence needed for a small, resource-limited organization like the XCF to optimize their planning. Through the iterations of the fuel classification, the fuel classification became more and more homogenous across the landscape. This necessitated the integration of the wind and access layers, which incorporated a broader understanding of the risks but brought assumptions and higher levels of data uncertainty to the wildfire risk assessment.

Even though the XCF team guided the process, the fuel, wind, and ignition assessments undertaken were unable to represent the complexity on the land, emphasizing that basing land management decisions on remote data and models has essential limitations for understanding the landscape and relationships with and on the land. Discussions with the XCF team determined that it would be appropriate to engage the community in small groups to interview Xáxli'p knowledge holders who have experience on the land and with fire. Given there are people much more knowledgeable about the landscape, who are living the relationships within the community and spending time on the land, it is critical to incorporate this information into the Indigenist approach of this gap analysis.

Chapter 3: Enhancing Wildfire Risk Datasets using Xáxli'p Community Knowledge of the Local Wildfire Landscape

Following a year and a half assessment of forest fuels, wind and ignition using existing data, classification maps were presented to the Xáxli'p Community Forest (XCF) board, employees and community members who provided feedback about specific details and concerns that were not being captured (see Chapter 2). Incorporating community knowledge holders in the process was proposed to provide additional context and nuance to the quantitative data.

Holding Conversations with Knowledge Holders

The XCF board and staff organized a focus group of Xáxli'p community members with recognized knowledge of the Xáxli'p territory to attend a workshop. The question I hoped to answer was: Where are the areas in the Xáxli'p Community Forest tenure that local knowledge holders were most concerned about wildfire risk? This local knowledge and perception of wildfire risk could then be displayed in a risk layer that could be combined with the existing categorized quantitative data assessing wildfire risk (wind, fuel and access), providing better context and nuance to narrow the spatial scope of priority risk areas.

The workshop was held over two days in July 2018, with 14 participants, including the Xáxli'p Range Riders, XCF forest crew, Elders, board members, and valley residents selected for their knowledge of the territory and an expressed interest or concern about wildfire. Some participants were able to attend both days, others only for parts. A mapping exercise on day one and a field trip on day two provided a space for participants to share and brainstorm with each other, as well as to provide information to the research team. The primary discussion question was,?" "Where is the greatest wildfire risk in Fountain Valley with subsequent inquiries about fuel, wind, access, and important assets to protect in the valley.

Identifying and Mapping Concerns About Wildfire

The first day with the focus group was held at the XCF office and started with a Xáxli'p prayer and an introduction to the larger project and workshop objectives. Each participant received a map of the fuel categories, access roads and wind levels that had been presented to the board and community from earlier research stages (Figure 25) to provide some context of our findings about wildfire risk to that point. Participants were asked to point out any areas of disagreement with their knowledge of the landscape or provide feedback on the maps.

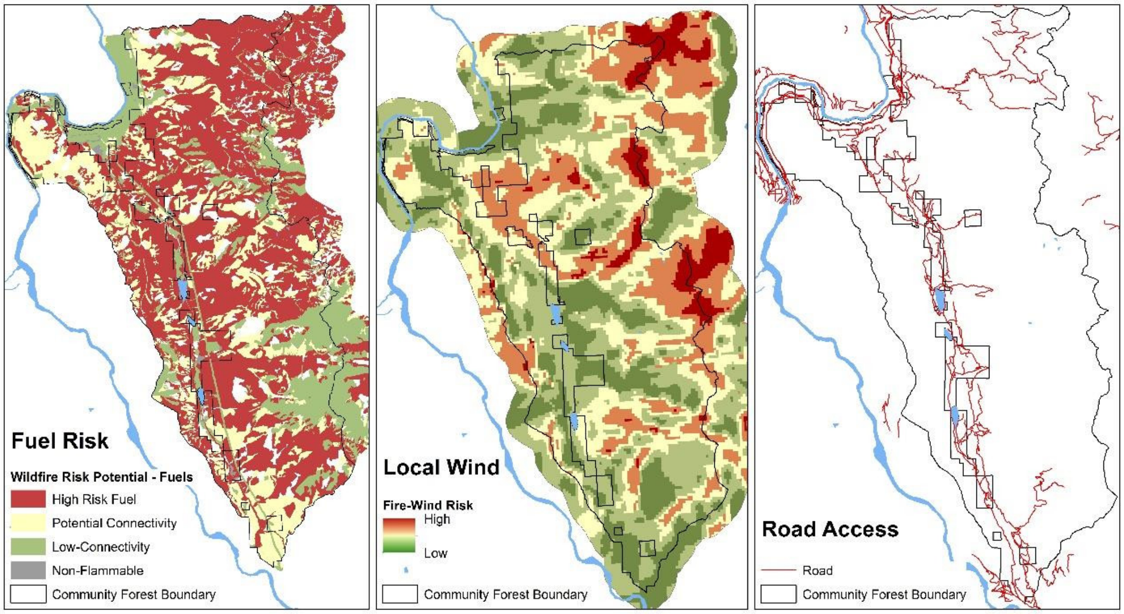


Figure 25: Quantitative data mapped in earlier research stages and presented for correction and comment to the focus group.

After introducing the research question and workshop objectives, the group conversation was roughly guided by a set of questions (Table 5) relating to participants' concerns, knowledge and observations of wildfire risk, while also following the natural direction of the conversation. Large poster-sized aerial imagery maps that spanned the Survival Territory from north to south in three sections were used to record areas identified by the participants (Figure 26). Areas were drawn on the maps by participants, or me when participants only provided verbal descriptions or gestures.

Table 5: Discussion questions used to guide the conversation with the focus group

1) What do you think matters most when you think about the wildfire risk in Xáxli'p? a. Where are you most concerned about a wildfire burning?
2) Are there areas in Fountain Valley that have a lot of combustible fuel?

a. What are the areas of highest concern? b. When you look at the map, is there anything that strikes you as incorrect?
3) Where is wind the biggest issue for wildfire risk? a. Does the map match high-wind areas from the Fraser? b. Is wind consistent throughout the day?
4) Where is there the biggest chance of a wildfire starting? a. What starts fires in Xáxli'p b. Which access roads have the highest traffic?
5) What areas are most important to avoid burning?
6) Where would adding fire too the landscape be good?
7) Are there any other fire risk aspects we are not considering?

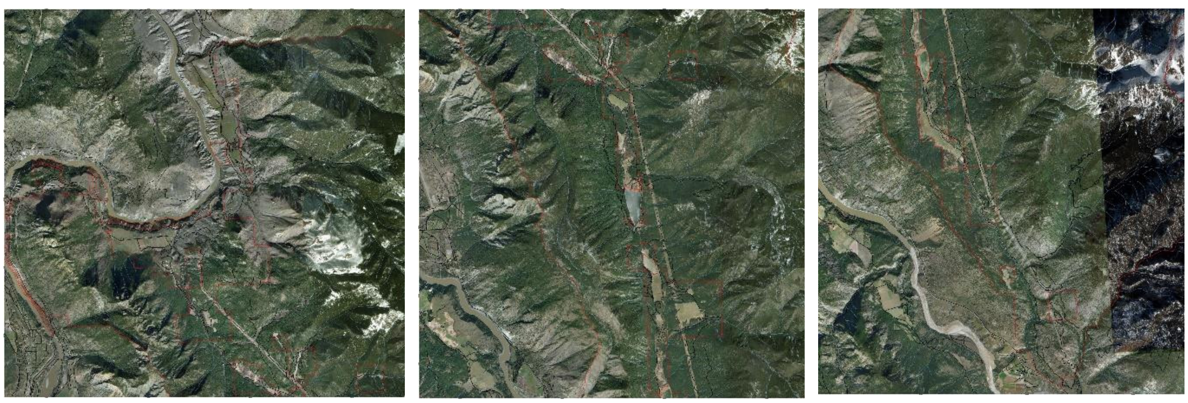


Figure 26: Wall maps used to capture areas identified by focus group participants.

At the end of the first day, participants were each given three coloured stickers to participate in a "dot-mocracy" data summary (Diceman, 2010) to help the group rank the identified areas. Red stickers for the locations they felt were "most important" regarding wildfire risk, green stickers for locations they felt were an "easy fix" (low-hanging fruit that could be easily or inexpensively addressed to reduce wildfire risk), and blue stickers for lower priority areas (Figure 27, A). Participants were given time to go up to the maps and study the risk areas the group had identified, to discuss with each other and to put their stickers on the maps (Figure 27, B). Following the workshop, the areas drawn and dots placed during the workshop were digitized and mapped for the following day.

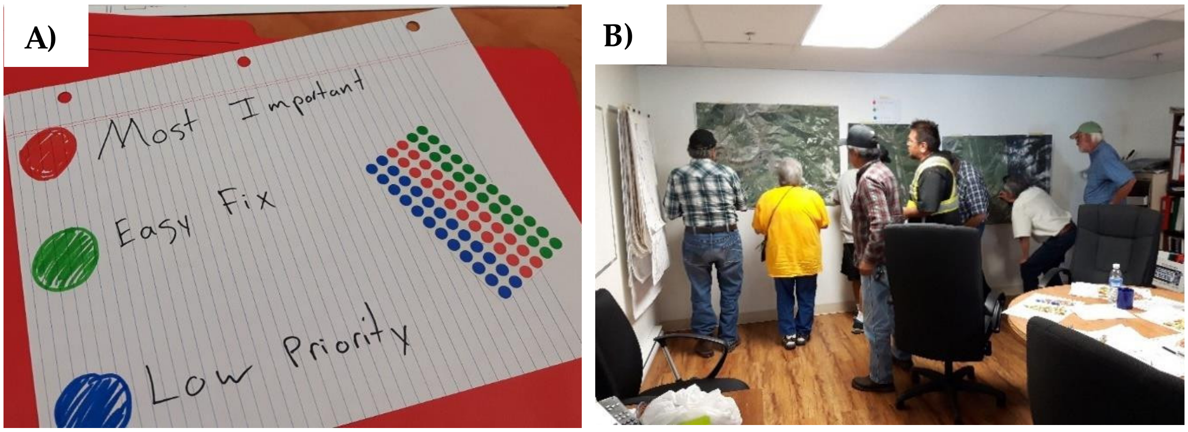


Figure 27: 'Dot-mocracy' colour legend (A) and participants placing 'dot-mocracy' stickers (B) (Bezzola, 2018)

Site Visits and Discussing Solutions

On the second workshop day, the group visited a few sites in the valley identified the day before as either high-risk or that provided a view of high-risk areas. Sites were chosen by the participants at the beginning of day two based on interest, accessibility and time constraints. The west side of Kwotlenemo Lake, Sobotka's Ranch and the area below the band office were visited over three hours (Figure 28).

