WILDFIRE RISK, RESILIENCE, AND ADAPTATION IN HIGH-LATITUDE REGIONS

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Chapters two, three, and four of this thesis comprise jointly authored publications. Authors are listed in order of contribution:

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ABSTRACT

Climate change and other socio-environmental changes are causing wildfire seasons to become longer and more extreme in many high latitude regions. This trend bears many consequences for communities, including the potential for the loss of lives, livelihoods, infrastructure, and valuable, essential ecosystem services. However, little work has examined how residents in high latitude regions prevent, respond to, and adapt to wildfires, with most research efforts focusing on the physical principles of high-latitude wildfires. In response, this thesis: 1) develops a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions, which is illustrated in a Siberian context; 2) systematically documents and critically evaluates regional wildfire policies and plans in the Russian Arctic; and 3) conducts an in-depth, community-level case study in western Canada to characterise local wildfire risk and resilience. The thesis therefore aims to understand how two different jurisdictions (i.e., local and regional) in two different locations (i.e., Canada and Russia) approach wildfire risk, resilience, and adaptation. This approach provides important insights into how risk, resilience, and adaptation changes across different geographic contexts, helping develop broader understanding. This knowledge can also help identify future opportunities for policy and support current national and international programmes addressing the growing wildfire needs in high latitude regions.

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ABBREVIATIONS

CCA	Climate Change Adaptation
DRR	Disaster Risk Reduction
EOC	Emergency Operations Centre
FRI	Fire Return Interval
GDP	Gross Domestic Product
HA	Hectares
HDCC	Human Dimensions of Climate Change
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
MASL	Meters Above Sea Level
NC	National Communications
NUGs	Non-Utility Generators
PM	Particulate Matter
RCP	Representative Concentration Pathway
SDG	Sustainable Development Goals
SRES	Special Report on Emissions Scenarios
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
VCF	Valemount Community Forest

Chapter 1: Introduction

1.1 Research rationale

Wildfires are becoming more frequent and severe in high-latitude regions. In Alaska, wildfires have burned 2.5 times more acres in the last 20 years (i.e., 2001-2020) than during the previous two decades (i.e., 1980-2000) (Alaska Fire Science Consortium, 2020). In Canada, both the area burned and the number of large fires (⩾200 ha) have significantly increased since 1959 (Hanes et al., 2019). Climate-driven changes, compounded by land use trends and historical fire suppression practices, are expected to further increase wildfire intensity and frequency across most of these regions (Masson-Delmotte et al., 2021; McCarty et al., 2021; Lund et al., 2023). It is anticipated that by the end of this century, Canada could see a threefold increase in burned areas (Boulanger *et al*., 2014), Finland a twofold rise in the number of fires (Lehtonen et al., 2016), and Alaska a doubling of its burned area (Young et al., 2017).

Current and projected increases in wildfire activity have severe consequences in high-latitude regions. From a biophysical perspective, high-latitude wildfires have already been associated with changing plant composition and successional patterns (Mekonnen et al., 2019), altered animal distribution and abundance (Gustine et al., 2014), increased soil carbon losses (Mekonnen et al., 2022), permafrost degradation (Li et al., 2021), and widespread thermokarst development (Jones et al., 2015). High-latitude wildfires have also been shown to decrease snow spectral albedo (Potter et al., 2020), emit large emissions of particulate matter ($PM_{2.5}$) and ozone (O_3) pollutants (Wizenberg et al., 2023), and alter watershed carbon and nutrient dynamics (Rodriguez-Cardona et al., 2020). While these changes have far-reaching global effects (for example by accelerating climate change) (Post and Mack, 2022), the impacts of high-latitude wildfires pose a particular threat to the lives and livelihoods of local communities.

Reliance on subsistence and nature-based livelihoods (e.g., hunting, trapping, small scale forestry), limited road networks, and social, cultural, and health inequalities are but a few reasons why communities in high-latitude regions – notably Indigenous and rural communities – are disproportionately affected by wildfires (Trainor et al., 2009; Montesanti et al., 2021). For instance, for a considerable number of people living in these regions caribou remains an important source of food, income, and cultural strength (Bali and Kofinas, 2014; Kenny et al., 2018; Parlee and Caine, 2018). Wildfire-driven changes to the abundance and health of these animals can therefore have serious implications for local culture, traditions, and environmental knowledge, including feelings of 'ecological grief' (Cunsolo et al., 2020). Similarly, high-latitude regions are characterised by their remoteness, low population densities, and limited availability of modern transport infrastructure, where roads, railways, and power lines constitute a key part of the region's supply systems and development (Povoroznyuk et al., 2022). Disruptions caused by wildfires to this infrastructure – which can occur hundreds of kilometres from communities – can significantly limit the supply of important goods and services to people and impede the access of rescue crews during evacuation processes (Debortoli et al., 2023). The existing shortage of skilled firefighters and volunteers in high-latitude regions, where there is also a lack of essential firefighting equipment (Burnasheva, and Osipova, 2023), makes managing and responding to these impacts notably challenging.

Despite the risk facing these communities, past scholarship has paid limited attention to the human dimensions of high-latitude wildfires. Instead, research has mainly explored the biophysical basis of wildfires, overlooking the role of human systems in wildfire risk, resilience, and adaptation. Indeed, most of the social science literature around wildfires is currently found at lower latitudes such as the United States (except for Alaska) and the Mediterranean (Millington, *et al.*, 2022), which often have completely different dynamics than those found in higher latitudes. There is a significant gap in our understanding around why communities are at risk, what impacts wildfires are having locally, and if and how people are preparing for and responding to increasing wildfire activity in high-latitude regions. This is a research topic that is receiving considerable interest lately, with increasing calls to conduct more research on the human dimensions of wildfire (Sankey, 2018).

1.2 Aims and objectives

The aim of this thesis is to improve our understanding of the human dimensions of wildfires in high-latitude regions, examining how communities and decision makers are experiencing, managing, and adapting to wildfires. Three key objectives will ensure that the aim of this thesis is achieved:

1. Develop a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions.
2. Systematically document and critically evaluate regional wildfire policies and plans in the Russian Arctic.
3. Conduct an in-depth, community-level case study to characterise local wildfire risk and resilience in Western Canada.

By pursuing these objectives, the thesis will help explore the dynamic nature of risk, resilience, and adaptation in high-latitude regions. More specifically, it will offer a glimpse into how (and to what extent) different demographic, cultural, economic, and governance structures (for instance those between Russia and Canada) influence how people interact with fire and vice versa. This knowledge base can eventually lead to a better understanding of the social and ecological factors and processes driving wildfire risk and resilience in different high-latitude regions, and also expand the geographical distribution of recent studies).

1.3 Research context

In this section, the thesis will introduce the physical and social aspects of high-latitude wildfires. This includes exploring where most of the high-latitude wildfires occur, what drives them, why communities are vulnerable to them, and why they are different from wildfires in lower latitudes. This section will also introduce how high-latitude wildfires have been examined in the social sciences scholarship and the theoretical context that underpins the research, situating the research in the broader socio-ecological context of high-latitude regions. Before contextualising the thesis, though, it should be noted that the term ‘high latitude’ refers to any territory that is in the northern hemisphere and covered by both tundra and boreal forests, roughly located between 50 to 80ºN latitude (Fig. 1.1). The transition zone between boreal and temperature domains, or also known as hemi-boreal or boreal-nemoral, is also included in this thesis as part of the delimitation of ‘high-latitude’; this region has been included because wildfires in the hemi-boreal domain are well known to impact and affect the distribution of boreal forests (Bergeron et al., 2004). This delimitation of high-latitude regions has also been a commonly used delineation in phytogeography reviews (Brandt, 2009) and adopted in many other wildfire-related studies (e.g., McCarty et al., 2021). Similarly, the thesis defines ‘wildfire’ as all human- and lightning-caused fire in the natural environment, including forests and peats, which is a definition that has been increasingly used everywhere and is able to accommodate the ecological and social components of risk (Tedim and Leone, 2020; UNEP, 2022).

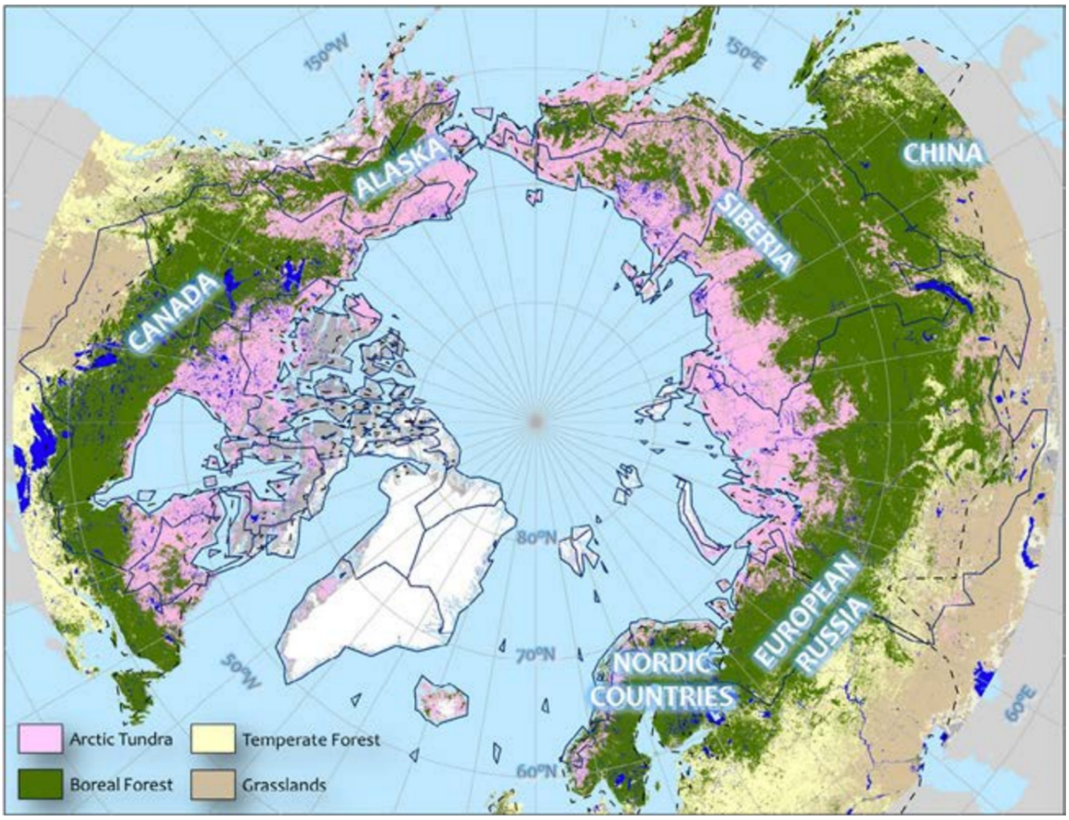

Figure 1.1.The geographic scope of this thesis follows the distribution of the boreal forest and tundra biome. The boreal forest is mostly located between 50°N and 65°N latitude, bordered by grasslands or temperate forest (<50ºN) to the south and arctic tundra to the north (>65ºN) (from (Hayes et al., 2022)).

1.3.1. High-latitude wildfire regimes

Wildfires are natural phenomenon that is, broadly speaking, determined by weather, available fuel, and the landscape (i.e., topography). Weather (also known as 'fire weather') includes wind speeds and directions, temperatures, and humidity, fuel relates to the moisture content, size (for example twigs, branches, grasses), and abundance (build-up, continuity) of trees, vegetation, or other organic matter, and the topography includes the slope, aspect, and the terrain of the landscape (BC Wildfire Service, 2023). These three factors interact to produce different wildfire characteristics, or also known as "fire behaviour". Additionally, for a wildfire to start and spread, there also needs to be heat (i.e., the ignition source). Ignition sources can be both of natural and human origin: ignitions from lighting strikes constitute natural wildfires, (i.e., wildfires not caused directly by human activity) while activities such as agricultural and timber practices (for example land clearing), cultural practices, and accidents are the main causes of human-driven wildfires.

Despite the low annual temperatures and short growing seasons, wildfires are not an unknown phenomenon in high-latitude ecosystems. In fact, wildfires are currently one of the most important ecological disturbances in boreal forests, one of the world's major biogeoclimatic zones: they regulate the effects of insects and diseases and influence species composition, structure, productivity, and age (Weber and Flannigan, 1997; Brandt et al., 2013). Wildfires in tundra – while smaller and less frequent compared to boreal regions – are also a relatively common occurrence in the region, and have even influenced parts of this ecosystem for millennia (French et al., 2015; Hu et al., 2015; Masrur et al., 2018).

1.3.1.1. Spatiotemporal variability

According to a recent fire monitoring study, 91.5% of all high-latitude wildfires burn in boreal forests, while the remaining 8.5% is comprised of tundra wildfires (Veraverbeke et al., 2021). Alaska, Canada, and Russia concentrate the highest number of wildfires and area burned, while in Greenland and the northern margins of Europe, there is little to no wildfire activity (Zhang et al., 2021; Kharuk et al., 2023; Xing and Wang, 2023). During 2000-2020, for example, 75% of all recorded wildfires within the Arctic circle (north of 66º) were documented in Russia, followed by North America (24%) and Scandinavia (<1%) (Kharuk et al., 2023). Within each region, the Interior of Alaska (corresponding roughly with the Yukon River basin), the western provinces of Canada (i.e., British Columbia, Alberta, Saskatchewan, and Northwest Territories), and the interior and east of Russia (i.e., Krasnoyarsk Krai, Irkutsk Oblast, Republic of Sakha, and Chukotka Autonomous Okrug) account for most annual wildfires and area burned.

Generally, wildfires in the boreal region start in spring (April/March) and finish in autumn (September/October), with their peak during the summer months when weather conditions (i.e., low precipitation and increasing air temperatures) make the ground cover highly susceptible to ignition (Justino et al., 2021; Chen et al., 2023). At higher latitudes, such as in the tundra, wildfires tend to start later in the year (i.e., early to middle of summer) mainly due to the difference in incoming solar radiation and low incoming heat, which is necessary to dry the fuel load (Masrur et al., 2018; Coogan et al., 2020; Kharuk et al., 2021). Depending on the weather conditions, however, wildfire seasons in high-latitude regions can start earlier (or later) than expected. For instance, the 2004 and 2005 wildfire season in Alaska, which typically begins in April and finishes in August, prolonged into the fall due to the absence of season-ending rain events (York et al., 2020). Naturally caused wildfires are more frequent during the summer months in most high-latitude regions, whereas human wildfires rather characterise spring and autumn (Coogan et al., 2020; Zhang et al., 2021). Any of these wildfires can exhibit 'overwintering' behaviour, in which they smoulder through the winter season and flare up in the subsequent spring; this behaviour is most likely to occur in boreal forests with deep organic soils (i.e., peats) and after hot summers, large annual wildfire extent, and deep burning (Scholten et al., 2021; Rein and Huang, 2021).

The majority of high-latitude wildfires are small in size (<200 ha), although large-scale wildfires are nevertheless common (especially in the boreal zone) and contribute substantially to the region's annual area burned (Stocks et al., 2002; Kharuk et al., 2021). In highly populated areas of high-latitude regions, wildfires are primarily caused by human activities (e.g., outdoor recreation activities, debris burning, etc.) and are more frequent than in rural, remote locations (Narita et al., 2020; Alaska Fire Science Consortium, 2020). The proximity of these well-developed areas to key infrastructure (e.g., roads, firefighters, etc), combined with 'let-it-burn' policies in most high-latitude regions, ensures a rapid and effective suppression of wildfires, which typically remain relatively small (often less than 100 ha) (Gabysheva and Protopopova, 2018; Narita et al., 2020). In northern, less populated, and remote areas, wildfires receive lower levels of suppression than human-started wildfires and consequently tend to grow bigger and be more intense; lighting is here the leading cause of most wildfires (Hanes et al., 2019; Kharuk et al., 2021; AICC, 2023). This contrasts with regions from lower latitudes (e.g., California, the Mediterranean, etc.), where most wildfires are set by humans and are suppressed as fast as possible (Mersmann, 2019).

The proportion of human- and lighting-caused wildfires varies considerably across space, with some high-latitude regions having a higher share of lightning-caused wildfires than others. In Canada and Alaska, for instance, up to 50% of all yearly wildfires are on average caused by lightning (Veraverbeke et al., 2017; Canadian Council of Forest Ministers, 2023). This percentage is, on the other hand, lower in Scandinavia and Russia, where humans cause 90% and 80% of all wildfires each year, respectively (Leskinen et al., 2020; Sjöström and Granström, 2023). Part of this spatial variability may stem from lower population densities in North America compared to Eurasia, along with the characteristics of the landscape (i.e., forest cover, moisture status, etc.) and fire weather conditions (i.e., temperature, precipitation) in each region, which influences the likelihood that an individual lightning strike starts a wildfire (Veraverbeke et al., 2017; Hessilt et al., 2022). These characteristics also determine, in turn, the number of years between successive wildfires in a particular area – known in the ecology and fire science literature as the Fire Return Interval (FRI) (Rogers et al., 2015). In the boreal forests of Russia, the average fire return interval was found to be on average 53 years, while in the Canadian boreal region this number increases up to 180 years. In the European boreal zone, the high human presence and decades of fire suppression practices has resulted in a return interval that has historically varied from 1 600 to as much as 37 000 years (de Groot et al., 2013). The fire interval in the tundra, on the other hand, has generally ranged from 135 up to 309 years (Hu et al., 2015).

Depending on the characteristics of the region, high-latitude wildfires can be of different types, including surface, crown, and (smouldering) peat wildfires, each with its own speed, combustion characteristics, and impacts (Ryan, 2002). Particularly, North American (boreal) forests typically support more high-intensity crown wildfires than Eurasia, where lower-intensity surface wildfires are common (de Groot et al., 2013; Rogers et al., 2015). This difference in wildfire behaviour has often been associated with the distribution (and dominance) of specific tree species within each region. Particularly, boreal forests in North America are characterised by species that are considered to be fire embracers, such as black spruce (*Picea mariana*), jack pine (*Pinus banksiana*) and white spruce (*Picea glauca*). In contrast, most forest in Eurasia are dominated by species that are fire resisters or avoiders, primarily Scots Pine (*Pinus sylvestris*) and larch (Rogers et al., 2015). Extreme winter conditions, poor soils, and shorter fire return times help explain why there are more to fire resister species in Eurasia than in North America. As a result of this spatial variability, burn severity (and the subsequent destruction of trees and vegetation) is generally lower in the boreal forest of Eurasia than in North America (Rogers et al., 2015). This variability also explains why the carbon emissions rate (t ha^{-1} of burned area) is lower in Eurasia than in North America, although it should be noted here that the total carbon emission (per 100 M ha of forest area) is much higher in Eurasia because of greater annual area burned (de Groot et al., 2013; Veraverbeke et al., 2021). Compared with other regions globally, (Shikwambana and Habarulema, 2022) found that high latitude wildfires emit more pollutants than mid latitude wildfires.

Over the last decades, trends in both area burned and number of large wildfires (⩾200 ha) have exponentially increased in Alaska, Canada, and Russia, which have been often attributed to climate change and the subsequent increases in lightning-caused wildfires (Hanes et al., 2019; York et al., 2020; Leskinen et al., 2020). In parts of northern Europe and Greenland, wildfire activity has remained relatively stable over time, though in recent years there have been particularly extreme wildfire seasons in both regions (e.g., 2018 in Sweden, 2017 and 2019 in Greenland) (Gosden et al., 2022; Sjöström and Granström, 2023; Bakke et al., 2023). Nevertheless, many high-latitude regions have witnessed some of the strongest changes in wildfire regimes globally, with other areas such as central South America, Southeast Asia, western Europe, and the northern Australia seeing a decrease in the total annual burned area (Wu et al., 2021; Jones et al., 2022). Projections further indicate changes in wildfire activity and behaviour in many high-latitude regions, with regions such as Canada, Europe, and Russia expected to experience an overall increase in both wildfire frequency, extent, and severity in the future (McCarty et al., 2021; Masson-Delmotte et al., 2021). Specifically, the length of the wildfire season is predicted to expand by as much as 20 days in many high-latitude regions, with a potential 40% to 50% increase in the total area burned across the region by the end of the 21st century (Flannigan et al., 2013; Krause et al., 2014).

1.3.1.2. Drivers of high-latitude wildfires

Recent regional studies have shown that wildfire activity in high-latitude regions is primarily controlled weather variables such as surface temperatures, precipitation, soil moisture, land evaporation, and high winds (Masrur et al., 2018; Drobyshev et al., 2021; Talucci et al., 2022; Xing and Wang, 2023). Particularly, temperature and precipitation were found to be central determinants of high-latitude wildfire activity because of the control that they exert over fuel ignition and fuel moisture. For instance, lightning-driven ignitions have been strongly correlated with temperature and precipitation in both the boreal and tundra region, particular in June–July when meteorological conditions are conducive to lightning (Veraverbeke et al., 2017; Holzworth et al., 2021). Hot summers were similarly associated with an increase in the number of overwintering ('zombie') fires in boreal regions (Scholten et al., 2021). Weather variables were historically associated with a greater number of wildfires during the Holocene (Molinari et al., 2018; Sim et al., 2023). Vegetation types were generally secondary to climatic controls, although it should be noted that fuel composition and accumulation were more important than climate in some areas of Alaska and north-western Canada (Walker et al., 2020).

Evidence is emerging that changes associated with human-induced climate change are fundamentally altering the weather conditions conducive to the ignition and spread of high-latitude wildfires, which are mostly associated with increases in temperature and decreases in humidity (i.e., precipitation) (Burrell et al., 2022). The prolonged heat that contributed to the 2020 wildfires in Siberia, for instance, was found to be 600 times more likely due to climate change (Ciavarella et al., 2021). More recently, the extreme fire weather conditions that prompted the 2023 wildfire season in eastern Canada (i.e., low precipitation levels and high temperatures) was similarly attributed to the impacts of climate change (Barnes et al., 2023). It is projected that climate change will continue to impact future temperature and precipitation dynamics from high-latitude regions, generating drier fuels, more severe fire weather, and increased lightning ignitions (Veraverbeke et al., 2017; Lund et al., 2023). Climate change is similarly expected to change the vegetation structure of many areas and compel a northward migration of boreal species into the tundra, which would result in more convection, lightning, fires, and carbon releases from organic soils, completely changing the wildfire regime of many high-latitude regions (McCarty et al., 2021).

Beyond climatic and weather conditions, humans have also shaped high-latitude wildfires for centuries (Sim et al., 2023; Topness et al., 2023). Alterations to spatial patterns of ignitions, wildfire seasons lengths, available fuels have all been attributed to human activity in some geographic regions. In Norway, (Rolstad et al., 2017) found that burning for improved livestock grazing conditions, slash-and-burn cultivation, and fire suppression have considerably altered the frequency and size of wildfires since the 17th century, overcoming climate as the main driver of the region's wildfire regime. Similar findings were reported by (Sjöström and Granström, 2023) which demonstrated that wildfire frequency and area burned were strongly correlated with population density in Sweden. In North America, researchers have substantially illustrated how past human fire suppression efforts have increased fuel loads and altered forest composition and structure, which in turn has led to more extreme wildfire behaviour in the region (Tymstra et al., 2020). The impacts of humans on high-latitude wildfires are expected to increase as climate change expands human-dominated landscapes northward, including increased shipping, resource extraction, urbanization, and agricultural expansion, which will bring more people to high-latitude regions and thus increase the risk of human-driven wildfires (Heleniak, 2020; Kettlewell et al., 2023). Of course, future climate-induced changes to high-latitude wildfire regimes are subject to large uncertainty and will vary greatly over space and time, although all evidence indicates that northern regions will generally become increasingly susceptible to burning.

1.3.2. High-latitude communities

The impacts of wildfire are already apparent and felt by many high-latitude communities. However, understanding the ways that wildfire and its impacts currently manifest in these communities requires a more nuanced understanding of the socioeconomic, cultural, and political contexts affecting the region. The section below reviews current scholarship on the social aspects of high-latitude regions, including the spatial distribution of people and communities, their lifestyles, and the socio-economic challenges that they are experiencing.

1.3.2.1. Socio-demographic characteristics

Although the population density is very low (except for Fennoscandia) compared with the rest of the world, there are approximately 13.5 million people currently living in high-latitude regions, of which 9% (or 1.2 million) are Indigenous peoples (Nitoslawski et al., 2019; Heleniak, 2020). Today, more than half of the total population lives in the northern parts of Russia (7 million, 51%), followed by Canada (3.7 million, 27%), Fennoscandia (1.6 million, 11%), and Alaska

(700 000, 5%). In Canada and Greenland, the Indigenous population is the highest, representing more than half of the total population (Young and Bjerregaard, 2019; Nitoslawski et al., 2019). Contrarily, in the rest of the region, less than half of the total population is Indigenous, except in the Republic of Sakha (Russia) and the southern and northern slopes of Alaska, where 50–75% of the population are Indigenous (Wang and Roto, 2019). Population is increasing in all regions except Russia, where the transition to a market economy is still having a significant demographic impact (Wang, 2019; Heleniak, 2020; Koffi et al., 2021).

Communities are found all over the high-latitude region, and take forms ranging from small, remote, seasonal, outposts to large cities such as Yellowknife (Canada), Yakutsk (Russia), and Tromsø (Norway). Most of the high-latitude population currently reside in urban centres, which are predominantly non-Indigenous because people typically came from outside the region in search of economic opportunities (e.g., oil extraction, tourism, etc.) (Heleniak, 2020). Out-migration from small high-latitude towns and settlements has nevertheless also been very common in recent years and has led to a significant growth of the region's urban centres, especially in the capital cities (Wang, 2019). Rural and remote areas – usually with large tracts of unhabitable space and limited transportation networks (i.e., roads, railways) – are largely inhibited by Indigenous groups including, among others, the Inuit, Sami, and the Athabaskan peoples (Koffi et al., 2021). Communities within the boreal zone are scattered along its southern border, whereas tundra communities are often located along coastal areas (Nitoslawski et al., 2019; Heleniak, 2020). Thus, there is a substantial geographic, linguistic, social, and cultural diversity in high-latitude communities and their peoples.

The majority of high-latitude peoples' lifestyles rely on a combination of subsistence and commercial-wage activities (Poppel, 2015; Ehrich et al., 2019). Indeed, it is common practice for many high-latitude individuals to use wages earned in the commercial sector to purchase equipment, fuel, and other supplies for engaging in subsistence activities. These activities are a major source of food, clothing, medicine, tools, and shelter, and hold deep cultural meaning for thousands of people, particularly for Indigenous groups from both the boreal and tundra regions (Poppel, 2015; Hueffer et al., 2019; Glomsrød et al., 2021). The wages that facilitate these subsistence activities mostly originate from the forestry, mining, oil and gas, and other resource-extraction sectors (e.g., commercial fishery in northern coastal areas), which also represent the highest share of the region's total annual gross domestic product (GDP) (Burton et al., 2010; Glomsrød et al., 2021). As such, high-latitude livelihoods, cultures, and identities are strongly connected to the natural environment and its resources. However, the remoteness of many high-latitude communities, and the limited availability of wage employment due to the fact that many industries import capital and labour, makes engaging in the commercial economy particularly difficult in some areas of the region (Larsen and Fondahl, 2014; Gladun et al., 2021). Moreover, the introduction of the commercial economy in high-latitude regions has tended to 1) increase the reliance of people on goods and services from lower latitudes (e.g., fuel, food, etc.) and 2) limit the time available to participate in subsistence activities, resulting in profound socio-economic changes including, for instance, significant health impacts from store-bought Western foods (Berman, 2018; AMAP, 2021).

High-latitude people – particularly Indigenous groups – experience profound socio-economic challenges, including housing shortages and overcrowding, poverty, and higher burdens of ill health (Larsen and Fondahl, 2014; Young et al., 2020; Glomsrød et al., 2021). Many of these challenges have been, in part, linked to the geography of the region and to historical acts associated with colonialism. On the one hand, the large distances separating high-latitude communities, along with the region's weather and climate conditions (including climate change), have been notable geographical elements that have considerably limited the extent to which individuals can access a wide range of good and services, including, for example, specialized health services (Huot et al., 2019; Shafiee et al., 2022). Particularly, the physical geography of the region (i.e., presence of permafrost, cold winters, etc.) hampered the construction and expansion of roads and railways, which have been associated with increased mobility and improved access to resources (at least, for some groups) (Povoroznyuk et al., 2022). Colonialism and assimilation (i.e., into mainstream Western society) practices, on the other hand, have had sweeping impacts on the health and well-being of many high-latitude communities. These practices included forced resettlements, land dispossession and fragmentation, and Western schooling, all of which have undermined Indigenous culture and traditional ways of life in multiple ways (e.g., loss of access to the land, loss of traditional knowledge and skills, etc.) (Pearce et al., 2015; Hueffer et al., 2019). Although efforts are currently being made in some countries and regions to counteract this tendency (e.g., the Truth and Reconciliation Commission in Canada), the effects of colonialism are still well entrenched in laws and society today, as exemplified in many policies regulating, amongst others, culturally important subsistence activities (MacDonald and Steenbeek, 2015; Whyte et al., 2019; Hueffer et al., 2019).

1.3.3. Theoretical context

This thesis draws on insights from the 'human dimensions of climate change' (also known as HDCC) scholarship to explore the capacities, exposures, and responses of human systems (e.g., individuals, communities, cultures, governments, and other organizations) to high-latitude wildfires. It is primarily rooted in insights from political economy, political ecology, and development studies and is currently widely adopted in the social science community today, including in the reports of the Intergovernmental Panel of Climate Change (IPCC) (Ford et al., 2012; Pörtner et al., 2022). Its objective is to better understand the social factors (e.g., wealth and financial stability, demography, power structures, etc.) that lead to differentiated experiences of environmental change among different social actors, with HDCC studies often utilising community-based research methodologies to this end. In high-latitude regions, studies adopting a HDCC lens have been steadily increasing since the 2000s, documenting observations of climate change and identifying new opportunities throughout the region (Ford et al., 2012). It has been argued that through documenting these processes, the study of HDCC is well suited to 1) understand (and deal with) environmental processes and changes and 2) link research to policy outcomes (National Research Council, 1991).

Despite the advantages of HDCC research, exploring high-latitude wildfires exclusively through this lens is insufficient given the dynamic and constantly changing nature of wildfire regimes. For this reason, the thesis also considers aspects of the broader socio-ecological research, which is particularly pertinent given the complexities and uncertainties surrounding wildfires, including the interactions between weather patterns, human behaviour, the availability of resources, or the localised impacts of climate change on wildfire activity (Chapin et al., 2008). The socio-ecological research field, broadly speaking, revolves around the idea that ecological and social systems are intrinsically linked over space and time rather than being two separate units of analysis, changing continuously and characterised by non-linear behaviour and limited predictability. It originated in the 1990s when scholars started to recognize that complex (environmental) problems cannot be analysed in disciplinary silos; instead, complex problems should be dealt with in an interdisciplinary way, involving both natural and social sciences (Folke, 2006; Huertas Herrera et al., 2023). These scholars recognized the usefulness of this approach in capturing change, uncertainty, and multiple forms of knowledge, and started to use it in several human-environment analysis (Fischer et al. 2016). Today, social-ecological research is considered necessary to overcome potential maladaptive feedbacks and is seen as one of the most comprehensive concepts for structured research (Binder et al., 2013). Consequently, and to reflect both of these research fields, the thesis uses the term ‘human dimensions of high-latitude wildfires’ to capture not only the factors influencing human experiences of, and responses to, climate-related changes related to wildfire but also the interdependencies, feedbacks, and trade-offs between high-latitude people and ecosystems.

There are three terms that have been commonly used in both the human dimensions and socio-ecological literatures: risk (which includes the concept of vulnerability), resilience, and adaptation (Goldman et al., 2018). This thesis is rooted in theoretical work related to all these three concepts, notably because they provide an important framing for understanding high-latitude wildfires, their increasingly negative impacts, and potential solutions. Although each of the terms are different conceptually, they also have overlapping and complementary points, which have been considerably discussed throughout the literature. The section below introduces these three concepts and explains how they are defined and related. Particularly, it introduces how these concepts evolved over time and provides the latest understanding of the terms in both the climate change adaptation and disaster risk reduction literature. In subsequent chapters of the thesis, the conceptualization specifically adopted for each term will be clarified.

1.3.3.1. Risk, resilience, and adaptation

Risk is a well-known topic of discussion by scholars and practitioners who are interested in environmental and climatic processes and changes. It has become an increasingly popular framing in recent years, with both climate change adaptation (CCA) and the disaster risk reduction (DRR) communities now using a risk framing, as illustrated in the latest works of the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Office for Disaster Risk Reduction (UNDRR) (Murray and Ebi, 2012; UNISDR, 2015; Begum et al., 2022). In the context of the IPCC, this meant a shift from earlier assessments (i.e., pre-2012), which were predominately conceptualized based on a contextual (or also denominated human-security) interpretation of vulnerability[1] (Parry et al., 2007). The shift from a vulnerability-based approach primarily echoes calls to integrate the CCA and the DRR research communities and improve the basis for interdisciplinary work (Begum et al., 2014; UNDRR, 2020).

Today, it is widely accepted that risk is typically defined as the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems (Begum et al., 2022). In the context of the CCA and DRR communities, risk is a function of three interacting elements: hazard, exposure, and vulnerability (Begum et al., 2022; UNDRR, 2023). Hazard refers to the potential occurrence of a natural or human-induced physical event or trend that may cause negative impacts, such as, amongst others, the loss of life or the damage and loss to property and infrastructure. Exposure relates to the presence of people, infrastructure, resources, and other socio-economic and cultural assets in places and settings that could be adversely affected by a

[1] O'Brien et al. (2007) offers a detailed description of each interpretation of the term 'vulnerability'. In short, there are two interpretations of the term: 'starting-point', which considers vulnerability as a present inability to cope with external pressures or changes; and 'end-point', which considers vulnerability as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, and the identification of adaptive options.

hazard. For example, a community located in a fire-prone region (e.g., the boreal) and surrounded by highly flammable pine forests is considered to be highly exposed to the potential negative impacts of wildfires. Lastly, vulnerability refers to the propensity or predisposition of human systems to be adversely affected by a hazard; it encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. This notion of vulnerability corresponds most closely to the term 'sensitivity' as used in vulnerability-based approaches (Füssel and Klein, 2006; Connelly et al., 2018), highlighting the role of societal factors and dynamics within the concept of risk . Each of the determinants of risk are often seen as mutually conditioning in the literature, meaning that neither of them can exit on its own, i.e., a hazard only becomes a risk when a system is exposed and vulnerable to it (Brooks, 2003; Cardona, 2004; Cardona et al., 2012). They also vary dynamically through space and time, according to context-specific factors such as income, age, education, and so forth.

While the previous conceptualisation of risk received several critiques over the years (for example that it has been predominantly framed in the context of potential climate change impacts), scholars have recently revisited some of the assumptions about the concept (Adger et al., 2018; Viner et al., 2020; Wassénius and Crona, 2022). The responses to change, and the dynamic interactions between these, are now seen by many scholars as a key determinant of risk, along with hazard, exposure, and vulnerability (Simpson et al., 2021; Andrews et al., 2023). Moreover, the interactions among multiple (concurring) risks (e.g., climate change and the coronavirus disease 2019), and how these compound, aggregate, or cascade over different spatial and temporal scales, have become an integral part of recent understandings of risk (Fig. 1.2) (Pescaroli and Alexander, 2018; Simpson et al., 2021). Previous risk assessments have often ignored these interactions in part or in full, although they are beginning to be used in, for example, the latest IPCC AR6 framing (Pörtner et al., 2022). Accounting for these interactions have been deemed necessary to capture the inherently uncertain and complex nature of the term risk, help identify the different interactions that exist between people and their environment, and offer a more detailed and accurate assessment for decision making (Mach and Field, 2017).

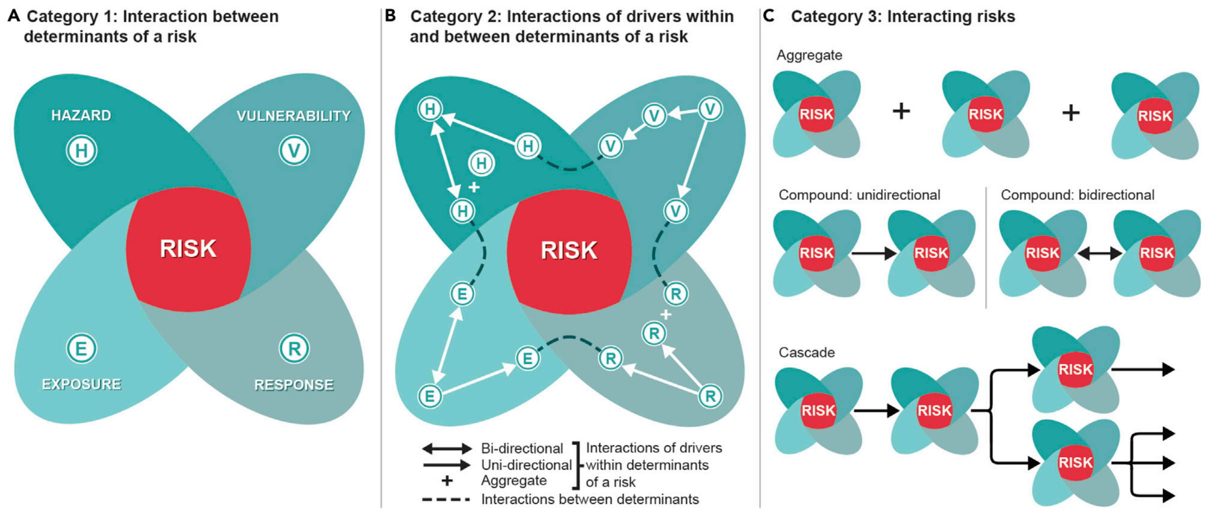

Figure 1.2 Figure shows the complexity involved in assessing risk (from Simpson et al., 2021). Category 1 (A) reflects the status quo of existing risk assessments, where risk is determined by hazard, vulnerability, exposure, and response to change. Category 2 (B) illustrates the interactions of multiple drivers (e.g., heavy precipitation) within each determinant of risk. Category 3 (C) reflects interacting risks (i.e., compound, cascade, aggregate).

Resilience is another term that has been used in many different ways by various research communities. Although its scholarly roots originally stem from ecology (Holling, 1973), the term resilience has been extensively used by many other disciplines interested in human-environment interactions (or social-ecological systems), including sustainability science (Folke et al., 2002), anthropology (Vayda and McCay, 1975), climate change adaptation (Rana, 2020; Nalau and Verrall, 2021), and disaster risk reduction (Coetzee et al., 2016; Rana, 2020). Given the wide use of the term, it is not surprising to find a plethora of definitions and conceptualisations of resilience throughout the literature. Initially, the term resilience referred to the capacity of a system to absorb disturbance while retaining the same population or state variables (Holling, 1973). This definition, though, was heavily critiqued over the years because it comprised a reactive stance – one that primarily preserves the status quo of the system (Manyena, 2006). As a result, resilience underwent continued theoretical revisions and was subject to a wide range of interpretations. Despite its many interpretations, there is now a general consensus in the social sciences that resilience encompasses not only the ability to absorb a disturbance but also the ability of a system (social, economic, environmental) to anticipate, accommodate, and recover from the effects of a potentially hazardous event. This ability (and by extension resilience in itself) is highly dynamic and contextual, as no one community is characterised by the same set of socio-economic, cultural, and political conditions (Adger et al., 2005; Gallopín, 2006; Coetzee et al., 2016). The contextual-specific nature of the term has led some scholars to suggest that resilience should be empirically tested at community levels (Cutter et al., 2008). In its general use, the term resilience has often been considered to be a positive attribute of a system, particularly when it maintains capacity for adaptation, learning and/or transformation (Brown, 2015; Arctic Council, 2016).

There are important similarities between resilience and other concepts used in the climate change adaptation and disaster risk reduction fields (Miller et al., 2010; Lei et al., 2014). Indeed, the conceptualisation of resilience – as defined above – bears some resemblance with the concepts of coping and adaptive capacity, which are two key terms that have been widely adopted in vulnerability-based (and thereby risk) approaches (Gallopín, 2006). The link between resilience and other concepts, especially with vulnerability, remains nevertheless a lively subject of discussion to this day. Some scholars, for instance, see resilience as one of the components of vulnerability (Turner et al., 2003; Pelling, 2012), while others argue that they are complimentary yet different from each other (Folke et al., 2002; Turner Ii, 2010). These discussions, in other words, involve whether or not resilience is the flip side (or antonym) of vulnerability. The nature of the relationship between resilience and vulnerability, however, is subjective (i.e., one person's resilience may be another's vulnerability) and strongly dependant on how they are defined (Manyena, 2006; Alexander, 2013; Kelman et al., 2015). Each of these terms remain sufficiently vague, ambiguous and malleable to help unite different research disciplines in multiple ways, which is why resilience has been referred to as a 'boundary object' (Biesbroek et al., 2017). While some find this troubling (Olsson et al., 2015), the concept of resilience remains an attractive framework to highlight interdependencies, feedbacks, and trade-offs between people and ecosystems (Walker et al., 2004; Folke, 2006; Nelson et al., 2007). This is particularly important in high-latitude regions, where livelihoods and biodiversity are intrinsically related.

Similar to the terms of risk and resilience, adaptation has been widely adopted in several research fields since the 1970s. It originated in the natural sciences (particularly evolutionary biology) and increasingly gained popularity among social scientists from different fields throughout the 1990s, including cultural ecologist and anthropologist (Smit and Wandel, 2006). In the climate change field, the term adaptation emerged concurrently with the growing awareness of climate change itself, and along mitigation, it became a very well-known approach for addressing climate change within international forums (e.g., IPCC), especially after the adoption of the Cancun Adaptation Framework in 2010 (Adaptation Committee, 2019; Pörtner et al., 2022). Although numerous definitions have been proposed for adaptation in each of these fields, they all broadly refer to adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects (Smithers and Smit, 1997). These adjustments (or responses) are primarily undertaken to help a system to better cope with, manage, or adjust to changing conditions, and to take advantage of new opportunities associated with such change (Smit and Wandel, 2006). Systems that are able to design, develop, and implement adaptations, and thus respond (adapt) to change, are often considered to have high adaptability (or better known as adaptive capacity) (Smit and Wandel, 2006). Hence, the term adaptation is intrinsically related to the concepts of vulnerability and resilience, as described above (Walker et al., 2006; Pelling, 2010).

Scholars have identified different types of adaptations over the years, and have classified them in terms of their timing, intent, scope, and form (Smithers and Smit, 1997; Smit et al., 2000). Timing indicates when adaptations occur relative to (environmental) stressors; they can be reactive (responsive or ex post), concurrent (during), and anticipatory (proactive or ex ante). Anticipatory adaptations are often viewed as preferable throughout the literature, as they reflect more dynamic approaches to planning that avoid and reduce risks (Ebi and Burton, 2008). Intent describes the extent to which adaptations are conceived and implemented: autonomous adaptations occur in the absence of specific initiatives, while planned adaptations represent a more formalized, deliberate approach. Scope refers to the spatial and temporal range of adaptations; they can be conceived and enacted at local, regional, and national scales and include short-term and long-term system adjustments. Form describes the type of adaptations employed to cope with, manage or adjust to environmental changes; these can take technological, institutional, and behavioural forms. Adaptations rarely occur in response to climate change and variability alone; instead, they are often enacted in response to multiple, interacting stressors, including social, economic, and cultural stressors (Huq and Reid, 2004; Ford et al., 2015). In recent years, the topics of unintended consequences, maladaptation, and transformative adaptation have been growing in importance. All of these themes provide an accepted framework for understanding, classifying, and comparing adaptations (Smit et al., 1999; Smit et al., 2000).

1.3.3.2. Social science research and high latitude wildfires

Social science research related to high-latitude wildfires has remained very limited until the final years of the 2000s, when interest started to grow among researchers and practitioners in understanding relevant social dynamics in the region. Extreme wildfire seasons (for example the summer of 2003 in Canada), along with the recognition that 1) anthropogenic climate change could significantly change wildfire behaviour and severity in the future, and 2) more and more people were moving into wildfire-prone areas, have particularly sparked interest in research related to the social aspects of high-latitude wildfires. Scholars such as Tara McGee, Hilary Faulkner, and Sarah Trainor were among the first scholars to become interested in understanding the human dimensions of wildfires in high-latitude regions, exploring how communities from Alaska and Canada were experiencing and responding to wildfires (Faulkner et al., 2009; McGee et al., 2009; Trainor et al., 2009).

While the first social science research studies focused on high-latitude wildfires were slowly emerging in North America in the second half of the 2000s, it was not until 2015 when this research field started to really gain some attraction elsewhere in the region, notably northern Europe and Russia (Lidskog et al., 2019; Christianson et al., 2019; Burnasheva, 2020; Garbis et al., 2023). However, despite the progress made over the years, the research field has remained significantly behind other regions globally. In a 2012 review of the available social science literature on wildfire, for example, only 7% of study locations in articles published between 2000 and 2008 were outside of the United States; between 2010 and 2014, a similar follow-up study found that the majority of articles related to the field were conducted in Australia (McCaffrey et al., 2012; McCaffrey, 2015). The prevalence of scholarly outputs from other regions still continues to this day (Millington et al., 2022), and is arguably due to the increased funding that institutions from the United States, Europe, and Australia have dedicated historically to wildfire-related social science research over the years (e.g., the Joint Fire Science Program, the Horizon2020 program, etc.). Funding dedicated to this research field was generally limited in most high-latitude regions, where a loss of expertise, experience, and leadership in wildfire research (particularly in Canada) has further contributed to the reduced number of scholarly outputs in the field compared to other regions (Sankey, 2018).

Despite the prevalence of scholarly outputs from other regions, much of the existing social science scholarship related to high-latitude wildfires currently follows a similar approach, drawing on theoretical insights from the social-ecological system literature (Chapin et al., 2006; Chapin et al., 2008). It views humans as active agents in how they experience and influence wildfires and explicitly addresses the interdependencies, feedbacks, and trade-offs between high-latitude peoples and ecosystems. Several studies from Canada and Alaska, for instance, demonstrated how subsistence-based activities, upon which many high-latitude communities rely, are being endangered because of the impacts that wildfires are having on the availability (i.e., abundance, distribution, accessibility) of key natural resources, including moose and reindeer (Brinkman et al., 2016; Dodd et al., 2018). Another important line of inquiry within this scholarship has similarly acknowledged the impacts of historical fire suppression practices on the accumulation of highly flammable fuels in boreal forests, which has increased the probability of ignition and the subsequent exposure of communities, infrastructure, and services (Campos-Ruiz et al., 2018; Hoffman et al., 2022). Research exploring the human dimensions of climate change (HDCC) has remained a rather small part of the high-latitude scholarship, with only a few examples exploring how high-latitude wildfires are being altered by climate-related changes and how this in turn is affecting human-environment interactions (Huntington et al., 2006; Trainor et al., 2009; Dodd et al., 2018; Rutherford and Schultz, 2019).

Much of the available research related to the human dimensions of high-latitude wildfires has also focused on exploring and identifying the factors that influence how homeowners, local municipalities, and Indigenous communities in high-latitude regions perceive, experience, and respond to wildfires. This research has revealed the critical role that factors such as remoteness, rurality, Indigeneity, socio-economic disparities, and governance structures (e.g., colonial practices) play in determining the vulnerability of many high-latitude communities, both to the direct and the indirect impacts of wildfires (Montesanti et al., 2021; Walker et al., 2021; Garbis et al., 2023; Burnasheva and Osipova, 2023). However, while this body of research has clearly identified the key factors affecting wildfire risk and resilience, it has remained limited in its scope, with most of its focus placed on a handful of Indigenous communities in the boreal region of Canada, mostly in the province of Alberta (Christianson et al., 2014; Montesanti et al., 2021). As a result, understanding of the social dynamics of high-latitude wildfires remains considerably skewed to the context and conditions present in these specific communities, underpinning the need for greater geographic and sectorial diversity in the wildfire scholarship.

1.4. Research design

Based on the overarching aim and objectives from section 1.2, and to better capture different factors and processes taking place across high-latitude regions, the approach of this thesis is underpinned by an epistemologically pluralist philosophical worldview. This paradigm values and integrates multiple epistemologies and sources of knowledge to achieve a deeper understanding of complex issues, such as those in social-ecological systems (Miller et al., 2008). In other words, it treats different research methods as equally valid, allowing differences in results to be interrogated as new data altogether. This approach consequently contrasts with monist research designs, which assert the validity or sufficiency of a single source or method of knowledge to solve a specific research problem. That said, an epistemological pluralist research design offers distinct advantages over such monist paradigms, including breaking down existing knowledge silos, identifying gaps between data sets, and unifying concepts like risk, resilience, and adaptation within a coherent research framework (Miller et al., 2010). The pluralist approach proves particularly effective in the context of high-latitude wildfires, where the intricate nature of these events necessitates integrating diverse inquiry methods into a cohesive research structure (Ford et al., 2021; Schuman et al., 2022). The integration of different methods in this context allows for a more comprehensive and rigorous understanding of the challenges posed by high-latitude wildfires, eventually leading to ecologically and politically robust solutions (Nightingale, 2016).

Throughout this thesis, the epistemological pluralist approach is manifested in the use of various methods across different geographical scales (local/regional). Systematic policy reviews, targeted literature analyses, and semi-structured interviews are employed throughout the work to explore alternative dimensions of the research problem (i.e., high-latitude wildfires), with each method providing different, unique findings. The following sections provide detailed explanations of each method and chapter 5 discusses in greater detail how they yield unique insights.

1.4.1. Methods

A combination of qualitative and quantitative methods was used throughout this thesis to evaluate the human dimensions of high-latitude wildfires. Specifically, this thesis combined targeted and systematic literature reviews and community-level research methods. These methods are based primarily on engagement with human subjects and peer-reviewed and grey literature. Each of these sources of data was analysed using content analysis to identify and extract key themes, patterns, and trends (Payne and Payne, 2004; Krippendorff, 2018). This approach provided a tractable set of methods for meeting the objectives of this thesis; these methods have also been widely adopted in other research projects that similarly focused on human adaptations to environmental change (e.g., McDowell, 2020; Naylor, 2022). The following sections elaborate and justify the application of these methods in greater detail. Details specific to each method can be found in subsequent chapters.

1.4.1.1. Targeted literature review

A targeted literature review was conducted to develop a conceptual framework on high-latitude wildfire risk and resilience[2]. This involved searching for both peer-reviewed articles and government-led reports focused on social science research related to high-latitude wildfires. The aim of this search was to review current literature on the human dimensions of high-latitude wildfires and illustrate the socio-economic, cultural, and ecological drivers and dynamics affecting community risk and resilience. This search helped identify if and how humans are vulnerable and resilient to high-latitude wildfires and determine what impacts wildfires have had on communities throughout the high-latitude region. Documents were

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[2] It should be noted that targeted literature reviews informed all thesis chapters. However, they were only integral to the methodological approach in chapter two.

identified through multiple sources, including Google Scholar searches using key term such as, for example, “high-latitude wildfire”, “boreal forests”, and “tundra wildfires”; recommendations from colleagues; and the bibliographies of particularly relevant texts. These documents were then thoroughly reviewed and summarised in a Word document. Insights that emerged from this targeted review are integral to the to the broader methodological approach utilized in chapter four. The targeted review provided a structured approach for data analysis and conceptual guidance for the empirical research in chapter four.

The document search did not specifically target a particular high-latitude region. Instead, documents were searched irrespective of where they were initially conducted to capture broader trends. This included wildfire-related studies from, among others, Alaska, Canada, Fennoscandia, and Russia. As such, the conceptual framework from chapter 2 was designed to have broad applicability, allowing the examination of wildfire risk and resilience in any territory of the high-latitude region. However, and to illustrate the applicability of the conceptual framework, chapter 2 focuses on a small, remote community in Siberia (i.e., Sebyan-Kyuyol); this community has only been selected for illustrative purposes and does not imply that the targeted literature review informing the conceptual framework used research specifically from Russia or Siberia. The community of Sebyan-Kyuyol was selected because 1) it offers important information on wildfire risk, resilience, and adaptation in a region that has normally been overlooked in the social science scholarship; 2) it allows meaningful comparison with the empirical findings of chapter four; and 3) it was initially involved in a research relationship with an international research team from the University of Leeds (Canosa, Ford) and the Arctic State Institute of Culture Arts (Burnasheva, Osipova); this relationship was part of what was known as the ‘Arctic Voices’ project, which was interrupted unfortunately when the Russian invasion of Ukraine (and the respective socio-economic sanctions) started in February 2022.

1.4.1.2. Systematic policy review

Chapter three uses a formal systematic policy review to clarify the state of wildfire adaptation policy in the Russian Arctic. This methodology represents a rigorous approach for synthesising literature; it promotes standardization and transparency and provides researchers, decision makers, and the broader public with credible information about a topic of interest (Ford and Berrang-Ford, 2016). While this methodology originated in the health sciences, there are many instances now where scholars employed systematic reviews to track and evaluate climate change adaptation policies, programs, and strategies in many different contexts, including, amongst others, the Arctic (McDowell et al., 2014; Ford et al., 2014; Canosa et al., 2020; Berrang-Ford et al., 2021). Peer-reviewed scholarship, UNFCCC National Communications, legislative outcomes, and organisation websites (e.g., health authorities, civil society organisations, etc.) are but some sources of information that these scholars have used in their systematic reviews. The increasing popularity of systematic reviews within the climate change adaptation scholarship primarily stems from their reproducibility. Indeed, systematic reviews provide a standardized means for characterising the state of a topic over time and across regions, countries, and sectors; they provide a number of methodological steps that a research (or any other individual interested in a field) can follow to analyse literature in a consistent and comprehensive manner (Berrang-Ford et al., 2015; Ford and Berrang-Ford, 2016).

1.4.1.3. Community-level research

Place-based case studies are a common approach within the social sciences to understand how individuals and communities experience and respond to environmental change in a particular context (Pearce et al., 2010; Galappaththi et al., 2019). They prioritize the integration of local knowledge and perceptions and provide a rich understanding of the lived realities of environmental change. Although the findings from individual case studies are highly specific and difficult to generalise (Stake, 2013), they have the ability to identify localised processes as well as options (adaptations) that are meaningful to individuals and communities (Ford et al., 2010). Research reported in chapter four of this thesis describes a place-based case study based on a rural community in the province of British Columbia (Canada).

Data in place-based case studies are commonly generated through multiple sources, including surveys, interviews, and focus groups. However, in this thesis, data was primarily generated through semi-structured (also termed ‘conversational’) interviews. These interviews involved verbal exchanges of information in which one person (the interviewer) asks open-ended questions to another person (the interviewee), with the interviewee answering the questions. They are a useful means of investigating diverse experiences, behaviours, and perspectives and create an understanding of different people’s opinions and meanings (Longhurst, 2003). Due to limited time and funding, this thesis could not gather data through focus groups or any other data collection techniques; still, semi-structured interviews provide a valuable means to explore 1) local perceptions of wildfire change and 2) the nature of risk and resilience at community level, addressing the last research objective of the thesis (Table 1.1).

Semi-structured interviews have been a widely used technique in qualitative research for several reasons: they provide researchers with some flexibility to explore important lines of inquiry beyond the baseline, allow participants to explore the issues that they feel are most important, and increase the likelihood of collecting data that has never been published before in the literature (Harvey-Jordan and Long, 2001; Dunn, 2003; Longhurst, 2003). Semi-structured interviews have also been considered to be one of the best ways to engage with

Indigenous peoples, as traditional lines of questioning and inquiry (i.e., predetermined direct questions) were found to be invasive and coercive in Indigenous contexts (Ferguson and Messier, 1997; Collings, 2009). Despite these strengths, this approach to interviewing has seen limited use in a wildfire context, where most of the social science studies have been conducted via surveys (e.g., Labossière and McGee, 2017; McGee and Healey, 2022). A copy of the semi-structured interview guide used in this thesis is included as an Appendix B.2, and further information on the question themes, structure, and format of interviews is covered in chapter four of this thesis.

Table 1.1 Overview of methods and data sources used in each chapter.

Research objective	Method	Data source	Thesis chapter
1. Develop a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions	Targeted literature reviews	Books, peer-reviewed articles, and grey literature documents	Chapter 2
2. Systematically document and critically evaluate regional wildfire policies and plans in the Russian Arctic	Systematic review	Peer-reviewed (n= 2710) and grey literature documents (n= 519) published over a 12-year period	Chapter 3
3. Conduct an in-depth, community-level case study to characterise local wildfire risk and resilience in Western Canada	Community-level case study	Semi-structured interviews (n=20)	Chapter 4

1.4.2. Case study selection

Chapter three and four of this thesis are based on two completely different regions and jurisdictional scales. On the one hand, chapter three (corresponding with the second research objective of the thesis) focuses on if and how regional governments in the Russian Arctic are adapting to wildfires. Conversely, chapter four (i.e., the third research objective of the thesis) presents a localised case study that was conducted to understand how the small, rural community of Valemount – located in the Canadian province of British Columbia – perceives, experiences, and responds to wildfires. The selection of these locations aimed to capture some of the socio-ecological diversity that exists in high-latitude regions and augment and diversify the existing wildfire-focused human dimensions research, which has mostly focused on the United States. It is not the objective of this thesis to compare these locations because of the ‘dependent variable problem’ (Dupuis and Biesbroek, 2013). Instead, the thesis aims to uncover the bigger picture of wildfire risk and resilience in high-latitude regions, which is currently a knowledge gap. Nevertheless, the spatial and scalar mismatch between the two objectives inevitably poses the following question: why was the thesis designed and implemented in that way?

The rationale for selecting these two locations (i.e., Russia and Canada) were fourfold. First, both of the selected countries concentrate the highest density of wildfire activity and area burned compared with other high-latitude regions, making them strong candidates to study the impacts of wildfires on people and communities (refer to section 1.3). Second, they are particularly susceptible to some of the severest impacts of climate change, with both locations projected to experience significant increases in wildfire activity and burned area (Senande-Rivera et al., 2022). Third, the two locations have different cultures, livelihoods, environmental characteristics, and political structures, which provides an exceptional opportunity to understand how wildfire risk and resilience differs from one region to another; this also provides a broader perspective of how different social-ecological systems experience, manage, and respond to wildfire. Fourth, the co-supervisor of this thesis, Dr. James Ford, has long-established contacts and ongoing projects in the two locations, facilitating research design and development.

In addition to incorporating these two locations, the thesis also focuses on two different jurisdictions (i.e., regional vs local) to reveal and reflect on the different directions and dynamics that characterise wildfire risk, resilience, and adaptation over space and time. Scholars have increasingly shown that, because of globalization, vulnerability (and by extension risk and resilience) has become intrinsically interdependent and teleconnected over space and time, meaning that decisions adopted in one location and at a specific jurisdictional scale can trigger shocks and new opportunities elsewhere via different processes of trade, communication, migration, and international policy (Adger et al., 2009; Eakin et al., 2009). Furthermore, risk, resilience, and adaptation are conceived and enacted differently at local, regional, and national scales, resulting from different objectives, priorities, constraints, and expectations that stakeholders have at the time of making decisions at each scale (Cash et al., 2006). As such, compiling evidence from multiple jurisdictions and locations becomes a valuable approach to 1) better understand the contextual nature of risk, resilience, and adaptation; 2) identify potential cross-scale linkages, interactions, and feed-backs; and 3) broaden the scope of current analyses, largely confined to sector- and geographic-specific boundaries (Ford et al., 2010; Keskitalo, 2010).

The rationale for choosing Russia as the location for the regional analysis in this thesis (and thus Canada for the localised, place-based case study) was due to the difficulty in accessing and conducting place-based research in the country, mainly driven by the conflict in Ukraine and the respective sanctions by Western governments in terms of travel and economic restrictions. Nevertheless, the targeted literature review (section 1.4.1.1 and chapter three of this thesis) and the subsequent conceptual framework includes a place-based case study example from a community in Russia, which allows for a certain (direct) comparison with the Canadian case study from chapter four. This case study was included in the third chapter of the thesis because there were plans to initially conduct local, place-based work in a Russian community to document how communities understand, manage, and respond to wildfire. This had to be cancelled due to the effects of the conflict on international travel and research.

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Chapter 2: Community risk and resilience to wildfires: rethinking the complex human-climate-fire relationship in high-latitude regions

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2.1. Abstract

Community risk and resilience to high-latitude wildfires has received limited conceptual attention, with a comprehensive, integrated framework that unpacks the complex human–fire–climate relationship in high-latitude environments largely missing. In this paper, we use insights from both the climate change adaptation and disaster risk reduction literature to build a conceptual framework to understand the factors and dynamics of risk and resilience to wildfires at the community level in high-latitude regions. Using an illustrative case study, the framework demonstrates how unique social and ecological features of high-latitude communities elevate their risk of wildfires and emphasizes the need to think holistically about the different spatial–temporal interactions and interdependencies between fire, humans, and climate in these regions. We find that remoteness, indigeneity, subsistence-based activities, and colonial practices, along with accelerated climate warming, are notable features influencing community risk and resilience to wildfires in high-latitude regions. This framework can help unravel the complex nature of wildfires, guide stakeholders through each phase of the disaster process, and facilitate the development and design of wildfire-related policies and strategies in high-latitude regions.

Keywords: climate change; wildfire; risk; resilience; adaptation; vulnerability; disaster; conceptual framework

2.2. Introduction

Many regions globally are experiencing increasingly extreme wildfire seasons. In North America, Australia, and parts of the Arctic, for example, observed wildfires are more intense and destructive than in the past (Senande-Rivera et al., 2022; Parmesan et al., 2022). These increases in the magnitude and severity of wildfires have been largely attributed to the complex interplay between climatic and non-climatic drivers, including ongoing and future human-caused climate change (Masson-Delmotte et al., 2021). Climatic factors include seasonal temperature, humidity, precipitation, and lightening, while non-climatic factors include landscape patterns, vegetation types and structure, and human dynamics (e.g., fuel and land management practices, agricultural and timber activities, cultural events, land use) (Lecina-Diaz et al., 2021; Duane et al., 2021; Iglesias et al., 2022). The way through which these (non-)climatic factors interact over space and time is considered a challenging problem (Chapin et al., 2008), yet one that is of particular importance for minimizing the negative impacts and maximizing the positive outcomes of wildfires.

Wildfires pose unique challenges in high-latitude regions, defined here to include roughly all boreal and tundra areas above 50º N (McCarty et al., 2021). Some of the most notable challenges include (1) increasing values-at-risk (Heleniak, 2021), (2) reduced fire suppression effectiveness (Wotton et al., 2017), (3) increasing fire-management costs (Melvin et al., 2017; Torzhkov et al., 2019), (4) significant physical and mental health impacts (Dodd et al., 2018), and (5) decreased ecosystem resilience (Kukavskaya et al., 2016; Baltzer et al., 2021), all of which could ultimately slowly progress towards achieving the United Nations Sustainable Development Goals (SDGs) and other environmental goals (Lang and Moeini-Meybodi, 2021). Although these challenges are not necessarily new, the nature of the challenges is fundamentally different than in mid-latitudes. High-latitude regions (especially the Arctic and sub-Arctic) will see some of the most rapid and extreme warming globally (a rate approximately three times the global average), with considerable cascading impacts on wildfire regimes, permafrost, and biodiversity (Masson-Delmotte et al., 2021). Additionally, wildfires in the more rural and remote high-latitude regions are often not immediately suppressed and are usually left to burn unless valuable assets are threatened, resulting in large areas burned and in the release of large amounts of particulate matter ($PM_{2.5}$) (Walsh et al., 2020; York et al., 2020). Furthermore, many communities are located in rural, sometimes remote, areas with limited access to emergency services and fire management infrastructure, where traditional fire knowledge is often undermined by socio-political structures (Zahara, 2020; Hoffman et al., 2022). In fact, high-latitude communities have limited decision-making powers, with wildfire prevention, mitigation, and response mostly regulated by regional and national authorities (Tymstra et al., 2020; Narita et al., 2020). Hence, wildfire management techniques adopted in lower latitudes might not work in higher latitudes given the changing climate, the magnitude of wildfires, and the limited preparedness of local communities, requiring alternative management strategies tailored to the local and regional context (French et al., 2015; McCarty et al., 2021).

Reflecting this, there has been increasing interest within the wildfire and climate change adaptation community in understanding human–climate–fire relationships that create and shape risk and resilience in high-latitude regions (Christianson, 2014; Sankey, 2018; McCaffrey et al., 2020). Notwithstanding, while these efforts have highlighted the role of multiple factors governing risk and resilience (e.g., fire management policies, risk perceptions), few capture the nature of these interactions holistically, particularly at the community level, with many focusing only on specific aspects of risk and resilience (Ford et al., 2021). For example, studies have overlooked how compounding (e.g., droughts, heatwaves) and cascading risks (e.g., water runoff, changes in biodiversity dynamics) associated with wildfires consecutively influence how communities experience, cope with, and plan for wildfires. This may ultimately lead to incomplete and fragmented approaches to fire policy and management, resulting in solutions that may be of limited use on the ground.

In this paper, we propose a conceptual framework to understand the factors and dynamics creating and sustaining community risk and resilience to wildfires in high-latitude regions. We integrate resilience and risk framings into a coherent structure based on the disaster risk reduction cycle, drawing upon the literature on natural hazards, disaster risk reduction, fire social science, wildfire ecology, and climate change vulnerability and adaptation. Structuring our framework by integrating risk-resilience approaches into the disaster risk reduction cycle, we seek to (1) create an enhanced understanding of the spatial–temporal interactions between climate, fire, and humans in high-latitude contexts; (2) provide a systematic way of breaking down the complexity of wildfire management into manageable pieces, which can then facilitate decision-making for adaptation; and (3) pinpoint where key mismatches and gaps exist to facilitate future research efforts and collaborations. For the purposes of this paper, wildfires are defined, consistent with UNEP (2022), as "… an unusual or extraordinary free-burning vegetation fire which may be started maliciously, accidentally, or through natural means, that negatively influences social, economic, or environmental values". We also focus our framework on the community scale, noting it has applicability in diverse global contexts.

2.3. Setting the scene: linking risk, resilience, and the disaster risk reduction cycle

The concepts of risk, resilience, and the disaster risk reduction cycle have been used, defined, and related in various ways in the literature. We understand risk as the combination of hazard, exposure, and vulnerability, thereby following the general disaster and adaptation literature (Jurgilevich et al., 2017; Begum et al., 2022). We also use resilience to think about the capacity or ability of communities to persist, recover, adapt, and/or transform in the face of hazards (Adger et al., 2005; Folke, 2006). Both vulnerability and resilience are linked here through the component of coping capacity (Joakim et al., 2015) and are considered related yet different (Miller et al., 2010). Moreover, risk and resilience are seen in this paper as dynamic and contextual elements that are determined by the continuous interaction of multiple social and natural factors; these factors can be either fast or slow in their onset and can derive from sources both exogenous and endogenous to the community (Naylor et al., 2020). In Table 2.1, we define each of the conceptual elements that are adopted in this paper.

Table 2.1 Definitions used in the conceptual framework.

Components of the framework	Definition	References
Risk	Potential for adverse consequences for human or ecological systems. It results from both the dynamic interactions between hazard with the exposure and vulnerability of the affected system, and from the potential for responses not achieving the intended objective(s), or from potential trade-offs or negative side-effects.	(Simpson et al., 2021; Begum et al., 2022)
Resilience	Describes the capacity of individuals, communities, and systems to persist, cope, adapt, and transform in the face of stress and shocks. It is a function of the combined result of coping, adaptive, and transformative capacities, which in turn lead to persistence, incremental adjustments, or transformational responses in the face of environmental change	(Brown, 2015; Ford et al., 2020)
Hazard	Possible, future occurrence of natural or human-induced (wildfire) events that may have adverse or beneficial effects on a system, including, amongst others, loss of life, injury, loss of infrastructure, or increased habitat regeneration.	(Field et al., 2012; Pachauri et al., 2014)
Direct impact	Effects on people and ecosystems resulting from the immediate consequence of the event. In the case of wildfire, this would include damages caused by the flames itself, radiant and convective heat, and burning debris, e.g. loss of timber resoursces, damages to infrastructure, etc.	(UNEP, 2022)
Indirect impact	Effects on people and ecosystems from a hazard occurring quite some distance from the event itself. These impacts have also been referred to as “secondary impacts” throughout the literature. Examples of a wildfire-related indirect impacts include the effects of smoke on human health, as well as changes in the structure and composition of vegetation.	(UNEP, 2022)
Exposure	Presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places where hazard events (i.e. wildfires) may occur.	(Masson-Delmotte et al., 2018; Meybeck et al., 2019)
Sensitivity	Describes pre-existing conditions and characteristics of human beings, livelihoods, infrastructure, and environmental assets and services within a system that govern its susceptibility to the effects of an exposure; it is tightly related with vulnerability	(Smit and Wandel, 2006; Cutter et al., 2008)
Vulnerability	The propensity or predisposition to be adversely affected by a hazard. It is a component of risk and	(Gallopín, 2006; UNISDR, 2015)

	is based upon a system's sensitivity or susceptibility to harm and lack of capacity to cope.	
Adaptation	The practice of implementing or utilizing adaptive capacity to alter behaviour or overcome drivers to decrease risk, to cope with possible impacts and exploit beneficial opportunities.	(Kates et al., 2012; Naylor et al., 2020)
Transformation	A change in the fundamental attributes of human systems in anticipation of future hazards and its impacts. It is adopted at a much larger scale, that are truly new to a particular region or resource system, and that transform places and shift locations. It results from implementing or utilizing transformative capacity.	(Nelson et al., 2007; Kates et al., 2012; O'Brien, 2012; Arctic Council, 2016)
Coping capacity	Ability of a system to draw on skills, resources, and experiences to immediately react to, cope, and reduce the adverse effects of experienced hazards, in this case wildfires; it is a component of resilience as used by Arctic Council (2016)	(Turner et al., 2003; Smit and Pilifosova, 2003)
Persist(ence)	Capacity of a system to absorb disturbance(s) and still maintain essentially the same structure, functions, feedbacks, identity, and relationships between variables. Also used in the literature to describe the ability of people and communities to recover or 'bounce back' to pre-disaster conditions.	(Holling, 1973; Walker et al., 2004; McWethy et al., 2019)
Adaptive capacity	Refers to the ability or potential of a system to adjust or make incremental changes in response to exposure-vulnerability. Adaptations are manifestations of adaptive capacity, and has been also used as a component of resilience within the wider literature. Adaptive capacity does not, however, necessarily result in adaptation; a community may have high adaptive capacity but not adopt adaptations to changing conditions (Mortreux et al., 2020).	(Turner et al., 2003; Ford et al., 2006; Cardona et al., 2012; Mortreux et al., 2020)
Transformative capacity	Creation of fundamentally new systems through profound shifts in human systems when existing conditions are untenable. It goes beyond incremental changes that maintain the status quo, bringing deeper changes to a system than does adaptation. Transformative capacity is also referred in the literature as 'transformability'.	(Nelson et al., 2007; Kates et al., 2012; O'Brien, 2012)
Endogenous factors	Factors internal to the system that govern its risk and resilience (e.g. local demographic patterns, livelihoods) and determines how systems are able (or not) to change its nature; endogenous factors are determined by both fast and slow moving factors.	(Brooks, 2003; Armitage, 2005)
Exogenous factors	Factors external to the system that govern its risk and resilience (e.g. regional governance systems, global climate change) and determines how system	(Brooks, 2003; Armitage, 2005)

	are able (or not) to change; exogenous factors are determined by both slow and fast factors.	
Fast moving factors	Variables that change on daily, seasonal, and interannual time scales and result in rapid variations in a system's vulnerability and resilience (e.g. pest outbreaks in forests, monthly changes to wildlife dynamics). Fast variables are also called fast-moving attributes, and can emanate from both exogenous and endogenous factors.	(Füssel and Klein, 2006; Crépin, 2007; Walker et al., 2012)
Slow moving factors	Slow variables describe trends that are constant over multiple years to decades, such as global climate change or changes in socio-political structures; they result in gradual change to a system's risk and resilience. Slow variable can emanate from both exogenous and endogenous factors.	(Füssel and Klein, 2006; Crépin, 2007; Walker et al., 2012)
Compound events	Describes the combination of single extreme events or multiple coincident sequential events that contributes to a system's risk-resilience. Compound events can be broadly grouped into (i) preconditioned events, where a weather-driven or climate-driven precondition aggravates the impacts of a hazard; and (ii) multivariate, whereby multiple hazards and/or drivers concurrently or successively (the latter known as cascading event) occur and exacerbate hazards impacts on a system.	(Pescaroli and Alexander, 2018; Zscheischler et al., 2020; Raymond et al., 2020)

In this framework, we also link risk and resilience with the disaster risk reduction cycle. The interpretation we make in this paper regarding risk, its associated elements, and resilience is complementary to the different phases of the disaster risk reduction cycle, which, broadly speaking, is a function of three interlinked yet separate over-arching stages: pre-disaster, during, and post-disaster event. Indeed, the concepts of risk and resilience have strong similarities with the terminology and notions used in the cycle (Lei et al., 2014; Manyena et al., 2019; Vázquez-González et al., 2021; Logan et al., 2022). During and post-hazard actions, for example, are consistent with the notions of resilience in the climate adaptation literature (Ford et al., 2020). Similarly, the pre- and during-disaster phases are strongly related to the concept of risk as currently understood in the adaptation community (Begum et al., 2022). Although some have questioned the use of these concepts (Cameron, 2012; Béné et al., 2014), this interpretation of risk, resilience, and the disaster risk reduction cycle remains useful to capture the interactions between human and natural systems (Bergstrand et al., 2015; Ford et al., 2018) and bridge disciplinary and stakeholder divides (Olsson et al., 2015; Matyas and Pelling, 2015). The linkage between risk, resilience, and the disaster risk reduction cycle is particularly helpful to (1) expand the range of potential responses available, which would be otherwise missed if risk and resilience were approached separately, and (2) recognize both longer-term system drivers and nuanced, contemporary and local socio-economic realities (Miller et al., 2010; Maru et al., 2014; Joakim et al., 2015). This linkage can also contribute to the harmonization of the adaptation literature with that of related disciplines, particularly with the disaster risk reduction community (Aven and Renn, 2015; Begum et al., 2022), and overcome the existing silos between the two disciplines, which is argued to be key in ensuring an adequate and appropriate distribution of funds (Begum et al., 2014).