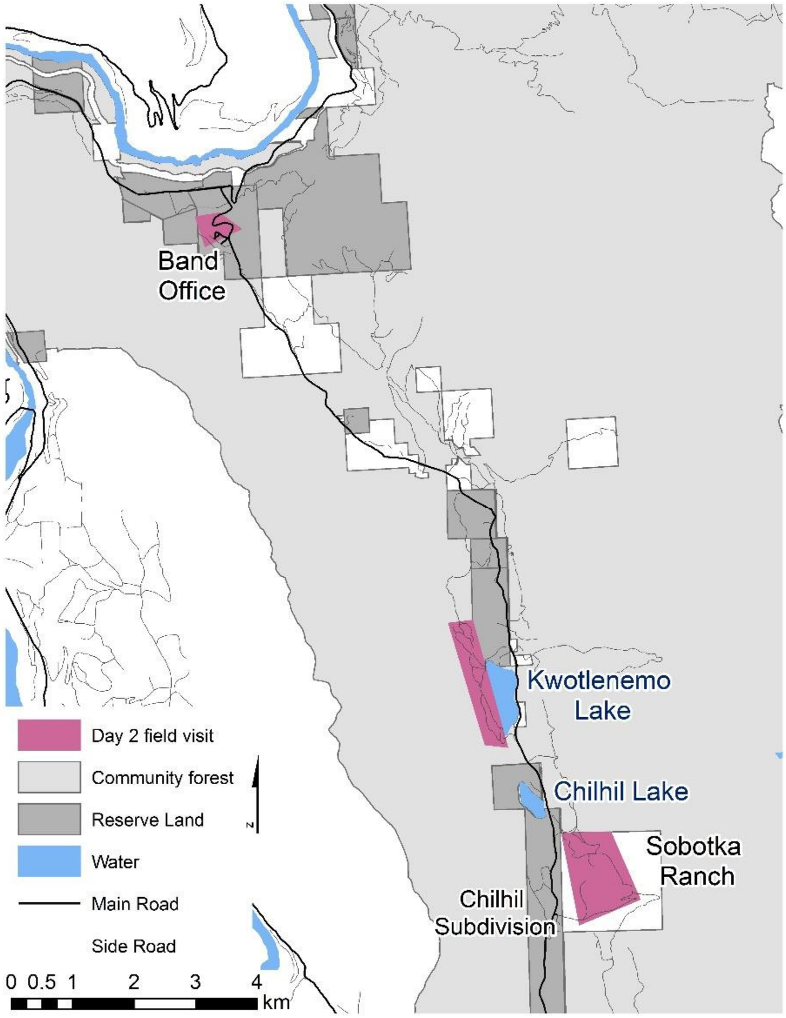


Figure 28: Sites visited with participants on the second workshop day to see some examples of wildfire issues identified on day 1.

Participants were provided with maps of the priority risk areas identified the previous day (Figure 29). While in the field, participants added some additional areas and details, but for the most part, participants observed and confirmed what had been expressed on the first day. Conversations in the field evolved toward identifying and discussing risk mitigation options that the XCF team and the wider Xáxli'p community and Fountain Valley residents could undertake. Following the field discussions, all the maps and meeting notes were synthesized into a report and shared back to participants through the XCF team.

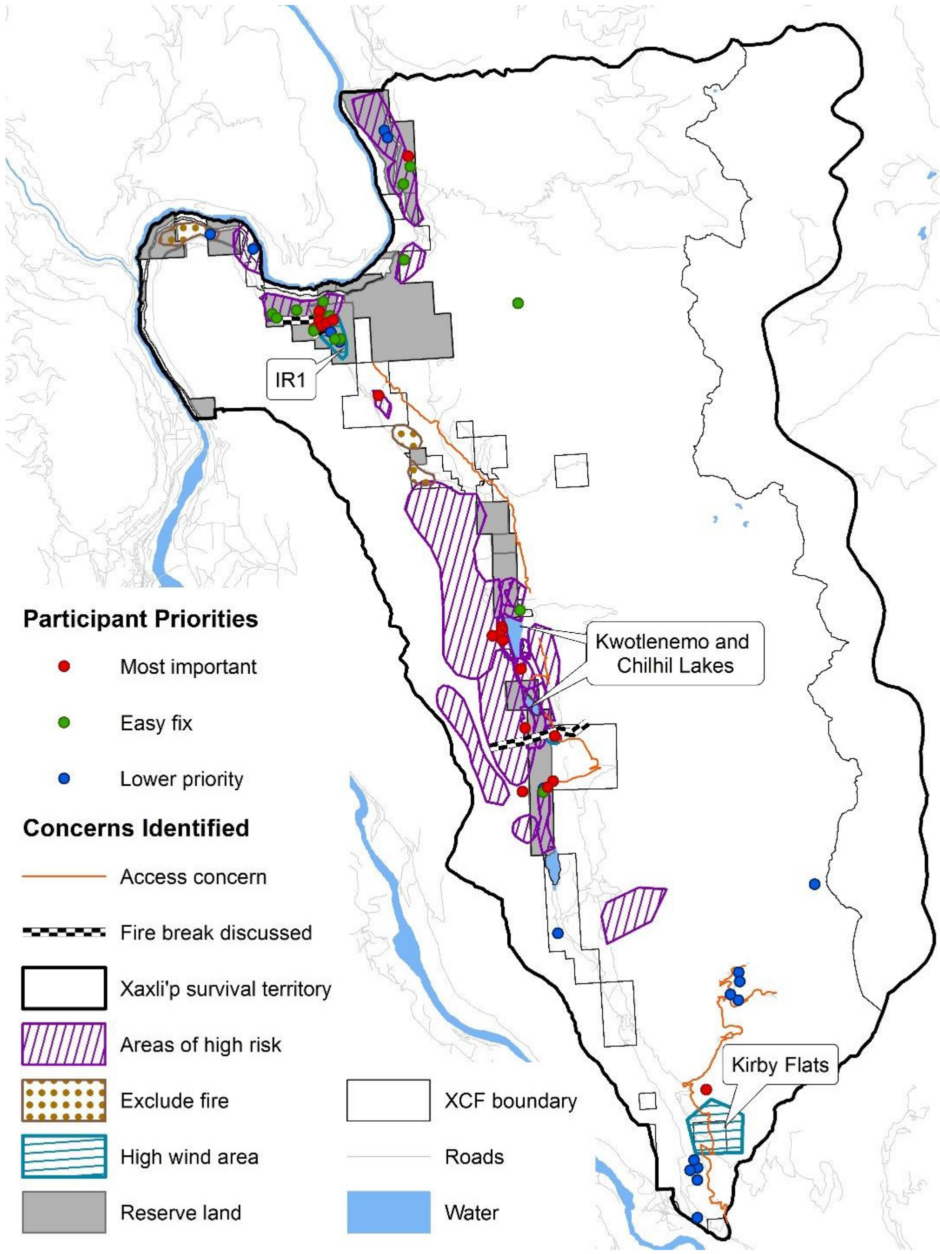


Figure 29: Areas contributing to wildfire risk identified by the focus group.

Wildfire Risks Discussed in the Workshop

Wildfire risk is not a new concern for the Xáxli'p community; they anticipate and experience wildfires of varying sizes and causes in their Survival Territory every season. Despite the Xaxli'pmec history of lighting fires to manage the landscape for food and safety, land management practises and wildfire suppression imposed by the government over the last century have increased fuel loading in the forest and curtailed the ability for Xaxli'pmec to manage the fuel levels in their Survival Territory (see Chapter 1 for more details). The workshop attendees were knowledgeable about wildfire risk, and their concerns over wildfire risk are not a recent phenom; they expressed that their concerns had been accumulating over years and referenced conversations or community efforts relating to wildfire risk undertaken over the last decade. Over the two days, there were recurring themes that highlighted locations and management practices that participants identified as contributing to increasing wildfire risk.

Clear patterns in the distribution of identified risk areas were generally mirrored in the dot-mocracy points (Figure 29). The north area around IR1, the middle of the valley around Kwotlenemo Lake and Chilhil Lake, and in the south around Kirby Flats were the primary areas of concern, with the first two coinciding with areas of high occupancy, while the south end has high recreation but fewer inhabitants.

Fuel Risks Identified Around High Occupancy Areas

Mirroring the homogeneous fuel pattern identified by the quantitative data classification, "the whole valley is high-risk" was a point that got brought up frequently, and this initially caused participants some difficulty in identifying specific areas of high fuel risk. The priority wildfire fuels identified by participants throughout the valley were grasslands that dry out in the hot summer and/or accumulate over years if they do not get mowed or grazed, dense forest fuels that have grown thick because of wildfire suppression and land management practices and dead trees from pest and disease. Additionally, in the southern end of the valley, the deep duff layer and deadfall were identified as a priority risk.

The initial fuel assessment using the existing quantitative datasets focused on dense, mature forest areas of C2, C3, C4 that were presumed to carry the greatest risk (see Chapter 2). However, the workshop participants expressed more concern over the grasslands as a fuel type due to their proximity to residential and recreation areas and their ability to act as a conduit between high ignition areas and forests.

Transmission of Wildfires from Ignition to Forest via Grasslands.

Most grasslands (excluding alpine meadows) are situated along the valley bottoms through Fountain Valley and along the wide flat terrace between the Fraser River and the entrance of Fountain Valley. Shrubs dominate the step up from the river terrace into Fountain Valley, around the band office (IR1), and the southern end of the valley has open ponderosa pine forest with a grassy understory. These grass and shrub fuels were identified by participants as being a major concern at the north end of the territory at the fishing grounds, in fields along the highway, as well as grassy yards on the reserves (Figure 30, Area A).

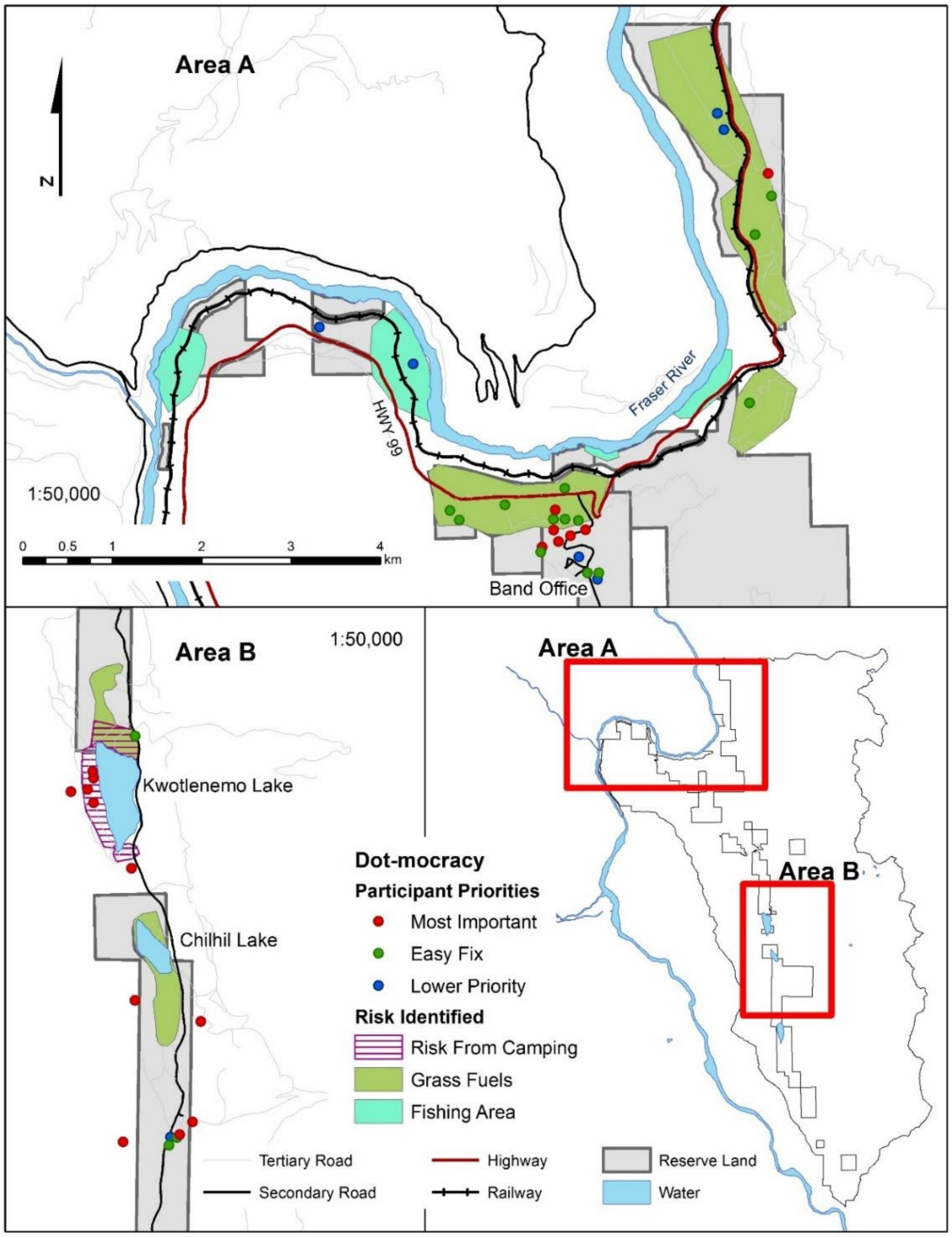


Figure 30: Grass and shrubland contributing to wildfire risk around the north of the valley and Kwotlenemo Lake and Chilhil Lake identified by the focus group.