2.4. Conceptual framework for understanding community risk and resilience to high-latitude wildfires

Based on our interpretation of risk, resilience, and the disaster risk reduction cycle (section 2.1), we propose a framework that is organized into three broad stages (Figure 2.1):

- The ex ante (before a wildfire) stage is focused on setting the stage for characterizing wildfire risk and resilience, which is considered here to be a combined result of a community's initial exposure, vulnerability, and the ability to anticipate, prepare, and plan for future wildfire events (i.e., adaptive and transformative capacity).
- The during wildfire stage relates to understanding the characteristics of the hazard and the ability of a community to cope with and survive the impacts of wildfires (coping capacity).
- The ex post stage of the framework relates to how risk and resilience change after a wildfire hits a community. This stage acknowledges that experiencing a wildfire can trigger major, sudden social transformations in the community that inevitably and often lead to changes in the nature of risk and resilience (Milkoreit et al., 2018). This is particularly pertinent in high-latitude regions, where wildfires are, and will continue to be, a natural feature impacting communities, especially in fire-prone boreal forests (Molinari et al., 2018). For this reason, we herein classify risk and resilience in two separate tiers, based on whether the community has already experienced a wildfire: 'risk$_1$' and 'resilience$_1$' as well as 'risk$_2$' and 'resilience$_2$'. Risk$_1$ and resilience$_1$ capture the conditions of a community both before and during a wildfire, whereas risk$_2$ and resilience$_2$ reflect the impacts that wildfires have on the community's exposure/vulnerability and its capacity to persist, adapt, or transform to future potential wildfires. The terminology, such as adaptive capacity or exposure, is also classified according to these tiers.

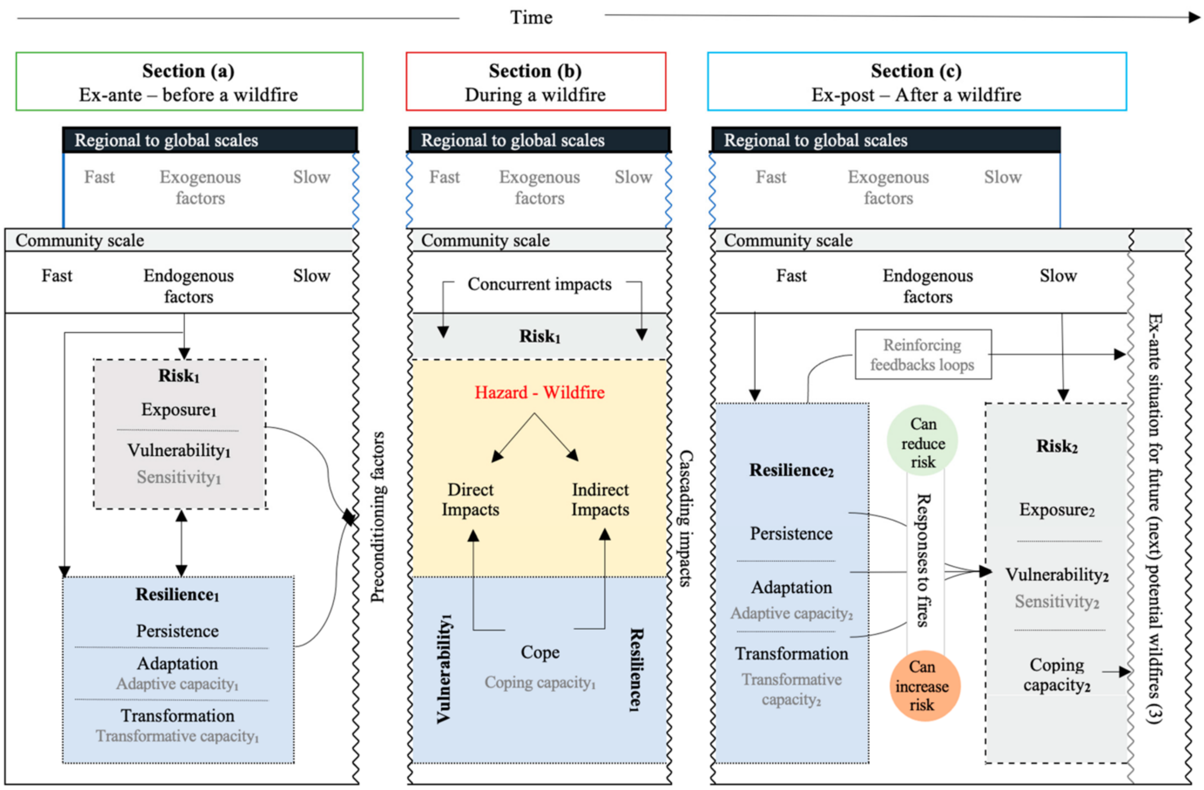

Figure 2.1 Overview of the conceptual framework. Section (a) shows the elements and dynamics of community risk and resilience before experiencing a wildfire, section (b) is during, and section (c) is after a wildfire. Figures 2.2–2.4. below provide more details for each stage of the framework (ex ante, during, ex post).

Each stage of our framework is regulated by multiple interacting fast- and slow-moving internal (endogenous) and external (exogenous) factors (Chapin et al., 2009; Walker et al., 2012). These vary between communities over space and time and often create different levels of risk and resilience among communities. For example, high-latitude communities, within and between nations, have different socio-economic development statuses (e.g., urban–rural) that have a variable magnitude of impact on the level of resources available to manage wildfires and potential impacts (Trainor et al., 2009). These are not mutually exclusive, such that factors influencing community risk can also determine its resilience and the extent to which impacts are experienced or managed (Naylor et al., 2020; Ford et al., 2020). Table 2.2 provides examples of factors affecting wildfire risk and resilience in high-latitude communities, noting that they should not be considered exhaustive as they are context-dependent. We also note that each of the factors included in our framework is subject to uncertainties, including, for example, the future development of the wildland–urban interface, the evolution of subsistence-based activities, and the efficacy of fuel treatments (Miller et al., 2022). The next sections discuss, in greater detail, these factors and how they vary across the three stages of the framework.

Table 2.2 Factors regulating wildfire risk and resilience at community level in high-latitude regions. Types are distributed into five categories: natural, place, socio-economic–demographical, institutional, and cultural. Symbols indicate decreases (↓), increase (↑), decreases and increases (▵), or unknown effect (?) in community risk and resilience to wildfires.

Type	Effects on resilience	Effects on risk	References
Natural environment			
Climate (and its short-term manifestation, weather)	↓	↑	(Hu et al., 2015; Young et al., 2017; Masrur et al., 2018; He, 2020; Lin et al., 2021; Ciavarella et al., 2021; Yasunari et al., 2021; Natole Jr et al., 2021; Scholten et al., 2021; He et al., 2022; Masrur et al., 2022)
Fuels (soil and vegetation types)	?	▵	(Hu et al., 2015; He, 2020; Lin et al., 2021; Scholten et al., 2021; Chen et al., 2021; He et al., 2022; Masrur et al., 2022)
Ignition sources (e.g., lighting, human-caused)	?	↑	(Veraverbeke et al., 2017; Scholten et al., 2021; He et al., 2022)
Topography	?	▵	(Linn et al., 2007; He, 2020; Natole Jr et al., 2021; Scholten et al., 2021; He et al., 2022; Masrur et al., 2022)
Place			
Settlement location, remoteness	↓	↑	(Trainor et al., 2009; Johnston and Flannigan, 2017; Dodd et al., 2018; Rodrigues, 2018; Parisien et al., 2020; Kehoe, 2020; Natole Jr et al., 2021; Walker et al., 2021; Montesanti et al., 2021; Tepley et al., 2022; Vinokurova et al., 2022)
Place attachments	▵	▵	(Ray, 2011; Oakes et al., 2016; Mottershead, 2017; Dodd et al., 2018; Asfaw, 2018; Lidskog et al., 2019; Mamontova, 2020; Montesanti et al., 2021; Lalani et al., 2021)
(Previous) experiences with wildfires	↑	▵	(Dodd et al., 2018; Lidskog et al., 2019; Herman-Mercer et al., 2020; McGee and Healey, 2022)
Infrastructure & access to resources	▵	▵	(Rodrigues, 2018; Lidskog et al., 2019; Christianson et al., 2019; Natole Jr et al., 2021; Tepley et al., 2022; Vinokurova et al., 2022; McGee and Healey, 2022)
Social networks & learning (e.g., community support)	↑	↓	(Mottershead, 2017; Dodd et al., 2018; Rodrigues, 2018; Asfaw, 2018;

			Montesanti et al., 2021; Kuklina et al., 2022)
Public perceptions, attitudes, awareness, and mistrust	△	△	(Ray, 2011; Oakes et al., 2016; Dodd et al., 2018; Rodrigues, 2018; Lidskog et al., 2019; Herman-Mercer et al., 2020; Vinokurova et al., 2022; McGee and Healey, 2022)
Socio-economic-demographical			
Demography (age, gender, race, ethnicity), population density	△	△	(Ray, 2011; Beverly and Bothwell, 2011; Asfaw, 2018; Campos-Ruiz et al., 2018; Burnasheva, 2020; Natole Jr et al., 2021; Montesanti et al., 2021; Walker et al., 2021; Howard et al., 2021; Hertelendy et al., 2022; McGee and Healey, 2022)
Livelihood (hunters, farmers, loggers, etc.)	↑	↑	(Ray, 2011; Christianson et al., 2014; Gustine et al., 2014; Dodd et al., 2018; Asfaw, 2018; Rodrigues, 2018; Brecka et al., 2018; Cold et al., 2020; Herman-Mercer et al., 2020; Montesanti et al., 2021; Kuklina et al., 2022)
Economic status and community income	△	△	(Mottershead, 2017; Rodrigues, 2018; Asfaw, 2018; Christianson et al., 2019; Montesanti et al., 2021; Howard et al., 2021; Vinokurova et al., 2022)
Health and mental conditions (e.g., chronic diseases)	↓	↑	(Mottershead, 2017; Asfaw, 2018; Christianson et al., 2019; Montesanti et al., 2021; Howard et al., 2021; Vinokurova et al., 2022; Hertelendy et al., 2022)
Institutional			
Colonialism, assimilation policies, land dispossession, racism and structural violence and disparities	↓	↑	(Mottershead, 2017; Kehoe, 2020; Walker et al., 2021; Montesanti et al., 2021; Van Vugt, 2021; Christianson et al., 2022)
Fire and fuel management practices and policies (including historical, past and current practices)	△	△	(Ray, 2011; Mottershead, 2017; Asfaw, 2018; Campos-Ruiz et al., 2018; Christianson et al., 2019; Cogos et al., 2019; Parisien et al., 2020; Montesanti et al., 2021; Sirina, 2021; Kuklina et al., 2022; Vinokurova et al., 2022; Roturier et al., 2023)

Cultural			
Traditional fire use and knowledge	↑	↓	(Varavina, 2013; Egorov et al., 2015; Sirina, 2021; Vinokurova et al., 2022; Kuklina et al., 2022; Christianson et al., 2022)
Cultural practices, beliefs, and rituals	△	△	(Varavina, 2013; Egorov et al., 2015; Dodd et al., 2018; Montesanti et al., 2021; Lalani et al., 2021; Sirina, 2021; Vinokurova et al., 2022; Christianson et al., 2022)

2.4.1. The ex ante stage: community risk and resilience before a wildfire event

Figure 2.2 details the key building blocks of this stage. Before a wildfire takes place, high-latitude communities are at risk$_1$ depending upon two interconnected factors: (1) community exposure and (2) (social) vulnerability. Exposure and vulnerability are broadly determined at this stage by the characteristics of climatic conditions (and its short-term manifestation, weather), the nature of the community under consideration, and the natural features present within or nearby the community that make a fire more likely to happen. Climate- and weather-related characteristics include the magnitude, frequency, duration, spatial dispersion, and novelty of lightning activity and fire weather conditions (i.e., temperature, humidity, wind, precipitation), which, in turn, influences landscape flammability, fuels, and fuel conditions (moisture), i.e., wildfire severity (He, 2020; Scholten et al., 2021). The nature of the community largely concerns its location and socio-demographic, economic, institutional, and cultural structure. For example, being situated within or near a matrix of flammable vegetation (i.e., wildland–urban interface areas), particularly in fire-susceptible regions in the boreal zone, increases the exposure of communities and the degree to which impacts are suffered (Johnston and Flannigan, 2017). Similarly, other distinctive factors of many high-latitude communities, including remoteness, socio-economic inequalities, limited access to fire infrastructure and resources (e.g., wildland–urban interface structure density data and mapping, computational and mathematical models), and a lack of fire management strategies, elevate their risk to wildfires (Christianson et al., 2019; Tepley et al., 2022; Vinokurova et al., 2022). Lastly, risk is further determined by the physical structure of the landscape present within or nearby the community (i.e., topography, forest canopy, geological substrate), which has an effect on ignition patterns, fire spread, and local fire weather (Linn et al., 2007; Coogan et al., 2019; He, 2020; Masrur et al., 2022).

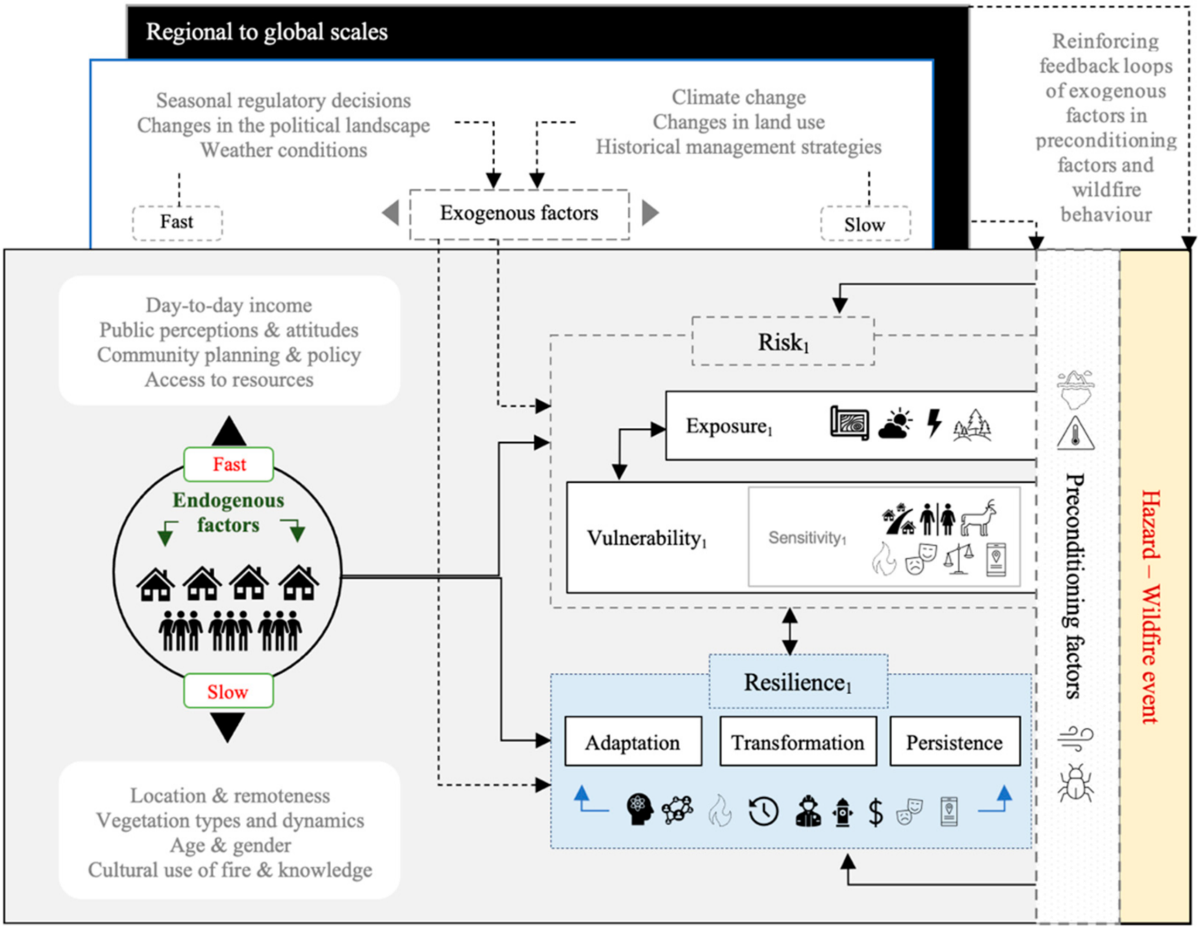

Figure 2.2 Conceptual framework for understanding the factors and dynamics of community risk, vulnerability, and resilience to wildfires in a high-latitude context before a wildfire. Refer to Table 2.2 for related icons. Solid lines represent the endogenous effects.

Moreover, the capacity and ability of a community to anticipate, prepare, and plan for (potential) future wildfires—also referred to as resilience$_1$—further determines whether a community may be at a higher risk of experiencing the negative impacts of wildfires (McWethy et al., 2019). The adaptive and/or transformative capacity of a community is largely moderated by multiple economic, demographic, cultural, social, and political factors that are characteristic of human systems. These factors include past and current fire policies, personal experiences with wildfire, and stakeholders' understanding of the role of fire as a landscape process (Ray, 2011; Christianson et al., 2014; Lidskog et al., 2019). For example, colonial policies in Canada and Alaska have often disrupted the transmission of traditional fire knowledge and reduced the use of fire by local communities in the landscape, leading to decreased resilience and increased risk due to the accumulation of fuels (Hoffman et al., 2022; Christianson et al., 2022). The combined result of adaptive and transformative capacity can lead to the adoption of both long- and short-term responses, including policies that address the potential cascading effects of wildfires on communities (i.e., after) or even the improvement of evacuation systems that would help a community cope during a wildfire (i.e., during). These responses can act on various components of the society–environment interaction, including measures that change the biophysical system (e.g., prescribed fires, removing small, shade-tolerant trees in low-lying forests) and/or the human system (e.g., fire infrastructure improvements, changes in livelihoods). Responses implemented at this stage are categorized into the so-called prevention (including mitigation) or anticipatory (proactive or ex ante) responses and can directly influence the severity of future wildfire events (Fischer, 2019).

Ultimately, preconditioning factors—that is, weather-driven or climate-driven events that precede a wildfire—are important for understanding high-latitude wildfire risk and resilience holistically (Zscheischler and Seneviratne, 2017; Zscheischler et al., 2020). These factors can diminish the ability to cope, manage, and respond to wildfires and, thus, exacerbate a community's risk and impacts. The outbreak of mountain pine beetle in Western Canada, for example, has increased the risk of wildfires in the region; indeed, analyses indicated that the magnitude of the 2017 and 2018 wildfires in British Columbia might have been exacerbated by such an insect epidemic (Abbott and Chapman, 2018; Bleiker et al., 2019). Long-lasting heat waves, which more often than not precede intense wildfire seasons, can also trigger permafrost thaw that may weaken crucial infrastructure necessary to respond to a potential wildfire as well as aggravate the effects of air pollution during a wildfire (Dobricic et al., 2020; Hjort et al., 2022). These stressors can involve many more events, including floods, strong winds, and droughts, which can be felt either through direct effects on the community (by cascading impacts from other local events) or by processes emanating from other locations (e.g., when a flood in another jurisdiction damages energy infrastructure, causing blackouts and financial and human impacts). Some of these preconditioning factors can be slow in their onset (such as droughts resulting from changes in temperature and precipitation), while others occur suddenly (e.g., storms, floods).

2.4.2. During wildfire stage: community risk and resilience during a wildfire event

In the event of a wildfire, community $risk_1$ and $resilience_1$ are largely modulated by the interaction between (i) the hazard's characteristics (measured by the magnitude, intensity, location, and duration) and (ii) the coping capacity of a community. This interaction determines the extent to which a wildfire may result in negative (or positive) economic, financial, environmental, and social impacts, in addition to determining how wildfires are experienced and whether the community is able to respond (Figure 2.3).

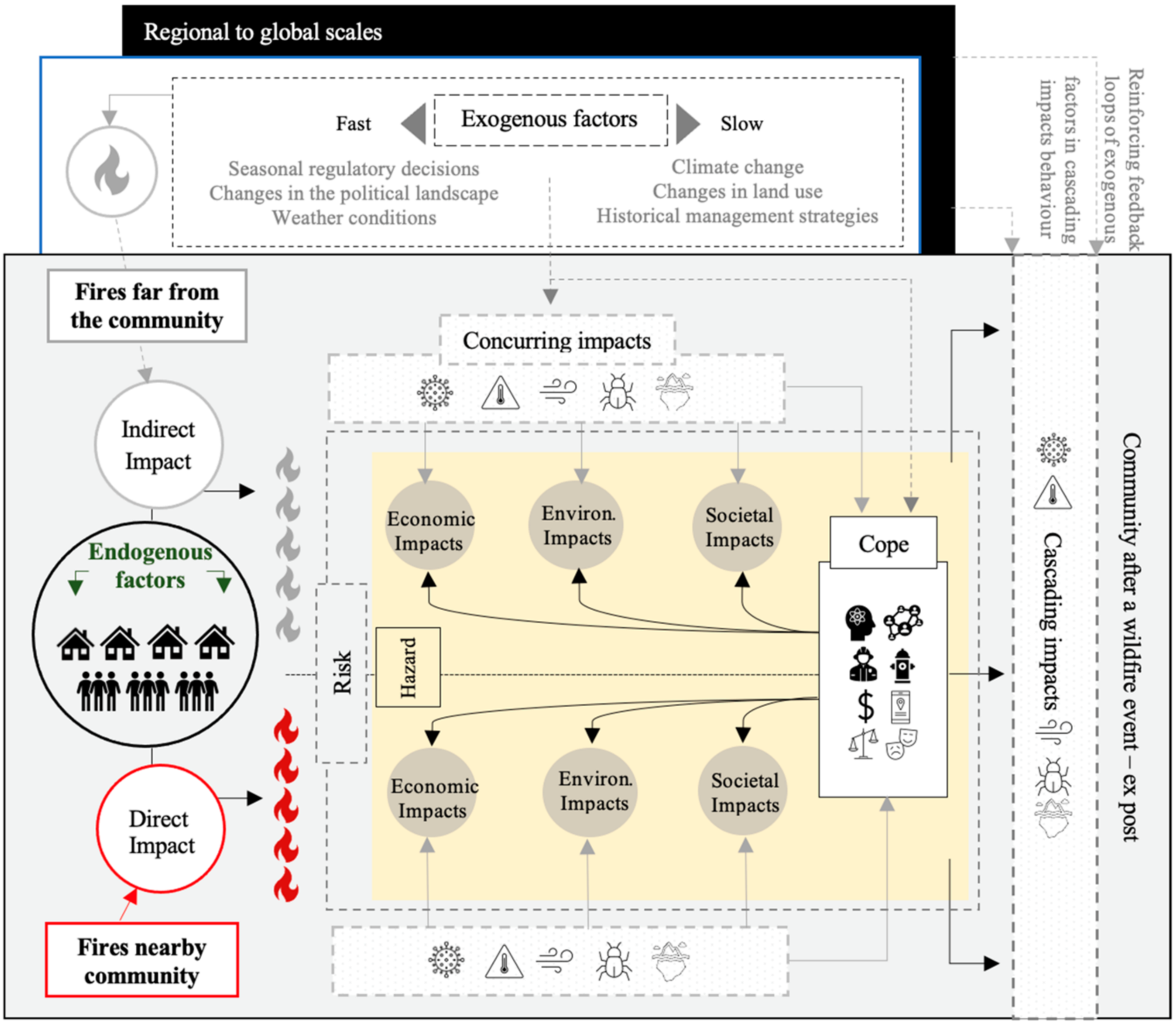

Figure 2.3 Conceptual framework for understanding the factors and dynamics of community risk, vulnerability, and resilience to wildfires in a high-latitude context during a wildfire. Refer to Table 2.2 for related icons. Solid lines represent the endogenous effects.

The characteristics of the hazard should be fully considered to comprehensively understand the nature of the risk that a community faces. Indeed, depending on the geographical location, magnitude, intensity, and duration of the wildfire event, community risk can take many different forms. On the one hand, there are the direct impacts of wildfires, which refer to wildfires that occur in the vicinity of a community and that pose an immediate threat to people and buildings. Conversely, the indirect impacts refer to wildfires that take place in other jurisdiction(s), yet with an effect on distant communities, particularly through water and smoke pollution and infrastructure disruption (Iglesias et al., 2022; Povoroznyuk et al., 2022). Both the indirect and direct impacts of wildfires can result in negative impacts such as loss of life, infrastructure, and properties, as well as ecological benefits from improved habitat heterogeneity, all of which can impact people's psychological, physical, and financial well-being (Walker et al., 2021; Howard et al., 2021). The extent to which these impacts are experienced by community members is highly dependent upon (i) the severity of the wildfire and (ii) the socio-demographic characteristics of the community (see section 2.3). Furthermore, concurrent impacts, whereby multiple hazards concurrently occur and interact, can exacerbate wildfire impacts on communities and reduce the ability of a community to react to and cope with wildfires. These stressors may involve events such as heat waves, droughts, strong winds, or forest insects and diseases (e.g., pine beetle) and may impact, among others, crucial infrastructure as well as firefighting suppression efforts (Zscheischler et al., 2018; Ford et al., 2022).

Whether a community can immediately respond to a wildfire and related multivariate stressors in a way that reduces their negative impacts and survive will depend on its coping capacity$_1$. Coping capacity refers to a community's ability or capacity to draw on skills, resources, and experiences to immediately react to and cope with a hazard; it is influenced by community characteristics, including social, economic, and demographic factors (e.g., economic wealth, social networks, infrastructure, or experience with previous risks) and broader exogenous factors such as national fire policies (Walker et al., 2021; Montesanti et al., 2021; Sirina, 2021). These factors, in turn, determine the extent to which a community can implement responses during a wildfire, including evacuating the community or halting all outdoor activities. Coping capacity can vary over time in response to social, economic, political, and future environmental changes and can also be undermined by the effects of cascading impacts from other hazards. Approaches that help ensure effective coping responses when a wildfire does occur would fall into the preparedness category of the cycle.

2.4.3. Ex post stage: community risk and resilience after a wildfire event

The aftermath of wildfires can result in multiple changes to the short- and long-term risk$_2$–resilience$_2$ dynamics of a community (Figure 2.4). In the disaster risk reduction literature, this is often regarded as the best opportunity to drive change (Brundiers and Eakin, 2018; Schumann III et al., 2020). First, after a wildfire event, the direct exposure$_2$ of a community may be reduced, given that most fuels in the surrounding are likely to be consumed, thereby reducing the short-term risk of future wildfire events (Rein and Huang, 2021). However, in boreal forests, wildfires might exhibit 'overwintering' behaviour, in which they smoulder through the non-wildfire season and flare up in the subsequent spring (i.e., 'zombie fires'), thereby resulting in different post-fire recovery trajectories (Scholten et al., 2021; Rein and Huang, 2021; Xu et al., 2022). Whether a wildfire exhibits overwintering behaviour will depend upon the presence of deep organic soils, along with accelerated climate warming, extreme weather conditions, and large annual fire extent (Scholten et al., 2021).

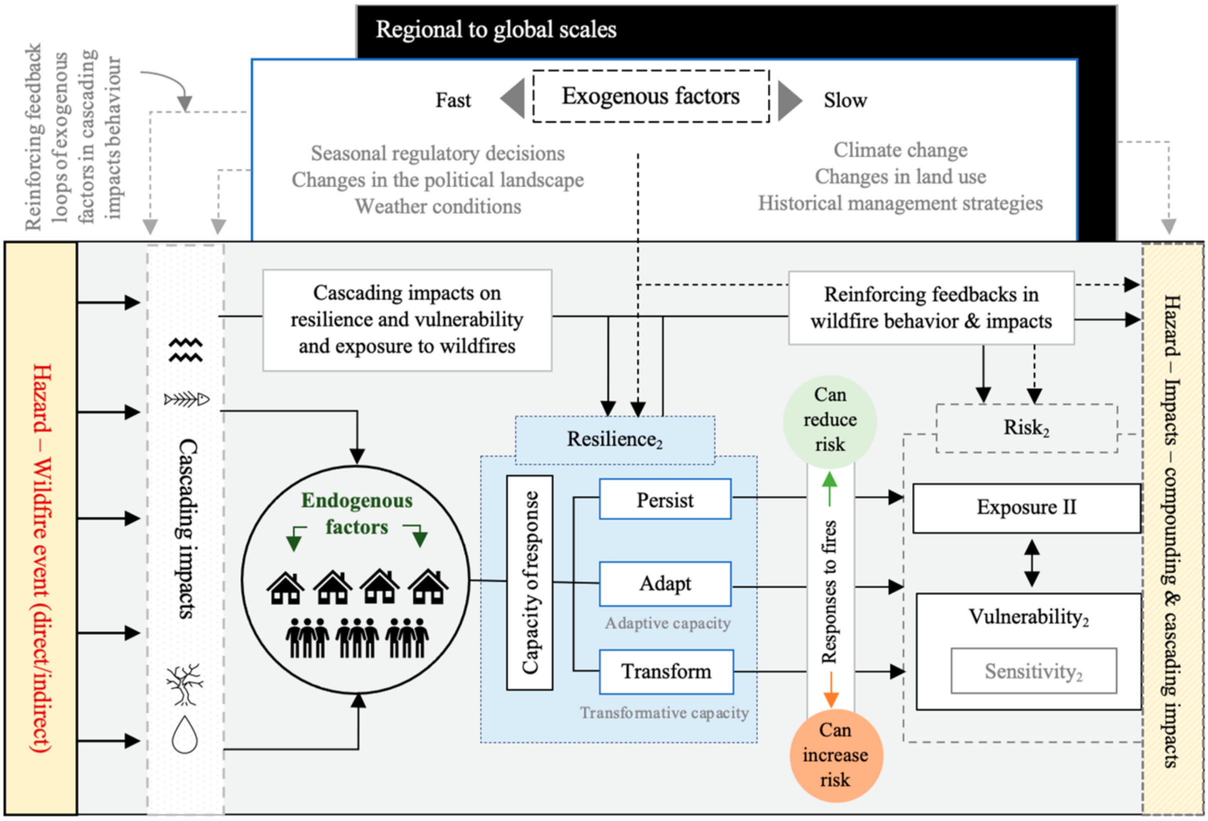

Figure 2.4 Conceptual framework for understanding the factors and dynamics of community risk, vulnerability, and resilience to wildfires in a high-latitude context after a wildfire. Solid lines represent the endogenous effects, and dashed lines represent the exogenous effects.

Second, experiencing wildfires—either directly or indirectly—can foster opportunities for communities to increase their ability and capacity to pursue incremental (adaptive capacity$_2$) or transformational (transformative capacity$_2$) responses. Following an event such as a wildfire, constraints that normally determine decision-making processes have been observed to dissipate due to changes in public opinion, awareness, and risk perception, leading to an enhanced ex post state of preparedness (Rosenzweig and Solecki, 2014; Lidskog and Sjödin, 2018; Jetten et al., 2021). In Canada, for example, new behavioural patterns and habits emerged post-wildfire among decision-makers and the public, resulting in the adoption of community resilience-building measures such as the incorporation of Indigenous knowledge in decision-making processes and the creation of inter-community sharing networks (Lei et al., 2014; Dodd et al., 2018; Tymstra et al., 2020). Scholars, however, caution that this window of opportunity is open for a short period of time and that the ability or capacity of a community to take advantage of this and implement measures that reduce future vulnerability depends on (i) the extent of the damages experienced; (ii) their access to longer-term support structures; (iii) and their pre-existing social, cultural, economic, demographic, and political conditions (Solecki and Michaels, 1994; Brundiers and Eakin, 2018). In high-latitude regions, governmental constraints, including insufficient available funds, professional expertise, and a lack of urgency and public support, are key factors that can explain why change is elusive and why the level of community risk and vulnerability remain static over time or even increase after a wildfire (Schultz et al., 2019).

Third, the cascading impacts of wildfires may also negatively impact a community toward future events. Wildfires can exacerbate the risk of burned landscapes to flooding, landslides, and debris flow, increasing the exposure of communities to these hazards one or two years after a major wildfire (AghaKouchak et al., 2020). For example, post-wildfire impacts were considered a contributing factor in driving runoff and debris flows during the devastating floods and landslides that impacted southern parts of British Columbia (Canada) in 2003 and 2021 (Jordan, 2015; Gillett et al., 2022). Similarly, wildfires can disrupt carbon cycling and ecological interactions, triggering biome shifts and leading to deteriorating water quality and changing snowpacks during subsequent seasons (Gustine et al., 2022). This, in turn, can cause, amongst other things, food insecurity, health issues triggered by a lack of sanitation, human displacement, and the loss of social ties and a sense of place and cultural identity, along with road network damages, power and communication infrastructure disruption, and business activity interruptions (Dodd et al., 2018; Hjort et al., 2022). Communities with network dependencies (e.g., transportation hubs), limited institutional and regulatory systems, limited sanitation services, an aging infrastructure, low incomes, and subsistence economies may be more exposed and sensitive to these cascading impacts (Gustine et al., 2014; Kuklina et al., 2022) to the point that these factors can overwhelm a community's capacity to respond and recover (resilience$_2$), heightening the risk of crossing unknown response capacity tipping points (Raymond et al., 2020).

2.5. Case study application of the conceptual framework

In this section, we use the community of Sebyan-Kyuyol (Russia) as a case study example to illustrate the potential application of the proposed framework. This particular case study was chosen purposefully due to the authors' prior research with the community and also because it presents an excellent opportunity to highlight the concepts of risk and resilience in a region where the human dimensions of wildfires are not well understood (Canosa et al., 2020). This community was also selected because (1) it is located in one of the most wildfire-prone regions globally, (2) it is projected to experience some of the greatest increases in wildfire frequency and severity globally, and (3) it shares considerable similarities with other high-latitude communities (e.g., remoteness, indigeneity, subsistence-based livelihoods) (Christianson, 2014; Rodrigues, 2018; Senande-Rivera et al., 2022). Secondary sources, including governmental reports, journal articles, books, and newspapers, were used here to provide context and information on the community's wildfire risk and resilience.

2.5.1. Case study description: Sebyan-Kyuyol, Republic of Sakha

The community of Sebyan-Kyuyol is a rural, remote settlement located in the Kobyaysky ulus (Republic of Sakha, Russia). It is located 350 km from the administrative center of the Republic, Yakutsk, and it has a total population of 754 (2016) inhabitants, of which 89% belong to the semi-nomadic Lamunkhinsky Even people (Kuzmina, 2016; Grigoriev, 2016). This Indigenous group lives in remote camps during different seasons and is highly reliant on traditional reindeer husbandry and hunting, berry picking, and other traditional industries associated with arts and crafts, which provide important food, nutrition, income, and cultural strength to the community (Kuzmina, 2016; Anatolievna, 2020). The community is surrounded by the Verkhoyansk mountains, dominated by tundra vegetation (e.g., mosses and lichens), and characterized by harsh climatic conditions with frequent droughts and low precipitation levels (Troeva et al., 2010; Grigoriev, 2016). Moreover, no road systems are connected with the community directly, non-wild food is expensive, employment and education opportunities are limited, and access to emergency services and fire management infrastructure are inadequate (Grigoriev, 2016; Edisonovich, 2019; Canosa et al., 2023). Community decision-making powers are being undermined by current policy and decision-making structures (Canosa et al., 2023), and despite no wildfires having been recorded to directly affect the community so far, seasonal wildfires consistently occur throughout the region.

2.5.2. Application of the framework to Sebyan-Kyuyol

To understand Sebyan-Kyuyol's wildfire risk and resilience using our framework, the first step is to characterize its initial exposure, vulnerability, and adaptive/transformative capacity by evaluating local threat conditions and the ability to adapt and transform. The ex ante exposure/vulnerability of Sebyan-Kyuyol derives from a combination of interacting climatic and non-climatic factors. Climatic factors include (i) local and regional weather patterns (Salva et al., 2015), (ii) climate-driven increases in the frequency and magnitude of extreme events (Callaghan et al., 2021), (iii) changing tundra vegetation (Kharuk et al., 2021), and (iv) increases in lighting activity and fire weather days (Chen et al., 2021). Non-climatic factors relate to the community's mountainous location in a remote and ice-rich landscape (Shestakova et al., 2021; NASA, 2023); the absence of highly flammable vegetation (Kharuk et al., 2021); and socio-demographic and institutional factors, including limited traditional fire uses, indigeneity, livelihoods, and forest and fire management policies (Grigoriev, 2016; Kharuk et al., 2021). These factors also determine the adaptive and transformative capacity of the community. For example, climate-driven increases in the frequency and magnitude of extreme events, such as floods and permafrost thaw, are impacting critical infrastructure throughout the Republic that is necessary for responding to wildfires (Durova, 2020). Similarly, current state support systems do not provide aid to Indigenous groups in the event of a wildfire, and the majority of wildfire adaptation policies overlook the role and needs of Indigenous peoples (IWGIA, 2019; Canosa et al., 2023). Indigenous people’s ability to adjust subsistence practices based on traditional knowledge and existing sharing networks, however, increases resilience to wildfires (Solovyeva and Kuklina, 2020).

The second step of our framework involves understanding the type of impact the community experiences from wildfires and its ability to cope with the impacts. While the Republic of Sakha is subject to frequent and severe wildfires (both natural and human-caused) during summer (Kharuk et al., 2021), the presence of less fire-prone tundra vegetation types within the community reduces the short-term likelihood of a wildfire impacting the community directly (Troeva et al., 2010). The frequent occurrence of wildfires in other parts of the Republic during summer, however, means that the community often experiences the indirect impacts of wildfires, particularly the increased air pollution caused by wildfire smoke (Burnasheva and Osipova, 2023). During the 2021 summer wildfires in Siberia, for example, the air quality in the Republic was ranked among some of the worst worldwide, exceeding the recommended parameters of the World Health Organization (Vinokurova et al., 2022). Consequently, these smoke events have had significant impacts on the community’s population, including disruptions to subsistence activities (Burnasheva and Osipova, 2023). Similarly, wildfires from southern parts of the Republic were documented to damage key transportation routes and negatively impact connectivity to other parts of the region, with consequences for food and fuel delivery (Durova, 2020). The extent to which these impacts are felt in the community varies by gender, age, and indigeneity and is often exacerbated by the remote location of the community and its limited transport network (Grigoriev, 2016; Burnasheva, 2020). People in the Republic of Sakha are nevertheless coping in different ways. Some have moved from the Republic to other regions of Russia until the wildfires are over; others have started social media campaigns locally to raise awareness and help firefighters with food supplies and inventory (Burnasheva, 2020; Vinokurova et al., 2022). These responses are underpinned by traditional sharing and support systems, high learning capacities and strong traditional knowledge and local knowledge, limited ownership of equipment required for managing wildfires, and current fire management response practices (Salva et al., 2015; Solovyeva and Kuklina, 2020; Vinokurova et al., 2022).

The third step of our framework focuses on characterizing the aftermath of wildfires. In the context of Sebyan-Kyuyol, the ex post impacts of wildfires are based on the natural features of the landscape and the socio-demographic characteristics of the community. While the absence of nearby peatlands reduces the likelihood of smouldering fires (Rein and Huang, 2021), the community's semi-nomadic and traditional livelihoods increase its exposure/vulnerability to changes in key plant and animal species driven by wildfires burning in other parts of Sakha, making reindeer herding, berry picking, and hunting more difficult (Lavrillier and Gabyshev, 2017; Kuklina et al., 2022; Burnasheva and Osipova, 2023). This situation, nevertheless, is expected to worsen with ongoing and projected climate change, which is increasing the availability of surface fuels and exacerbating the risk of the direct impacts of wildfires (McCarty et al., 2021). These impacts can cause permafrost to thaw near the community and lead to land subsidence, localized flooding, and the formation of lakes and wetlands, along with significant damages to infrastructure and human lives and livelihoods (McCarty et al., 2020). Given the mountainous location of the community, nearby wildfires can also lead to increased water runoff, erosion, and landslides, with the potential to contaminate key potable water sources (McCarty et al., 2020). Here, the community's lack of health and water treatment infrastructure exacerbates their risk of these cascading impacts (Kirdyanov et al., 2020). Despite this, there is evidence showing that people throughout the Republic are not remaining static and are using social media to attract attention to the ex post impacts of wildfires (IWGIA, 2019; Vinokurova et al., 2022). This has been attributed to the combination of recent wildfire seasons and the discontent with how wildfires were managed and responded to by the government, and this was made possible by people's access to technology and strong support networks (IWGIA, 2019; Vinokurova et al., 2022). This activism caused the Russian government to increase its financial investments in fire suppression mechanisms and evaluate their role in managing wildfires, with consequences for community risk and resilience (IWGIA, 2019).

By focusing explicitly on the situation of the community before, during, and after a wildfire, our framework, if adopted, can help provide important insights into different aspects of Sebyan-Kyuyol's risk and resilience. First, the framework provides important insights into why and how the community is at risk of wildfires and illustrates the factors that govern the ability of the community to adapt and transform in the event of wildfires. Second, it distinguishes two types of wildfire impacts and how these result in different disruptions to the livelihoods and well-being of the community. Third, the framework reveals the types, likelihood, and magnitude of extreme compound impacts emerging from wildfires and highlights the ways people are responding to these impacts. This approach allows us to identify the factors that play a greater role in community risk and resilience and understand the weaknesses and strengths of Sebyan-Kyuyol before, during, and after a wildfire, facilitating the identification of adaptation gaps and needs. For example, the exposure/vulnerability of the community to the recurrent impacts of wildfire smoke every summer can be reduced by investing in ventilation systems that maintain indoor air quality (Howard et al., 2021). Equally important, efforts can focus on improving firefighting, health, and water treatment infrastructure so the community can withstand future projected increases in wildfire activity near the community (Kuklina et al., 2022). Implementing these responses in Sebyan-Kyuyol would also likely increase the resilience of the community to other extreme climate events, including permafrost thaw, floods, or extreme temperatures (Callaghan et al., 2021; Vinokurova et al., 2022).

2.6. Discussion and Conclusions

This paper proposes and illustrates a conceptual framework for understanding community risk and resilience to wildfires in high-latitude regions. It builds upon the climate adaptation and disaster risk literature and uses the disaster risk reduction cycle to bring together the concepts of risk and resilience. For each stage of the framework, we characterized the factors and dynamics affecting community risk and resilience to wildfires in high-latitude regions. Here, a particular combination of biophysical and social factors that include vegetation types; remoteness; nature-based livelihoods; social, cultural, and health inequalities; limited infrastructure; and rapid environmental and socio-economical changes were observed to determine community risk and resilience to high-latitude wildfires. Previous research demonstrated the influence of each of these factors on community risk and resilience, yet a coherent framework largely remained absent, with most existing studies overlooking either important biophysical or social factors. Our framework integrates these factors in a holistic framework, providing a means to comprehensively think about the biophysical and social factors driving community risk and resilience to high-latitude wildfires.

Moreover, existing research on the human dimensions of high-latitude wildfires remains highly selective about which aspects of the human–climate–fire interaction to include in their assessments, leading to a poor basis for developing policies and management practices (Ford et al., 2021; Iglesias et al., 2022). This framework addresses this critique by integrating (1) why and how high-latitude communities are at risk of wildfires, (2) the nature of the impacts that wildfires can have on high-latitude communities, (3) the resilience of high-latitude communities to wildfire-related impacts, and (4) the compound drivers and impacts affecting community risk and resilience. We have illustrated how each of these aspects changes over a range of temporal scales (for example, after a wildfire), addressing concerns directed at previous approaches, particularly that they have largely focused on single, static points in time (Naylor et al., 2020). By integrating these aspects, not only does this framework provide a more holistic approach to identify (non-)climatic factors governing community risk and resilience to high-latitude wildfires over space and time, but its integrated focus on risk and resilience also promotes a more efficient use of resources (Joakim et al., 2015; Begum et al., 2022; Logan et al., 2022). Our framework can, therefore, help practitioners and organizations, such as the Canadian Interagency Forest Fire Centre or the Arctic Council, become aware of what factors have greater influence on community risk and resilience and ensure that their policies are well-grounded ecologically and socially.

Another major advantage of our framework is the consideration of compound drivers and impacts on community risk and resilience. This reflects the fact that wildfire-related events are not the only hazard facing high-latitude communities but are part of broader ongoing climate-driven changes (Masson-Delmotte et al., 2018). In our case study, for example, ongoing permafrost thaw was found to negatively affect risk and resilience before, during, and after a wildfire event, either through damages to fire infrastructure and housing or accelerating thaw processes. The consideration of these dynamics has often been neglected in both high-latitude and global social science and humanities research despite being increasingly demanded by both researchers and institutions (Schlumberger et al., 2022; Environment and Climate Change Canada, 2022). There are only a few case studies, reviews, and assessment reports globally that highlight the need to consider compound risks in our assessments, yet rarely has this work focused on hazard-specific applications (van den Hurk et al., 2023). By considering compound factors in our framework, however, we do not seek to make the high-latitude wildfire challenge even more complex or problematic. Instead, this paper sustains what researchers in other regions globally have identified as building wildfire-adapted communities, which is the imperative need to incorporate and account for the complexity of wildfires, including compounding and cascading risk interactions (Essen et al., 2021; Iglesias et al., 2022; Simpson et al., 2023). Failing to do so can otherwise bias our future assessments towards a few determinants of risk and resilience and lead to the development and adoption of strategies and policies that ignore local socio-ecological realities and, therefore, are inadequate to address wildfire risk in high-latitude communities.

Despite these advantages, our framework only offers a conceptual description of the dynamics and factors affecting community risk and resilience to high-latitude wildfires and an illustrative example. There is now a need to empirically test the framework and examine its value. A profitable line of inquiry, where our framework could be particularly useful, would be to examine wildfire risk and resilience in (1) high-latitude urban centres and (2) smaller, more remote settlements in the tundra region. While both of these areas are at increased risk of wildfires (Parmesan et al., 2022), they have historically received less scholarly attention compared to rural, Indigenous communities from the boreal region (Canosa et al., 2020; Canosa et al., 2023). Researchers and practitioners who are interested in these less-studied areas could use our framework here to become aware of the different spatial–temporal characteristics of high-latitude wildfires and ask questions based on them. For example, compound risks have been consistently overlooked in recent wildfire analyses, but with our framework, we encourage researchers and practitioners to think about how these risks can affect wildfire risk and resilience. They will then be able to better capture the conditions that make these areas more (or less) exposed and vulnerable to wildfires and explore opportunities for adaptation. This will ultimately improve our understanding of the human dimensions of high-latitude wildfires and help local, regional, and national governments find suitable wildfire management solutions and strategies for these areas. Although the proposed framework is not explicitly tied to a set of methods, researchers and practitioners can use it with several community-based methodologies, remote sensing tools, or ethnoclimatology modelling (Ford et al., 2023). This can involve, for example, documenting how wildfire risks are perceived and managed in different high-latitude communities and using this knowledge to map at-risk areas with fire spread and global vegetation–fire models. Such works can help develop a range of strategies and plans that can then be applied variably across communities, following, for example, the fire adaptation "pathways" concept from Paveglio et al. (2018). As we face the challenges posed by wildfires in high-latitude regions, developing a knowledge base that addresses and recognizes why and how people who live in high-latitude regions are at risk needs to be a priority for the future.

2.7. Author contributions

I.V.C. conceptualized the framework and coordinated and led the writing of the article. All authors contributed to discussions on the content, text, and ideas. All authors have read and agreed to the published version of the manuscript.

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2.9. Institutional Review Board Statement

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2.10. Informed Consent Statement

Not applicable.

2.11. Data Availability Statement

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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2.13. Conflicts of Interest

The authors declare no conflicts of interest.

2.14. References

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Chapter 3: Wildfire adaptation in the Russian Arctic: a systematic policy review

Chapter published as an ‘Article’ in *Climate Risk Management*

3.1 Abstract

A scientific consensus acknowledges that climate change has increased wildfire activity in the Russian Arctic, a trend projected to continue in response to further warming. Regional governments across Russia have started to design and develop adaptation policies and plans (i.e. outputs) to this end. Our comprehensive understanding on the state of wildfire adaptation in policy is limited. In this article we systematically review policies and plans developed to adapt to wildfires in the Russian Arctic. Using systematic approaches, we identify 12 wildfire adaptation outputs adopted between 2008 and 2020. Our findings indicate that wildfire adaptation outputs are aimed at reducing the risk of wildfires and improve wildland fire response, implemented through legislative and regulatory mechanisms, developed at the regional level, adopted in response to national mandates, and mainstreamed into existing forest management policies. Although there is evidence of wildfire adaptation planning occurring in the Russian Arctic, we find that the nature and extent of wildfire adaptation outputs are not sufficient to address the seriousness and severity of climate change, with key shortcomings found in relation to the scientific, human, and management characteristics. We argue that expanding the profile of climate change research in the Russian Arctic and improving the dialogue among researchers, local and Indigenous peoples, and decision-makers are critical for providing useful recommendations for policy makers to accelerate wildfire adaptation in the Russian Arctic.

Keywords: Wildfire, Arctic, Russia, Climate change, Adaptation, Systematic review

3.2 Introduction

There is an emerging consensus that climate change has increased wildfire activity across the Arctic region (IPCC, 2019; Ciavarella et al., 2021). Area burned as well as fire frequency and severity are higher now than in the last 10,000 years (IPCC, 2019), and further increases are projected as a result of climate-driven changes in fire danger conditions (de Groot et al., 2013; Kelly et al., 2013; Akenteva et al., 2017; Seidl et al., 2017; Torzhkov et al., 2019; Son et al., 2021). In the Russian Arctic, wildfires are becoming a particular problem, with recent years witnessing intense fire activity (Leskinen et al., 2020; York et al., 2020; Kirillina et al., 2020). The number of fire events in the Siberian region of Krasnoyarsk Krai, for instance, increased from 733 in 2007 to 2,400 by 2019, and the total area affected by fires from less than 0,03

Mha to 2,000 Mha over the same period (Government of Krasnoyarsk, 2020). This increased fire activity portends significant repercussions for ecosystems and humans. Of particular concern are the health effects associated with contaminated water systems (Robinne et al., 2018) and smoke pollution (Liu et al., 2015), which are expected to increase the risk of a range of respiratory, cardiovascular, and psychiatric problems (Reid et al., 2016; Kizer, 2020; Zhang et al., 2020), also interacting with the COVID-19 pandemic (Ford et al., 2022). Increased wildfire activity is also projected to increase the damage to critical infrastructure and services; challenge the preparedness and effectiveness of fire management and planning; alter ecologically important fire-vegetation interactions; and disrupt livelihoods activities due to the loss of important ecosystem services and habitats (Akenteva et al., 2017; Brecka et al., 2018; IUFRO, 2018; Coogan et al., 2019; Durova, 2020; World Bank Group, 2020). New opportunities associated with biodiversity conservation and economic productivity are also expected to arise (Musetta-Lambert et al., 2017; Torzhkov et al., 2019). To manage these impacts and take advantage of new ones, it is important to incorporate climate change adaptation policies and measures into fire management and planning in the Russian Arctic.

Some regional governments across Russia have already addressed increased wildfire activity. In 2013, for instance, the St. Petersburg's Climate Adaptation Strategy identified forest fires as a concern for the future development of the city (Government of St. Petersburg, 2013). In the Ural District, the Khanty-Mansi Autonomous Okrug recently set out a roadmap to adapt to increasing wildfire activity through 2030 (Government of the Khantsy-Mansi Automous Okrug, 2018), and the Government of the Moscow Region approved a set of regulatory mechanisms to reduce the risk of future forest and peatland fires. In the Arctic region, wildfires were identified as a potential threat in the 'Adaptation strategy to the impacts of climate change on public health in the Arkhangelsk Region and the Nenets Autonomous Okrug' (Sidorov et al., 2012), highlighting how wildfires are becoming more dangerous and how they will have significant repercussions to human health and well-being.

At the national level, the Government of the Russian Federation requested through the Climate Doctrine (2009) that interested ministries and departments include long-term measures to adapt to wildfires in the development and implementation of their planning documents. The most recent National Adaptation Plan (2019) identified increased fire hazard in forest as a projected negative impact of climate change (Government of the Russian Federation, 2009; Government of the Russian Federation, 2019).

Despite evidence of adaptation outputs in the form of policies and plans, synthesized knowledge on the state of wildfire adaptation policy and planning has been limited in the Russian Arctic. The first attempts to systematically assess the state of knowledge of adaptation across the Arctic demonstrated that limited adaptation efforts occur in Russia, finding no evidence of adaptation policies and plans specifically developed to adapt to wildfires over a 15-year period (2004–2020) (Ford et al., 2014; Ford et al., 2015; Canosa et al., 2020). While these reviews have helped to deepen our knowledge about adaptation in the Arctic, they focused on reviewing adaptations reported exclusively in the English-language peer-reviewed literature and may have thus omitted wildfire adaptation policies and plans reported in the 'grey literature' (e.g., government reports, websites, national assessments, etc.) and much Russian language research. Evidence of such limitation is found when examining recent assessment reports (AMAP, 2017; Leskinen et al., 2020) as well as a number of adaptation-focused studies in Russian (Semenov et al., 2019; Lipka et al., 2020), in which examples of wildfire adaptation policies and plans are discussed. It remains unclear, however, if these efforts represent a comprehensive profile of what is and is not being done on wildfire adaptation policy and planning in the Russian Arctic, with the majority focusing on Russia at a more general level and with only the Arctic Monitoring and Assessment Programme (AMAP, 2017) report documenting wildfire adaptation policies and plans from the Barents region. Similarly, the criteria by which these policies and plans were selected were not provided, limiting our ability to perform consistent, comparable, and comprehensive examination (Ford and Berrang-Ford, 2016). This constrains our ability to effectively characterize the current status of adaptation policy and planning in Russia and in the Arctic more generally; to assess the types and adequacy of wildfire adaptation policies and plans taking place; to inform future research directions and investments in climate change adaptation; to exchange insights from different regions facing related climatic stresses, and; to assess progress over time.

To address these problems, this study systematically reviews policy documents, strategies, initiatives, and programs (i.e. outputs) developed to adapt to wildfires in the Russian Arctic, combining three different data sources widely utilised in adaptation tracking studies (Araos et al., 2016; Lesnikowski et al., 2016; Biesbroek and Delaney, 2020). By using multiple sources, this review fills existing knowledge gaps and develops a comprehensive dataset of wildfire adaptation outputs while maintaining a consistent, coherent, comprehensive, and comparable approach for tracking adaptation (Ford and Berrang-Ford, 2016). The aims are: (i) to identify, characterize, and assess the state of knowledge on climate change adaptation outputs to wildfires in the Russia Arctic; (ii) to build up a more comprehensive profile of Arctic adaptation; and (iii) to inform a research agenda on human adaptation in the Russian Arctic and raise its profile within the climate change adaptation scholarship.

3.3 Wildfires in the Russian Arctic and the need for climate change adaptation

Wildfires are dominant ecological disturbance affecting ecosystems in the Russian Arctic (Shvidenko and Schepaschenko, 2013; Kharuk and Ponomarev, 2020; FAO, 2020; Leskinen et al., 2020). From 2000 to 2020, more than 70 % of all wildfires registered in Russia, and up to 90 % of the total area burned, were documented in the boreal forest belt of Siberia (between 55°-65° N), while 3 % of the total number of fires occurred in the tundra and forest-tundra zones over the same period (above 65°N) (Conard and Ponomarev, 2020; York et al., 2020; Kharuk et al., 2021). Many have argued that in high latitudes of Siberia the main source of fires (up to 90 % of cases) is lightning strikes in Larch (Larix sibirica) forests, especially during "dry thunderstorms" with minimal precipitation occurring at high temperatures and low relative humidity (Ivanov and Ivanova, 2010; Kharuk et al., 2021). Fires occurring in remote areas are not suppressed – they are left to burn naturally because of low population density, absence of effective detection and monitoring, and lack of a threat to settlements and economic facilities. Yet, approximately 70 % of all detected fires are extinguished within two days from detection in most regions that extend into the Russian Arctic, particularly below 65°N (Conard and Ponomarev, 2020). Wildfires in the Russian Arctic have considerably increased in recent years and are expected to further increase as a result of climate-induced changes, challenging socio-ecological relationships and the ability of fire management agencies to cope with increased wildfire activity, maintain important ecological processes, and protect human health and assets.

The Russian Arctic is experiencing some of the most dramatic climate change anywhere on the planet, with temperatures rising four times faster than the average global rate because of the polar-dependent amplifying effect (Akenteva et al., 2017; Edel'geriev and Romanovskaya, 2020). As a consequence, evapotranspiration is increasing, winter snowpacks are melting earlier, lighting activity is rising (Holzworth et al., 2021), and available surface and ground fuels are growing (McCarty et al., 2020), all of which is increasing the likelihood of a fire starting, its intensity and the speed at which it spreads. This is altering the structure and function of forest ecosystems by driving phenological changes (Davis et al., 2019); causing permafrost to thaw more rapidly (Gibson et al., 2018; Chevychelov, 2019); altering the hydrological controls over ecosystem processes (Li and Lawrence, 2017); and challenging the ecological resilience of the Arctic (Johnstone et al., 2016; Stevens‐Rumann et al., 2018; Barber et al., 2018; Whitman et al., 2019). Wildfires are also affecting albedo as well as organic carbon stocks and sequestration capacities, which are significant factors in regulating global and regional climates (Walker et al., 2019; Liu et al., 2019). Thus, the effects of climate change on the physical and biological characteristics of wildfires are significant in the Russian Arctic, with future, long-term projections indicating further transformational changes by the end of the century.

Climate-induced changes on northern fire regimes are also expected to physically and economically challenge fire management and planning (prevention, detection, monitoring, suppression) in Russia, and Arctic-wide (Isaev, 2011; Balalaev, 2018; Shpakovsky, 2018; Tymstra et al., 2020). Model estimations found that the number of wildfires could double in Russia by the end of the century under changing climatic conditions, which in turn is expected to increase the number of days when fire intensity exceeds suppression capabilities (Flannigan et al., 2009; Podur and Wotton, 2010; Shvidenko and Schepaschenko, 2013; Melvin et al., 2017; Wotton et al., 2017). The costs of managing such increased wildfire activity will also rise in the future. Torzhkov et al. (2019) estimated that the cost of wildfire management in Russia could increase by 249 million rubles per year (~3 million EUR) by the end of the century due to increased climate-induced wildfire activity. These findings are a cause for concern, given that Russian fire management agencies have reduced budgets to respond to wildfires and are already struggling to manage large and severe wildfires (Goldammer, 2013; Sokolov et al., 2013; Balalaev, 2018). Human-ignited fires, socioeconomic transitions, political conditions, and changes in forest fuel composition, structure and load due to decades of fire suppression also contribute to the challenge of managing wildfires in a changing climate.

At the same time, the effects of climate change on Russia’s fire regime may lead to large economic and social damages and losses. Impacts include increased exposure to air pollution; contamination of water resources; diminished forest productivity and economic activity; and disrupted transportation routes and supply chains, with consequences well beyond the Arctic (Bondur et al., 2020; Rodriguez-Cardona et al., 2020). The impacts of wildfires are particularly pertinent for Indigenous groups in the Russian Arctic, many of whom directly depend on the tundra, forest-tundra, and boreal forests (AMAP, 2017; Lavrillier and Gabyshev, 2017). For example, recent studies documented that increased fire activity is affecting the health, abundance, and migration patterns of many mammal, fruit-bearing shrubs, and tree species throughout the Arctic region (Johnstone et al., 2016; Barber et al., 2018; Whitman et al., 2019; Kharuk et al., 2021). This, in turn, is impacting many rural and Indigenous communities whose livelihoods, community social networks, and lifestyles rely on traditional subsistence-based practices (Bogdanova et al., 2021). Indigenous communities in the Russian Arctic also have limited access to emergency services, inadequate wildfire protection infrastructure, and weak capacity and preparedness to fire risk disturbances, which may lead to premature deaths, critical health effects, and economic losses in light of projected increases in wildfire activity (Leskinen et al., 2020; Solovyeva and Kuklina, 2020).

Forest ecosystems in northern Russia are a basic pillar of the socio-economic development of the Russian Federation, providing valuable ecosystem services to local and Indigenous communities as well as to a significant proportion of the global population (e.g., food, raw materials) (FAO, 2020; Carr et al., 2021). Russian forests also perform important climate control functions at the local, regional, and global level, with great potential to alter the rate of climate change through fire-related greenhouse gas emissions and associated feedbacks (Prosperi et al., 2020). Failing to adapt to increased wildfire activity in a sustainable manner would therefore have major implications well beyond the Arctic, particularly by contaminating freshwater resources, increasing air pollution, and releasing greenhouse gases (Robinne et al., 2018; Rodriguez-Cardona et al., 2020). Such impacts would jeopardize the fulfilment of internationally recognized mitigation and adaptation climate targets and goals, including objectives delineated in the Paris Agreement's '1.5° Goal' (Article 2), 'Global Goal on Adaptation' (Article 7), and the UN Sustainable Development Goals (SDGs) (United Nations, 2015; UNFCCC, 2015). Thus, the burning of the Russian Arctic should be viewed as a global issue. It is in this context that the understanding of if and how authorities in Russia are addressing increased wildfire activity is urgently needed in order to ensure and support the development of accountability mechanisms and evaluation of adaptation outputs.

3.4 Methodology

For the purpose of this study, adaptation outputs were defined as policy instruments adopted by governments at different administrative levels that are intentionally designed to address current and/or projected impacts of climate change on northern wildfire regimes (Dupuis and Biesbroek, 2013). Hence, our review only includes policy instruments that were purposefully designed to respond to both the current and/or projected impacts of climate change. This means that policy instruments that reduce vulnerability and increase adaptive capacity but do not explicitly refer to adaptation were not included in this review, consistent with other adaptation tracking research (e.g. Lesnikowski et al., 2016, Biesbroek and Delaney, 2020). For example, actions taken to improve fire response or concerned with general climate processes or weather were not included if there was not an explicit mention of climate change. Other concepts closely associated but different to adaptation – e.g. resilience, disaster risk reduction, sustainability, etc. – were also excluded (Gallopín, 2006; Mercer, 2010). As long as there is an explicit intentionality in the design of the policy instrument to climate change adaptation, these are included in our review (Dupuis and Biesbroek, 2013). Furthermore, it should be noted that we do not follow any particular definition throughout this review; instead, we recognize the diversity and ambiguity of key terms (e.g. vulnerability, resilience) and thus understand them according to the general consensus to avoid the exclusion of different framings and discourses. Similarly, the terms “forest fire”, “wildland fire”, “wildfire”, and “fire” are often used interchangeably. We use the term “wildfire” to refer to all human- and lightning-caused fire in the natural environment, including forests and peats. Detailed information methodology, metadata and search methods, is presented in the supplementary material.

3.4.1. Data collection

The data source was publicly available information in both English and Russian-language reported in peer-reviewed literature journal articles, submissions to the United Nations Framework Convention on Climate Change (UNFCCC), and documents and contents from official governmental websites published over a 12-year period (January 2008-December 2020). The beginning of this period is marked by the publication of the first assessment report on climate change issued by the Russian Government, which led to the establishment of the Climate Doctrine in 2009 and the emergence of climate change as focal point of policy regulations and programs in the Russian Federation. Governmental websites were selected based on the premises included in this Doctrine, which established all the Ministries and Departments that are responsible for pursuing wildfire-related adaptation policies; these included both national and regional governmental entities (for a complete list of the ministries/departments included in the website search, see page 2 of the supplementary materials or the Climate Doctrine itself). In selecting these entities, we therefore ensure that key adaptation policies developed by Russian institutions are identified, selected, and analysed. The searches from both peer-reviewed journals and UNFCCC submissions help complement these efforts through identifying potential adaptation outputs that were developed by other governmental entities. The review focuses on northern Russia, following the geographical boundaries used in the Russian Presidential Decree N° 296, May 2, 2014, Land Territories of the Arctic Zone of Russia encompassing Murmansk Oblast, Republic of Karelia, Arkhangelsk Oblast, Komi Republic, Nenets Autonomous Okrug, Yamalo-Nenets Autonomous Okrug, Krasnoyarsk Krai, Republic of Sakha, and Chukotka Autonomous Okrug (Figure 3.1). We limit our review to documents of national and regional (i.e., oblast, okrug, krai, republics) authorities, excluding adaptation outputs reported at the local level (e.g., district towns, municipal formations).

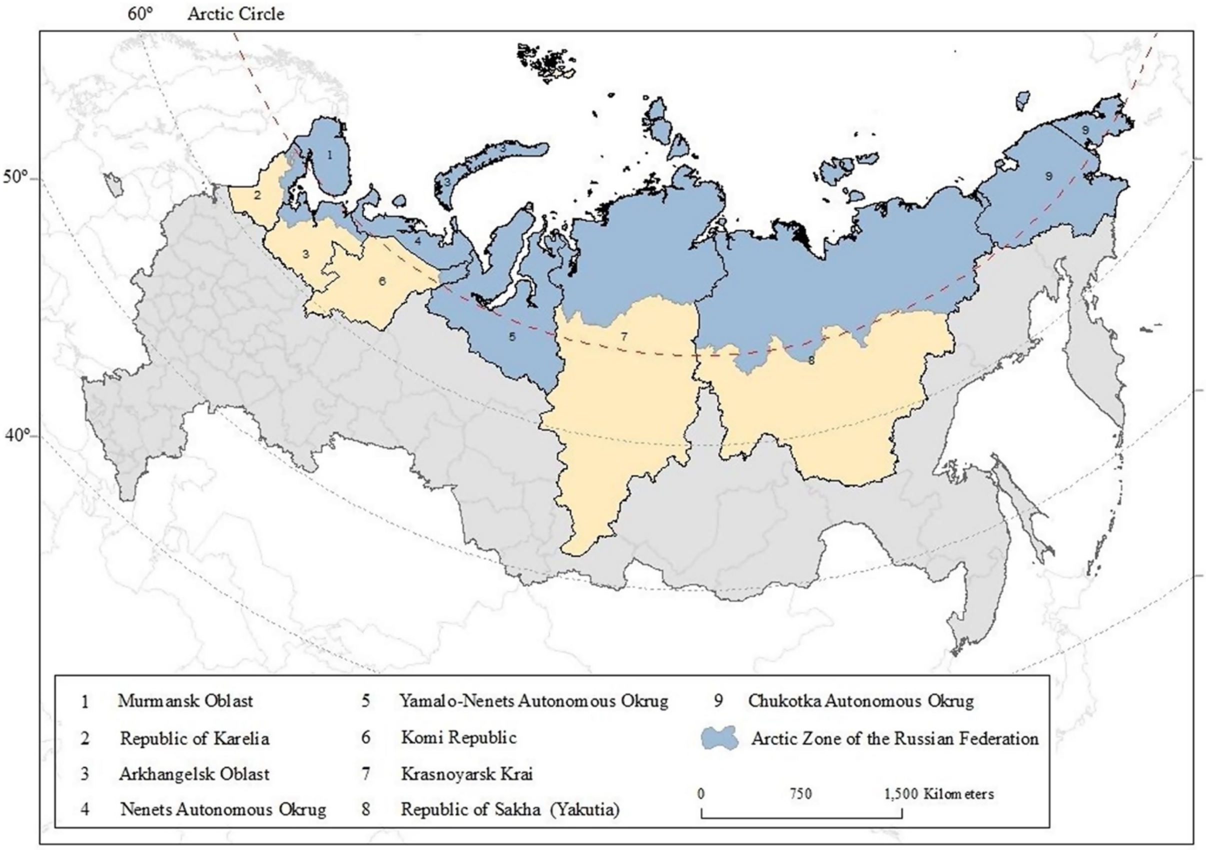

Figure 3.1 Review's geographical focus as established in the Russian the Russian Presidential Decree N° 296, 2 May 2014, Land Territories of the Arctic Zone of Russia.

Data collection took place in three stages, combining three different data sources normally used in tracking studies (Lesnikowski et al., 2016; Austin et al., 2019; Biesbroek and Delaney, 2020). First, we used a search string based on terms related to climate change, adaptation, and wildfires to identify potentially relevant peer-reviewed articles in Web of Science, Scopus, Russian Science Citation Index, and 11 pertinent Russian journals. Secondly, a hand-based web search was performed on official Russian government websites to identify any content or files related to climate change adaptation to wildfires; this search used the search bar function available within each website, with the resulting results being screened based on the review's inclusion/exclusion criteria. Finally, content-analysis was conducted to all submissions (n = 3) of the Russian Federation to the UNFCCC to identify potential outputs designed to adapt to wildfires. After screening over 3,000 documents, only 12 documents were included in this study. The majority of the retrieved documents were excluded as no explicit mention to climate change was found. The inclusion of documents and contents that had a specific focus on climate change alone is a clear limitation of this review, which is discussed in greater detail in section 3.4.3 of this chapter.

To check the completeness of the search, the list of included scientific articles and policy documents was presented to 11 scholars working on climate change adaptation, wildfires, and Russia. The selection of scholars was based on authorship of key articles on the topic and on our list of included adaptation outputs and included both non- and Russian native speakers. Four scholars responded, suggesting no additional outputs that met our inclusion criteria and thus confirming the robustness of the search protocol. Adaptation outputs found from peer-reviewed searches, UNFCCC submissions, and official governmental websites were cross-referenced to avoid double counting (Figure 3.2). For a detailed description on how the sources were identified, including the inclusion/exclusion criteria and the rationale for selecting peer-reviewed journals, UNFCCC submissions, and official governmental websites as our data source, please refer to the supplementary materials.

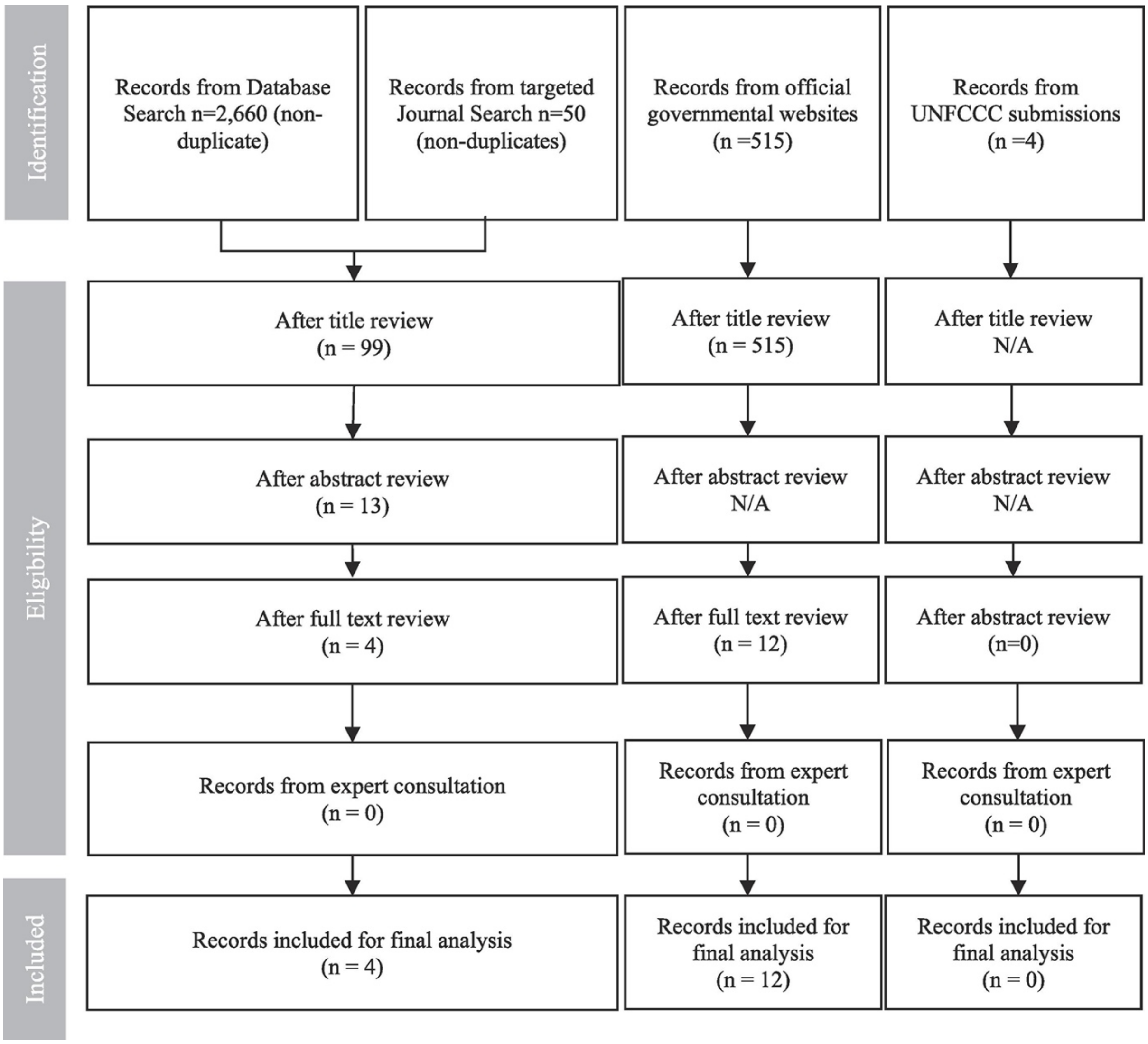

Figure 3.2 Document identification, eligibility, and inclusion. Adapted from McDowell et al., 2019, Canosa et al., 2020.

3.4.2. Data analysis

The final set of wildfire adaptation outputs were documented in a detailed Excel spreadsheet and coded using a protocol identifying key impacts and risks, goals, and instrument characteristics (see supplementary material). The protocol included 23 indicators such as implementing entity, year of instrument adoption, adaptation approach, nature of climate drivers, climate models and scenarios, policy aim, policy implementation, policy approach, policy goal, spatial approach, nature of governing resource, policy target and target, governance level, monitoring, and consideration of vulnerable groups. Under the “nature of governing resources” indicator, adaptation outputs were catalogued using NATO typology (Hood, 1983), which has been used in many adaptation tracking studies (e.g. Lesnikowski et al., 2019): (i) information/knowledge (nodality); (ii) legislation/regulation (authority); (iii) finance (treasure); and governmental functioning (organization). Adaptations were coded for policy goals and targets: policy goals constitute the strategic policy goal (e.g. improve fire response), while policy targets constitute the specific means by which these goals will be implemented (e.g. improvement of forest tracks) (Howlett and Cashore, 2009). Furthermore, adaptation outputs were coded by the temperature (1.5, 2, 3, 4 °C) and models and scenarios (e.g., RCP, SRES) used to inform policy instruments choice. Following data entry, descriptive statistics were used to characterize and quantify information about wildfire adaptation outputs in the Russian Arctic, comparing the nature and scope of reported outputs, along with the total number of adaptations documented (i.e., adaptation intensity). The full coding scheme and associated descriptions are provided in the supplementary materials.

3.4.3. Limitations

Despite efforts to develop a comprehensive search syntax, this study should be read with several caveats in mind. First, the study poses some challenges regarding the comprehensiveness of the dataset as policies or programs that increase resilience or reduce vulnerability to climate change may not be labelled as adaptation, and therefore not captured by the search methods. Indeed, it is very likely that, despite not being labelled ‘adaptation’ per se, current wildfire policies and programs contribute to reduce the negative impacts of both ongoing and projected climate-related changes in wildfire activity. This can lead to results that overemphasize some policy outputs over others, potentially causing important trends and patterns to be overlooked, including those related to the indicators introduced in the previous section. We can expect that some of these measures, however, are directed to coping and responding to ongoing changes rather than anticipating the long-term, projected impacts, consequently leading to potential maladaptive outcomes in the face of future climatic changes

(Dupuis and Biesbroek, 2013; Dilling et al., 2015). Additionally, identifying policies and programs that are not labelled ‘adaptation’ but contribute to reduce climate change impacts remains complicated and contentious, particularly as policy outcomes are challenging to measure and adaptation actions have been argued to take many different forms (Knill et al., 2012; Dewulf, 2013; Berrang-Ford et al., 2021). We thus rely on governments to frame their actions as ‘adaptation’ when referring to measures that address both current and longer impacts of climate change. Comparing policy outcomes labelled adaptation with others that are not can provide crucial information on the nature of the reported adaptation outputs, particularly to determine whether these measures represent substantial changes to the status quo or only a symbolic change in the face of public perceptions. Second, local governments were also omitted in this study, despite being important players in adaptation. Future studies including local-level adaptations would complement our findings and enhance our understanding of wildfire adaptation in Arctic systems, particularly if and how adaptation is implemented and with what outcomes. Third, ministries/departments that were not included in our list may have developed wildfire adaptation outputs during our review period. Finally, this study is affected by limitations common to all systematic reviews, namely data extraction is influenced by researcher subjectivity to some extent and relevant documents may have been missed. Nonetheless, the review offers a proxy of how wildfire adaptation is occurring in northern Russia and is well suited for future comparative analysis across and between regions, for identifying general trends and patterns, and for monitoring progress over time.