In the center of the valley around the Kwotlenemo Lake and Chilhil Lake (Figure 30, Area B), participants were concerned that the grassy fuels around the houses, campsites and fields would transmit wildfire easily to the dense forest west of the lakes. This dense forest west of the lakes was the primary concern for forest fuels in the territory, flagged for the forest density and high amounts of dead standing trees (Figure 31). Participants identified an increase in grassland fuels associated with recent decreases in grassland management and less cleaning up around fishing grounds. Grassy fuels in the fields north of Kwotlenemo Lake and south of Chilhil Lake (Figure 31) have become an increased concern since the ranch stopped haying the fields, and horses or cattle are no longer grazing other fields like they used to. Along the Fraser River are the traditional Xáxli'p fishing grounds where participants expressed concern over the dead grasses and other debris building up around the fishing racks (Figure 30, Area A). Traditionally, these areas were burned to clean them, but this is a practise that no longer occurs regularly. Recorded wildfires have swept up the hillside that started at the fishing grounds because of this issue.

Figure 31: View looking south-east over Chilhil lake showing Fountain Valley Road providing easy access to the lake and fields that have an accumulation of dry grassy fuels. In the foreground, you can see dead standing trees on the hillside on the west side of the lake (XCF Forest Crew, 2017).

Risks Posed by Dense Forest Fuels.

Many workshop participants commented that they had observed the forest getting increasingly dense throughout the valley over the years and that because old trails have grown in, it has changed how they access specific locations in the Survival Territory. A particular concern over forest fuels focused on the center of the territory, along the valley bottom and a bit up the valley sides (Figure 32). The west side of Kwotlenemo Lake was the first area identified in the workshop, described with comments like "it is going to burn soon" (Figure 32). They have observed high tree density with plenty of ladder fuels and dead standing trees in this area, and the area nearby was identified as a risk for grass fires that could transmit wildfire from the high probability ignition campsites to the forests with the highest fuel concern (Figure 32).

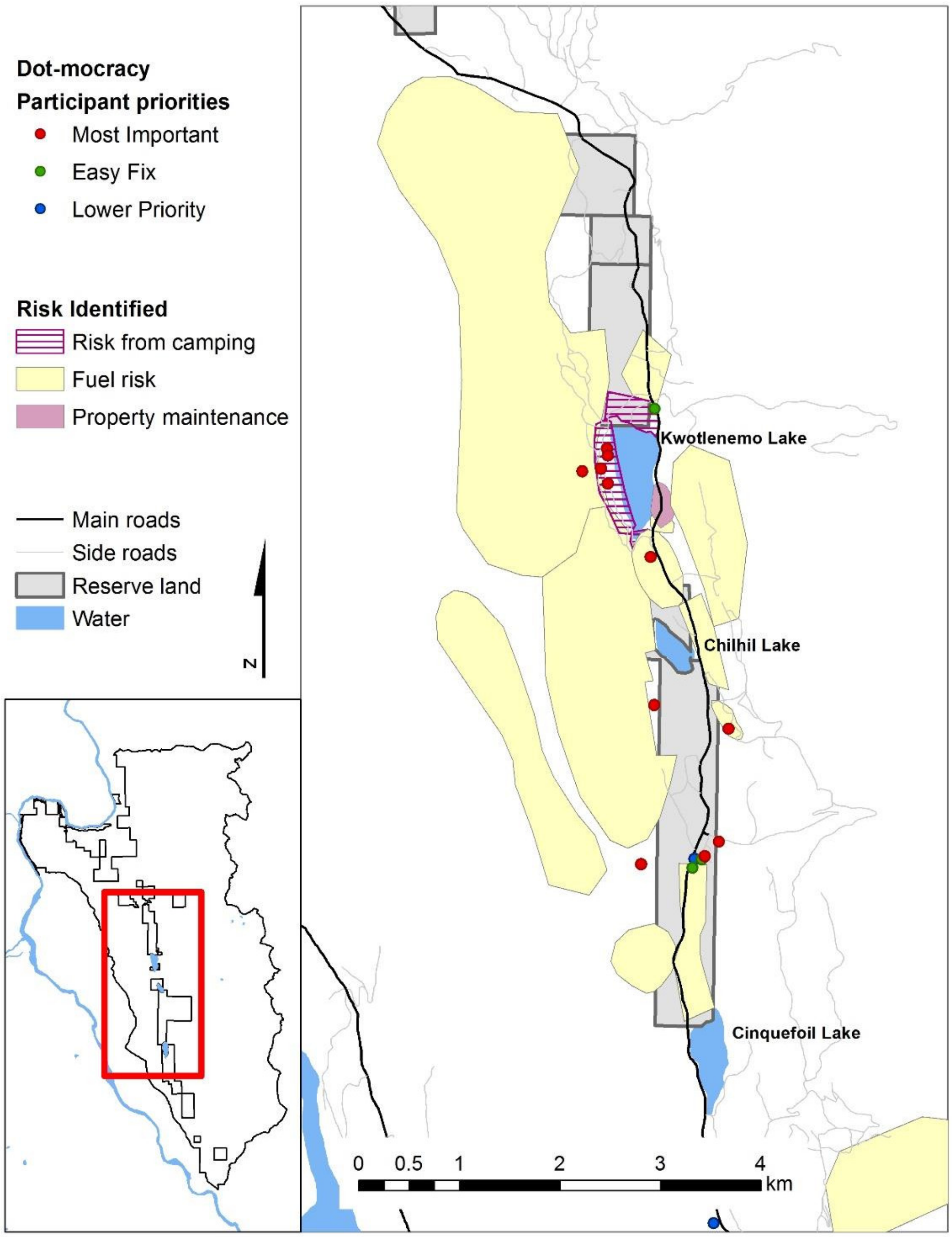


Figure 32: Forest areas contributing to wildfire risk identified through the centre of the valley by workshop participants.

Other Fuel Concerns.

Standing and fallen woody debris and duff were concerns throughout the valley, both during the focus group and the field trip. The dead trees in the forest, identified by participants as "bug-kill," contributing to the fuel load were a concern for some participants, "the bugs are going to get the valley, or the fire is going to get the valley." The viewpoint above Sobotka's ranch visited during the field trip was chosen partially because from there, the dead trees were visible on the west side of the valley (Figure 33).

Figure 33: Fieldtrip viewpoint from Sobotka's ranch overlooking the valley and the dead standing trees on the west side of Fountain Valley (Bezzola, 2018).

The open grassy ponderosa pine forest at the south end of Fountain Valley around Kirby Flats was identified as a fuel risk for its deep duff layer. There was also concern expressed over the fuel loading around the Kwotlenemo Lake and

Chilhil Lake because residents are getting older and less able to manage the fuels on their properties in an area of higher ignition potential.

The role of deciduous trees in a wildfire landscape was not clear to all participants. Some participants with experience fighting wildfires explained the lower flammability of deciduous trees when they are leafed out. The understanding of many was that all dense vegetation would increase the wildfire risk, and they felt safer after cottonwood removal; however, others were concerned over losing cottonwoods for both cultural and wildfire risk reasons.

Ignition Risks Identified

According to provincial records, historically, the predominant cause of wildfires in the Survival Territory has been human activities, with limited observation of wildfires ignited by lightning by workshop participants, which was reflected in the quantitative data (see Chapter 1 & 2). The grassland areas align with land-uses that are associated with higher ignition risk areas: valley bottoms where people live, roads, campgrounds, fishing grounds. Ignitions from lightning, backcountry access, and people accessing roads were not identified to point sources by the focus group but were raised as a concern throughout the valley, with some regions of higher likelihood identified. Managing the activities of people to limit the chance of ignition through fire-bans, access restrictions (Figure 34), and patrolling the backcountry on the part of the Range Riders contributes to Xáxli'p wildfire prevention throughout the summer.

Figure 34: Sign at the northern entrance of Fountain Valley, informing residents and visitors of wildfire hazard rating, access limitation and fire ban to reduce the risk of ignition (Bezzola, 2018).

Human Ignition Patterns in the Territory.

The portion of the Survival Territory that is in the Fraser Valley has some of the highest concerns for wildfires starting, with highway traffic, sparks from the railway tracks, and activity at the fishing grounds which have started wildfires in the past. Just up-slope at the mouth of Fountain Valley is the main reserve (IR1), with a higher concentration of houses creating higher safety and cost consequences if a wildfire were to burn there. This human-wildland interface creates more complex management conditions to keep ground fuels low relative to areas with no houses or off-reserve land.

At the campsite, ignitions from campfires are a significant concern because even with measures in place to control this risk with fire bans and posted signs, there are often still fires getting lit. Just days before the workshop, an abandoned fire was found by residents despite the fire ban and extreme fire danger rating. Activity at the fishing grounds, the gathering place, and the campsites is seasonal, with elevated risks occurring when the areas are most used and when the fuels are driest.

Road Access Associated with Ignition Patterns.

Road access is a concern for fire ignition because it increases the area accessible to the public, and therefore, the area with a higher chance of human ignited wildfire. The main areas of ignition concern identified by the focus group were along Fountain Valley Road, Rough Creek, the bike trails around Kirby Flats, and Sobotka's ranch (Figure 35). To the east of Kwotlenemo Lake, there is road access to the powerline; this concerned the focus group because the high traffic increases the ignition risk. Participants suggested reducing traffic and posting information signs during times of higher risk and reducing fuels 10-20 m on either side of the road to reduce the likely hood that sparks evolve into wildfires.