3.5. Results

Twelve adaptation outputs were identified, documented, and reviewed for the 12-year study period (2008–2020) (Table 3.1). The adaptation outputs were mostly reported at the regional level (n = 9; 75 %) followed by the national level (n = 3; 25 %), with each federal constituent entity reporting only one adaptation policy output. The majority of reported outputs were published in 2017 or later, with the earliest one published in 2011. Between the periods of 2008–2010 and 2012–2017, no wildfire adaptation outputs were identified, even with extreme fire years in European Russia in 2010 (Krol et al., 2013) and Siberia in 2001, 2005, and 2013 (Conard and Ponomarev, 2020). It is possible that more wildfire adaptation outputs were developed but were not accessible via the web or were replaced or removed from the internet. For instance, the UNFCCC submissions refer to a methodology for calculating the risks and consequences of forest fires not available online, and thus was not included in this study. The target of the majority of reported adaptation outputs were regional entities (n = 9; 75 %), indicating the predominance of outputs reported at the regional level. This highlights the federalist political system in the Russian Federation, where national authorities establish the legislative and regulatory framework that constituent entities follow and implement. For example, state authorities of the Russian Federation are required by the Forest Code (2006) to establish fire safety requirements and measures in forests that authorities of the federal regions organize and implement in their territories. (See supplementary materials for a brief introduction to fire management in the Russian Federation).

Table 3.1 List of adaptation outputs documented between 2008 and 2020 in the Russian Arctic, by district and document year.

Jurisdiction	District	Year	Adaptation output
Federal	Russia	2017	Clarifications in the order of preparation of sections 3.11 and 4.2 of the Standard form and composition forest plan of the constituent entity of the Russian Federation
Federal	Russia	2017	On approval of the standard form and composition of the forest plan of a constituent entity of the Russian Federation, the procedure for its preparation and amendments to it
Federal	Russia	2011	On the approval of a comprehensive plan for the implementation of the Russian Federation Climate Doctrine for the period up to 2020
Federal Constituent Entity	Northwest	2018	Forest Plan of the Arkhangelsk Region
Federal Constituent Entity	Northwest	2018	Forest Plan of the Republic of Karelia for the years 2019–2028
Federal Constituent Entity	Northwest	2019	On approval of the Forest Plan of the Nenets Autonomous Okrug
Federal Constituent Entity	Northwest	2019	Forest Plan of the Republic of Komi 2019–2028
Federal Constituent Entity	Northwest	2019	Forest Plan Murmansk Region
Federal Constituent Entity	Ural	2019	On approval of the Yamalo-Nenets Forest Autonomous Region Plan
Federal Constituent Entity	Siberia	2018	On approval of the forest plan of the Krasnoyarsk Territory
Federal Constituent Entity	Far East	2019	On approval of the Forest Plan of the Republic of Sakha for the period 2019–2028
Federal Constituent Entity	Far East	2019	Forest Plan of Chukotka Autonomous District

3.5.1. Key climate impacts, risks, timeframes, and scenarios

The most common climate drivers listed in the Russian government documents included changing snow and rain patterns (22 %); extreme and prolonged heat attributed to higher temperatures and drought (17 %); increased frequency and intensity of extreme weather events (17 %); and temperature average changes (17 %). Sometimes increased wind speeds (11 %) and increased frequency of lightning events (6 %) were key biophysical drivers of adaptation. Some documents combined multiple drivers such as drought and increased wind speeds. In others, it was unclear what types of climate risks affected or would affect forest fires in the long-term (28 %), with a general need to adapt to increased wildfire activity. No adaptation output mentioned wildfires to be affected by conditions of fuels/vegetation or thawing permafrost, which will be exacerbated due to future climate change. Only one document (Forest Plan of the Republic of Karelia for the years 2019–2028) neglected the influence of climate drivers and referred to the expansion of transport accessibility and the development of mass tourism as the main driver of adaptation. Climate risk projections or temporal scales (i.e., short, medium, long term) were not explicitly considered in any of the included adaptation outputs, with all the outputs exclusively tailored to the period of validity of the Forest Plans (2018–2028).

3.5.2. Policy instruments, goals, and targets

The majority of the documented adaptation outputs (n = 11; 92 %) were related to the elaboration and validation of the section on "Information on planned measures to preserve the ecological potential of forests, adapt to climate change and increase the sustainability of forest", included in the latest forest plans of all federal regions. It was first introduced by Russian national forestry authorities in the 2017 Order of the Russian Ministry of Natural Resources and Ecology "On approval of the standard form and composition of the forest plan of a constituent entity of the Russian Federation, the procedure for its preparation and amendments to it", which set outs how regional forest plans must be structured and developed. The specific contents of the plans as well as the specific adaptation measures were a responsibility of every regional authority. As such, Russian regions are reactively responding to the national mandate, rather than following a comprehensive adaptation planning framework. Most of the adaptation outputs (n = 11) are thus mainstreamed (integrated) into existing policies rather than developed as stand-alone plans specifically addressing climate change. The one output (n = 1; 8 %) was associated with the implementation of the Russian Climate Doctrine in 2011 (Government of the Russian Federation, 2011), when executive bodies were requested to include long-term measures to adapt to wildfires in the development and implementation of their planning documents. No evidence has been found linking the introduction of climate change adaptation into recent forestry planning efforts to the provisions considered in the 2011 Climate Doctrine.

We find a high reliance on authority (legislation, inter-governmental mandates, and regulations) to govern resources (11 out of 12 outputs). The remaining output fell under the nodal (i.e., informational) typology, consisting of an order approved by the Russian Ministry of Natural Resources in 2017 which clarifies sections 3.11 and 4.2 of the latest forest plans. There is also a high prevalence of simple policy mixes (multiple goals and one instrument) in our database (Lesnikowski et al., 2019). Most adaptation outputs (n = 11; 92 %) have two specific policy goals: (i) improve the effectiveness of firefighting, including warning of forest fires and fire hazard monitoring in forests; and (ii) adjust plans for extinguishing wildfires. These goals have been set at the national level by federal authorities, entrusting the development of specific means by which these goals will be achieved to regional authorities (Table 3.2). Accordingly, reducing the risk of wildfires and improving fire response is the predominant approach to adapt to wildfires in 11 and six of the reported outputs, while reducing human exposure to fires were considered in four outputs. No evidence of how adaptations are going to be implemented or monitored was identified.

Table 3.2 Illustrative adaptations from Russian Arctic regions between 2008 and 2020, by district, policy goal, and policy target. Federal Districts based on the 2000 Decree of the President of the Russian Federation “On the Plenipotentiary Representative of the President of the Russian Federation in the Federal District”.

Constituent Entity	District	Policy goal	Policy target
Murmansk Oblast	Northwestern	Improving the effectiveness of fire safety measures in forests, including forest fire prevention, monitoring of fire hazards in forests and forest fires	Creation of firebreaks
			Cleaning and updating firebreaks
			Carrying out preventive controlled burning of brushwood, forest bedding, dry grass and other forest fuels materials
			Installation and placement of stands and other signs and pointers containing information on fire safety measures in forests
			Monitoring fire dangers in forests and forest fires, aviation zone guard

		Adjustment of plans for extinguishing forest fires	No specific measures envisaged
Yamalo-Nenets Autonomous Okrug	Ural	Improving the effectiveness of fire safety measures in forests, including forest fire prevention, monitoring of fire hazards in forests and forest fires	Construction of firebreaks
			Cleaning of firebreaks
			Installation and placement of stands, signs and signs containing information on fire safety measures in forests
			Installation and operation of barriers, the device of barriers to limit the stay of citizens in the forests in order to ensure fire safety
			Monitoring of fire hazards in forests and forest fires
			Fire danger monitoring by aircraft
			Satellite monitoring of fire hazard
		Adjustment of plans for extinguishing forest fires	No specific measures envisaged
Krasnoyarsk	Siberia	Improving the effectiveness of fire safety measures in forests, including forest fire prevention, monitoring of fire hazards in forests and forest fires	Maintenance of forest roads designed to protect forests from fires
			Reconstruction of forest roads designed to protect forests from fires
			Installation and placement of stands and other signs and indicators containing information on fire safety measures in forests
			Clearing of glades and firebreaks and their renewal
		Adjustment of plans for extinguishing forest fires	Development and adjustment of plans for extinguishing sub-Arctic forest fires, taking into account the burning of the region
Republic of Sakha	Far Eastern	Improving the effectiveness of fire safety measures in forests, including forest fire prevention, monitoring of fire hazards in forests and forest fires	Installation and placement of stands and signs containing information on fire safety measures in forests
			Monitoring of fire hazards in sub-Arctic forests

		Adjustment of plans for extinguishing forest fires	Organization of ground, aviation, and satellite detection and ground and aircraft suppression

Finally, vulnerable groups such as the elderly, women, children, and/or disabled persons, as well as Indigenous Peoples, were not considered in any of the adaptation outputs. This is in line with the other adaptation tracking studies where the inclusion of vulnerable peoples in policy design happened in less than 5 % of the cases (Lesnikowski et al., 2016). No differentiation between tundra and the taiga forest was documented in the reviewed outputs. We also found hardly any information on the implementation procedures allocating actors and rules. The exception here was the 2011 Order of the Government of the Russian Federation “On the approval of a comprehensive plan for the implementation of the Russian Federation Climate Doctrine for the period up to 2020″, where the implementation of wildfire adaptations was delegated to the environment, natural resource units, executive and legislative bodies, and forest planning departments. No monitoring process for documented adaptation policy instruments, strategy, and program were identified. A comprehensive presentation of the results can be found in our supplementary materials.

3.6. Discussion and conclusion

With the changing and intensifying Arctic fire regime, climate change adaptation policy has become a priority. The 2019 and 2020 fire seasons in the Russian Arctic offer a worrying glimpse of what a future world with increased fire activity might look like if we fail to mitigate and adapt to climate change. Efforts to understand if and how wildfire adaptation planning is occurring in northern Russia is lacking. To our knowledge, this study provides the first systematic review of the state of climate change adaptation policy and planning to wildfires in the Russian North, using a combination of three adaptation tracking approaches. Our findings demonstrate that Russia and its northernmost regions have started wildfire adaptation planning, but also highlight a number of critical shortcomings that are important to discuss below. Given the recent war in Ukraine, the results of this work represent the pre-conflict understanding of climate policies for the Russian Arctic and provide a baseline for understanding future dynamics in a changed and changing Arctic climate and geopolitical region.

Firstly, the biophysical drivers motivating adaptations are generally consistent with observed climate-related changes affecting fire regimes in northern Russia; temperature and hydrological changes related to changing snow and rain patterns. However, none of the outputs we reviewed integrated potential future projections of climate change, which suggests that reported adaptations are not informed by contextually accurate scientific information about changing Arctic systems. The reported adaptations were exclusively tailored to the period of validity of the Forest Plans (2018–2028), disregarding any potential changes that may happen in the medium to long term (greater than 2030). This finding raises concerns about the long-term viability of reported adaptations, echoing observations made across the adaptation literature (McDowell et al., 2019; Canosa et al., 2020), that the impacts of climate change are being underestimated, potentially leading to maladaptive responses. A key maladaptation that we can identify from this lack of engagement with the future projections of climate change is the reduction in Russia's future wildfire suppression effectiveness. Specifically, management agencies in Russia will face more days when suppression efforts will be unable to effectively manage uncontrolled wildfires, unless they start to consider the projected climate-related changes in fire weather and behaviour conditions (Tymstra et al., 2020). The inability to forecast these medium to long-term changes will in turn lead to increased environmental and socio-economic impacts that will range from higher fire suppression costs to diminished economic contributions from the forestry sector, with consequences well beyond Russia and the Arctic (Torzhkov et al., 2019; Prosperi et al., 2020). Russia's recent policy discourse around climate change, influenced by its reliance on the fossil fuel industry and an authoritarian regime, can help explain why these adaptation outputs lack a significant engagement with future climate projections (Tynkkynen et al., 2018; Martus, 2021; Beuerle, 2023). Therefore, to ensure implemented adaptations are consistent with potential future trajectories of climate change, policymakers in Russia should seek out and extensively engage with available scientific information when developing adaptations outputs. At the same time, when planning adaptations, it is important to integrate observations from Indigenous/local stakeholders whose familiarity with the local environment can complement scientific assessments (Ford et al., 2018). These needs have been advocated by both the international scientific community as well as by the Russian public (Martus, 2021).

Secondly, there has been insufficient engagement with the human dimensions of climate change. Most of reported adaptation outputs did not contemplate the role of human-ignited fires in future fire regimes, even though half of all the registered wildfires in the Russian Arctic were initiated by anthropogenic influences. Likewise, none of the reported adaptations were explicit about the role and needs of marginalized and vulnerable groups, which may in some cases contribute to maladaptation. The lack of reporting on the human dimensions of climate change brings into question the extent to which the current wildfire adaptation outputs in Russia will be able to reduce underlying inequalities that increase exposure-sensitivity and vulnerability and increase adaptive capacity to wildfires. This finding contrasts with what has been done at different governmental levels in other Arctic nations, where wildfire outputs addressing the human dimensions of climate change are evident (Hennessey and Streicker, 2011; Government of Yukon, 2017; MOA (Municipality of Anchorage), 2019; Alaska Division of Forestry, 2020; Fire Adapted Communities Coalition, 2020). For example, the 'Climate Preparedness and Adaptation Strategy' (2021) developed by the government of British Columbia (Canada) recognises the differential impacts that wildfire smoke have on unhoused and housing insecure populations, highlighting specific actions to improve the provincial response in this regard. It is therefore important that adaptation planners in Russia recognize that different populations will have varying degrees of exposure-sensitivity and adaptive capacity to changing fire regimes, depending on cultural and socio-economic factors. Enhanced communications between Russian fire managers (federal and regional), local and Indigenous communities, non-profit organizations, the private sector, and other Arctic nations can be an effective way forward to make relevant decision makers aware of who gains and who loses from changing fire regimes and implemented adaptation policy responses (Zamolodchikov, 2013; Shmatkov et al., 2013; Callaghan et al., 2020). This can be achieved, for example, by enhancing data-sharing and integration of citizens' views and opinions within the 'Voluntary Fire Brigade', and cooperatively develop new decision support tools, guidelines, and preparedness strategies. Further gains can also be made by researchers, practitioners, and stakeholders, who can help provide essential information to fire managers and decision makers by making marginalized groups' needs explicit as well as provide recommendations to create concrete provision to address their needs.

Thirdly, the lack of adaptation outputs addressing the differentiated structural and pyrogenic characteristics of taiga and tundra forests indicates that adaptation outputs in all Russian regions are overlooking critical context-specific and place-based climatic exposures, and thus not targeting realistic processes of change (Shur et al., 2020). All of the adaptation outputs were developed to manage fires occurring in sub-Arctic boreal forests, overlooking fires in the treeless tundra region. This carries the risk of increasing the adverse impacts of climate-induced wildfires, as well as missing new opportunities, as increase in fire activity in the Russian tundra are projected for this century (Chen et al., 2021; Holzworth et al., 2021). Carbon emissions from wildfires could significantly accelerate under future scenarios of climate change if tundra-specific adaptation outputs are not developed or implemented (Mack et al., 2011). Burning of the Arctic tundra could also catalyse other biogeochemical and biophysical changes if left unmanaged, such as permafrost thaw; increase human health and safety impacts from smoke pollution; and limit new economic opportunities in the forestry sector associated with the transition from tundra to taiga forests (Pan et al., 2011; Heim et al., 2019). Similarly, land-managers and policy makers therefore need to include tundra fires in their adaptation planning and tailor current fire management practices and land-use planning approaches to the tundra region, building upon current fire trends and anticipation of the changes projected with climate change. When developing wildfire adaptation outputs for the tundra region, particular attention should be given to potential trade-offs between fires' ecological role and their socioeconomic impacts. Similarly, current firefighting techniques used in the boreal forest may not be appropriate for the more fragile Arctic tundra, requiring innovative fire management approaches and methods.

Notwithstanding the shortcomings outlined above, the majority of reported adaptations were mainstreamed into existing policy instruments such as forest plans, which has been identified in the adaptation literature as the most effective way to reduce vulnerability and adapt to climate change; promote innovation; and distribute resources from an administrative and budgetary point of view (Rauken et al., 2015; Lorenz et al., 2017; Runhaar et al., 2018). The prevalence of authority instruments in our dataset indicates a mandate from Russian policymakers to stimulate adaptation, implement specific policy objectives, and move forward in the climate change agenda in meeting the challenge of adapting to wildfires in Arctic systems. However, the lack of nodal and organisational instruments – both integral components for informing and preparing adaptation outputs (Lesnikowski et al., 2019) – questions whether planned policies and measures are suitable in the long-term; we note, however, that these efforts may have been conducted but not yet reported or published online. Adaptation outputs were also developed relatively recently, which indicates that experiences in understanding the effects of planned measures is yet to develop. The lack of information on how adaptations are going to be implemented and/or monitored can here prove problematic in the future, particularly for measuring the performance and evaluating and measuring the effectiveness of adaptation outputs. Thus, research addressing how reported adaptations will be implemented in practice is very much needed for future works.

Our final observation is that the nature and extent of documented wildfire adaptation outputs in Russia are not sufficient to address the seriousness and severity of climate change. Despite efforts to adapt to increased wildfire activity in the Russian Arctic, key shortcomings were found in relation to the scientific, human, and policy management characteristics of documented adaptation outputs, all of which puts into question whether reported adaptation outputs are sufficient in meeting increased wildfire activity in the Russian Arctic. These shortcoming can be overcome with political will, institutional change, financial support, creative management, and by individual or collective efforts but there are many factors constraining adaptation, including an absence of political leadership on adaptation in the Russian Federation, unclear or ill-defined responsibilities, the existence of other pressing socio-economic problems, lack of financial resources and lack of technical data on future climate risks (FAO, 2012; Sharmina et al., 2013; Skryzhevska et al., 2015). Nevertheless, existing pan-Arctic intergovernmental forums, such as the Arctic Council, are well placed to catalyse the attention of policymakers to address the challenge of adapting to wildfires in the Russian Arctic, driven by knowledge co-production and continuous information and resource exchanges. Indigenous, traditional, and local communities who are the first in experiencing the impacts of wildfires must play a critical role in leading and contributing to these efforts. Moreover, further collaborative, inclusive, and multidisciplinary studies are needed to inform and develop effective and place-based and context-specific suitable wildfire adaptations for the Russian Arctic. Key research needs include improving our understanding on how climate is changing and the impacts it is having on wildfires throughout the Russian Arctic; assess how people manage changing fire regimes and what factors affect this; and examine opportunities for adapting to changing wildfires. Developing such a knowledge base is both necessary and a priority.

3.7. Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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3.9. Author contributions

IVC coordinated the review, created and designed the figures, tables, and supplementary materials, and wrote the manuscript. RB, JF, JLM, RO, JP, and DB provided guidance on manuscript organization and contributed to the interpretation of the findings and writing of the manuscript.

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3.11. Data availability

The data used in this review is publicly available.

3.12. References

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Chapter 4: Community risk and resilience to wildfire in British Columbia, Canada

Chapter ready for submission to *Weather, Climate, and Society* (WCAS)

4.1 Abstract

Wildfires increasingly threaten communities in the province of British Columbia (BC), Canada. Yet there is little empirical work evaluating how these communities manage, experience, and respond to wildfire risk. This research, conducted prior to the catastrophic wildfire season of 2023, in the village of Valemount examines how a community in BC is preparing and responding to wildfire risk. We interviewed 20 key informants about their perceptions of wildfire risk, lived experiences, and management approaches. We further explored the barriers to and opportunities for wildfire management. Our findings demonstrate that despite local wildfire risk increasing due to climate change and decades of successful fire exclusion, the community focused on the secondary impacts of wildfires such as power outages and smoke. We discuss the shortcomings of using backup generators as a suitable response to wildfire-caused outages and illustrate the need for improved cross-boundary cooperation across different jurisdictions and organizations. Our study complements existing research on the human dimensions of wildfires and provides a basis to understand community risk and resilience to the secondary impacts of wildfires.

Keywords: wildland fire, wildfire, North America, cross-border impacts, adaptation, risk, climate change, Canada

4.2 Introduction

Wildfire risk to communities is growing in the Canadian province of British Columbia (BC), increasingly threatening human lives and livelihoods. The convergence of historical policies of fire suppression and exclusion (Copes-Gerbitz, Hagerman, et al., 2022; Baron et al., 2022), financial and social constraints (time and expertise) (Copes-Gerbitz, Dickson-Hoyle, et al., 2022), and climate change impacts (Kirchmeier-Young et al., 2019; Parisien et al., 2023) are interacting to create a complex new wildfire reality that cannot be addressed only by using reactive fire suppression approaches (Tymstra et al., 2020). Researchers, practitioners, and management agencies in BC (and also in Canada more broadly) have increasingly recognized the need to adopt new approaches to managing this new wildfire reality and reduce wildfire risks to communities, including increased use of prescribed fire and cultural burning practices and proactive fuel mitigation (Abbott and Chapman, 2018; Daniels et al., 2020; Hoffman, Christianson, Gray, et al., 2022). Enacting new thinking on wildfire management however, requires a comprehensive understanding of the social determinants of wildfire risk, including attention to public risk perceptions, attitudes, and wildfire responses. Works of this nature are key to identify appropriate pathways for increasing community resilience to wildfire.

In Canada, much of the social science literature related to wildfires seeks to document, describe, and explain the impacts of wildfires and how people prepare, respond, and recover. The field has grown rapidly and has provided important insights into the social characteristics and processes driving wildfire risk and resilience at community level. For example, a combination of remoteness, ethnicity, and socio-economical inequalities have been found to strongly influence the capacity of communities to manage, cope, and respond to both the indirect and direct impacts of wildfires (Dodd et al., 2018; Christianson et al., 2019; Tepley et al., 2022; McGee and Healey, 2022; Copes-Gerbitz, Dickson-Hoyle, et al., 2022). Despite this, social science research remains limited compared with efforts dedicated to understanding fire regimes, behaviour, and ecological processes (Wildfire Analytics, 2023). The Blueprint for Wildland Fire Science in Canada (2019-2029) recognizes the lack of such work in the wildfire domain, and identified a need for more research in the field (Sankey, 2018), including understanding risk perceptions of wildfire risk and mitigation efforts, and the social-ecological aspects of wildfire risk and resilience of communities and individuals (Johnston et al., 2020). This need is notably important in communities that are predominately non-Indigenous, given that the majority of social science studies in Canada are currently focused on understanding wildfire risk and resilience in Indigenous communities (Christianson et al., 2019; Hoffman et al., 2022).

Our paper responds to this call by identifying and characterizing how wildfires are experienced, understood, and responded to at a community level in Canada, examining perceptions of risk, preferred actions and approaches, and barriers to action. We focus on the province on British Columbia and use a case study of the community of Valemount to develop an in-depth understanding. Our findings contribute to a growing literature on the human dimensions of wildfire in Canada (see Dodd et al., 2018; Walker et al., 2021) by providing important insights into the conditions that foster or limit local wildfire action, which can later be used to inform and facilitate adaptation efforts for reducing future wildfire risk in the country (Paveglio et al., 2016; Copes-Gerbitz, Dickson-Hoyle, et al., 2022).

4.3 Methods and study area

4.3.1. Study area

The Village of Valemount is a small, rural mountain community of □1,000 permanent residents (3% First Nations, 9% Métis) located on the western edge of the Canadian Rockies in the Regional District of Fraser-Fort George of central-eastern British Columbia, Canada (Statistics Canada, 2023). It covers 517 ha and is located in the traditional unceded territory of the Simpcw First Nation–a division of the Secwepemc (or Shuswap) Nation (Simpcw First Nation, 2023). It was established during the late 1920s, with the relocation of the Swift Creek railway station (Valemount Historic Society, 1984). In 1962, Valemount was incorporated as a village municipality under the Municipal Act and since then is responsible for providing a range of services to the community, including water and sewer services, road maintenance, and emergency management. For more than thirty years, the forestry sector was the backbone of Valemount's economy, but a combination of socio-political factors resulted in the withdrawal from the sector over the last decades and in the closure of the local sawmill in 2006. Today, the economy of Valemount has shifted away from this sector and is now largely based on industries that include accommodation and food services, retail trade, construction, and health care and social assistance (Statistics Canada, 2021). In recent years, however, the establishment of the Valemount Community Forest (VCF) – a long-term, area-based tenure granted to Indigenous and/or local communities – has enhanced local manufacturing of wood products, contributing to the diversification of the community's economy (Valemount Community Forest, 2023). At the time of writing, the community was facing significant housing challenges brought by the Trans Mountain Expansion Project, which is a significant infrastructure initiative consisting of the construction of a new oil pipeline system between Strathcona County (near Edmonton), Alberta, and Burnaby, BC (Transmountain, 2023). This project has led to a shortage of skilled labour and disrupted local services in the community (The Rocky Mountain Goat, 2022). The community is connected to the rest of the province through the Yellowhead Highway 5 and the Canada National Railway track (Figure 4.1).

The landscape of Valemount is characterised by its unique location between the Rocky Mountains, the Monashee Mountains, and the Cariboo Mountains. Elevations range from 720 to 3,500 m above sea level (MASL) and the topography varies from alluvial plains at lower elevations to steep valley cliffs in high mountainous areas. There are four different bioclimatic zones in the area, including Interior Cedar (Hemlock), Engleman Spruce (Subalpine Fir), Sub-Boreal Spruce, and Alpine Tundra (Meidinger and Pojar, 1991). The climate is continental and strongly influenced by the topography of the area. At lower elevations, average monthly temperature range from 16ºC in July to -7ºC in December; the total annual precipitation is 428 mm, with the highest rainfall in July ($\bar{x}$=55 mm) and highest snowfall in January ($\bar{x}$=45 cm) (Government of Canada, 2023). In higher elevations, the climate becomes wetter and cooler, where the total annual precipitation is 665 mm, and the highest snowfall is in January with an average of 117.5 cm (Columbia Basin Rural Development Institute, 2021). Climate change is projected to increase both annual average temperatures and precipitation and reduce the number of total frost days across the region over the next century (Climate Data Canada, 2023). Recent changes to climate and weather patterns have resulted in the expansion of bark beetle populations throughout the region, causing widespread mortality of mature lodgepole pines from 2002 to 2012 (Meidinger and Pojar, 1991; Ministry of Forests Lands and Natural Resource Operations, 2013).

Based on historical wildfire data from 1917 to 2023, there were only small, scattered wildfires near Valemount since it was established in the first half of the 20th century (Figure 4.1). The total number and size of wildfires near the community has steadily decreased over time, with half of the total ignitions caused by humans while the other half were caused by lighting. However, human activities have caused the majority of wildfires in the first half of the 20th century, arguably to expand the community and the forestry sector; in recent decades, lighting has caused most of the recorded wildfires. In the last decade, ten wildfires that burned 10,000 ha in total ignited in the area near Valemount (within 10 km), although none had imminently threatened the community. According to official records, no wildfire evacuation orders and alerts were issued for the community. Despite this, the threat of wildfire in Valemount has been rated as medium to high by BC's Wildfire Service due to its proximity to highly flammable vegetation and structure density (BC Wildfire Service, 2021). This risk is similarly increasing with climate change, which is leading to a warmer and drier landscape and to a subsequent increase in extreme fire-conducive weather conditions (Columbia Basin Climate Source, 2021; Parisien et al., 2023). Furthermore, the cumulative impacts of insect outbreaks, human land-use practices (e.g., tourism, logging, urban development), and decades of successful fire exclusion, combined with the suppression of Indigenous cultural burning practices, has led to an increase in the likelihood of large, high-intensity wildfires across BC (Parisien et al., 2023).

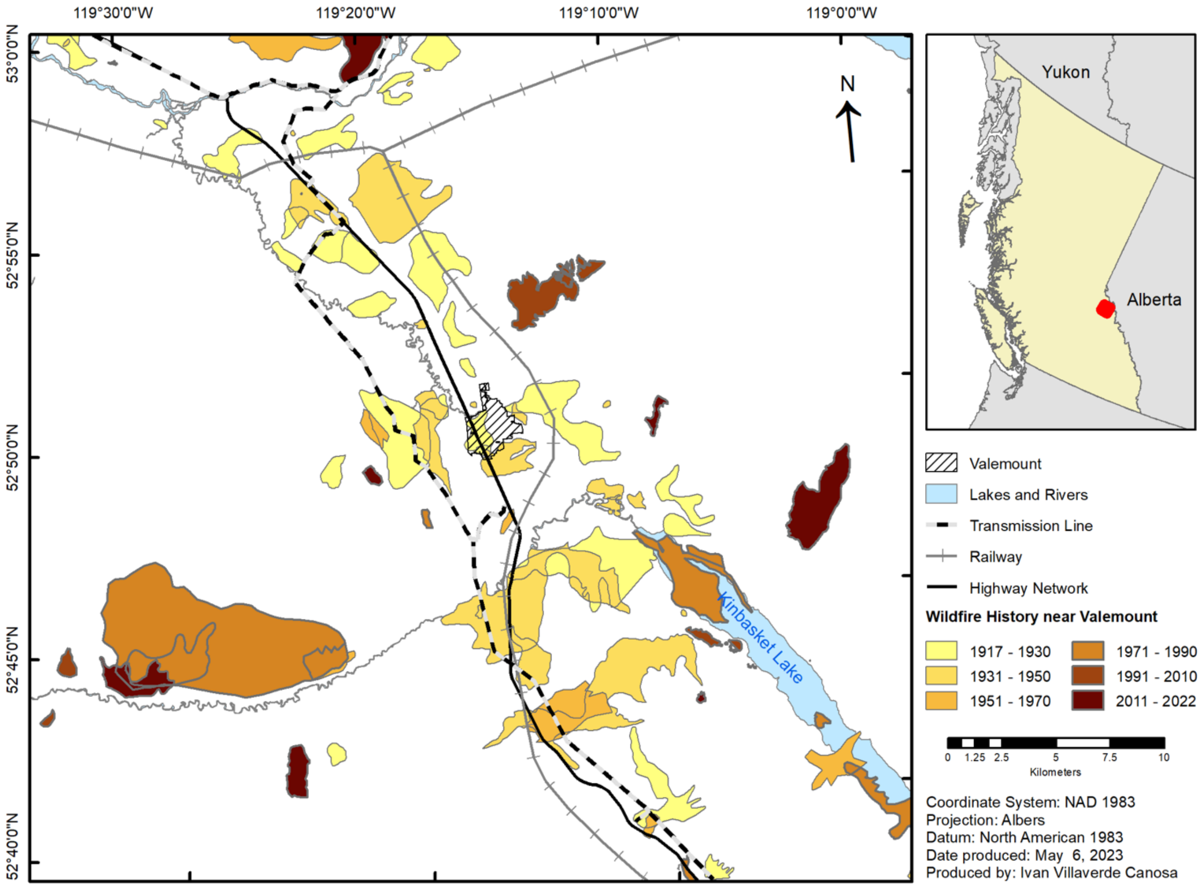

Figure 4.1 Map of Valemount, illustrating local transport infrastructure and historical wildfire events.

4.3.2. Conceptual framework

We use the integrated risk-resilience framework of Canosa et al (2024) to identify and characterize how wildfires are experienced, understood, and responded to at community level. The framework conceptualises risk as a function of hazard, exposure, social and contextual vulnerability, and resilience as a function of coping, adaptive, and transformative capacities (see Table 4.1 for definitions). The framework integrates the concepts of risk and resilience into the disaster risk reduction cycle to better understand the human-fire-climate interdependencies and interactions over different spatial and temporal scales. It was developed based on scholarship on disaster risk reduction, wildfire social science and ecology, and climate change adaptation. Integrating risk and resilience into the disaster risk reduction cycle helps understand why a community is at risk and explore how it prepares, copes, and responds to wildfires, and how experiences with wildfires influence community preparedness.

Table 4.1 Key terms used in Canosa et al's framework.

Terms	Description	References
Risk	Potential for adverse consequences for human or ecological systems. It results from the dynamic interactions between hazard, exposure, and vulnerability of the affected system. It can also result from responses not achieving the intended objective(s), or from potential trade-offs or negative side-effects.	(Simpson et al., 2021; Begum et al., 2022)
Resilience	Describes the capacity of individuals, communities, and systems to respond in the face of stress and shocks. It is a function of the combined result of coping, adaptive, and transformative capacities, which in turn lead to persistence, incremental adjustments, or transformational responses in the face of environmental change	(Brown, 2015; Ford et al., 2020)
Hazard	Occurrence of natural or human-induced (wildfire) events that may have adverse or beneficial effects on a system, including, amongst others, loss of life, injury, loss of infrastructure, or increased habitat regeneration.	(Field et al., 2012; Pachauri et al., 2014)
Exposure	Presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places where hazard events (i.e. wildfires) may occur.	(Meybeck et al., 2019; Masson-Delmotte et al., 2021)
Vulnerability	The propensity or predisposition to be adversely affected by a hazard. It is a component of risk and is based upon a system's sensitivity or susceptibility to harm and lack of capacity to cope.	(Gallopín, 2006; UNISDR, 2015)

The building blocks of the conceptual framework helped design both the interview guide and the qualitative analysis of this research. More specifically, the use of the disaster risk reduction cycle in the framework guided questions related to how risk and resilience change after a wildfire impacts a community, thereby capturing different temporal dynamics at the local level. Similarly, the framework's consideration of cascading risks also prompted inquiries into how previous wildfires influenced both social and ecological conditions within the community and how internal and external factors affected their capacity to manage new challenges. This study's use of a conceptual framework aligns with the broader literature on disaster risk reduction and climate change adaptation, which recognizes the value of frameworks for guiding empirical data collection and analysis processes (Galappaththi et al., 2019; Naylor, 2022).

4.3.3. Data collection

We conducted semi-structured interviews (n=20) with key informants to collect qualitative data on community risk and resilience to wildfires in BC. The rationale for selecting semi-structured interviews over other qualitative data collection methods (e.g., surveys, focus groups) was based on two key reasons. Firstly, semi-structured interviews offered a useful means for gathering in-depth and rich data. Scholars have widely recognized the advantages of semi-structured interviews as a data collection method, which include, among others, enabling interviewees to explore and raise issues they consider important (Longhurst, 2003). Secondly, the financial and time constraints faced during this research (see section 5.5.2.4 for more details on financial and budget limitations) limited the feasibility of combining different approaches in this study. While integrating different data collection methods could have offered a greater range of opinions and experiences (breadth), the level of detail or specificity (depth) of the data would be considerably reduced given these constraints. The use of semi-structured interviews therefore allowed the research team to strike a balance between breadth and depth, capturing a wide range of experiences while at the same time developing an in-depth understanding of the topic (Longhurst, 2003).

Semi-structured interviews were based on an interview guide to ensure that major topic areas were covered and to increase the consistency across interviews. The guide was comprised of both closed and open choice questions to allow participants to elaborate on the issues that they viewed as most important. The guide inquired about the participant's biographical data; perceptions of wildfire risk; perceived changes in wildfire activity; levels of support and preferences for current wildfire management approaches; barriers and facilitators to respond to wildfires; and compound impacts on wildfire risk and resilience. The interview guide was structured by the conceptual framework and developed by the research team.

A combination of purposive and snowball sampling techniques was used to select participants (Gill, 2020). Key informants with previous knowledge or experience on wildfire management in the community were selected to participate; our purposive sample included local government officials, foresters and land managers, business owners, and private-sector fire practitioners. Individual email invitations were sent to these informants who, upon acceptance, were then asked to recommend other participants. While the majority of informants were from or working in the study site, several interviews were also completed with relevant experts from Vancouver and Vernon (two cities in the same study region). These interviews were conducted to gain a deeper understanding on the topics identified through local informants. The lead author purposively selected multiple informants with different socioeconomic backgrounds and roles to avoid recruiting like-minded people. Other population groups, including long-time homeowners, were excluded from this research because we sought to understand the perspectives of community-level decision-makers, often identified as important leaders in motivating action in their communities (Copes-Gerbitz et al., 2022). All interviews were conducted by the same researcher in English and were audio recorded.

Fieldwork in Valemount was carried out in September – October 2022. During this time, sixteen face-to-face interviews were conducted with key informants in the community. From October to December 2022, four additional interviews were conducted online. This study prioritized the equal inclusion of different groups to ensure that a variety of contexts and roles was represented (Table 4.2). Informed oral or written consent was obtained from all participants, and study protocols were approved by the University of Leeds (AREA 21-166).