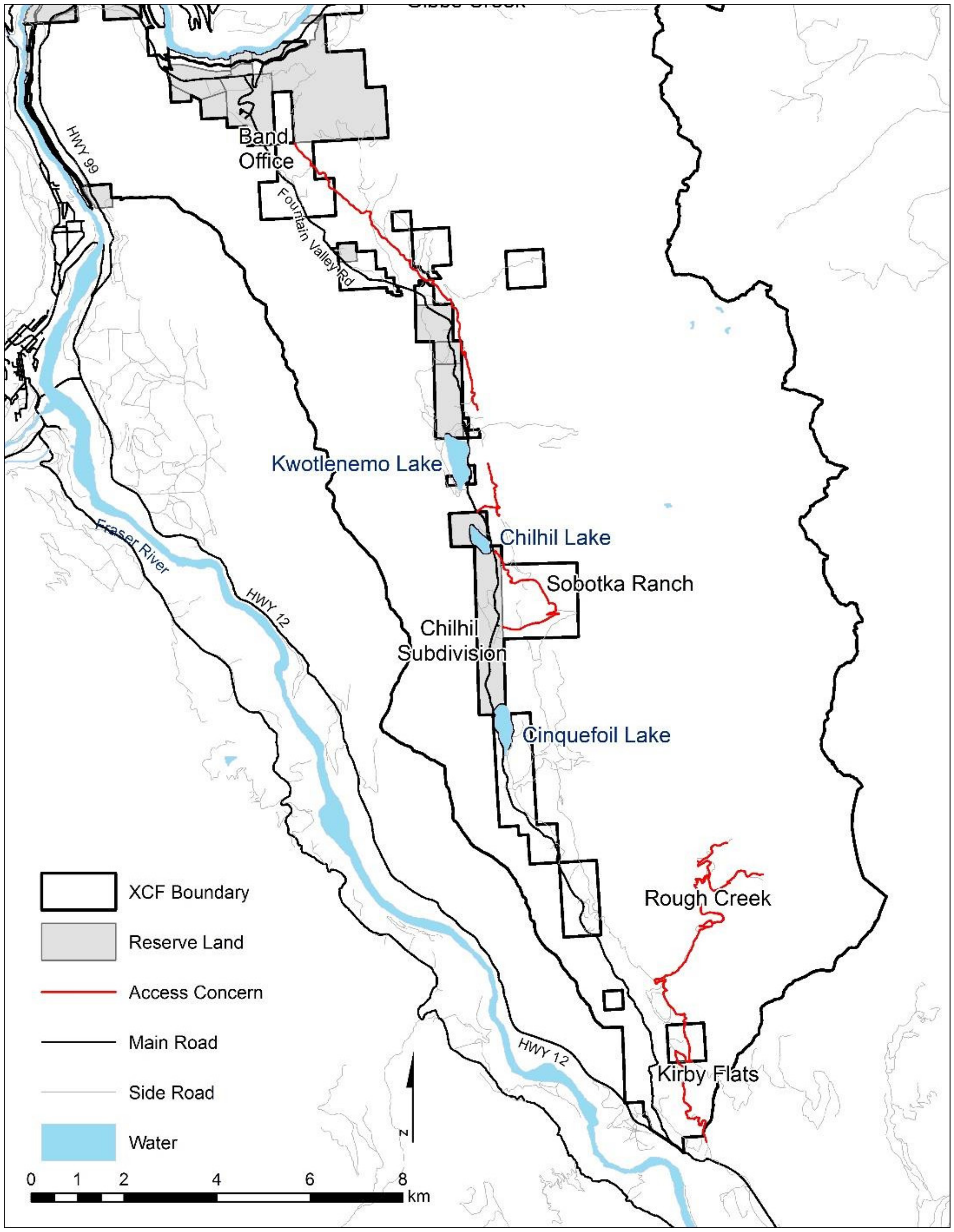


Figure 35: Areas identified for high ignition risk associated with road access.

In the event of a wildfire, access is a limiting factor for both public safety and wildfire suppression. The main Fountain Valley Road connects Highway 99 at the north to Highway 12 in the south, providing the only other access into the valley.

Lightning Ignitions.

The pattern of lightning in the valley and associated wildfire risk was unclear to most participants. In conversations about ignition, there were questions from participants whether lightning was a threat, some observations that there was not much lightning or observations that wildfire ignited by lightning tend to stay small.

Wind Patterns

During the workshop, there was little detail about the wind patterns because of its variability throughout the day and territory. Out in the field, it was not a topic that came up at all, perhaps reflecting that the wind weighed less on the minds of participants than other issues. The key characteristic of wind in the Survival Territory identified by participants was the wind tunnel effect created by the topography, with the wind blowing mostly from the north or south, though down at the Fraser River, the wind from the south is funnelled up-river. It was identified by a few participants that it is "windy all the time at the main reserve" with the wind coming off the Fraser River and over the high ignition risk areas of the highway/tracks/fishing grounds up to the band office which therefore has a high-risk for quickly pushing a wildfire south into Fountain Valley (Figure 36). The grassland areas are susceptible to wind-blown wildfires in these areas, transmitting the fire to surrounding forests, which participants identified as a high concern. The southern end of the valley around Kirby Flats was also identified as a risk for high wind.

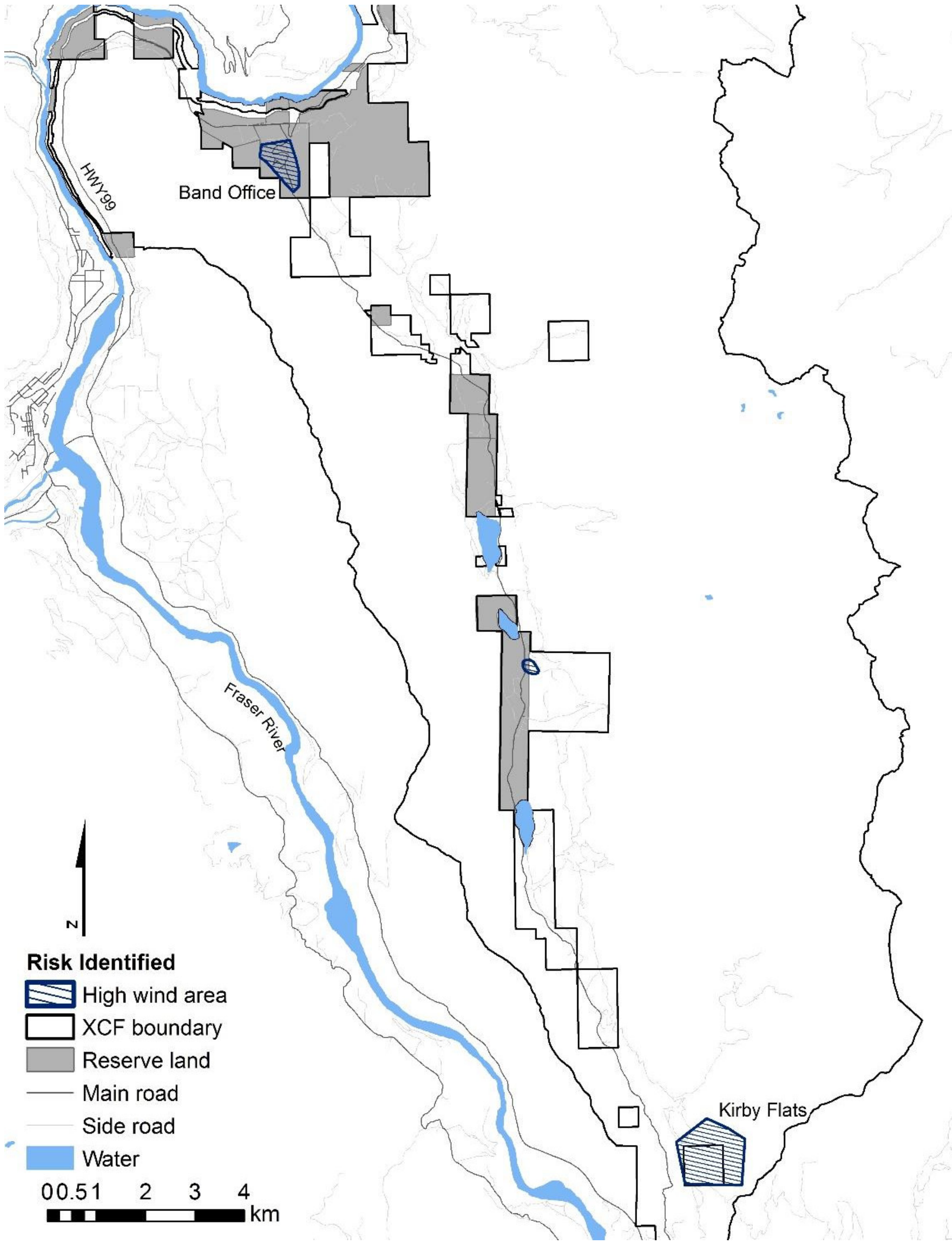


Figure 36: Areas identified for particularly high wind by the focus group.

The variability of wind was highlighted with comments about the wind switching every hour, the strongest winds in spring and fall, the diurnal patterns of the wind coming downslope at night, and a shift in the wind behaviour at one participant's house after the 10-Mile burn.

Risk Mitigation Measures Discussed

After highlighting the main areas and causes of wildfire risk, participants started to suggest options for reducing fuels and managing the community's safety. This natural progression of the conversation was not planned, but it was evident that participants had considered these threats over the years and developed ideas about potential solutions.

Creating Fuel Management Areas

Fuel management areas (called firebreaks, fireguards, or fuel breaks by some community members) were raised as a wildfire risk mitigation option multiple times by participants. Viewing the landscape in the field prompted participants to identify and discuss potential fuel management locations. Two specific locations were identified in the valley, both tied into natural low risk landscape features and to isolate high-risk fuel conditions that could threaten the nearby residences.

In the north end of the valley, participants suggested the creation of a fuel management area to mitigate wildfire risk posed by the high probability of ignition, grassy fuels and high winds (Figure 37, Area A). Measures included keeping a well-mowed area along the edge of the field at the mouth of the valley (Figure 37, Field Fuel Break), as well as a fuel break in the shrub/deciduous area between Fountain

Valley Road and Rose Ellen's house on IR1 west of the Band Office (Figure 37, IR1 Fuel Break). During the field trip, the viewpoint looking over the valley from Sobotka's ranch provided an opportunity to identify where a fuel management area could be tied into existing low fuel-risk features in this area (Figure 37 Area B). From the more open, rocky bluffs on the west side of the valley, to the field at the valley bottom up the east side along a creek draw, these features could be further thinned and maintained, while dense connecting forest could be cleared or aggressively thinned to provide a fuel break that connects with the transmission line running parallel with the valley.