Table 4.2 Summary of interviewees

Participant's affiliation	**Valemount**	**Simpcw First Nation**	**Province**
Local government officials	6 (4 males; 2 female) Lived in Valemount for an average of 42 years	1 (1 male; 1 female) Residence outside of Valemount	0
Foresters and land managers	2 (1 male, 1 female) Lived in Valemount for an average of 42 years	1* (1 male; 0 female) Residence outside of Valemount	0
Business managers	4 (1 male; 3 females) Lived in Valemount for an average of 22 years	0	0
Private-sector fire practitioners	1 (1 male; 0 female) Lived In Valemount for 37 years	0	0
Community organizations	2 (1 male; 1 female) Lived in Valemount for an average of 30 years	1* (1 female) Residence outside of Valemount	0
Experts	0	0	2 (2 males; 0 female) Residence outside of Valemount

*Note: These participants do not represent the official views of the Simpcw First Nation.

4.3.4. Data analysis

Audio recordings from each interview were transcribed and then analysed by the lead author using 'manifest' (explicit) and 'latent' (implicit) content analysis (Berg, 2001; Bengtsson, 2016).

Guided by the conceptual framework, the analysis characterised how participants articulated exposure-vulnerability (risk), hazard (impacts), and resilience to wildfires, and identified areas of confluence and difference between informants. This analysis was based on the broad area of inquiry outlined in the interview guide. Direct quotes were used to represent themes that were articulated in each area by multiple participants in a manner that was suitable for the presentation of the data. Some quotes were edited to facilitate readability only (for example removing irrelevant text), always preserving the original point of view of the participants. Each interview transcript was analysed using the qualitative research software (QSR) NVivo 11. The results and interpretation from the interviews were reviewed and evaluated by the research team.

4.4. Results

4.4.1. Exposure: perceptions of risk and changes in wildfire activity

When asked about the risks facing Valemount, wildfires were perceived as one of the most urgent issues by interview participants, followed by wood burning, silica dust, train derailment, landslides, avalanches, labour shortages, and lack of housing. Many local participants attributed the increased risk to wildfires to the age and type of forest surrounding Valemount, the proximity of community values to flammable vegetation, the mountain pine beetle, the railway tracks, and the increased presence of tourists and pipeline workers in nearby forests. Others were associated with the natural role of fire, the geography and climate of the region, and the prevailing winds from the Kinbasket lake, although these were less frequently identified. Interestingly, the natural role of fire in the landscape was only considered to affect the exposure of the community by local foresters, land managers, and one local government official. As one male forester participant indicated:

> “It happens every year. Wildfire at this latitude in the boreal or montane forest type are a permanent part of the forest, right? It's an evolved part of the ecosystem. There’s a fire within several kilometres of town every single year. The question is whether or not it will grow to become anything significant.”

In addition to explaining why the community is at risk, participants also discussed how fuel treatments (i.e., prescribed burns, selective cutting and ladder fuel removal) that have been recently conducted by Valemount’s Community Forest has contributed to reducing the community’s exposure. These treatments were mostly considered beneficial in reducing the fuels around the community by most participants, regardless of their profession, although some participants highlighted that more prevention work was needed (see section ‘Resilience’). Other wildfire prevention initiatives that were discussed during interviews included FireSmart initiatives – a national program that helps Canadians increase neighbourhood resilience to wildfire (FireSmart, 2023) – which were seen as an effective tool to educate the public about the risks of wildfire. As one male official indicated:

> “Education is a big key too [referring to FireSmart]. I've seen proof of it in the fire service. When I started 25 years ago, probably 90% of our calls were structured chimney fires, and through education and in only a decade, we've got that down to probably maybe 10% of our calls. So, you know, as people get educated then they start thinking about these things.”

Furthermore, many participants, but not all, perceived changes in wildfire activity in the last 30 years, particularly in the frequency and severity of wildfires. Increased dryness, climate change, and fire suppression activities were commonly reported by interview participants at both local and provincial level. The participants that did not perceive any change was because they either have not seen wildfires in the area or recognized the annual variability between seasons. One male participant that was not certain about seeing an increase in wildfire activity in the region attributed this to the media’s role in communicating wildfire events.

> “I don't know if there's actually an increase or if we just hear about it more because of the ability to share news. You know, your news feed, you know, what you search on Google, what I search, is going to give us both different feeds. So, I don't know. I can't say for certain that there's more fires, but it appears like there is, for sure. I mean, if you don't get the numbers from 15 years ago to now, there seems like there's definitely a lot more fire, but whether it's a fact or not like… I'd have to look into it more for sure. Seems like there's bigger ones, if there's not more, there's definitely bigger.”

Despite diverging perceptions, many participants recognized the inevitably of wildfire in the landscape and considered that living in the region meant living alongside wildfires. As one male official described:

> “People live here because there is mountains and trees, so I don’t think you can get rid of all the risks. We’re always going to be in the fire interface here. That’s the reasons for being for this town.”

4.4.2. Vulnerability: community weaknesses and strengths

For many participants, the egress of the community – that is, the means by which people can exit a location in the event of an emergency – featured prominently in discussions about the vulnerability of the community. However, responses varied considerably here, particularly between local decision-makers, foresters, and land managers. On the one hand, local government officials viewed having only two ways of leaving the community (either north towards Tete Jaune Cache or south towards Kamloops) as an important factor increasing the vulnerability of the community. This factor was also mentioned by the two experts that were consulted at the provincial level, who recognized the difficulties that communities with one road in and out face, for example, when issuing evacuation alerts and orders. As one male expert explained:

> “Some of these communities can be remote, and so […] vulnerabilities around one road in one road out. And that at times can certainly impact when alerts and orders are issued. For example, if there's any risk in the route, having to be closed or… that certainly impacts the speed in which the evacuation orders are given for obvious reasons.”

Contrarily, one male official disagreed with this view and discussed how Valemount’s local airstrip could be used to facilitate a potential evacuation of the community in the event of a wildfire. Similarly, another male participant directly involved with forestry discussed how Valemount’s immediate access to the Kimbasket Lake would facilitate any evacuation effort issued for the community.

Furthermore, in addition to the egress, the community’s limited power infrastructure was notably recognized as increasing the community’s vulnerability to wildfires, particularly to the indirect impacts of wildfires. Participants explained that because most of their power is delivered to the community via a single transmission line that comes from the city of Kamloops, wildfires in-between these places can result in power outages and disrupt the energy supply to the community. As one female business owner commented:

> “Part of our concerns are any major fire that happened between Kamloops and here. We're at the end of a 320-kilometer-long extension cord, so anything happens at that end, it takes out our power.”

Another male official cited:

> “It's not just locally impacts, but regionally, as we're at the end of a 320-kilometer extension cord called the transmission line, and so a fire anywhere between here and Kamloops, nearer, around, in proximity to electrical infrastructure means power goes out there.”

These wildfire-caused power outages have been identified by many local participants, including local government officials, business owners, and members affiliated with community organizations, as a growing concern. Given that a significant number of residents rely on freezers to store food throughout the year, participants acknowledged that any disruption to the community’s power supply can lead to food degradation, thereby worsening the food security of the community. Additionally, participants recognized that many administrative buildings within the community rely on out-of-community power, acknowledging that any power disruptions negatively impact essential community services, including emergency response. As one male official explained when asked about the potential impacts of power outages:

> “Depending on the time of year, that means food degradation. It might mean things like this building [referring to the municipal building] doesn't have backup power; it's also our emergency operations centre.”

Interestingly, only one male participant affiliated with a community organization acknowledged that vulnerability to wildfire-caused power outages varies between groups. Specifically, this participant explained that many residents of the community are not significantly reliant on external power to obtain food, and therefore can survive for extended periods of time, contrasting with people whose lifestyle relies more on store-bought products:

> “As we do raise our own chickens, we raise our own beef, I have large gardens every summer, own cold storage room… We are in a position because of our lifestyle where we can go weeks on end without a trip to the grocery store. If there's no grocery store open because there's no power, and there's no coolers and stuff like that, we can survive quite a long time on our own because where we get our food from so. Somebody in this village not the same scenario at all, right? So, I mean, there's not that many people that I know that live in Valemount that have, you know, an extensive supply of food. It's convenience to go to the grocery store, and when you need something, go get it. But I mean, I'm sure everybody will last for a week or two, but beyond that, I don't think there would be a lot of people in the village that would.”

To a lesser extent, there were a few occasions where some participants recognized the challenges that certain individuals, some with pre-existing health problems, face during wildfires. Discussions about this were held by four individuals who were business owners and local government officials from both Valemount and the Simpcw First Nation, who discussed why some residents were more vulnerable than others. Elders, young children, and individuals with lung problems featured prominently throughout these discussions, with participants worrying about the impacts of wildfires on them. A lack of critical health facilities, fully insulated houses, and air conditioning, and limited financial resources were some of the underlying determinants that were identified by participants as increasing the sensitivity of these groups to the impacts of wildfires, particularly in relation to evacuation orders and smoke events. As one female business owner cited:

> “In Valemount, we don’t have the care facility, so we don’t have the in-house resident patients, but we do have the seniors, what do we do for them? And we rely on volunteers to get them out, because not all of them have families… […] And yes, they are in town, but they are much vulnerable population, so their anxiety around the what-ifs… I can hoop in my truck and leave.”

Although many discussions focused on the weaknesses of the community, participants also spoke about its strengths. For instance, in three of the interviews, two local government officials and a forest manager discussed the role of the Trans Mountain extension project in relation to the community's wildfire preparedness and response. Although some recognized the negative impacts that the project caused on the local housing market, many participants acknowledged the unique opportunity that the project offered and spoke about how Trans Mountain's resources (e.g., equipment, personnel) could be used to improve the response of the community in the event of a potential wildfire event. As a male official explained:

> "I would see [the expansion project] as a positive aspect to have all of those kind of workers in the area, right, because they could help and assist during the emergency."

Similarly, vulnerability has also been linked to both community networks and the presence of people within the community with strong local knowledge and expertise, which were notably seen as strengths by a few of the participants from both Valemount and the Simpcw First Nation. Community networks have been identified to facilitate the sharing of knowledge, food, and equipment (i.e., freezers) between residents during emergency times, while local knowledge and expertise included the presence of loggers within the community, with many recognising this as a key component of coping capacity. As one local male official explained:

> "We are fortunate here though, in that this was a logging town, so there are quite a few fire contractors here that are quite familiar with fire and how to deal with it right away. And a lot of them don't even wait for the authorities to ask them."

For these participants, familiarity with local infrastructure, geographical features, and wildfires constituted critical aspects for enhancing the capacity to deal with wildfire events, mostly by foresters and local government officials.

4.4.3. Hazard: impacts and lived experiences of wildfires

The impacts of distant wildfires were consistently described by almost all local participants. Most descriptions focused on the McLure wildfire, which burned near the community of Barriere (almost 280 km south of Valemount) in 2003, and the impacts that it had on the community's power and fuel supply. As one female participant described:

> "In 2003, there was the fire in Barriere that took out the power transmission line, and this fill corridor was affected for four weeks, with no power, you know. It was a dry season and lots of lighting. Everybody was on edge. Where do we go? You've got no access to fuel. You've got three towns over who has no access to fuel. Everybody is on the highway"

Several local participants also spoke about how the consistent presence of dense smoke over the last few years was affecting the community's economy and well-being. Particularly, participants noted significant reductions in visibility because of wildfires burning in other parts of British Columbia, Canada, and even the United States. Most of these participants worried that such a prolonged exposure to smoke and the reduced visibility would reduce the natural appeal of the community and negatively impact the tourism sector in the future. This perception featured prominently in discussions with business owners and some local government officials.

> "The smoke alone in the past three or four years has had negative impacts. One could say if this keeps happening every summer, right, we may lose the type of summer tourism appeal, right, because it's no longer a nice experience. We had one summer… I forget which year… four or five years ago, for 2-3 weeks you could not see a mountain peak, so why would somebody travel through the area, right? That's all what we can really offer: it's the beautiful landscape, but if it's covered by smoke…"

In discussing the impacts of wildfire smoke, some local participants also described the impacts that smoke was having on their physical activity and well-being, including reduced time outdoors and mild physical symptoms such as difficulty to breath. These participants recognized, however, that health and well-being impacts from smoke pollution were present all-year-round because of the community's woodstove burning during winter, which led to some to admit that they were already used to living in a poor air quality environment; this was the most common sentiment among all the local participants when discussing the impacts of wildfire smoke. Only two participants – one female involved with the Indigenous community and one male expert – recognized the mental health impacts of wildfires. Specifically, these participants noted the emotional and psychological toll that the last few wildfire seasons had on communities, explaining how they were a source of uncertainty, anxiety, and stress:

> "We had a pretty bad wildfire season last summer, right? It was pretty horrible. […] What it does psychologically to a community and to the province shouldn't be underlined because living on edge like that for that length of time is stressful. It has a serious impact on the community and on mental health […]. I don't know how to articulate it better than that, but I think that the impacts of those seasons and seeing all of that and witnessing and being in the middle of those kinds of summer, those kinds of moments, are hard. […] The stress of every day, worrying about the animals, and worrying about all these other components. Again, not very articulate but something that, you know, two months of that, three months of that, it's very wearying on a person and the community."

Beyond the power and smoke impacts, some participants also recognized the effects that distant wildfires have had on the community's response capacity. Specifically, a local male official and an expert explained how wildfires in other regions of BC have led to the relocation of critical wildfire personnel, reducing the number of resources locally available to potentially respond to wildfires within the community. The official illustrated this while discussing the involvement of local wildfire personnel in responding to the 2003 Barriere wildfire:

> "Several of us from the Structural Fire Department went to work on that [referring to the 2003 Barriere wildfire], and there were even some logging contractors from here that went to work on that. So that took resources out of Valemount, right, to work somewhere else, and that increases the risk to Valemount itself, because now we have even fewer resources left, right?" […] Quite often, our forest firefighters can end up getting sent to other areas through the summer, firefighting, and we're left without it, because I think as a whole our risk might be high here but our incidents are low compared to other jurisdictions"

Although most discussions focused on the indirect impacts of wildfire, some participants, particularly foresters, land managers, and some business owners from the community, referred to the impacts that nearby wildfires had on local logging operations. Most of the impacts mentioned here were in relation to the Hugh Allen wildfire, which burned in 2018 at the shores of the Kimbasket lake, approximately 60 km southeast of Valemount. This wildfire was reported to have caused significant damages to forestry equipment, soil conditions, and forest resources, with participants highlighting the loss of financial revenues resulting from it. One local female business owner explained:

> "I think it was 2018, there was a fire on the east side of Kimbasket lake in Valemount, and it was a 5000 ha and there was an active logging operation going on. They lost all of their equipment; they lost all the revenue they would've gotten from logs that they got out (...) on the land… You have wildlife impacts… A friend had a trappers cabin there; he lost that… like it was massive. And the (…) equipment alone, we're taking over a million dollars, and that's someone's livelihood."

These participants also reported the destruction of trapping cabins and holiday trailers nearby the community, but these discussions were less frequently identified during interviews. Similarly, there was little recognition of the cascading impacts of wildfire (e.g., landslides, flooding) among the participants.

4.4.4. Resilience: responses, barriers, and proposed solutions

Reflecting the lived experiences of the community, many local participants, particularly local government officials, consistently indicated responses targeted at addressing the indirect impacts of wildfires. Here, the purchase and use of generators in public buildings were notably discussed by several local participants as one of the main measures that were adopted to cope with power outages. These participants recognized the importance of using these generators to allow local officials to continue providing services to the community in the event of a wildfire, including water and sewage treatment. Similarly, other participants, including local business owners and members involved with community organizations, referred to the use of generators, although these references were mostly made in relation to the residences' own food supply. Interestingly, some of these participants attributed the purchase and use of generators to the impacts of the 2003 Barriere wildfire on Valemount's food security. As one local female business owner mentioned:

> "After that [referring to the 2003 wildfires], we did purchase a generator. Now we have a couple, so that we can plug in fridges."

Participants explained how the use of these generators played a critical role in powering freezers and storing resident's food during wildfire-caused power outages; these freezers were regularly shared with neighbours to support the community's response to emergencies.

Many of the local participants that recognized the use of generators also highlighted the importance of other critical infrastructure in coping with the indirect impacts of wildfires. Such infrastructure included nearby Independent Power Producers (IPPs) or non-utility generators (NUG), which were recognized to generate enough power for some parts of the community. However, participants that referred to this infrastructure consistently recognized the shortcomings of using it during power outages. As one local decision making discussed:

> "We do have the ability for backup with the independent power producers, but you know, that takes time and depends on the time of year too, whether there's good water flow to generate enough."

In addition to adopting generators and IPPs, participants also spoke about the use of advisories and alerts as an action to cope with the indirect impacts of wildfire smoke. Specifically, some participants cited using an app to monitor the air quality in the community whenever it becomes smoky, which they would then use to decide whether they would personally avoid engaging in any outdoor physical activities or remain indoors. However, most of these discussions predominantly focused on the limitations of these alerts rather than on its benefits. One female participant from Valemount explained:

> "They [referring to the alerts] come to me through my phone. I think it's an app now. They usually get them though my weather app I think, yeah. But I mean, they are not that useful to

> be honest. They usually don’t come until it’s been smoky for three days, so by then you are like ‘yeah, I know.’.”

Another male participant from Valemount shared a similar sentiment:

> “I’m not really sure what the alerts are for to be honest, because when they kick in, it’s so obvious. It’s smoky already.”

Delays reporting on air quality were attributed by some local participants to the lack of a weather station within the community. One local male government official explained that because of this, and despite the presence of small stations within the community, their air quality index had to be based on the data from the community of McBride (80 km from Valemount), therefore resulting in inappropriate smoke advisories and burning recommendations for Valemount.

Despite the shortcomings that were described above, most local participants accepted smoke as a reality – a consequence of wildfires that cannot be changed or controlled and is an inherent part of the area where they live. This stoic acceptance of smoke was particularly common among local decision makers, business owners, and members involved with community organizations, all of whom consistently acknowledged the lack of specific plans and strategies within the community to cope with wildfire smoke. Participants nevertheless cited closing windows and remaining indoors as two of the main ways through which the community responds to degraded air quality, although some of them recognized the limited effectiveness of these actions. For example, as one male official cited:

> “We just continue on. You know, the little old lady might stay home, but you know, they're still breathing the same air as we are. It's not like we have ultra-airtight houses here. Nobody can afford that around here.”

Concerns related to how the community responds to wildfire smoke were also raised by one of the experts that were consulted at the provincial level, who indicated that “closing your window is not an option” and highlighted the lack of proper air conditioning as a contributing factor inhibiting communities’ coping capacity. Despite these concerns, most local participants did not identify alternatives to reduce the impacts of degraded air quality. Instead, solutions were proposed by only two participants (i.e., one local government official and one of the experts), who saw the need to (1) implement localized and accurate smoke monitoring and (2) create shelters to host people when air quality is considerably degraded.

While many participants referred to the indirect impacts of wildfires, there were instances where some local participants, both Indigenous and non-Indigenous, referred to the resiliency of the community to the imminent, direct impacts of wildfires. Most of these discussions were held with local government officials, business owners, and community organizations, who focused on the emergency operations centre (EOC), the local emergency plan, the proximity to the Robson Valley Fire Zone, and the adoption of FireSmart educational and awareness campaigns in the community. The reason behind implementing these measures were not considered by most participants; only one participant representing the First Nation indicated that they have started an Indigenous initial attack crew as a response to the impacts of the 2021 wildfire season on the community. Participants nevertheless consistently described how the implementation of these measures improved the preparedness of the community towards the potential future direct impacts of wildfires, by allowing them, for instance, to establish evacuation routes and send evacuation notices. As one local official indicated when asked about the preparedness of the community:

> “We have a plan in place. We haven't had to have a huge emergency, like obviously the one I'm thinking of is where everybody went to Prince George, right? We haven't had that kind of an emergency, but we have the plans in place.”

Another local female participant from Valemount mentioned:

> “We have a fire base right in town. We have an initial attack crew […] who could go to a fire within minutes if there was one close. And there is also a helicopter base right out of town.”

However, participants recognized significant socio-political factors as limiting progress towards improving the resiliency of the community towards wildfires. In most cases, both Indigenous and non-Indigenous participants indicated a lack of resources at the community level as a major barrier to action, which included both financial and human constraints. Financial barriers primarily revolved around the municipality's inability to implement additional wildfire prevention practices and programs, including FireSmart, and the purchase of additional infrastructure. Human barriers encompassed a lack of personnel dedicated solely to wildfire prevention and response, as well as challenges in recruiting and retaining individuals for positions related to wildfires. These two barriers featured prominently in conversations with local government officials and foresters. As one local female official discussed:

> “Municipalities don't have money to send people, you know. I mean, maybe they'd be funded for handout booklets or something, but to go and offer to do an assessment… We don't have the funds to do that as far as I know. And so, there may be more if, you know, I mean, if they go around and see that there's somebody has firewood banked up against the house, you know,

> maybe rather than singling them out, they could, you know, say we're in your neighbourhood and we noticed or, you know, this type of thing."

Similarly, one local government official shared:

> "I think the big point here is that if it's anything beyond, you know, like a small fire, we're evacuating anyway. We just don't have the resources within our town to manage a big fire. So, once it gets beyond a certain level, we're leaving, and we're asking people to leave, not asking them, we're telling them that they need to leave so. […] The fire department itself has a capacity to protect 10 homes, I think […]. So, we have pumps and sprinklers and all that kind of stuff on the trailer to be able to protect up to 10 homes. There's, you know, considerably more than that within the interface, especially on the east side."

Another barrier that emerged during different conversations included a lack of readily accessible information during wildfire events, which was mostly considered by business owners and by one of the experts. In the words of one local female business owner:

> "Nowhere […] do they have visible, readily available signage or updates. They have these emergency centres… Oh, you can go talk to the mayor at the community hall – nobody knew that. The tourist passing through town or checking out the hotels, they didn't know that. The community members didn't know that. You know, sure they talk their handful of volunteer fireman and have them going knock on doors saying: "are you okay?". We are asking ten, twenty people to canvass an entire neighbourhood? […] They are not telling the information out to people, and so by the time we have to act, we'd be a little to late. […] So, I don't think that they are communicating out to the public clearly enough, because if something was to happen, the residents would have to act quickly, and it's more than someone driving town, every street, with a bullhorn saying "evacuate, evacuate"."

Interestingly, this concern was in stark contrast with what some local government officials spoke about during interviews. They recognized the use social media or other institutional sites to promote multiple wildfire prevention measures to the community but cited a lack of education and awareness from community members as limiting the adoption of measures, including FireSmart. When asked about the level of preparedness of Valemount, one local government official explained:

> "Well, we put out lots of information. Whether they read it or not, whether they go… I find, personally, I find people to be a bit complacent in that they think that local government is going to take care of it, which we, I mean, we do, we have that obligation, but people also need to be prepared as well, and we try to put it out as much as we can. We put it on our web page. We put it in the paper. We have training sessions. We put it out there and whether people… I guess

> there's no way of knowing if they're taking it on, you know, unless you went house to house and ask them."

Some participants attributed this to how priorities and concerns shift throughout the year, particularly during winter. As one male official cited:

> "I know some people are very aware, you know, and probably more so depending on the season and how our weather is like. You know, with an extended hot spell, I mean, people start thinking about it a little more."

Lastly, there were several participants that discussed the difficulties in involving community members in wildfire response in the area. Participants, particularly local foresters, land managers, private-sector fire practitioners, and business owners, expressed a strong frustration with how wildfire management shifted from a community-based approach to a more regulated and bureaucratic process to wildfire fighting. Additional training requirements, increased regulations to use heavy equipment, and stricter safety regulations were here cited as regulatory and policy barriers. Furthermore, many participants recognized the critical role that local knowledge and expertise play at the time of wildfire prevention and response, yet regretted the lack of significant local involvement that currently exists in wildfire management practices. As one local private fire contractor explained:

> "There is a massive resentment in the private industry in BC with how much money spent on out of, not just out of province, but like out of country resources, because you have like loggers who a lot of them were even on fire crews when they were younger, and they're sitting there like what the hell?"

Reflecting all of these challenges, participants indicated several actions that could be adopted to reduce wildfire risk and improve wildfire response. Almost all participants, irrespective of profession, cited here the need to: 1) increase the uptake of FireSmart measures and initiatives at the community level, either through increased funding, personnel, or improved education and community outreach efforts; 2) expand the use prescribed and cultural burning practices, selective logging, and tree thinning to remove fuels around the community; 3) transition to year-round employment for firefighting staff rather than seasonal positions; and 4) create a unified command structure involving the province, the Regional District, the municipality, and the Simpcw First Nation. Furthermore, some local participants recommended the adoption of backup power plans for every new gas station and fuel distribution centre within the community to stabilise its power system, as well as create emergency boards and marquees to disseminate crucial updates and instructions to ensure residents are well-informed during wildfires.

4.5. Discussion

This paper examined how a community in BC experienced, responded to, and prepared for wildfire. Overall, this study shows that wildfires do not only affect their immediate surroundings, but also communities that are located far away through power outages and air pollution. Recognition of these impacts in the literature are not new, although empirical research documenting the secondary impacts in communities remains generally sparse in a wildfire context (Thomas et al., 2022). Thus, our research supports and contributes to the wildfire literature by illustrating how the secondary impacts of wildfire cascade over space, highlighting the importance of pursuing cross-boundary cooperation across different jurisdictions and organizations, including, among others, local councils, utility companies, Indigenous councils, and provincial governments (Ager et al., 2018; Nowell et al., 2022; Hamilton et al., 2023). More broadly, our findings complement other scholarly work by illustrating the teleconnected nature of risk, in which vulnerabilities are not only geographically bounded to a community but, rather, are linked at different scales through economic market linkages and flows of resources, people, and information (Adger et al., 2009; Eakin et al., 2009).

Before we contextualize each of our findings below, it should be noted that the sampling procedures and methods used in this study present some limitations to the generalizability of the results. Similar to the shortcomings facing other place-based case studies, we focus on only one community in north-eastern BC, which does not allow for broader generalizations as every community and village is different (Ford et al., 2010). Similarly, this study presents data collected at a specific point in time and is therefore unable to account for temporal, real-time changes. Our findings nevertheless provide important insights that are relevant for other communities and the broader climate change adaptation and disaster risk reduction efforts.

One of the key findings of our study is the fact that Valemount's dependency on regionally managed infrastructure has rendered it highly susceptible to power outages caused by distant wildfires. Interview participants recognized that the community is highly reliant on this infrastructure and that any disruption to the power supply challenges the ability of its members to store food and provide essential services to the community. There is research in other regions globally and in Canada that has identified rural, under-resourced communities, and certain social groups, including those using electricity-dependent durable medical equipment, as particularly sensitive to power outages (Pearce et al., 2020; Andresen et al., 2023; Debortoli et al., 2023; Do et al., 2023). Researchers have similarly recognized how climate-related impacts, including wildfire, can disrupt critical junctures in infrastructure systems (also known as “chokepoints”) and lead to systematic consequences along them, such as reduced route accessibility and interrupted flows of commodity (Bailey and Wellesley, 2017; Pearce et al., 2020). Few studies have, however, evaluated how power outages impact communities in a wildfire context, and our understanding of the impacts of wildfires on the provincial electrical system has generally been limited in BC and, more broadly, in Canada (Pearce et al., 2020; Clark and Kanduth, 2021; Debortoli et al., 2023). As such, our study contributes to the literature on power outages and corroborates that communities with 1) limited power infrastructure and 2) food systems dependent on electrical power are highly vulnerable to wildfire-caused power outages. This research also demonstrates that strong sense of community and mutual support are key to address the impacts of power outages, which are factors that are well known in the wildfire, climate change adaptation (CCA), and disaster risk reduction (DRR) literature (McCaffrey, 2015; Fletcher et al., 2020).

The finding that generators were notably used to address power outages was particularly noteworthy. After the 2003 Barriere wildfires, interview participants reported purchasing generators to power 1) key buildings to provide essential services; and 2) freezers to ensure food safety during power outages. While this finding corroborates that hazards can open a window of opportunity to build resiliency (Labossière and McGee, 2017), it also raises concerns about the long-term viability of using generators to address outages. Prior research has shown that the improper and unsafe usage of backup generators can result in carbon monoxide (CO) poisoning, with children and people with limited English proficiency facing greater risk exposure and health impacts (Klinger et al., 2014; Andresen et al., 2023). Similarly, backup generators have high operating costs and be highly susceptible to volatile fuel prices, which can pose significant challenges for residents on low income (Canada Energy Regulator, 2018). Embracing alternative and renewable energy sources within the community, such as local wind and solar projects, offers a promising opportunity to reduce the community's dependence on the provincial electrical grid and mitigate the adverse impacts of wildfire-related outages (Daley, 2016; de Coninck et al., 2018). Furthermore, utility companies and policymakers could improve and re-design critical electrical infrastructure to remain functional during wildfires, which could involve, for example, the use of microgrids (Yang et al., 2022; Mullen, 2023). This solution could complement existing wildfire mitigation actions (e.g., prescribed burns, thinning, etc.) and reduce the impacts of geographically distant wildfires on communities.

The findings of our study also provide insights into how communities experience, prepare for, and respond to wildfire-related smoke events. Our research revealed that recent smoke events have significantly reduced visibility around the community, becoming a growing concern among our interview participants because of the long-term impacts that repeated smoke events can have on the local tourism sector, and the physical and mental well-being of individuals, including stress and anxiety. These findings echo the results of similar research conducted elsewhere, which has consistently reported substantial negative impacts on both the economy and public health due to wildfire-related smoke (Haider et al., 2019; McGee and Healey, 2022; Garbis et al., 2023). These impacts highlight the need to further improve public health preparedness to wildfire-related smoke events (Webster, 2023).

Despite the need to prepare for wildfire smoke, our study found that most of the interview participants were not actively preparing for it. This was notably due to their lack of internal locus of control (i.e., feeling that there is not much that can be done about it) and cultural attitudes associated with their lifestyles (i.e., viewing smoke as an inherent part of the area where they live). While these barriers were similarly found in research elsewhere (D'Antoni et al., 2017; Hamilton et al., 2018; Santana et al., 2021), evidence of the factors influencing smoke-related behaviours has remained considerably limited in Canada. As a result, our research offers important insights for governance processes at both provincial and national levels to help decision-makers develop smoke-related strategies. For instance, our participants acknowledged the need to improve the community's data monitoring infrastructure so they can obtain locally relevant, timely, accurate, and reliable information about smoke, which has been widely known to facilitate decision making at community levels (Steelman and McCaffrey, 2013; Maguet, 2018; Maguet, 2019). Some other participants also recognized that smoke advisories and alerts were of limited use for them, questioning the effectiveness of current provincial and national systems – an issue that has already been documented since the 1990s (Stieb et al., 1996). These shortcomings demonstrate that more needs to be done to empower communities and better prepare them for future wildfire smoke events (D'Evelyn et al., 2023).

While the secondary impacts of wildfire featured prominently in our discussions, this study also provides information about the sources of risk and resilience to the primary impacts of wildfire. For example, respondents consistently recognized the immediate threat that wildfires pose to the community and reported the uptake of several initiatives to address this risk. Generally, these initiatives were similarly adopted in other communities throughout BC, such as the use of roof sprinklers or the development of a community wildfire plan (Labossière and McGee, 2017). However, the initiatives implemented by the Community Forest were particularly noteworthy in our research, with our findings contributing to a growing literature that demonstrates the leading role that these organizations play in proactively managing wildfires throughout the province (Labossière and McGee, 2017; Devisscher et al., 2021). These initiatives, along with FireSmart education and awareness campaigns, were highly supported and considered effective for managing the risk of wildfires by participants, both now and in the future, which is consistent with one of the few studies from BC that also found these initiatives to be effective and supported by most communities (Copes-Gerbitz et al., 2022).

Our research also revealed the socio-political barriers that limited community engagement with proactive wildfire approaches. Participants indicated that they were unable to implement more wildfire prevention practices and programs (e.g., FireSmart) and purchase additional infrastructure because of limited funds available; they also recognized difficulties recruiting and retaining individuals exclusively dedicated for wildfire issues and generally felt unheard in decision-making processes. These findings, while important, are not surprising as they have already been reported in other studies from BC, Canada, and North America more broadly (Trainor et al., 2009; Paveglio et al., 2015; Copes-Gerbitz et al., 2022; Morris J. Wosk Centre for Dialogue, 2023). What is unique here is the fact that those barriers were identified in a community that is predominately non-Indigenous, which contrast with the existing scholarship that has identified these barriers mostly in Indigenous communities. Our findings reinforce the fact that financial, social, and policy barriers remain major obstacles for many communities in North America, and support recent calls to address these and help communities minimize the catastrophic impacts of future wildfires (Copes-Gerbitz et al., 2020).

4.6. Conclusion

We have illustrated how a community in BC experiences and respond to wildfire. Our research revealed that wildfires not only create an immediate safety threat to lives and lands, but also pose important cascading risks. Specifically, this research illustrated how a community with limited power infrastructure and grid-dependent individuals is highly susceptible to power outages caused by wildfires burning in geographically distant wildfires, and revealed important financial and social, and policy barriers limiting community engagement in proactive wildfire management. We discussed why the use of generators are insufficient to cope with power outages and explored potential venues for improving community preparedness to the secondary impacts of wildfire. The research also reveals how cultural attitudes associated with people's lifestyles and perceived lack of control influence decisions to respond to wildfire smoke. We demonstrate that cooperation across jurisdictions and organizations is critical to collectively address wildfire risk and manage the secondary impacts of wildfires, including power outages and smoke. While this research introduces findings from one community in BC, we believe that the insights presented throughout this study have relevance to localities that have similar structures and characteristics. Future research is necessary to develop more insights into the cascading, secondary implications of wildfires in different settings, and explore how these are shaped by social and environmental factors. This research would help develop more concrete understandings of how wildfires impact communities across jurisdictions and better inform policies that would help communities co-exist with wildfire.

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4.8. Author contributions

IVC coordinated and led the writing of the article. JF, JP, TP, and JW provided guidance on manuscript organization and contributed to the interpretation of the findings and writing of the manuscript.

4.9. References

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Chapter 5: Discussion and conclusion

5.1 Introduction

The aim of this thesis was to examine how communities and decision makers from high-latitude regions experience, manage, and adapt to wildfire. It addresses three research objectives:

1. Develop a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions.
2. Systematically document and critically evaluate regional wildfire policies and plans in the Russian Arctic.
3. Conduct an in-depth, community-level case study to characterise local wildfire risk and resilience in Western Canada

Each of these objectives are addressed in chapters two, three, and four of this thesis. Specifically, chapter two introduced the conceptual framework that has been used throughout the thesis to understand community risk and resilience to high-latitude wildfires. Objectives two and three are addressed in chapter three and four, respectively, and provide important insights into how communities and decision-makers understand, experience, and respond to wildfire activity in Canada and Russia. The following chapter summarizes the key findings from these chapters, describes their theoretical, methodological, and empirical contributions to the literature, discusses important limitations, and proposes potential directions for future research.

5.2 Summary of key findings and contributions

Chapter two of this thesis proposed a conceptual framework to understand the factors and dynamics affecting community risk and resilience to high-latitude wildfires. It combined conceptual elements from the theoretical areas of climate change adaptation and the disaster risk reduction literature to clarify important interdependencies between fire, humans, and climate in high-latitude regions. More specifically, the framework integrated the concepts of risk and resilience into the disaster risk cycle to emphasize the differences between preparing for, experiencing, and recovering from a wildfire. It goes beyond previous frameworks by addressing in an integrative manner 1) the conditions that make a community at risk from wildfires and 2) the actions that can be taken to respond to and recover from wildfire. Also, the framework helps thinking about the influence other natural hazards (e.g., drought, heatwaves, etc.) on wildfire risk and resilience, which has been an issue that was consistently overlooked in the exiting wildfire-related scholarship to this day, despite being increasingly used in other contexts. Although the principles developed in the chapter are focused on high-latitude wildfires, they can be amended for research focused on other stressors and geographies (e.g., tsunami in the Pacific, spring river flooding in the Arctic, etc.). Particularly, research targeting fast-onset events—those that occur with little warning and can have severe short-term impacts on ecosystems, human communities, and infrastructure—can benefit from using this framework, as it focuses on understanding a rapidly developing stressor (i.e.., wildfires) rather than slower events such as sea-level rise or increasing global temperatures.

The second chapter of this thesis reflects the need to better capture the existing social and ecological differences that currently exist between high-latitude wildfires and those from lower latitudes. There is evidence, for instance, that wildfires in high-latitude regions emit more emissions of smoke than other regions globally (Shikwambana and Habarulema, 2022). Similarly, high-latitude economies present considerable differences compared with other economic models, where subsistence, environmental awareness (i.e., awareness of the consequences of their activities), and the use of a limited pool of natural resources are distinct features of many high-latitude livelihoods (Gladun et al., 2021). Detailed consideration of these place-specific attributes has often been considered critical for designing effective initiatives for communities (Cutter et al., 2008). Chapter two is one of the first attempts throughout the literature to capture these attributes in a high-latitude wildfire context, providing a socially and ecologically sound basis for understanding wildfire risk and resilience in such regions. It illustrated how remoteness, indigeneity, subsistence-based activities, colonial practices, and climate change play a key role in determining community risk and resilience to wildfires in high-latitude regions (Table 5.1). While not a systematic review per se, chapter two also offers one of the most recent and comprehensive reviews of the current state of wildfire-related research focused on high-latitude regions; the latest synthesis of wildfire research dates to 2015 (McCaffrey, 2015), and since then, there was no article that specifically provided a deeper and more nuanced understanding of wildfire risk and resilience in high-latitude regions.

Chapter three used systematic review methods to evaluate existing wildfire-related adaptation policy outputs in the Russian Arctic. It indicated that most adaptation outputs were developed and adopted by regional governments, in response to national mandates, and aimed at reducing the risk of wildfires and improve fire response. It also documented evidence of climate-related changes already affecting wildfire regimes in northern Russia, particularly changing snow and rain patterns; however, most of these outputs were not motivated by a specific stimulus and simply recognized the need to adapt to increased wildfire activity. The chapter concluded by highlighting a number of critical shortcomings, which included an insufficient engagement with the role and needs of marginalized and vulnerable groups. It discussed the consequences of these shortcomings (for example that they challenge the suitability of existing adaptation outputs to address increasing wildfire activity in the region) and identified future needs that would accelerate wildfire adaptation in the Russian Arctic.

The third chapter of this thesis is the first of its type to systematically document and review adaptation policy outputs developed to adapt to wildfire in the Russian Arctic. However, it is not the first or only effort that has been done to synthesise knowledge of adaptation in high-latitude regions; Ford et al (2014) and Canosa et al (2020), for instance, adopted a systematic review methodology to document the state of adaptation, resilience, and vulnerability research in the Arctic. This methodology was similarly used by other researchers who explored adaptation action and research in other contexts, including forests and mountain areas (McDowell et al., 2019; Fischer et al., 2023). While this body of research has yielded valuable insights into global adaptation efforts, a notable limitation lies in the exclusion of certain types of documents, particularly those that are originally published in Russian (or any non-English language) and those found in the grey literature (Ford and Berrang-Ford, 2016). To address this gap, chapter three intentionally incorporated these underrepresented data sources, thereby expanding our understanding on the state of adaptation in the region. This inclusive approach did not necessarily compromise the comparability of its findings with global research; rather, meaningful comparisons can still be drawn with global research endeavours, provided there is consistency in spatial and temporal units of analysis (Ford et al., 2015). The contextual similarities between Russia and other regions facing rapid warming and centralized governance structures further reinforce the relevance of chapter three's insights to broader global adaptation strategies. Ultimately, chapter three contributes significantly to advancing the monitoring and understanding of adaptation strategies worldwide.

Chapter four explored wildfire risk and resilience in a small community from British Columbia (Canada) called Valemount, using the characteristics of the conceptual framework that was introduced in chapter two of the thesis. It analysed 20 semi-structured interviews with informants directly related to forestry and local governance and documented how they were preparing and responding to wildfire. Particularly, the chapter captured informants' perceptions of risk, lived experiences, management approaches, and barriers to action. It revealed the importance of considering the secondary, indirect impacts of wildfires burning in distant areas in future analysis, especially those related with power outages and road closures, and the inherently social origins of risk. It also highlighted the desire of local community members to engage in wildfire fighting and be proactively involved in its management. These insights contribute to a growing body of research investigating the human dimensions of wildfires at the local level, enabling a better understanding of the underlying causes of community risk, resilience, and adaptation. This empirical contribution is noteworthy as it addresses a research need and priority identified for the upcoming decade in Canada (Sankey, 2018). Insights from this chapter also complement the previous chapter of the thesis by elucidating the importance of considering both place-specific characteristics and Indigenous/local knowledge for designing and developing wildfire-related policies.

The fourth chapter of the thesis represents, at the time of writing, the first analysis that has ever been conducted on wildfire risk, resilience, and adaptation in the small community of Valemount (British Columbia). It is also one of the first studies that has ever focused on the human dimensions of wildfire in the Robson Valley more generally (Whitehead, 2023). Moreover, it is among the first of its type (in terms of studies focused on high-latitude regions) to conduct semi-structured interviews in a community where the majority of its population has a non-Indigenous background, further deepening our understanding of wildfire risk, resilience, and adaptation in high-latitude regions. While most participants were non-Indigenous, the chapter also included the perspectives of participants that were either involved in Indigenous organizations or had an Indigenous background; the inclusion of both of these perspectives (i.e., non-Indigenous and Indigenous) has been rarely been adopted in wildfire studies, despite the fact that it can create a better understanding of the natural world and consequently enhance social-ecological management (Muir et al., 2023). The following section 5.3. will discuss in greater detail the major findings of each of the chapters of this thesis and place them within the broader wildfire-related literature.

Table 5.1 Contributions of this thesis by research objective

Research objective	**Major findings**	**Contribution**
Develop a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions	- Social and ecological features of high-latitude regions, especially remoteness, indigeneity, subsistence-based activities, colonial practices, and climate change, determine community risk and resilience to wildfires	- Provided a socially and ecological sound framework to guide future wildfire-related research and practice in high-latitude regions
Systematically document and critically evaluate regional wildfire policies and plans in the Russian Arctic	- The nature and extent of wildfire adaptation outputs are not sufficient to address the seriousness and severity of climate change	- Clarified the state of adaptation in the Russian Arctic in relation to wildfires and identified key issues that can be addressed in future research and practice

Conduct an in-depth, community-level case study to characterise local wildfire risk and resilience in Western Canada	- Wildfire not only directly impacts communities but they also cascade over space to cause important secondary impacts	- Improved understanding how of communities in high-latitude regions prepare for and respond to wildfires, illustrating the need for better collaboration between governments and community members

In addition to the contributions made by each individual chapter, the thesis also yields important insights as a consolidated whole. Specifically, it provided evidence that people living in high-latitude regions are highly vulnerable to the impacts of wildfires. This vulnerability was highlighted in chapter three, which revealed that existing policies overlooked at least one of the scientific, human, and management dimensions of wildfire. The vulnerability of high-latitude people was further illustrated in chapter four, which demonstrated how limited power infrastructure increased the sensitivity of the community to the impacts of wildfire. Despite the vulnerability of people to the impacts of high-latitude wildfire, the thesis showed that responses to wildfire are already occurring in high-latitude regions, an important finding that underscores the need for a better understanding of risk, resilience, and adaptation to wildfire in these areas.

More generally, the thesis contributes to the theoretical areas that informed its chapters. First, the community-level work presented in chapter four illustrates how in-depth place-based case studies are indeed crucial to understand the effects of wildfires on people and the social and ecological drivers of risk and resilience (Ford et al., 2010). Second, the thesis expands the geographical scope of the existing social science research related to wildfires (currently limited to the United States, Australia, and Europe) and raised the profile of high-latitude research, issues, challenges, and opportunities within the broader scholarly debates related to global environmental change. Finally, it addressed some of the shortcomings recently identified within broader scholarship, including the need for greater engagement between the climate change adaptation and disaster risk reduction communities (UNDRR, 2020; Rana, 2020). Through such contributions, this thesis has substantially helped to advance research related to wildfires and our contemporary understanding of high-latitude systems. These contributions may ultimately stimulate discussions and collaborations between researchers and practitioners interested in high-latitude regions, social sciences, and wildfires.

5.3 Discussion of key findings

The primary finding of this thesis is that different high-latitude populations respond to and manage wildfires differently, influenced by various factors such as socioeconomic status, cultural norms, governance, and geographical location. This contrasts with findings from other regions and contexts worldwide, where research has shown that people often respond similarly to different environmental conditions (Galappaththi, 2019). Consequently, the differences uncovered by this thesis in relation to wildfire risk, resilience, and adaptation call for flexible and adaptive risk management strategies capable of evolving in response to new information and changing conditions, particularly those emerging at the local level. Such strategies have gained prominence in recent studies, with researchers advocating for governance structures that can implement dynamic hazard-responsive strategies (Haasnoot et al., 2013; Renn, 2017; Muccione et al., 2024). Two key insights from the thesis deserve special attention as they are critical themes for designing effective strategies and achieving successful adaptation. These insights are discussed in detail below.

5.3.1. The management of high-latitude wildfires with community members

Research has repeatedly recognised the negative impacts that wildfires in high-latitude regions can have on community members, including the destruction of homes, property, hunting grounds, and health-related illnesses. However, this thesis demonstrated how legal and policy barriers are currently limiting the ability of high-latitude communities to prepare for and respond to wildfire and its subsequent impacts. Specifically, the findings of the thesis illustrated how existing policies and governance structures are (for now) not enough to help these communities address wildfire risk. For instance, interviews from the community in Canada highlighted how provincial decision-making processes restricted the involvement of its members (especially those with previous knowledge or experience on wildfire management) in suppressing wildfires. Similarly, the finding that wildfire-related adaptation policies in Russia did not contemplate the role and needs of marginalized and vulnerable groups suggests that these are ill-equipped to reduce the impacts of wildfires at the local level (UN Development Programme, 2020). Given that communities are often considered as key stakeholders in managing wildfires, it is imperative to overcome these barriers and facilitate the involvement of communities in managing wildfire (Hoffman et al., 2022).

Today, there is no doubt among scholars that communities are critical agents to manage wildfire. Its members not only contribute through fire starts or unmitigated properties, but they also bear numerous responsibilities and possess valuable knowledge on wildfire risk mitigation. Indigenous knowledge and local expertise, for instance are often presented as an important and effective solution to help mitigate both current and future wildfire risk worldwide. Many authors recognize the historical use of fire by many Indigenous communities and favour the uptake of these practices to enhance ecosystem diversity and lessen fuel loads (Christianson et al., 2022; Hoffman et al., 2022). Furthermore, local authorities in several countries are often tasked with managing wildfire risk within their jurisdictions, including the development and implementation of local emergency plans or the implementation of vegetation management approaches (e.g., prescribed burning) (Harris et al., 2011). This is reflected in chapter four of this thesis, where interview participants reported on the development and implementation of a community wildfire plan by the local government.

Efforts to empower and involve communities in wildfire management are increasingly being conducted by national and provincial governments across the world, but most notably in North America. Here, initiatives, such as the Munro collaborative burn project (FireSmartBC, 2022), are evident, although they remain relatively limited to a small number of cases and are yet to be fully implemented by most wildfire agencies within the region (Hoffman et al., 2022). In fact, it is widely acknowledged (and recommended) that countries, such as the United States and Canada, should do more to include Indigenous knowledge and local knowledge in wildfire-related decisions, policy action, and implementation; this has also been the case in many other regions globally, such as Venezuela or Brazil, where communities similarly use fire for cultural and ecological purposes, yet are systematically ignored in policy processes (Bilbao et al., 2019; UNEP, 2022; Pandey et al., 2023). Despite this exclusion and marginalisation, communities are interested and want to be more involved in wildfire-related management decisions, as illustrated, for instance, in chapter four of this thesis and elsewhere (Rodríguez et al., 2023). Involving communities in decision-making processes can help governments capture both the contextual diversity of communities and positively effect local wildfire preparedness efforts (Paveglio and Edgeley, 2017; McCaffrey et al., 2020; Kirschner et al., 2023).

The Arctic Council's *Circumpolar Wildland Fire* project (2019) provides an interesting avenue for cooperating with communities and improve how wildfires are manged in high-latitude regions. This work is notably important in Russia, where civil society, including local volunteers and NGOs, has been systematically weakened and supressed by the authorities over the years (Ross, 2015; Rebechenko, 2023). Because there is a weak civil society in Russia, it is not surprising that the adaptation outputs that were documented in chapter three of this thesis overlooked the needs of Indigenous and marginalised people. This contrasts with policy outputs from other high-latitude regions with strong civil society movements, where Indigenous and marginalised peoples are well-recognized groups in decision-making processes (Environment and Climate Change Canada, 2022). However, the exclusion of these groups in wildfire management approaches can have important global effects. For example, the exclusion of Indigenous-led fire practices[3] in Russia's adaptation outputs may result in

[3] Similar to Indigenous communities in North America, Indigenous peoples in Russia – particularly those from the Republic of Sakha – have used fire as a land management tool for centuries yet are currently banned from

increased fuels in the landscape, increasing the risk of destructive wildfires and subsequently of large-scale impacts, including smoke pollution that can reach communities located hundreds of miles away from the source (Johnson et al., 2021). For this reason, cooperation and knowledge exchange efforts – not only between other nations and Russian institutions but also between Russian local communities and Indigenous peoples, decision-makers and scientists – can be a valuable effort to change the country's current approach to community engagement (Kontar and Beer, 2018; Callaghan et al., 2020), although the geopolitical conflict in Ukraine, along with Russia's authoritarian regime, makes this highly challenging and not likely to happen in the near future (Kopra, 2023).

The empirical chapters of this thesis can contribute significantly to the exchange of knowledge and information. In fact, the findings from each of the empirical chapters can inform the others, enriching insights into effective wildfire management. Particularly, and despite the challenges in Russia, the two independent empirical chapters of the thesis—one from Russia and the other from Canada—can help identify best practices applicable across varied contexts. These studies can similarly help reveal common pitfalls to avoid, offering a comprehensive understanding of effective wildfire management in high-latitude regions. For instance, the Canadian case study underscores the importance of community involvement in wildfire suppression, along with integrating Indigenous perspectives, which Russian decision-makers can acknowledge and consider in their future strategies. Similarly, Canadian practitioners can learn from shortcomings identified in the Russian study, adapting governance insights to enhance their own practices; an example of this could include a better understanding on the limitations of exclusively adopting top-down approaches for managing wildfire at community levels (Conway et al., 2019; Essen et al., 2021). While directly comparing the findings of each chapter requires caution (refer to the limitation section for more information), each empirical chapter still offers valuable insights for both Canadian and Russian researchers, stakeholders, and policymakers to improve policy development and practices in their respective areas and jurisdictions, facilitating the advancement towards more effective solutions in wildfire management in high-latitude contexts (Callaghan et al., 2020).

5.3.2. The drivers of community risk and resilience to high-latitude wildfires

It is not surprising that climate change alone is not the sole driver of risk and resilience at community level. As illustrated in other works (both from the Arctic and elsewhere), non-

conducting any type of burning. They used fire to achieve high quality pastures so that horses could be fed during the winter time (Vinokurova et al., 2022).

climatic factors play a major role in determining how people experience and respond to natural hazards (Galappaththi et al., 2019; Naylor, 2022). This fact was further illustrated in this thesis, where non-biophysical factors – arising from socioeconomic marginalisation and colonialism – such as financial or policy constrains, interacted with ecological drivers to determine the degree to which a community is exposed or vulnerable to wildfire. These socioeconomic factors even played here a greater role in community risk and resilience than climatic or biophysical drivers, as shown in chapter four when interview participants mentioned financial, human, and policy barriers as important constraints limiting progress. The wider wildfire-focused research conducted in North America, Latin America, Australia, and Europe similarly (and repeatedly) identified – across multiple communities (urban and rural) – both climatic and non-climatic factors as important drivers of wildfire risk and resilience at community level (McCaffrey, 2015; Lambrou et al., 2023). Within this body of research, the strength of social relationships, engendered poverty, remoteness, and land ownership were among the most crucial determinants of wildfire risk, resilience, and adaptation – factors that also emerged as important drivers in chapters two and four of this thesis.

While the role of both climatic and non-climatic factors has been highlighted in the literature, the comprehensive integration of all the drivers of risk, resilience, and adaptation remains a considerable management challenge in many areas of the world (Tymstra et al., 2020). For one, the impacts of anthropogenic climate change on the distribution of different vegetation types, and thus fuel flammability, are highly uncertain in both high- and mid-latitude regions (McCarty et al., 2021). Further, there are significant challenges associated with how land uses will change in the future worldwide, including the development and expansion of the wildland-urban, -industrial, and -infrastructure interface (Erni et al., 2021). Balancing the positive effects of prescribed burns (i.e., they consume vegetation and thereby reduce the amount of fuel available to burn) with the negative health-related impacts that they create through smoke pollution can also lead to tensions and conflicts between different actors (or stakeholder groups), potentially slowing down the uptake of important risk reduction measures. Thus, the management of wildfires can be viewed as a “wicked problem”, one that is characterised by different spatial and temporal feedbacks, thresholds, and uncertainties (Chapin et al., 2008).

The wickedness of wildfires gained considerable attention over the years, with scholars worldwide suggesting ways through with stakeholders can better understand and govern the complexity of wildfires (Nowell and Steelman, 2019; Kirschner et al., 2023). These solutions mostly involved applying a social-ecological perspective to wildfire risk, which has been frequently acknowledged as critical for understanding the problem and framing appropriate policies (Fischer et al., 2016). Governments in many high-latitude regions are increasingly recognising the usefulness of this perspective and are, to some extent, adopting it in their decision-making processes (Canadian Council of Forest Ministers, 2021). However, existing governance approaches across the region remain highly focused on the spatial dimension (jurisdiction, ownership) of social-ecological systems and overlook important temporal interactions, specifically those related to time lags and feedbacks such as the long-term impacts of fire suppression policies on future wildfire activity. The findings of this thesis – such as those from chapter four, where interview participants discussed how priorities and concerns shifted throughout the year – exemplify the significance of considering these temporal interactions to properly understand if and how communities prepare for future wildfire events. This has been similarly highlighted in wildfire research from both North America and Europe, where governance approaches are also overlooking important interactions (Fischer et al., 2016; Pandey et al., 2023). Neglecting these interactions in future policy outputs will reduce the overall efficacy of wildfire management approaches and eventually fall short of meeting the grand challenge posed by wildfires.

It is within the context of these spatio-temporal interactions where the use of risk, resilience and adaptation-based thinking (combined with a social-ecological systems approach) has proven to be considerably useful for this thesis. Specifically, the integration of these scholarly debates has helped unravel the complexity of high-latitude wildfires and capture how different social and ecological drivers change and evolve over space and time. For instance, the approach adopted for this thesis was able to reflect the potential cascading impacts (e.g., flooding, landslides, etc.) that high-latitude wildfires can have on communities, which have not been widely incorporated into current wildfire planning and management. Similarly, the thesis was able to identify both the exogenous and endogenous factors that affected the ability of communities to prepare for and respond to wildfires. Some scholars have previously critiqued the use of risk, resilience, and adaptation-based thinking, arguing that researchers should avoid using these approaches altogether (Cameron, 2012). One critique focused on vulnerability (which in thesis is part of the term risk) and the fact that it favours the role of climate change (Cameron, 2012). However, the finding that non-climatic stressors played an even greater role that climate-related factors suggests that these concerns are weakly justified, with other studies similarly finding that there is little foundation to these critiques (Ford et al., 2018). There have also been critiques related to resilience, including that it fails to account for power, politics, and agency (Béné et al., 2014; Brown, 2015), although the consideration of place-based attributes (e.g., local knowledge) within this thesis helps address most of these concerns. As such, the findings of this thesis provide a clear rationale for the future continued use of risk, resilience, and adaptation-based approaches. They have been crucial for identifying why communities are vulnerable, while at the same time bridging the disciplinary gap between the complementary fields of climate change adaptation and disaster risk reduction.

5.4 Implications for policy and practice

Ultimately, wildfires are not expected to disappear from high-latitude regions; they will continue to burn each year and potentially increase in severity and frequency in the future. Governments and communities will therefore need to co-exist with this reality and learn to find the balance between the positive effects of wildfire (e.g., ecological benefits) with the negative ones (e.g., destruction of property). This thesis demonstrated that communities located in high-latitude regions are increasingly at risk of experiencing the negative impacts of wildfires yet face important socioeconomic and policy barriers. The findings of this thesis call for multiple policy and practice interventions that would improve the way they prepare for wildfires, including:

- Actively consider the local scale in wildfire governance. Future wildfire policies should recognize the localised nature of risk and resilience and support community-based processes, as these reflect community strengths, weaknesses, and desires that are relevant for its members. The consideration of place-based attributes would increase the local relevance and legitimacy of future policies and better reflect the differential capacities of populations and organizations (Essen et al., 2021).

- Wildfire policy should embrace the complexity of wildfires and capture the broad range of factors (both temporal and spatial) that are relevant for assessing risk and resilience in high-latitude regions. Overlooking some of these aspects could create barriers for the successful implementation and adoption of policies, including those related with the development of prescribed burns.

- Ethically and equitably collaborate with Indigenous peoples, where government and Indigenous communities are true partners through all levels of decision making. Indigenous knowledge should be actively taken into consideration in wildfire governance approaches, as it can provide valuable insights into different ways of managing wildfire risk. Often regarded as an important action in the literature, this thesis further illustrates the need to integrate Indigenous peoples and their knowledge in firefighting and fuel reduction activities (Nikolakis and Roberts, 2022; Pandey et al., 2023). This also extends to other (non-Indigenous) communities with strong local knowledge and expertise, such as the one introduced in chapter four of this thesis.

5.5 Strengths and limitations

5.5.1. Strengths

The primary strength of this thesis is the use (and incorporation) of multiple sources of data, i.e., interviews with stakeholders, peer-reviewed journal articles, and policy outputs. The use of different sources of data allowed for a better understanding of the different drivers of risk, resilience, and adaptation to high-latitude wildfires, and helped clarify the relationship between people and wildfire in different (high latitude) social and ecological settings. This approach directly responds to the need to provide more access to information that is not readily available through standard reporting structures, including findings from place-based case studies (Ford and Berrang-Ford, 2016). The combination of different data sources is not new within the literature, and many authors have previously used, to some extent, this approach to enhance the depth of their analysis (Tompkins et al., 2010; Kolström et al., 2011; Murtinho and Hayes, 2012).

5.5.2. Limitations

There are several limitations that should be taken into consideration when reading this thesis. While each chapter already elaborated on these limitations, the section below discusses in greater detail the limitations that pertain to the overall design and implementation of the thesis.

5.5.2.1. Conceptual framework

The concepts of risk, resilience, and adaptation received significant space in this thesis, but one might criticise the fact that they are unevenly acknowledged in each chapter: chapter three only considers adaptation in its framing (excluding other concepts associated with the term, such as resilience, disaster risk reduction, sustainability, etc.), while chapter two and three put a greater emphasis on risk and resilience. Including risk and resilience in chapter three would be different from the current approach and thus might have resulted in different results. It could also lead to a greater understanding of the different approaches used to manage wildfires in Russia, as adaptation initiatives generally remain here a limited component of policymaking processes compared with other high-latitude regions (Ford et al., 2014; Canosa et al., 2020). However, excluding the concepts of risk and resilience in chapter three ensures that its findings are usable and comparable, particularly with those studies that focused on tracking adaptation outputs across nations and sectors (Dupuis and Biesbroek, 2013; Ford and Berrang-Ford, 2016).

5.5.2.2. Two regions, two scales

Another limitation of this thesis relates to the difficulty in comparing and contrasting the findings from chapters three and four, notably due to the fact that each chapter focuses on a specific administrative scale and location. For instance, it is currently difficult to discern how the regional outputs documented in chapter three influence directly wildfire risk and resilience in communities located in Russia. Similarly, the lived experiences that were documented in chapter four may also not be comparable to those of other communities, including those located within Canada or in other high-latitude regions more broadly; after all, chapter four examines how a community in the hemi-boreal experiences and responds to wildfires, which can be completely different to the lived-experiences of communities located in the tundra. Thus, although this thesis provides valuable information related to wildfire risk, resilience, and adaptation in high-latitude regions, it is possible that some socio-economic, cultural, and political conditions might have been overlooked, potentially leading to an underestimation (or overemphasis) of the role of some of the drivers of wildfire risk, resilience, adaptation that were documented in the thesis.

5.5.2.3. Positionality considerations

The research introduced in this thesis is inevitably conditioned by my positionality (Sultana, 2007). As a White, non-Indigenous, Caucasian male educated at universities in Spain and England, my understanding of high-latitude regions, high-latitude people, and global environmental change has been predominately founded in Euro-western conceptions of places and people. Moreover, I have never lived in Canada (or in any other high-latitude region for that matter) and therefore am not familiar with the local culture and context. Although my training was informed by topics such as traditional ecological knowledge and anti-colonial theory, the situatedness of my knowledge has inevitably conditioned my work and how I have conducted the research for the thesis. For these reasons, it should be recognized that much of the context of this thesis, including the analysis of the data and the production of outputs (e.g., academic papers), reflects my own understanding of high-latitude ways of life.

5.5.2.4. Budget and time constraints

In addition to my socio-cultural background and understanding of the world, limited budgets for travel and significant time constraints have created a meaningful barrier for engaging with the community introduced in chapter three. It is widely recognized that sustained, strong, and meaningful relationships based on mutual respect, open-mindedness, accountability, and trust are critical elements to conduct socially responsible research at the local level (Whyte et al., 2019). However, the fact that the research objectives of this thesis had to be modified halfway through the doctorate because of the conflict that erupted in Ukraine in 2022 meant that there was not enough time to create these sorts of relationships with the community from chapter three (>2 years including research preparation). Establishing these long-standing relationships in the community were further challenged by the restricted lengths of a UK doctorate programme (<4 years including writing) and the high cost involved in doing field-based work (and the lack of funding to do so). This resulted in the community not being properly involved (or at least not as much as I had hoped) in the interpretation of the data obtained from the interviews, as I was not able to return to the community and disseminate the results before the thesis's submission deadline. The dissemination of the results in the community would have helped ensure the accuracy of the results and provide a direct opportunity for community members to give potentially important feedback on the research (Pearce et al., 2009).

Furthermore, due to the limited budget and time constrains, it was decided to focus exclusively on interviewing key stakeholders within the community, namely policymakers, foresters, business owners. These stakeholders were rapidly involved in the research process because there was an ongoing project in the region that facilitated their identification; this project was known by one of the co-supervisors of the thesis, Dr. James Ford, who had a long-standing relationship with the research team working in the region. Other stakeholders, including long-time community residents, were consequently not a part of the cohort in the third chapter of this thesis, which may have resulted in the loss of important (potential) perspectives. The fact that these residents were not a part of the chapter's research represents a limitation of this thesis, but also a direction for future research.

5.6. Research needs and opportunities

The findings and limitations of this thesis point to several avenues for future research:

a. *The need for greater geographic and sectoral diversity in the scholarship related to the human dimensions of high-latitude wildfires*: this thesis has provided evidence of how a community located in the hemi-boreal forest of Canada experiences and responds to wildfires. However, as climate change is expected to lead to regional increases in wildfire frequency and intensity, there is a need to further expand our knowledge base and explore if and how communities located in less wildfire-prone areas (for instance the tundra) prevent, respond, and adapt to wildfires, including the different social-ecological factors that undermine or enhance community resilience. As already introduced in the first chapter of the thesis, the current scholarship on high-latitude wildfires has increasingly focused on local processes from the boreal forest of Canada; this focus may have led to findings that potentially overemphasize the role of certain drivers over others. Approaching wildfires solely based on these findings could have unintended consequences in regions that have historically experienced lower wildfire frequency and intensity and have limited to no fire culture, either through traditional burning knowledge or direct firefighting experience. For this reason, researching wildfire risk, resilience, and adaptation in these areas could create new opportunities for conceptual and methodological advancement and ultimately help local, regional, and national governments find suitable wildfire management solutions and strategies for these areas.

Similar benefits could be obtained with more social science research in other high-latitude regions, particularly in Russia and Scandinavia. Most high-latitude research to date has focused on North America (Ford et al., 2014; Canosa et al., 2020), and while such a focus remains critically important, it is also appropriate to explore wildfire risk, resilience, and adaptation elsewhere. In regions such as Russia (both in the boreal and tundra), there are wildfires that similarly impact people and ecosystems; here, people also face significant socio-economic challenges related to colonial legacies (Burnasheva, 2020).

b. *Assess wildfire risk, resilience, and adaptation over longer periods of time*: most of the current wildfire-related scholarship still examines risk, resilience, and adaptation at a specific point in time: it explores wildfire risk perceptions and responses either in a specific year or immediately after a wildfire season or event, such as the 2014 wildfire season in the Northwest Territories (Canada) or the 2016 wildfire in Fort McMurray in Alberta (Canada) (Dodd et al., 2018; Mamuji and Rozdilsky, 2019). There are often no long-term (more than one year) analyses that explore temporal changes in wildfire risk perceptions, preferences, and barriers to action in high-latitude regions, and those that do account for these changes exclusively rely on participant’s recall of past events and therefore are subject to recall bias (Naylor et al., 2020). Although this thesis provided a baseline understanding of wildfire risk, resilience, and adaptation in regions within Canada and Russia, it was unable to fully characterise the dynamic nature of social and ecological contexts. There is a need for sustained, real-time, longitudinal assessments of the human dimension of high-latitude wildfires, particularly given the ever-evolving nature of both social and ecological conditions. These assessments are particularly important (and appropriate) for advancing understanding of how risk, resilience, and adaption change over time in response to changing hazard conditions, and have been often identified by other scholars as a key research need in both wildfire and the broader adaptation scholarship (Ford et al., 2013; Archer et al., 2017; Hamilton et al., 2018).

c. *Community-governed projects to prevent exploitative research models and create opportunities for learning*: while this thesis made use of culturally appropriate semi-structured interviews, the financial and time constraints restricted a meaningful engagement with local/Indigenous knowledge holders. Also, most wildfire-related studies to date are rooted in western scientific and socio-cultural traditions and have been conducted by researchers (often non-Indigenous) who study community processes from an external, objective perspective. For these reasons, there is a need to actively co-develop research projects on the human dimensions of high-latitude wildfires and collaborate more with community members. Specifically, community members should have more control and oversight of any potential project so as to 1) ensure that projects are aligned with the concerns and needs of the community and findings disseminated in a culturally appropriate way; 2) prevent exploitative models of research and follow best practices for engagement; 3) facilitate co-learning practices between participants and researchers; and 4) address some of the power dynamics that are often involved in community-based research projects (Pearce et al., 2009). Projects adopting such a collaborative, participatory approach are not new and have already been adopted in multiple contexts, including wildfire, forestry, hydrometeorological extremes, and climate change (Kaul, 2019; Copes-Gerbitz, 2021; Naylor, 2022).

d. *The implications of responses and the role of compound, cascading risks*: this thesis has illustrated the ways through which wildfires burning in distant places cascade over space and negatively impact community members. However, research assessing how multiple natural hazards (droughts, floods, landslides, etc.) influence and interact with wildfire risk, resilience, and adaptation over space and time has remained rather limited throughout the literature. There is also a considerable lack of evidence regarding the extent to which responses in one community might affect places, sectors, or groups elsewhere. Even at the global scale, this body of research requires important conceptual, sectoral, and geographic advancements (Simpson et al., 2023). Future research should therefore explore these topics in greater detail. This is essential for making more informed decisions that reduce the negative impacts of wildfires (Simpson et al., 2021). It will require researchers to engage with a much broader body of literatures (e.g. systems thinking) and pursue transdisciplinary collaboration with colleagues from disparate disciplines.

e. *Understanding wildfire risk, behaviours, and responses of community residents*: one limitation of this thesis was that it focused specifically on the perceptions and experiences of local decision-makers, including foresters, emergency personnel, and community policymakers. In order to fully comprehend the impacts of wildfires, the factors affecting risk, resilience, and adaptation, and the responses that were implemented to cope with the impacts of wildfire, future research needs to better capture the role of residents. Specifically, an important, and profitable, line of inquiry would be to explore resident's wildfire risk perceptions, acceptability of community wildfire risk reduction strategies (for example FireSmart initiatives), wildfire risk communication preferences, and mitigation and preparedness activities. Residents in many high-latitude regions are increasingly encouraged to adopt voluntary wildfire-related risk reduction measures; consequently, they are critical actors to consider when exploring wildfires in high-latitude regions.

5.7. Concluding remarks

This thesis sought to explore how communities and decision makers from high-latitude regions experience, manage, and adapt to wildfire. It 1) developed a conceptual framework to understand and support future research on the human dimensions of wildfire risk and resilience in high latitude regions; 2) used systematically review methods to document and critically evaluate regional wildfire policies and plans in the Russian Arctic; and 3) conducted an in-depth, community-level case study to characterise local wildfire risk and resilience in Western Canada. The findings from these outcomes highlighted the fact that while communities in high-latitude regions are at increased risk of wildfire, they are also highly resilient to its impacts. More specifically, this thesis demonstrated that while climate change can be a key driver of risk, resilience, and adaptation to high-latitude wildfires, other non-climatic factors, such as remoteness, Indigeneity, subsistence-based economies, and colonialism often play a greater role on a day-to-day basis. Although the role of climate change may change in the future, the present nature of wildfire risk, resilience, and adaptation calls into question the current focus of (sub-)national initiatives aimed at managing wildfire on any high-latitude landscape; these initiatives consistently overlook important spatial and temporal dynamics, ranging from the potential cascading risks of wildfire to the marginalisation of Indigenous fire knowledge on policy processes. The findings of this thesis therefore represent a modest yet salient contribution highlighting the factors that would need to be considered when developing future wildfire-related policy outcomes. Indeed, the framing of wildfires has considerable implications on how to approach the problem and what solutions are promoted.

It is without saying that the completion of this thesis has been both professionally and personally challenging. The impacts of the war in Ukraine, along with my positionality as non-native English speaker and outsider, made the research an (ongoing) challenge. While this thesis is nowhere near what I have imagined when I first started it in 2020, I sincerely hope that (at least) I have upheld the expectations that my supervisors, colleagues, experts, and community members had on me when I was undertaking this research. Ultimately, it is my hope that this research will have a positive impact on the lives of people living in high-latitude regions, including by attracting attention to the important role of Indigenous-led fire practices and the wide range of social-ecological factors that shape wildfire risk and resilience in such regions. Even if the impact of this thesis is limited to the academic realm, the research had a great impact on myself as both a researcher and a citizen: from when I first started this journey, I have now a completely new way of looking at fire, the forest, and the people living in high-latitude regions. It was uniquely rewarding to hear the fascinating stories of both experts and community members (both Indigenous and non-Indigenous) and witness their relentless efforts to change how we perceive and manage wildfire in high-latitude regions – they are truly inspiring people.