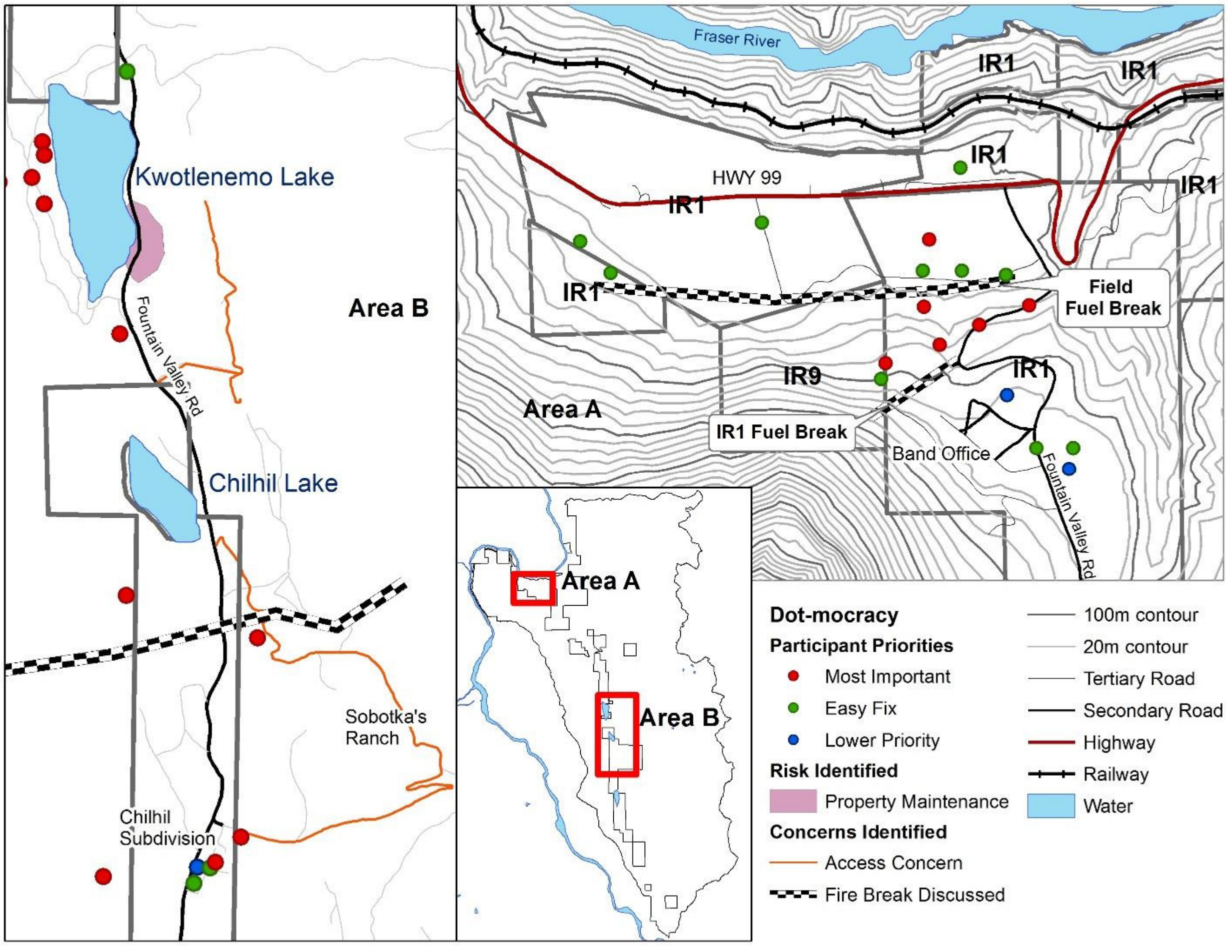


Figure 37: Fuel breaks identified by focus group participants.

Views on what targeted fuel management areas should look like ranged from logging most of the valley, to clearing strips across the valley at regular intervals (1/2-mile-wide breaks, every 5 km), to creating a few breaks that build on natural low fuel-risk features. There were some conflicting views on the role of logging; on one side was the suggestion that more of the forest should be logged, and on the other side that the focus needs to be on restoring the ecosystems, not logging. If the thinning and creation of fuel management areas can be profitable it can provide some income to the XCF to increase other wildfire mitigation measures and can be tied into eco-cultural restoration work.

Controlled Burns

Some Xáxli'p community members and the XCF forest crew use fires to reduce grassy fuels, particularly around houses. The option of increasing the use of controlled burns, specifically south of Chilhil Lake, between Kwotlenemo Lake and Chilhil Lake (using the road as a break), below the Xáxli'p band office, and around the fishing grounds were discussed during the workshop. There was a suggestion to increase fall burning, which tied into a separate comment about the higher amounts of dry grass fuels they are expecting next spring because of the wet summer and that with fall burning this fuel risk could be reduced in the spring. There was a reminder from the group that with the amount of fuel in the forest, it was not going to be easy to reintroduce wildfire to large areas in the territory. Participants rely on the XCF forest crew to decide where to burn, and people feel safer after the burning undertaken by the crew.

Maintenance to Reduce Fuels

Workshop participants wanted to see more routine fuel management happen on properties throughout the valley. This included helping older people who can no longer manage to clean up fuels around the lake, cleaning up around the reserve and the fishing racks along the Fraser River. They identified grasslands as straight-forward fuels that could be directly managed with grazing, mowing, haying and spring burning. Participants mentioned that there had been a study done to identify how many head of cattle could be run in the valley, and there was further discussion around bringing back horses to graze or other animals such as pigs or goats for cleaning the ground.

Participants expressed support for work the XCF forest crew has undertaken to reduce forest fuels such as tree density thinning, live branch pruning, and slash management as well as the plans to re-introducing wildfire (Figure 38). The XCF staff had already scheduled some specific areas identified by the focus group for high-risk fuels for fuel reduction work, which was another positive reinforcement for the work of the XCF.

Figure 38: Example of forest thinning undertaken by the forest crew for eco-cultural restoration near Chilhil Lake (Green, S. 2017).

The positive view of ongoing eco-cultural restoration work was tempered by feedback from a participant with experience doing prescribed burns who indicated that clearing underbrush would need to happen as frequently as every five years to keep the new seedlings down and bringing back wildfires will need to be done very carefully. They advised that the fire regime has shifted so that areas can not just be lit at the bottom and let go. Additionally, the manual fuel reduction work has limitations because of limited resources available to the XCF; one participant estimated that it would take 40 years to thin the valley at the current rate.

Emergency Response

The participants recognized that in a massive wildfire event, there would be nothing the community or fire-fighters could do to stop it even with extensive thinning and fuel management areas. In this case, participants felt the priority should be to focus on "saving" the valley bottom, not on the upper elevations because of the risk to lives. Logistical concerns about ensuring the safety of residents included how to evacuate the valley inhabitants without having the correct addresses of valley residents and poor communications infrastructure.

The desire for the formation of a Xáxli'p wildfire crew to fight wildfires in the valley was expressed, with concerns over the current capacity and resources available in the valley to extinguish wildfires. Ensuring access to water throughout the valley by stationing water throughout the valley and fixing the waterline on the flats was suggested. Additionally, there are improvements needed to the road and bridge that currently prevent access to the west side of Kwotlenemo Lake with the fire wagon.

Conclusion

Patterns in the distribution of high-risk areas became apparent when the focus group mapped out their concerns. The north around the main reserve (IR1), the middle of the valley around Kwotlenemo Lake and Chilhil Lake, and in the south around Kirby Flats were the major clusters of identified risks, with the south generally identified as a lower priority. The first two areas coincide with areas of high occupancy, while the south end has high recreation but fewer inhabitants.

The significant concern participants expressed for the risk posed by grass and shrubland contrasts with the greater focus on forest fuels in Chapter 2, this prompted a re-assessment of the context of the fuel categories and how it fits in with the eco-cultural landscape. The workshop also focused the priority on the lower elevations with the higher ignition risk, greater consequences because of habitation and more detailed information about the landscape.

Chapter 4: Integrating Data Types and Exploring Key Learnings

Keeping this research grounded in the relationships between people, information, ecosystems, and history was vital to maintaining the relevance of finding and solution that aligned with the Xáxli'p priorities for their Survival Territory. As the initial phase of a long-term partnership between the University of Northern British Columbia and the Xáxli'p Community, the objective was to examine the utility of existing datasets, information, and methods as surrogates for wildfire risk in usable and suitable outputs for XCF eco-cultural restoration planning. Through the research process, existing quantitative datasets for ecosystem structure, weather and road access were adapted to represent the fuel, wind and ignition conditions. As proxies for risk, we found inherent limitations in this approach; consulting community members attempted to explore, validate and mitigate these limitations.

As individual elements, the value of the wildfire risk classification layers (fuel type and connectivity, average wind conditions throughout the valley, and ignition source and distribution) for supporting eco-cultural restoration planning remains unclear. Building on these classifications, the conversations and information gathered in the community workshop brought together the fuel, wind, and ignition issues, weaving between different concerns and locations to build a more holistic and spatially focused view. Combining the quantitative and community data was not an attempt to discredit either, but to contextualize and prioritize the different risk factors and to identify patterns and shortcomings. Bringing the layers together provided a more spatially focused view where overlapping wildfire concerns highlighted potential priority areas for mitigation activities, and differences in risk perception highlighted locations and systems that would benefit from further research.

Integrating the Quantitative Categorical Data

As stand-alone risk layers, the fuel, wind, and ignition risk data individually fail to capture the relationships on the landscape, providing an incomplete assessment of the overall risk. Identifying critical overlaps in high-risks of the fuel, wind and human access were examined to identify potential high-priority areas. Ecosystem Based Conservation Plan data were used for fuel classifications and provided a unit of aggregation to examine the modelled wind speed, and the ignition/access areas for each ecosystem patch to spatially refine potential priority risk areas.

Combining Fuel and Wind Risk Data

Higher wind areas that would stoke the spread of wildfires tended to occur at higher elevations, while lower winds tended to occur in the valley bottom. When isolated to high-risk fuels (C4, C3, and M1-75), ecosystems classified in the highest categories (>15 m/s) made up a very small portion of the landscape, with most areas in the 5-10 and 10-15 m/s wind speed categories (Figure 39). The dispersal of the high wind (>10m/s) covers about half the high fuel-risk landscape, an area too large to apply fuel mitigation and mainly at higher elevations, inaccessible areas in the Survival Territory, while the high fuel-risk ecosystems with lower average wind speeds (<10 m/s) are nearer in the valley bottom.

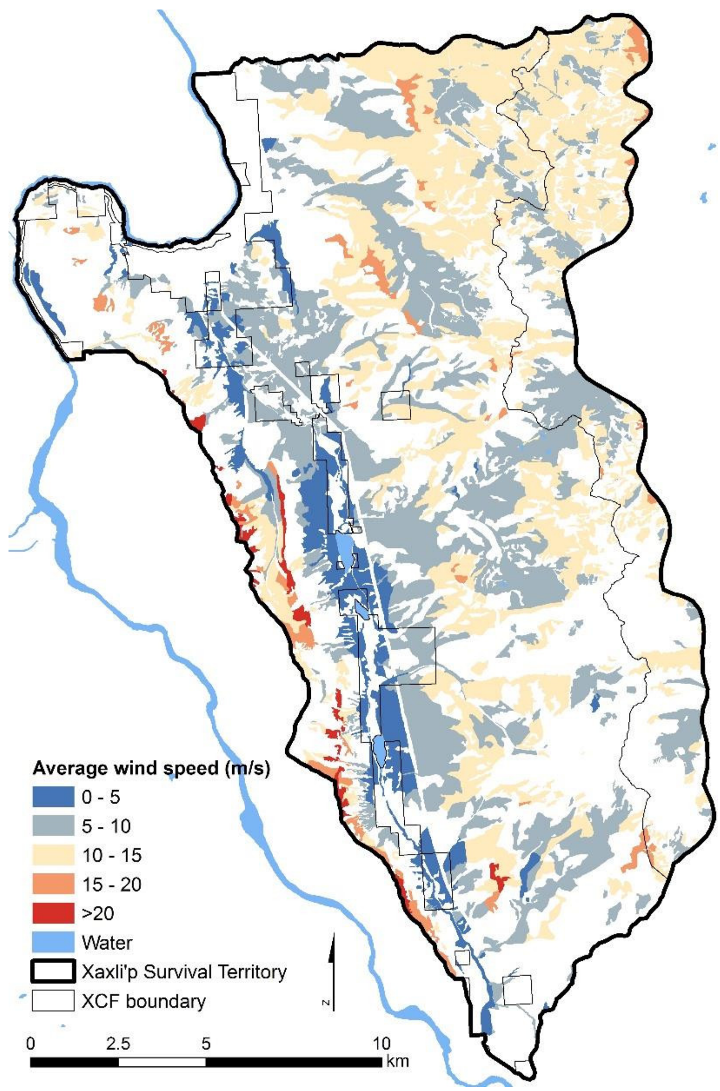


Figure 39: Average wind speed in ecosystem units with high-risk fuels (C4, C3, and M1-75).

Wildfire Ignition Risk Attributed to Road Access Narrows the Focus Area

Historically, wildfires started by humans have been the dominant ignition in the Survival Territory with the ignition of wildfires heavily concentrated to within 500 metres of roads (described in Chapter 2). Consequently, human-caused fires may indicate a primary factor in identifying priority treatment areas. While it is more likely that wildfires start within 500 metres of a road, there remains a risk of an ignition occurring anywhere else in the territory, either by human cause or lightning.

Integrating ignition probability as a wildfire risk factor reduces the high-risk area substantially, providing smaller locations for eco-cultural restoration work to target. Within 500 metres of a road, high-risk fuels (C4, C3, M1-75) dominate much of the valley bottom and a large area in the northeast region (Figure 40). Lower risks fuels are more common near the road at the south and northwest ends of the valley. Low modelled wind speeds characterize most of the valley bottom (below 10 m/s), with many areas below 5 m/s. Higher wind speeds expected in the higher elevation roads in the northeast and steep highway sections in the northwest (Figure 41). The high-risk fuel areas within the road access buffer highlight areas for fuel reduction where the chance of ignition is higher and can be accessed without adding more road infrastructure.

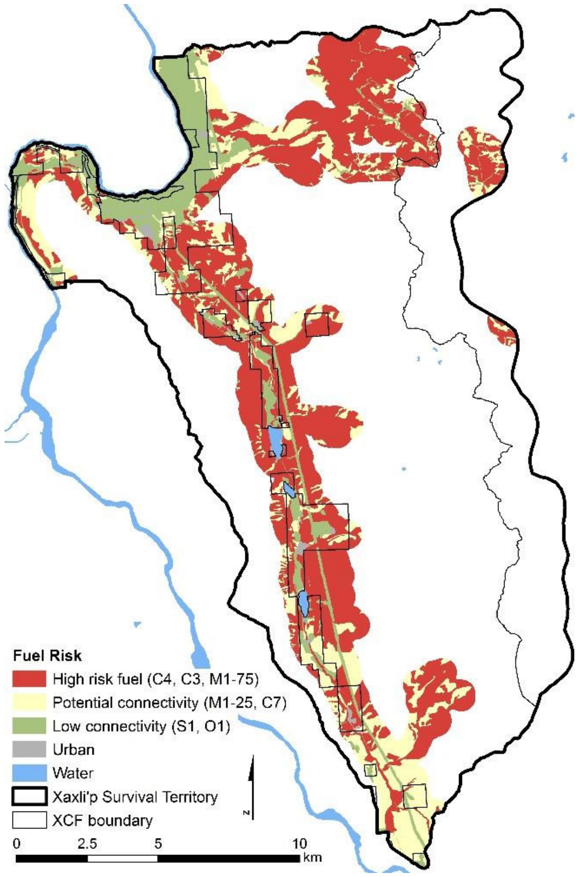


Figure 40: Fuel risk categories within 500 metres of roads.

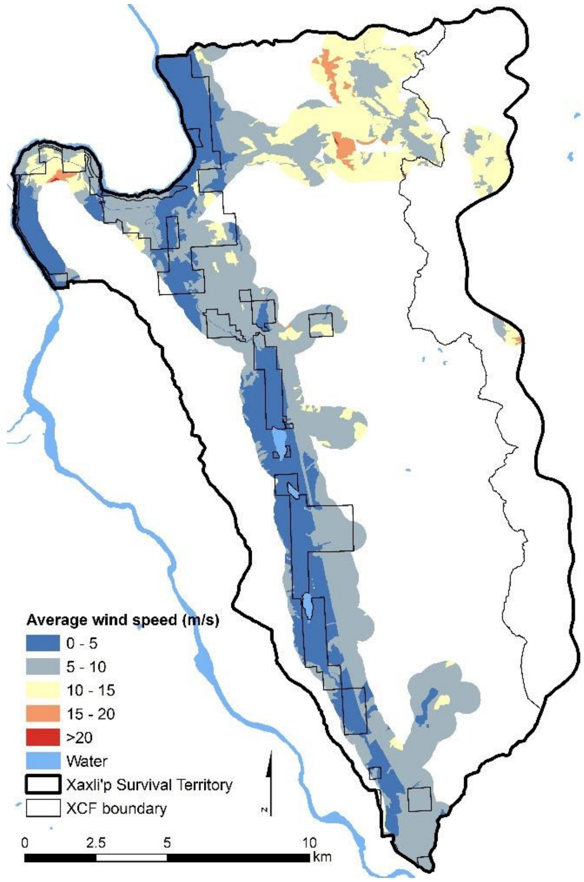


Figure 41: Average windspeeds for ecosystem units within 500 metres of roads.

Lower wind in the valley bottom where there is a higher ignition risk reduces the overall risk for this corridor. However, the high ignition risk area simply has a higher probability of ignition than surrounding areas; it only represents a more likely scenario. There is a risk of ignition outside of this area, by lightning for example, that may be less likely but needs to be considered along with other scenarios for land-use planning and risk management.

Overlaps in High Fuel, Wind and Ignition Risks

Combining all three quantitative datasets highlights potential priority areas for eco-cultural restoration. In the area 500 metres from roads with high-risk (C4, C3, and M1-75) fuel types, the high wind areas tend to be in the northeast, a few small pockets mid-slope in Fountain Valley where side roads go up the hillside, and a few pockets in the northwest up from the Fraser River (Figure 42).

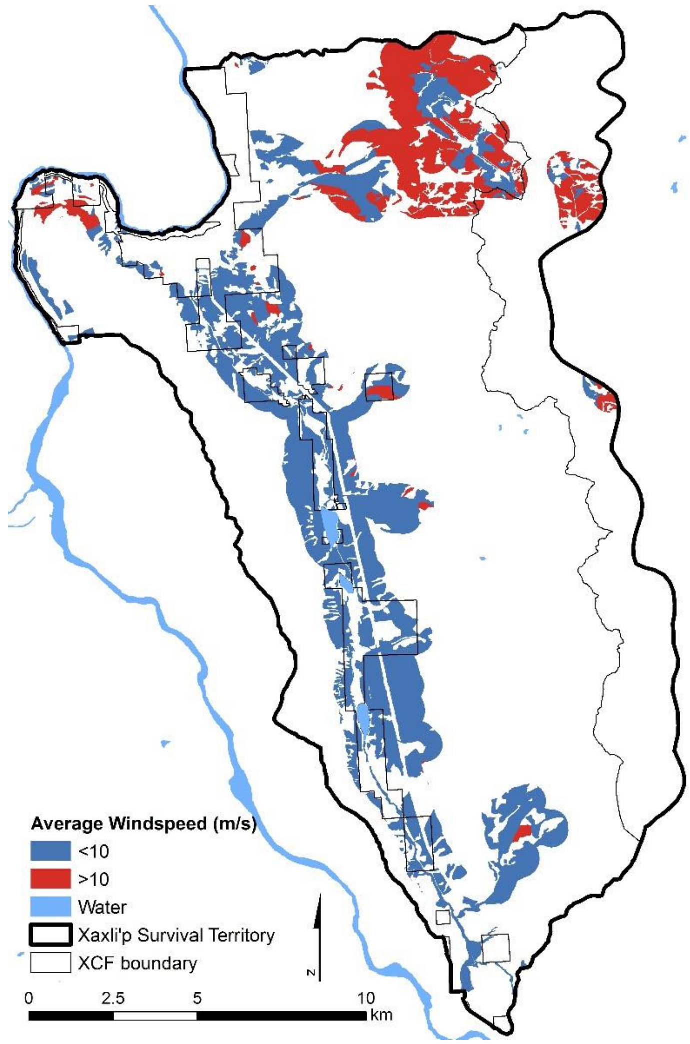


Figure 42: Average wind speeds stratified into high (<10 m/s) and low categories (>10 m/s) in high-risk fuel types (C4, C3, M1-75) and high ignition risk areas (within 500m of roads) to show the integration of the three key risk variables.

While the northeast access area may have the highest risk of severe wildfire in the Survival Territory, there is less risk to public safety and community infrastructure, potentially making it a lower priority for fuel reduction than the classification would suggest. There is uncertainty about the value and utility of the indicators used to assess the wildfire risk because they do not embody community interests and values; community input was incorporated to clarify, confirm or revise the utility of the indicators.

Refining Risk Indicators Using Community Perspectives

In order to capture more nuance and understand the local wildfire risk and restoration priorities, the priority areas identified by the community workshop were overlaid on the quantitative categories for fuel, wind, and ignition risk. The differences and similarities between the community perspectives and the quantitative datasets were examined to show the priorities of each dataset.

Community Experience with Access and Ignition Patterns

Community workshop participants were confident about which roads presented a greater ignition risk because of increased use, the type of use or limited monitoring (Figure 43). The northeast section disappears entirely as a priority risk area because the focus was on the locations people use most for recreation through the valley bottom and fishing along the Fraser River. The fuel risk in this high ignition area is highest around the lakes, on the slopes west of the lakes and higher up the valley sides near Rough Creek in the south. In the more open forest at the south and the shrub/grassland areas around the fishing grounds at the north end of the valley have lower risk fuel classifications for these higher ignition risk areas (Figure 43).

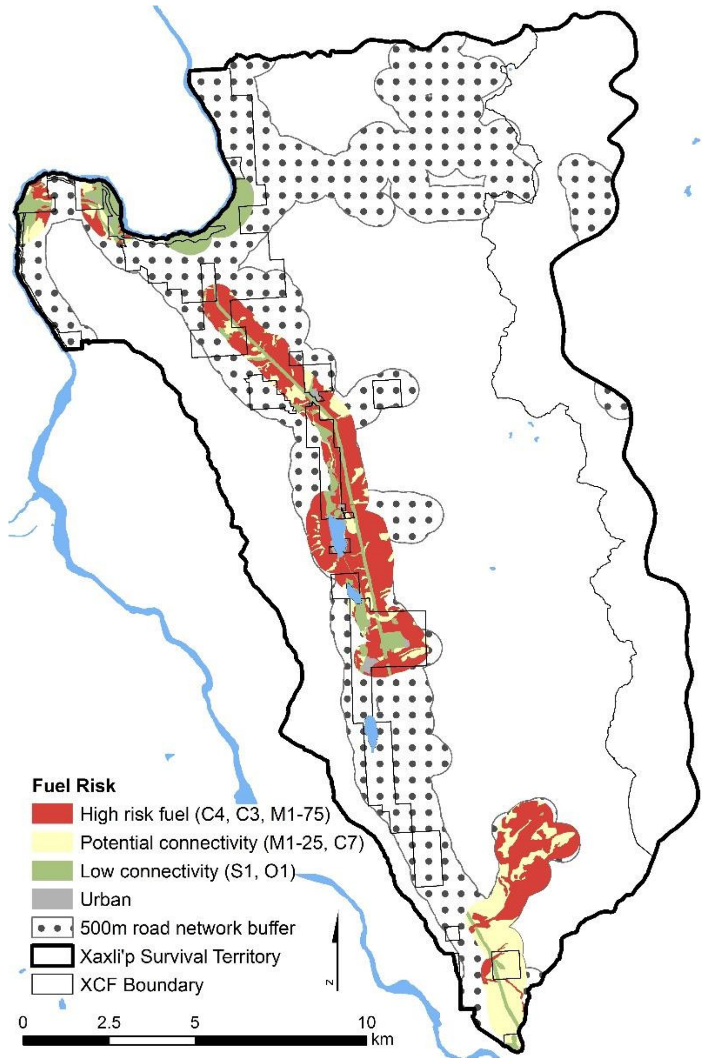


Figure 43: Fuel risk categories in the high ignition risk areas identified in the community workshop compared to the ignition risk of the entire road network buffer.

Community Fuel Priorities Emphasize the Risk of Grasslands

When restricted to the priority areas identified by community workshop participants, the critical fuel risk areas emerged along the west side of the lakes and up the adjacent hillsides (Figure 44) in a pattern similar to the ignition risk (Figure 43). In the quantitative data exploration, the quantitative fuel risk assessment associates hazardous fuel categories with continuous, dense forest stands with plenty of ladder fuels that support intense crown fires with high tree mortality. In contrast to this, for the community members that participated in the workshop, the assessment of fuel type priority reflected more about whether it could support wildfire spread across the landscape from high ignition areas, with particular concern regarding grasslands.

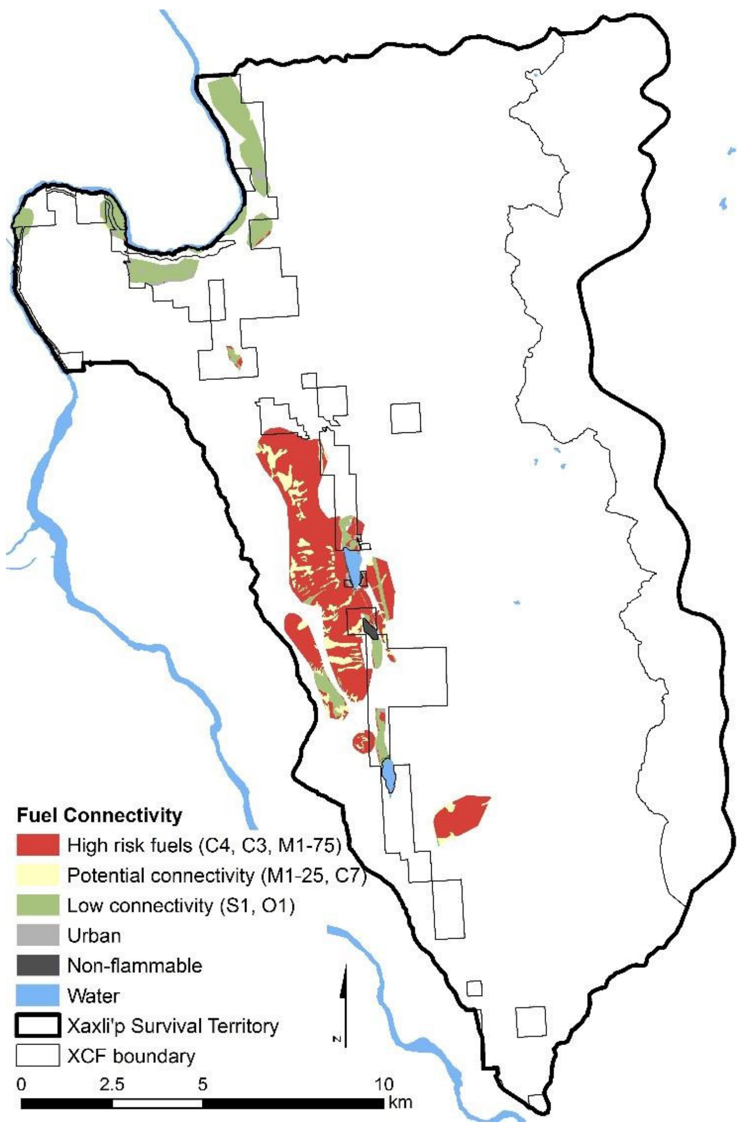


Figure 44: The fuel classifications in the areas of fuel concern identified by the community.

Grasslands that can quickly transmit wildfire to adjacent forest fuels (Figure 45) are a hazardous fuel area despite not burning as intensely as a dense forest. Because of this, these grasslands pose a substantial risk of supporting large-landscape wildfire events – the worst-case scenario for the Xáxli'p priority of cultural continuance. Dense forests and grasslands display distinct wildfire behaviour and require different management treatments to reduce risk. The prioritization by the workshop attendees identified grasslands, like those at the north end of the territory, as priority fuels requiring different fuel treatments (grazing or mowing) than the high-risk forest fuels (thinning).

Figure 45: Grassland area near Chilhil lake that could quickly transmit fire to surrounding dense forests under the right conditions (Green, S. 2017).

Community Identified Wind Patterns

As was identified in Chapter 3, the information collected from the community members in the workshop was too limited to identify high-risk areas for wind. The two areas of high wind identified by the community members are modelled as low wind with the quantitative data model. The conflicting information and limited community information highlights the need to have more wind monitoring in the Survival Territory to provide more systematic and accurate information for decision making and planning.

Data and Research Limitations

The data used and created in this research could be input into predictive fire models to evaluate the productivity, patterns, and behaviour of wildfire on the landscape; however, some important limitations should be considered when using the data at this stage. The quality of input data determines the quality of the model outputs; differences in measurements, models, and terms applied by practitioners propagate errors and inconsistencies and may underpredict the wildfire risk in many fire models (Alexander et al., 2013). Even with high-quality data and good models, wildfire predictions reflect probabilities that cannot reconcile stochastic, random, emergent and unpredictable events. There is a higher probability of ignition near roads in the Survival Territory, but a random event such as sparks from a nearby wildfire or a lightning strike in a remote area cannot be predicted.

Additionally, efforts to reduce wildfire risk through fuel treatments have varying degrees of success when modelled (Alexander et al., 2013), and in the event of extreme fire weather or a severe wildfire, the most drastic fuel reduction treatment will not guarantee that wildfires will not start or spread.

Uncertain Accuracy of Fuel Data

There are a few factors that could influence the reliability of the data and methods for fuel classification. The collection of the photo-points introduces potential misrepresentation because of the uncertain accuracy of the GPS units. Some photo-points were on the edge of two distinct ecosystems. With the range of GPS accuracy, this variation could result in point coordinates being in a neighbouring ecosystem from the ecosystem captured in the pictures or on the border looking into two different ecosystems. With only ten photo-points to capture the nature of an ecosystem type, there may be some bias and misrepresentation for the ecosystem. The dispersal of the photo-points is not randomized; there is some clustering of points, and the whole range of any given ecosystem was sampled as best as could be done by the crew. In ecosystems that did not get all ten photo-points, there may be a higher risk of sample bias.

Though there are some accuracy concerns with the sampling, additionally, the visual review of pictures suggests that considerable natural variability exists in some ecosystem units, more so than might be seen in other environments (such as boreal forests, where classifications were developed). The fuel categories assume a homogeneous fuel structure throughout a single fuel type and the variability indicated from the pictures indicates that some ecosystems may have more variation than should be grouped to a single fuel category.

Localized Wind Data for Complex Topography

Modelling the natural environment always requires simplifying assumptions and generalized results in the output. In the case of the WindNinja model for the Xáxli'p Survival Territory, it is unclear how the wind observation values from the Lillooet airport might affect the accuracy of the model outputs for the territory. There is significant terrain variability in this area, and mountains separate the Lillooet airport from the Survival Territory. With strong diurnal wind patterns coming up from and along the Fraser River, it is unclear whether the model input should reflect that, or whether the model is sensitive to that pattern. The information provided by community members was very localized to areas they spend a great deal of time (ex. the main reserve, where they live); this small sample size prevents comparison with the wind model.

Ignition Depends on More than Roads

A better proxy for ignition risk in the Survival Territory needs development. The road network is a starting framework because it is the limiting factor for where people go. However, based on community input, not all roads are used equally or for the same activities, with the northeast road network seeing less traffic than the valley, for example. The stratification of the road network by how often, and for what purpose, roads are used would then be able to put greater emphasis on areas that have more traffic and higher risk activities such as campfires. The roads identified in the community workshop is a good first start but could be further enhanced with a more systematic review of road conditions and traffic counts.

Synthesis of Findings

As an examination of available indicators of wildfire risk in the Survival Territory to help prioritize Xáxli'p eco-cultural restoration areas and activities, the research scope and objectives evolved as new limitations and possibilities came to light. The initial focus of the research was on developing an accurate characterization of fuels, which was assumed to be the critical factor in defining mitigation measures (BC Wildfire Service, 2015; Thompson & Calkin, 2011). Each iteration of fuel classification resulted in a more homogenous fuel landscape, making it more challenging to define spatial priorities to support XCF strategic planning for eco-cultural restoration. The incorporation of wind and road access added more holistic and locally relevant information on risk. However, the limitations (primarily questions about relevance and accuracy) in all the datasets left a great deal of uncertainty and focused the project on a 'gap analysis' process from which further work could build on.

Community Perspectives Focus Broad Data Assumptions

Preceding the community workshop, the research was primarily focused on forest fuels, followed by wind and ignition considerations, but with limited information about how the community used the land and perceived wildfire risk. The knowledge and experience shared by the community workshop participants regarding the critical importance of grassy fuels broadened the primary focus on forest fuels, particularly in the absence of comprehensive fire modelling. The re-evaluation of grassy fuels is confirmed by Ray et al. (2012) in that Traditional Ecological Knowledge (TEK) provides localized calibration to national narratives and that disagreements do not invalidate either side. The localized knowledge refined the potential treatment areas, which were initially less focused and specific with the broad, general information from the quantitative data classifications. Local input helped to identify relevant, more targeted areas and activities that could be addressed by a small forest crew. Even though the knowledge holders frequently mentioned that "the whole valley is high-risk," on a secondary level of risk assessment, they identified the more nuanced relationships on the landscape relative to the quantitative information.

Growth and Challenges for the Researcher

The process of undertaking a thesis project, cultivating a new perspective with Indigenist research, and exploring my responsibility for reconciliation provided many opportunities to grow and reflect, and accept the underlying uncertainties involved. Following a community's lead and pace in community-led research was a lesson in becoming comfortable with the uncertainty of not knowing, and not insisting on controlling, where and when things will occur or evolve.

A crucial learning for myself as a researcher was the challenges and barriers for Indigenist research, which relies on the ability to build relationships (Figure 46), that being removed from the research location, both geographically and culturally, pose. Access to the Survival Territory was available in day trips on paved highways; however, winter weather, large wildfires, and mudslides all presented challenges during the research, preventing visits or doubling driving time (and therefore restricting time spent in the community). Additionally, over half of the planned in-person meetings got rescheduled because of weather or unexpected events in the community.

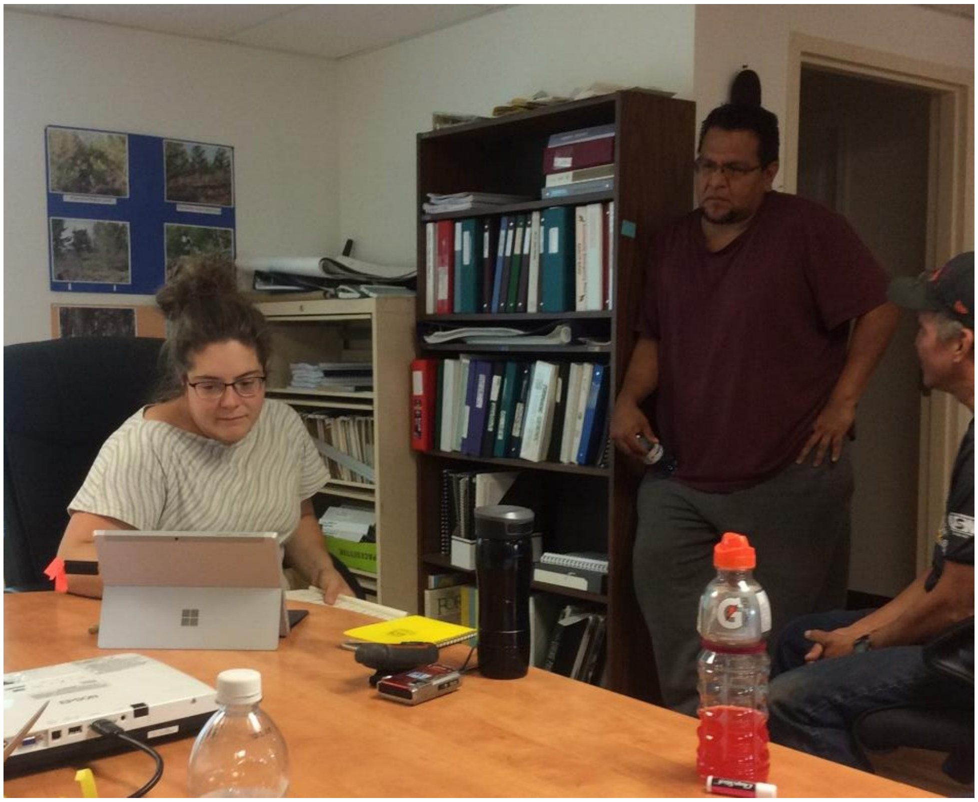


Figure 46: Discussing photopoints and field data with the XCF forest crew (XCF Forest Crew, 2017).

Not being from the community or having an established relationship was also a barrier to doing the best possible research and delivering the most useful outputs to the community because without the relationships, knowing the culture and land, there was a limit to what I even knew to enquire about or follow up on. During the workshop with knowledge holders, there were references to spiritual sites without any detail, which I avoided asking about because I did not want to overstep. This is an assumption I made, which may have been appropriate or may have prevented a useful and enlightening conversation for myself, the workshop participants, and the research. This shortcoming reinforces the importance of the work of Indigenous researchers in their communities and the importance of building strong partnerships where both sides have the time and resources to feel comfortable and safe to have open and honest dialogue.

Beyond respecting Xáxli'p values and honouring the Indigenist research approach, there was a process of learning and understanding my ethical responsibilities to the community when producing outputs and discussing findings. There is an ethical responsibility to not just produce isolated outputs, but to explain the risks and limitations of the datasets and outputs created and to contextualize the benefits and dangers of applying the maps and conclusions so that there is no wrongly placed confusion, fear, confidence that could affect land-use and community decision making. Maps display discrete results which can create a false sense of certainty. With most of my outputs and results communicated in maps, it was important to ensure the limitations were well communicated.

Recommendations for Research and Management

As a gap analysis to explore the existing datasets, the gaps and strengths identified in this research can be used as a foundation for further study in the Xáxli'p Survival Territory to provide more tailored and nuanced guidance. In the interim, the following sections outline broad recommendations for land management and highlight gaps in the quality and type of quantitative data available for fuel, ignition and wind.

Future Research Opportunities

There is significant uncertainty in both the fuel and wind data for the Survival Territory. Increased data quality for both would enable more in-depth fire modelling using Burn-P3 (Parisien et al., 2012), allowing for more significant predictive research into the effects of climate change in the Survival Territory, the effectiveness of existing and planned restoration treatments and plans for safety and evacuations. The combined quantitative fuel, wind and ignition risk layers identified a high-risk area in the northeast, where the most clear-cut logging and plantations are located. This calls for a closer look at whether plantations increase the wildfire risk significantly in this landscape (and to what stocking standard) and should be managed differently going forward, or whether the existing fuel risk categorization should be adjusted for plantations.

Improving Fuel Data.

Emerging methods for assessing forest fuels (such as airborne laser scanning or LiDAR) can provide very detailed information about the ground surface, forest understory, and canopy, such as tree spacing and forest history. It could be used to model forest fuels to a very fine resolution, with consistent coverage and accuracy of the territory, to establish tree-spacing objectives that resemble historic fire-resilient forests and many other uses. Increased photo-sampling of the Survival Territory to include all ecosystem types and more uniform coverage beyond restoration sites and valley bottoms would also increase the quality of the fuel data for relatively low cost and provide valuable ground-truthing and insight into the ecosystem. An important outcome of this research is already underway with the initiation of the second phase of the research partnership between UNBC and the XCF to address this need with LiDAR data gathered in 2019 and 2020.

Implementation of Wind Monitoring.

Data from a weather station in the Survival Territory, or more basic ad-hoc sampling could provide a higher degree of accuracy in the wind model (Forthofer et al., 2018; Turner & Lawson, 1978), and therefore greater confidence in wildfire models. More localized wind monitoring and modelling could also support local fire fighting, increasing efficacy and safety. Any future research projects in the Survival Territory may also benefit from having local weather data available, helping the XCF planning and operations. Recognizing that resources are limited in such a small organization, as a first step, simple hand-held wind measurement units could be taken out into the field and be used to do spot measurements, which would be better than having no wind measurements at all.

Assessment of Temporal Variability.

Seasonal variation in many aspects of the wildfire risk in the Survival Territory, particularly activities that cause ignitions, pose an ongoing challenge in prioritizing areas and activities in Xáxli'p eco-cultural restoration planning. For example, the high ignition risk identified around the fishing sites is most relevant during the times these areas are in use for fishing, or when the sites are maintained. Further refinement of the wildfire risk assessment should take a closer look at temporal variability to provide more useful management strategies.

Land Management Recommendations

The ongoing eco-cultural restoration approach and fieldwork by the XCF align with many practices for creating a fire-absorbent landscape and managing the wildfire risk. Continuation of this work is essential, and a few recommended new practices and locations of new eco-cultural restoration work are offered below. All suggestions should be aligned with the EBCP and Traditional Use Study to ensure they are suitable for the Xáxli'p community and eco-cultural objectives.

Managing Grassland Fuels.

A recurrent grassland management program should be considered for low-elevation grasslands to reduce fuels on reserve land, private property, at fishing sites, in fields that are no longer being worked and around the camping areas. Some of these grassland areas may be good target areas to reintroduce prescribed burning because their fuel loads are more manageable and less risk of escape than the forest. In addition to prescribed burning, mowing or grazing could be used to reduce these fuels, but all three will need to occur regularly to be effective.

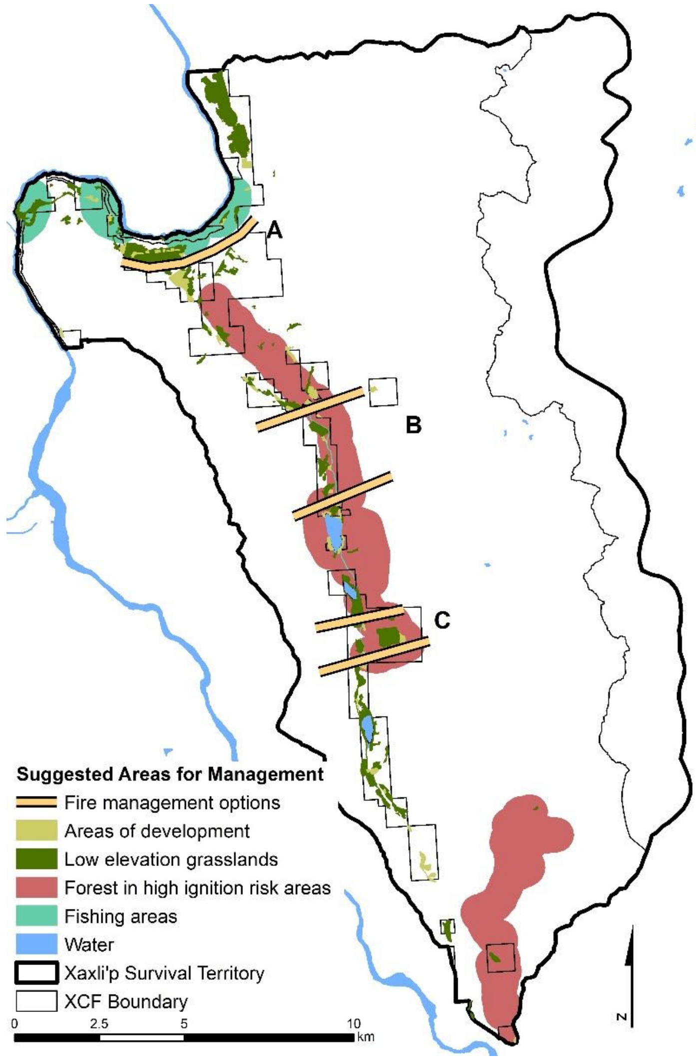


Figure 47: Areas recommended for targeted fuel management.

Continued Forest Thinning.

The forest thinning undertaken through eco-cultural restoration treatments should continue and new areas can be built into a landscape patchwork, targeting forest areas where ignition is more likely such as on the west side of the lakes and in the forests around the campgrounds and the areas within 500 meters of roads (Figure 47, rust colour). The ability for the landscape to absorb and withstand wildfire can be enhanced by creating greater patchiness in the forest by breaking up the continuous fuel as well as building connectivity between surrounding ecosystems that resist the spread of fire such as cliffs, boulder fields and lakes (Figure 48). The densities and spacing required in these management areas to sufficiently reduce the fuel risk is beyond the scope of this project; consultation with the local Lillooet fire crew or other wildfire professionals is recommended.

Figure 48: Example of natural fire-resistant ecosystems that could be tied into other eco-cultural restoration activities to create larger fire management areas (Green, S. 2017).

Creation of Fire Management Areas.

Workshop participants identified specific management options that should be considered for wildfire risk mitigation. The features drawn in Figure 47 are only intended to note the suggested location, not the actual spatial configuration on the ground. Maintaining a strip of land with reduced fuels through mowing or plowing along the edge of the fields at the north end of the valley would help prevent the spread of grassfires from the roads, railway and fishing areas up into the valley with the winds from the Fraser River (Figure 47, **A**). The creation of fire management features through the forest near the south end of the Survival Territory was suggested (Figure 47, **C**) with a few options of where it would protect houses and tie together existing open forest types and natural fire-resistant ecosystems. It could be supplemented with another fire management area farther up the valley (Figure 47 **B**) that connects and reinforces low fuel areas on the valley slopes and provides another break to prevent wildfires from taking off through the whole valley. These potential fire management areas could be integrated into the Ecosystem Based Conservation Plan.

Community Communication and Monitoring.

Creating a more fire absorbent landscape, particularly near populated areas, will increase community safety but should be complemented by the creation of an evacuation plan in case of an emergency. Though most of the recommendations of this work are tailored to fit within the landscape level eco-cultural restoration plan, a FireSmart inventory (British Columbia FireSmart Committee, 2020) to assess the current risk to infrastructure is recommended to bring greater detail to the fine scale around reserve land and housing areas. Continuing efforts to reduce human ignitions through patrols and information is also necessary, with possible benefits to eliminating or reducing access on side roads during high-risk weather. The presence of the Range Riders and the XCF forest crew out on the land as responsible and informed community members is an essential component to monitoring activities throughout the valley and fostering a conversation about wildfire risk. To complement these efforts, education on fuel types and wildfire risk for the community through presentations and pamphlets can be delivered in the lead-up to the wildfire season to proactively inform and prepare the community.

Conclusion

The physiographic, biogeographic, and community data identified some areas of high-risk in the XCF, but with a high degree of uncertainty. Further research is recommended to refine the fuel dataset to enable the use of fire models to assess the efficacy of fuel treatments and plan for wildfire in the Xáxli'p Survival Territory. Additionally, a significant lack of information on the localized wind patterns is a prime opportunity for collecting baseline data that could be useful for many applications.

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