5.8. References

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Appendix A: Supplementary materials for Chapter 3

A.1. Project overview

Temporal Scope	Start: 1 January 2008 (i.e. year when the first assessment report on climate change was issued by the Russian Government) End: 31 December 2020
Geographical Scope	Northern Russia *Northern Russia* = Murmansk Oblast, Republic of Karelia, Arkhangelsk Oblast, Komi Republic, Nenets Autonomous Okrug, Yamalo-Nenets Autonomous Okrug, Krasnoyarsk Krai, Republic of Sakha, Chukotka Autonomous Okrug (Russian Presidential Decree Nº 296, May 2, 2014, Land Territories of the Arctic Zone of Russia)
Linguistic Scope	English, Russian
Materials Included	1. Official websites from Russian federal and regional ministries/departments 2. Peer-reviewed journals articles 3. UNFCCC Submissions submitted by the Russian Federation (e.g. National Communications, National Determined Contributions) 4. Expert consultation
Search official governmental websites	See section “Data source – Official governmental websites”
Search databases for peer reviewed documents	**Database name**
	Web of Science
	Scopus
	Russian Science Citation Index
Journals to directly search for peer-reviewed documents	**Journal name**
	Арктика: экология и экономика (http://arctica-ac.ru/)
	Фундаментальная и прикладная климатология (http://www.igce.ru/journals/fac)
	Ученые записки Российского государственного гидрометеорологического университета (http://www.rshu.ru/university/notes/)

	Труды Санкт-Петербургского научно-исследовательского института лесного хозяйства (http://journal.spb-niilh.ru/)
	Лесохозяйственная информация (http://lhi.vniilm.ru/index.php/ru/)
	Лесной вестник (https://les-vest.msfu.ru/)
	Использование и охрана природных ресурсов в России (http://priroda.ru/bulletin/)
	Известия высших учебных заведений. Лесной журнал (http://lesnoizhurnal.ru/)
	Вестник Поволжского государственного технологического университета. Серия "Лес. Экология. Природопользование" (https://www.volgatech.net/)
	Вестник Бурятской государственной сельскохозяйственной академии имени В.Р. Филиппова (http://www.bgsha.ru/zhurnal-vestnik.html)
	Устойчивое лесопользование (https://wwf.ru/resources/publications/periodicals/zhurnal-ustoychivoe-lesopolzovanie/)
UNFCCC submissions	**Documents**
	National Communications submitted in 2010 (NC5), 2013 (NC6), and 2017 (NC7)
	National Determined Contribution submitted in 2015
Expert consultation	Email asking a group of experts if they know of any critically important studies and/or policy policy instruments that are not present in the initial search

A.2. Data source – Official governmental websites

Data will be gathered primarily from both documents and contents found on official governmental websites of all Ministries/Departments that deal with forest management in the Russian Federation and the federal constituent entities included in the Russian Presidential Decree Nº 296, May 2, 2014, Land Territories of the Arctic Zone of Russia (Указ Президента от 02.05.2014 г. № 296 «Сухопутные территории Арктической зоны Российской Федерации»). Ministries and Departments responsible for the development and implementation of measures to adapt to wildfires were selected according to the premises established on the Climate Doctrine. If, however, policy documents and programs outlining adaptation outputs from other ministries/departments emerge during the initial search, they will be included and undergo full screening process (see information retrieval process). The included ministries/departments are:

Jurisdiction	Ministry/Department	Mission, objectives, mandates or visions	URL
Russian Federation	Ministry of Civil Defence, Emergencies and Disaster Relief of the Russian Federation	• Elaborate and fulfil state policy in the field of civil defence, protection of the population and territories against emergencies, provision of fire safety and safety of people on water bodies • Prevent, forecast and mitigate the consequences of emergencies and fires	https://en.mchs.gov.ru/
	Ministry of Natural Resources and Environment of the Russian Federation	• Ensure rational and safe use of natural resources, excluding the depletion of natural resources and irreversible deterioration of the quality of the environment	http://www.mnr.gov.ru/en/
	Federal Agency for Forestry	• Extinguish forest fires located within the boundaries of the forest zoning and forest parks • Develop interregional plans for manoeuvring forest fire units, fire fighting vehicles and equipment • Coordinate all forces and means of extinguishing forest fires, as well as the creation of a federal headquarters to coordinate activities to extinguish forest fires and the corresponding headquarters in federal districts	http://rosleshoz.gov.ru/
Murmansk Oblast	Ministry of Natural Resources and Ecology of the Murmansk Region	• Use of natural resources, environmental protection and ecological safety • Use, protection, protection and reproduction of forests	https://mpr.gov-murman.ru/
	Committee for ensuring the safety of the population of the Murmansk region	• Civil defence, fire safety and protection of the population and territories from natural and man-made emergencies	https://safety.gov-murman.ru/
Republic of Karelia	Ministry of Natural Resources and Ecology of the Republic of Karelia	• Carry out functions in the field of forest and water relations, subsoil use relations, environmental expertise, environmental protection, and pursuing state policy in the field of timber and mining complexes, in the field of protection and in the use of objects of the animal world	http://ecology.gov.karelia.ru/
	State Committee of the Republic of Karelia for	• Ensure fire safety, protecting the population and territories from natural and man-made emergencies, civil	http://emercom.gov.karelia.ru/

	Life Support and Population Safety	defence, ensuring radiation safety, safety of people at water bodies	
Arkhangelsk Oblast	Ministry of Natural Resources and Timber Industry of the Arkhangelsk Region	• Develops and approves forest plans and other forestry regulations; provides state services, organizes the use of forests, their protection (including the implementation of fire safety measures and extinguishing forest fires), and the protection, reproduction on the lands of the forest fund.	https://dvinaland.ru/gov/iogv/minlpk/
	Agency of the State Fire Service and Civil Protection of the Arkhangelsk Region	• Carries out civil defense measures and protects the population from natural and man-made emergencies, fires, searches and rescues people at water bodies. Responsible for the evacuation and functioning of the evacuated organizations. Carries out work to prevent emergencies, including ensuring fire safety.	https://dvinaland.ru/gov/iogv/agps/
Nenets Autonomous Okrug	Department of Natural Resources, Ecology and Agroindustrial Complex of the Nenets Autonomous Okrug	• Carries out legal regulation and implements state policy in the areas of: (i) environmental protection, nature management, subsoil use, land use, forest use and water use; (ii) management of specially protected natural areas of regional significance; (iii) ensuring environmental safety	http://dprea.adm-nao.ru/
	Department of Civil Protection and Fire Safety of the Nenets Autonomous Okrug	• Performing functions in the field of civil defence; prevention and elimination of inter-municipal and regional emergencies; ensuring fire safety; search and rescuing people in the internal waters and the territorial sea of the Russian Federation; creating, maintaining and organizing the activities of emergency rescue services and emergency rescue teams.	http://oborona.adm-nao.ru/
Yamalo-Nenets Autonomous Okrug	Department of Civil Protection and Fire Safety	• Conducts state policy and carries out executive and administrative activities in the following areas: civil defence and protection of the population and territories from natural and man-made emergencies; prevention of inter-municipal and regional emergencies, natural disasters and elimination of their consequences; fire safety; radiation safety; creation, maintenance and organization of the activities of emergency rescue services and emergency rescue teams.	https://dgzp.yanao.ru/
	Department of Natural Resources Regulation, Forestry Relations and	• Conducts state policy, carries out executive and administrative activities and state supervision, as well as ensures	https://dprr.yanao.ru/

	Development of the Oil and Gas Complex	the implementation of the powers of the Autonomous Okrug as a subject of the Russian Federation in the following areas: use and protection of subsoil, water bodies, forests, including forest lands, objects of the animal world; environmental protection, as well as the organization and conduct of state environmental expertise of regional facilities; education, protection and use of specially protected natural areas of regional significance.	
Krasnoyarsk Krai	Ministry of Ecology and Rational Nature Management of the Krasnoyarsk Territory	• Protect, improve the state of the environment; preserve biological diversity, natural complexes and objects of special nature conservation, scientific, cultural and recreational value • Ensure the rational use of natural resources	http://www.mpr.krskstate.ru/
	Ministry of Forestry of the Krasnoyarsk Territory	• Provision of multipurpose, rational, continuous, sustainable use of forests to meet the needs of society in forest resources on the territory of the region. • Ensuring compliance with forestry legislation.	http://www.mlx.krskstate.ru/
	Agency for Civil Defence, Emergency Situations and Fire Safety of the Krasnoyarsk Territory	• Ensuring the prevention of the occurrence and development of natural and man-made emergencies, reducing damage and losses from emergencies of an intermunicipal and regional nature and prevent fires.	http://www.krskstate.ru/ag_goichs
Republic of Sakha	Ministry of Ecology, Nature Management and Forestry	• Implementation of state policy in the field of environmental and waste management • Protect special protected natural areas and wildlife and promote environmental education and awareness	https://minpriroda.sakha.gov.ru/
	State Committee for Ensuring the Life Safety of the Population	• Protect the population and territories from natural and man-made emergencies • Ensure fire security and the delivery of material and technical resources	https://gkobzgn.sakha.gov.ru/
Chukotka Autonomous Okrug	Department of Natural Resources and Ecology of the Chukotka Autonomous Okrug	• Carries out activities in the field of environmental management and ecology, forestry and water relations, and in the protection and use of objects of the animal world	http://xn--80atapud1a.xn--p1ai/vlast/organy-vlasti/komitet-prirod-resurs-i-eko/
Republic of Komi	Ministry of Natural Resources and	• Regulates the reproduction, use and protection of subsoil resources, water	https://mpr.rkomi.ru/

	Environmental Protection of the Komi Republic	bodies and resources, objects of the animal world and their habitat, hunting and conservation of hunting resources, environmental protection, and forest	
	Committee of the Komi Republic for Civil Defence and Emergencies	• Protect the population and territory from emergencies of intermunicipal and municipal regional character and ensure fire safety	https://gochs.rkomi.ru/

A.3. Inclusion/Exclusion criteria

Working definition of adaptation for inclusion/exclusion
Inclusion is determined based on whether the text is relevant to climate change adaptation and wildfires and whether it has sufficient level of information to be included. This review will include for analysis all policies/programs/strategies (i.e. outputs) that are purposefully designed to (i) address climate-induced wildfires, (ii) reduce vulnerability to climate-induced wildfires of actor groups, sectors, or territories, and (iii) take advantage of new opportunities brought by climate change in the field of wildfire management (adapted from Dupuis and Biesbroek, 2013). This means that there must be an explicit mention to climate change to consider existing outputs, not general climate processes or weather. The inclusion and exclusion criteria for each data source are summarized in the tables below.

Inclusion Criteria – Peer-reviewed	
Inclusion criteria	**Exclusion criteria**
English or Russian Language	Non-English or Russian Language
Published in peer reviewed journals	Not published in peer reviewed journals
Published between 1 January 2008 and 31 December 2020	Not published between 1 January 2008 and 31 December 2020
Study conducted in or focused on northern Russia	Study is outside northern Russia
Include/mention adaptation(s) to climate-induced wildfires	Documents unrelated to climate change adaptation and wildfires
Can include: - Empirical assessment of adaptation policies and programs (e.g. case studies; policy evaluation) - Systematic review of empirical studies - Commentary - Non-adaptation focused articles that nevertheless include substantial evaluations of adaptation (e.g. a	Cannot include: - Studies focused primarily on methodological or theoretical development, without application through case study - Articles that mention but do not evaluate adaptation policies and programs - Literature review

vulnerability focused articles that also evaluates adaptation policies) - Research based on modelling	

Inclusion Criteria – Official governmental websites & UNFCCC submissions	
Inclusion criteria	**Exclusion criteria**
English or Russian Language	Non-English or Russian Language
Documents published by federal and/or regional ministries/departments or submitted to the UNFCCC	Documents published by non-governmental organizations, private companies, communities, households, or individuals
Jurisdictionally appropriate documents and initiatives	Jurisdictionally inappropriate documents and initiatives (e.g. municipal documents when searching for regional documents)
Documents that include/mention adaptation(s) to climate-induced wildfires	Documents unrelated to climate change adaptation and wildfires
Technical documents, laws, regulations, adaptation plans, national reports, adaptation and vulnerability assessments, or statements of recognition on the need for developing wildfire adaptation measures/actions	Opinion pieces, public speeches, meetings, conference, or presentations

A.4. Document Search Information – Peer-reviewed

Academic databases search				
Database	**Search string**	**Date**	**Returns**	**Instructions**
Web of Science (WoS)	TS=((“climat* change*” OR “extreme event” OR “anthropogenic warming” OR “global warming”) AND (“adapt*” OR “resilien*” OR “cope” OR “coping” OR “adjust*” OR “interven*” OR “modif*” OR “react*” OR “mitigat*”) AND (“Russia” OR “Russian Federation” OR “Murmansk Oblast” OR “Murmansk” OR “Republic of Karelia” OR “Arkhangelsk” OR “Arkhangelsk Oblast” OR “Komi” OR “Republic of Komi” OR “Nenets Autonomous	5 Jan 2021	8	1. Choose advanced search 2. Set 2008-2020 3. Choose All Databases 4. Choose English and Russian 5. Choose Article for return type

	Okrug" OR "Yamalo-Nenets" OR "Yamalo-Nenets Autonomous Okrug" "Krasnoyarsk Krai" OR "Krasnoyarsk" OR "Chukotka" OR "Chukotka Autonomous District" OR "Siberia" OR "Siberian" OR "Yakutia" OR "Yakutiya" OR "Ural" OR "Far Eastern District" OR "Northwestern Federal District" OR "Sakha" OR "Sakha Republic") AND ("polic* instrument*" OR "govern" OR "governing resource*" OR "governance arrangement" OR "program" OR "programs" OR "action" OR "document" OR "plan" OR "plans" OR "planning" OR "strateg*" OR "capacity building" OR "intervention" OR "tool" OR "measure" OR "option" OR "federal") AND ("wildfire*" OR "forest fires"))			
	TS=(("изменение климата" OR "глобальное потепление") AND ("адаптация") AND ("лесной пожар"))	5 Jan 2021	0	
Scopus	TITLE-ABS-KEY(("climat* change*" OR "extreme event" OR "anthropogenic warming" OR "global warming") AND ("adapt*" OR "resilien*" OR "cope" OR "coping" OR "adjust*" OR "interven*" OR "modif*" OR "react*" OR "mitigat*") AND ("Russia" OR "Russian Federation" OR "Murmansk Oblast" OR "Murmansk" OR "Republic of Karelia" OR "Arkhangelsk" OR "Arkhangelsk Oblast" OR "Komi" OR "Republic of Komi" OR "Nenets Autonomous Okrug" OR "Yamalo-Nenets" OR "Yamalo-Nenets Autonomous Okrug" "Krasnoyarsk Krai" OR "Krasnoyarsk" OR "Chukotka" OR "Chukotka Autonomous District" OR "Siberia" OR "Siberian" OR "Yakutia" OR "Yakutiya" OR "Ural" OR "Far Eastern District" OR "Northwestern Federal District" OR "Sakha" OR	5 Jan 2021	0	1. Choose Advanced Search; 2. Limit to 2008-2020; 3. Limit to English; 4. Choose Article for return type"

	"Sakha Republic") AND ("polic* instrument*" OR "govern" OR "governing resource*" OR "governance arrangement" OR "program" OR "programs" OR "action" OR "document" OR "plan" OR "plans" OR "planning" OR "strateg*" OR "capacity building" OR "intervention" OR "tool" OR "measure" OR "option" OR "federal") AND ("wildfire*" OR "forest fires"))			
Russian Citation Index (elibrary)	("изменение климата" OR "глобальное потепление") AND ("адаптация") AND (лесной пожар)	10 Jan 2021	2,674	1. Choose "в названии публикации"; "в аннотации"; "в ключевых словах" 2. Limit to "статьи в журналах" 3. Choose "искать с учетом морфологии" 4. Set to 2008-2020

Targeted journal searches - Search and review protocol (apply to each journal included)		
Instructions	**Date**	**Returns**
1. Open journal website 2. Identify native 'search' function and/or 'publications' page 3. Search key terms (i.e. "adapt*, climate change, адапта*, изменение климата) 4. Evaluate relevant returns against inclusion/exclusion criteria for peer-reviewed, excluding as necessary If 'search' function and/or 'publications' page not available: 1. Identify 'Volume/Issue' page 2. Scan titles and abstract of all articles published, according to inclusion/exclusion criteria for peer-reviewed literature 3. Evaluate full text against inclusion/exclusion criteria for peer-reviewed, excluding as necessary	1 Feb 2021	50

A.5. Document review process – Peer-reviewed

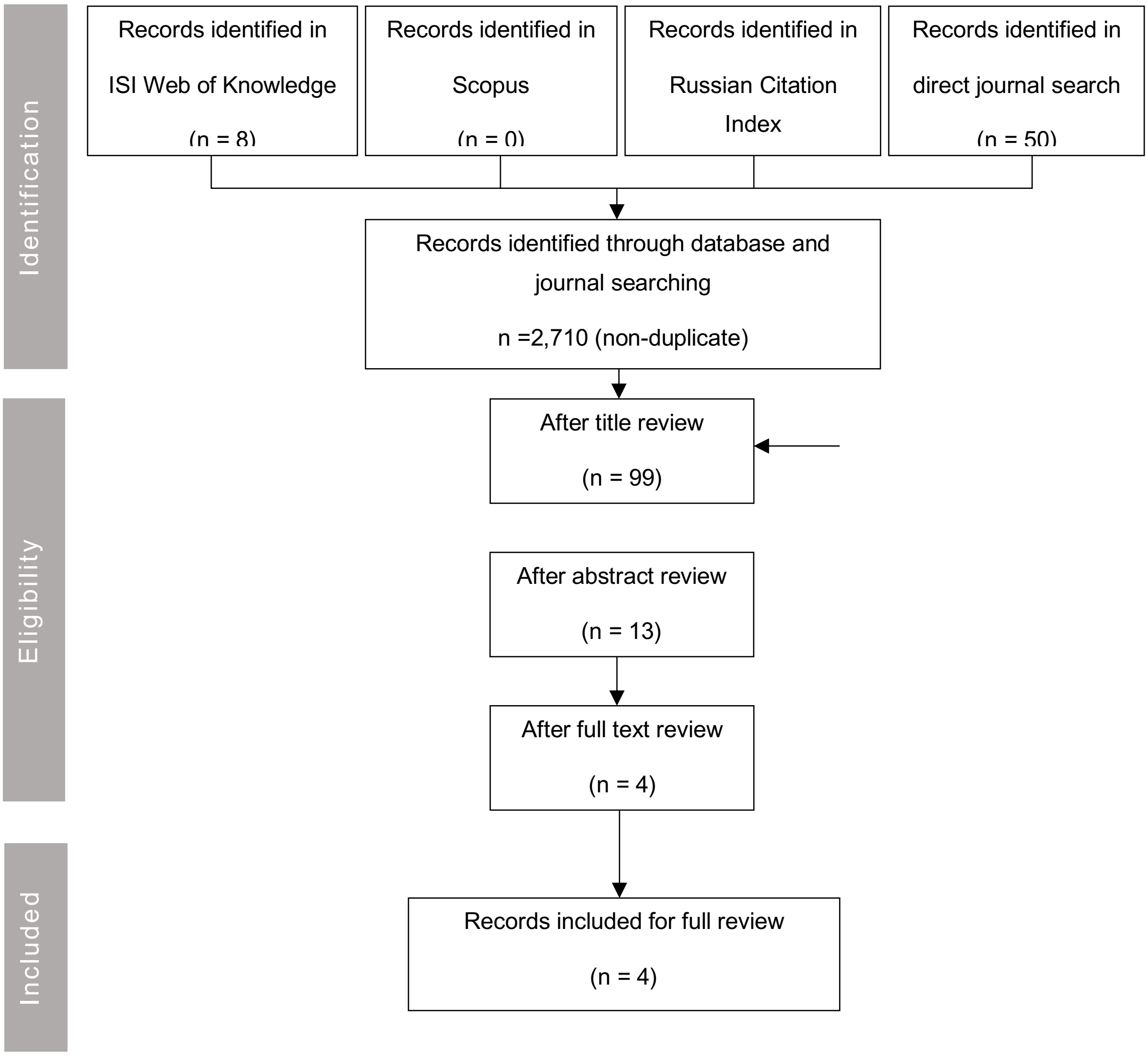

Figure A.1: Article identification, eligibility, and inclusion progression based on Ford et al (2014). Adapted from PRISMA Flow Diagram and McDowell, 2019.

A.6. Document Search Information – Official governmental websites

Search and review protocol for official governmental websites (apply to each website included)		
Instructions	**Date**	**Returns**
1. Open government website: a. Identify native 'search' function and/or 'publications' page i. Search key terms (i.e. "adapt*, climate change, адапта*, изменение климата) b. Access relevant sections and/or headings of the website	1 Feb 2021	515

i. Identify documents relevant to forests and fires Evaluate relevant returns against inclusion/exclusion criteria for governmental websites and UNFCCC submissions, excluding as necessary		

A.7. Document review process – Official governmental websites

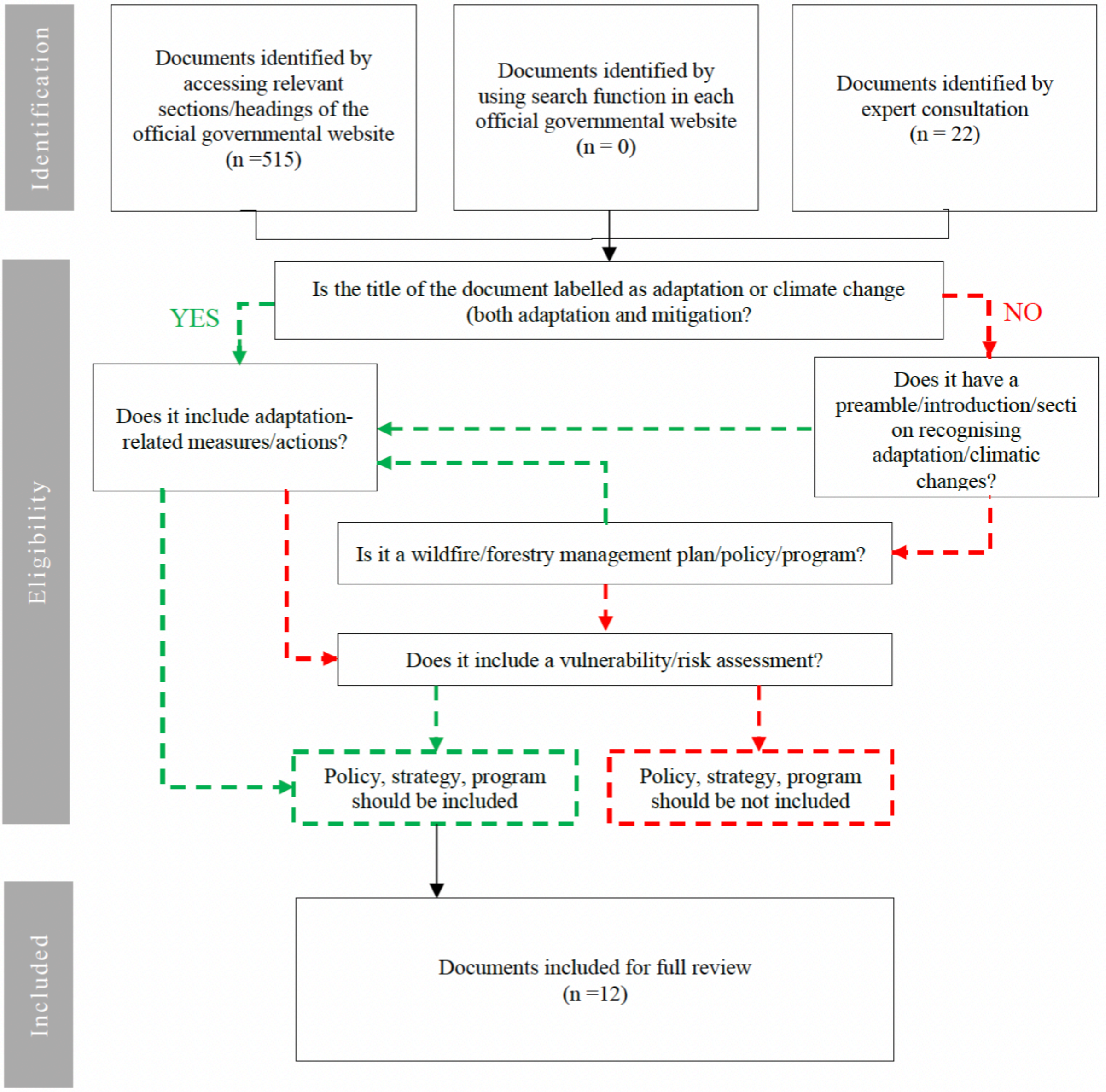

Figure A.2: Document eligibility, inclusion, and analysis progression for official governmental websites. Adapted from PRISMA Flow Diagram, McDowell, 2019 and Olazabal et al 2019

A.8. Document Search Information – UNFCCC Submissions

Search and review protocol for UNFCCC Submissions (apply to each document included)		
Instructions	**Date**	**Returns**
1. Identify submission made by the Russian Federation to the UNFCCC from 2008 to 2010 2. Search key terms (i.e. “adapt*, адапта*) OR access relevant sections and/or headings of the document (e.g. chapter on vulnerability and adaptation) 3. Identify discrete adaptation policies/strategies/programs developed to adapt to wildfires 4. Search for original documents 5. Evaluate against inclusion/exclusion criteria for governmental websites, excluding as necessary	15 Jan 2021	0

A.9. Document Search Information – Expert Consultation

After screening full texts of all articles retrieved from the peer-reviewed and documents and contents from both official websites searches and UNFCCC submissions, the list of included studies and policies were presented to a group of external experts, which were asked if they knew of any other critically important studies that are not in the list. A short survey was created for this end (see link on email drafts below). Any articles and/or policy instruments suggested by the experts were screened following inclusion/exclusion criteria (see document review process).

Email drafts for the round of consultation are presented below:

<u>IN ENGLISH</u>

Dear [Name],

I hope this email finds you well.

[Project Title] is a newly launched international project funded by [Funder] with the participation of the [Collaborations]. Its overarching goal is to understand the factors that affect resilience to climate change among Indigenous and local communities in Siberia in the face of increasing wildfire activity, using this knowledge to identify, evaluate, and communicate opportunities for adaptation.

As part of the project, we are currently in the process of systematically identifying, characterising, and evaluating policies/programs/strategies/plans that have been developed to adapt to wildfires in the Russian Federation in general, and focusing on the Russian North in particular. Part of our methodology is to ask a group of experts to identify potential omissions in our final set of included documents. Given that you have conducted research on wildfires and/or climate change adaptation, and Russia, we would like to know if you would be able to go over the attached list and let us know – to the best of your knowledge – if we have omitted any other critically important articles published/online since 2008, including your own work, and if you are aware of any other laws, regulations, plans, and programmes that contain adaptations to wildfires. We have created a short online survey to this end (https://docs.google.com/forms/d/e/1FAIpQLSc84v9q3VfMfxshxlUWIiytSeFIm-0U1IX5YoPdqPMuA7RyHw/viewform?usp=sf_link). I am attaching the inclusion/exclusion criteria used in this study for your reference. We would be happy to mention you in the acknowledgment section of the article we produce from the work.

We would greatly appreciate any suggestions you may have and hope to receive a response from you before the [Deadline]. Please do not hesitate to contact me directly at [Email address] if you have any further questions.

Thank you very much in advance for your help! Stay safe and take care.

Kind regards,

[Sign]

IN RUSSIAN

Уважаемая Сурина [Name],

[Project Title] - новый международный проект, финансируемый [Funder] при участии [Collaborations]. Его главная цель - понять факторы, которые влияют на устойчивость к изменению климата среди коренных и местных сообществ в Сибири перед лицом возрастающей активности лесных пожаров, используя эти знания для выявления, оценки и распространения возможностей для адаптации.

В рамках проекта мы в настоящее время находимся в процессе систематического выявления, характеристики и оценки политик/программ/стратегий/планов, которые были разработаны для адаптации к лесным пожарам в Российской Федерации в целом, и уделяя особое внимание Северу России в частности. Часть нашей методологии состоит в том, чтобы попросить группу экспертов выявить потенциальные упущения в окончательном наборе включенных документов. Учитывая, что Вы участвовали в проведении исследований в области изучения лесных пожаров и / или адаптации к изменению климата, и России, мы хотели бы знать, сможете ли Вы просмотреть прилагаемый список и сообщить нам, насколько вам известно, если мы пропустили какие-либо другие критически важные статьи, опубликованные / в Интернете с 2008 года, включая ваши собственные работы, и если вам известны какие-либо другие законы, постановления, планы и программы, которые содержат меры по адаптации к лесным пожарам. С этой целью мы создали небольшой онлайн-опрос (https://docs.google.com/forms/d/e/1FAIpQLSel66ZktSLxa_HHnTfTP9iKJXU8EYXa5RBF4dzc4dFzM0iPnQ/viewform?usp=sf_link). Я прилагаю для справки критерии включения / исключения, использованные в этом исследовании. Мы будем рады упомянуть вас в разделе благодарностей статьи, которую мы подготовим на основе работы.

Мы будем очень признательны за любые предложения и надеемся получить от вас ответ до [Deadline]. Пожалуйста, обращайтесь к [Contact] напрямую по адресу [Email address], если у вас возникнут дополнительные вопросы.

Заранее большое спасибо за вашу помощь!

С уважением,

[Sign]

A.10. Included Documents – Peer-reviewed (n=4)

Семёнов М.А., Высоцкий А.А., Пащенко В.И. Прогноз адаптивных приспособлений в лесном хозяйстве в связи с возможными климатическими изменениями [Forecast of adaptive adaptations in forestry in connection with possible climatic changes]. Лесн. журн. 2019. № 5. С. 57–69. (Изв. высш. учеб. заведений). DOI: 10.17238/issn0536-1036.2019.5.57

Липка О., Романовская А., Семенов С. М. 2020. Прикладные аспекты адаптации к изменениям климата в России [Applied aspects of adaptation to climate change in Russia]. Фундаментальная и прикладная климатология. Т. 1. С. 65-90.

Н.Е. Сердитова and К.С. Кириллина. 2020. Обзор современного состояния и перспективных подходов к проблеме адаптации к изменению климата в Российской Федерации [Review of the current state and promising approaches to the problem of adaptation to climate change in the Russian Federation]. Тверской государственный университет. OAI: oai:rour.neicon.ru:rour/435688

Григорьев, А. Щеголев, Д. Глобальное. 2019. изменение климата и адаптация к нему лесного комплекса Северо: Западного федерального округа России использование опыта Швеции и Луговая Финляндии [Climate change and adaptation to it of the forestry complex of the North: Western Federal District of Russia using the experience of Sweden and Lugovaya Finland]. Канд, биол. Наук.

A.11. Included Documents – Official governmental websites (n=12)

Разъяснения по порядку подготовки разделов 3.11 и 4.2 Типовой формы и состава лесного плана субъекта Российской Федерации [Clarifications in the order of preparation of sections 3.11 and 4.2 of the Standard form and composition forest plan of the constituent entity of the Russian Federation]

Приказ Министерства природных ресурсов и экологии Российской Федерации от 20 декабря 2017 г. N 692 «Об утверждении типовой формы и состава лесного плана субъекта Российской Федерации, порядка его составления и внесения изменений в Это" [Order of the Ministry of Natural Resources and Ecology of the Russian Federation dated December 20, 2017 N 692 "On approval of the standard form and composition of the forest plan of a constituent entity of the Russian Federation, the procedure for its preparation and amendments to it"]

Распоряжение Правительства Российской Федерации от 25.04.2011 № 730-р «Об утверждении Комплексного плана реализации Климатической доктрины Российской Федерации на период до 2020 года» [Order of the Government of the Russian Federation dated 25.04.2011 No. 730-r "On the approval of a comprehensive plan for the implementation of the Russian Federation Climate Doctrine for the period up to 2020"]

Приказ Главы Республики Саха (Якутия) от 04 декабря 2019 г. No 700-РГ "Об утверждении Лесного плана Республики Саха (Якутия) на период 2019-2028 гг." [Order of the Head Republic of Sakha (Yakutia) dated December 04, 2019 No. 700-RG "On approval of the Forest Plan of the Republic of Sakha for the period 2019-2028"]

Распоряжению губернатора Ненецкого автономного округа от 25 января 2019 № 18-рг «Об утверждении Лесного плана Ненецкого автономного округа» [Order of the Governor of the Nenets Autonomous Okrug dated January 25, 2019 No 18-rg "On approval of the Forest Plan of the Nenets Autonomous Okrug"]

Лесной план Республики Коми на 2019-2028 годы [Forest Plan of the Republic of Komi 2019-2028]

Лесной план Архангельской области 2019/2028 [Forest Plan of the Arkhangelsk Region]

Заявление к Распоряжению Губернатора Чукотский автономный округ от 28 января 2019 г. N 49-рг "ЛЕСНОЙ ПЛАН Чукотский автономный округ" [Statement to the Governor's Order Chukotka Autonomous District dated January 28, 2019 N 49-rg "FOREST PLAN of Chukotka Autonomous District"]

Заказ Руководители Республики Карелия от 24 декабря 2018 г. № 731-р "ЛЕСНОЙ ПЛАН РЕСПУБЛИКА КАРЕЛИЯ в 2019-2028 годах" [Order of the Head of the Republic of Karelia dated December 24, 2018 No. 731-r "Forest Plan of the Republic of Karelia for the years 2019-2028"]

Распоряжение Губернатора Мурманской области от 20.03.2019 № 29-ПГ «Лесной план Мурманской области» [Order of Governor of the Murmansk Region dated 20.03.2019 No. 29-PG "Forest Plan Murmansk Region]

Распоряжение Губернатора Ямало-Ненецкого автономного округа от 22 февраля 2019 г. № 19-ПГ «Об утверждении Плана Ямало-Ненецкого лесного автономного округа» [Decree of the Governor of the Yamalo-Nenets Autonomous District dated February 22, 2019 No. 19-PG "On approval of the Yamalo-Nenets Forest Autonomous Region Plan"]

Распоряжение Губернатора Красноярского края от 21 декабря 2018 г. № 332-уг «Об утверждении лесного плана Красноярского края» [Decree of the Governor of the Krasnoyarsk Territory dated December 21, 2018 No. 332-ug" On approval of the forest plan of the Krasnoyarsk Territory"]

A.12. Data extraction - Codebook

All policy documents, strategies, program reports on adaptation and wildfires identified in the peer-reviewed literature, official governmental websites, UNFCCC submissions, and expert consultation that meet inclusion criteria will be coded according to the following indicator list, adapted from Araos et al (2016), Olazabal et al (2019) and Schaffrin et al (2015):

Indicator	Definition	Field options
META-DATA		
Bibliometric information (complete for peer-reviewed articles only)		
Title	Title of the article	*Open*
Journal	Title of the journal in which the paper was published	*Open*

Year published	Year the study was published in	*Open*
ADAPTATION POLICY, STRATEGY, PROGRAM (complete for each instrument identified)		
Jurisdiction	Jurisdiction policy/program came into force	*1. Federal* *2. Federal Constituent Entity*
Jurisdiction Name	Federal state, oblast', republic, krai, autonomous okrug, autonomous oblast' in which adaptation policy and program came into force	*1. Russia* *2. Murmansk Oblast* *3. Republic of Karelia* *4. Arkhangelsk Oblast* *5. Komi Republic* *6. Nenets Autonomous Okrug* *7. Yamalo-Nenets Autonomous Okrug* *8. Krasnoyarsk Krai* *9. Republic of Sakha* *10. Chukotka Autonomous Okrug*
Region	Federal district in which adaptation policy and program came into force	*1. Northwest* *2. Ural* *3. Siberia* *4. Far East*
Policy, Program, Project or Initiative Description	Title of the policy, program, strategy or initiative	*Open*
Document Year	Year instrument came into force	*1. 2008* *2. 2009* *3. 2010* *4. 2011* *5. 2012* *6. 2013* *7. 2014* *8. 2015* *9. 2016* *10. 2017* *11. 2018* *12. 2019* *13. 2020*
Implementing Ministry/Department	Ministry or Department (or document author if implementing ministry or body is unclear) that carries out policies/programs/strategies	*Open*
Policy aim	How adaptation is framed (e.g. following IPCC definition)	1. *Climate change adaptation:* Adapting to anthropogenic climate change impacts
		2. *Vulnerability-centred adaptation:* Reduction of structural drivers of vulnerability to climate change impacts
		3. *Resilience*: Systems-based thinking that emphasizes recovery

		from sudden shocks; adapting to climate variability as deviation from climate norms regardless of cause
		4. *Sustainability*: Adaptation linked to green growth objectives and broad balancing of economic and environmental objectives
		5. *Unclear*
		6. *Other*
Adaptation approach	How adaptation is developed designed	1. *Stand alone:* New/stand-alone plan, strategy, framework or policy developed to deal specifically with climate change adaptation 2. *Mainstreamed into other programs:* Integrates climate change adaptation into an existing program, institution, framework, policy, or law 3. *Indeterminate*
Nature of climate drivers	Type of climate risks affecting wildfires	1. *Extreme and prolonged heat*: wildfires attributed to higher temperatures and drought
		2. *Changing snow and rain patterns*: changes in snow and rain that give plants and soils longer to dry out
		3. *Lighting events*: wildfires attributed to lightning strikes
		4. *Thawing permafrost*: wildfires triggered by thawing permafrost
		5. *Condition of fuels/vegetation/build-up index*
		6. *Increased wind speeds*
		7. Unclear
		8. Other
Policy/Program approach	How wildfire risk is managed	1. *Wildfire risk reduction*: Reduce the likelihood of unwanted, uncontrolled, or escaped wildfires in the first place (e.g. zoning, public education, fire enforcement laws, etc.)
		2. *Reduce human exposure*: Protect human communities and assets from wildfires (e.g. expansion of

		“critical” and “full” protection buffers around communities, creation of large-scale breaks in flammable fuels around communities to aid suppression, etc.)
		3. *Improved fire response*: Improve the ability of the fire emergency services to tackle wildfires (e.g. provision of better equipment, investments in firefighting efforts, etc.)
		4. *Other*
Spatial approach	Does the policy policy/program differentiate between boreal and Arctic forests?	1. *Yes* 2. *No* 3. *Indeterminate*
Nature of the governing resource	Policy instrument type, categorized according to Henstra (2016)	1. *Nodality:* Use of information dissemination, knowledge generation and knowledge mobilization to inform adaptation responses (e.g. education, training programs, conference and workshop hostings, etc.)
		2. *Authority:* Use of legislation, inter-governmental mandates, and/or regulation to permit, prohibit, or command adaptation action (e.g. zoning, standards, etc.)
		3. *Treasure:* Use of funds (e.g. subsidies, tax, research funding, interest group funding, etc.)
		4. *Organization:* Use of government resources and personnel to implement adaptation policy objectives (e.g. working group creation, department re-organization or creation, hearing, etc.)
Policy goal	Specified goal of the adaptation policy/program	*Verbatim description of policy goal* *Example: “Reduce climate-induced wildfires and associated consequences”*
Policy target	Specific policy target	*Verbatim description of policy target* *Example: “Implement fire prevention measures”*
Policy target (group)		1. *Individuals*: Population at large

	Nature of the group targeted by the policy instrument and programs	2. *Households*: Residents of single-family homes or occupants of multi-unit buildings
		3. *Private sector*: Local businesses, real estate development (including multi-unit buildings under application/consideration or construction)
		4. *Local government*: Municipal operations, agencies, departments
		5. *Senior government*: Regional or national governments, international organizations
		6. *Other*
Consideration of vulnerable groups	Does the policy/program include vulnerable groups?	1. *Yes* 2. *No* 3. *Not specified*
Vulnerable populations addressed specifically in adaptation	What vulnerable groups (if any) are targeted in policy/program?	*Open* *Example: Indigenous peoples, disabled, older persons, etc.*
Climatic scenarios projected	Does the policy/program include future projections of climate change?	*4.*
Timescale of climate impacts projections		*5.*
Governance level	Scale of the policy instrument's target	1. *Neighbourhood*: Area-specific
		2. *City-wide*: Not area-specific
		3. *Metropolitan area*: Multiple local governments, regional governments
		4. *Rural area: villages*
		5. *Region*: Provincial, state government
		6. *Country*: Country-level government
		7. *Multiple*
		8. *Unclear*
		9. *Other*

Policy Implementation	Is there a statement about implementation procedures specifically allocating actors and rules?	1. *No statement about implementation procedures found* 2. *Implementation is specifically allocated to actors and rules* *Only one specific actor coordinated implementation*
Administrative responsibility	Governmental unit responsible for implementation	1. *Environment, natural resources, sustainability or climate change unit*: Departments or offices within departments dedicated to climate change policy planning
		2. *Executive or legislative bodies*: City manager's office, City Council
		3. *Planning and development department*: Department responsible for land use planning
		4. *Public works*: Including infrastructure, and transportation: water, roads, public transportation
		5. *Economic development*: Department responsible for jobs and local business support
		6. *Emergency services*: Public safety services responsible for crime prevention, fires services, emergency medical response
		7. *Community and Health*: Public health services, community services
		8. *Energy and environment*: Parks, water and air management, energy production and delivery services
		9. *Unclear*
		10. *Other*
Budget	What are the set expenditures/impositions of the policy instrument, strategy or program?	*Open*
Monitoring	Is there a specific monitoring process for the policy instrument, strategy, and program and by whom?	1. *No monitoring* 2. *Monitoring by the implementing agency* 3. *Special group/institution is established for monitoring*

URL	Link to the policy, program, strategy document	*Open*

Data will be extracted and entered into a Microsoft Excel spreadsheet, where policy/program information and adaptation characteristics will be organized in rows and columns. Rows will order individual documents containing wildfire adaptation outputs identified within single documents, while columns will correspond to the characteristics of the identified policies/programs (setting, target, year of implementation, etc.).

A.13. Results – All documents (n=12)

Indicator	**Results (in nº)**	**Results (in %)**
META-DATA		
Bibliometric information (complete for peer-reviewed articles only)		
Title		
Journal		
Year published		
ADAPTATION POLICY, STRATEGY, PROGRAM (complete for each instrument identified)		
Jurisdiction		
1. Federal	3	25
2. Federal Constituent Entity	9	75
Jurisdiction Name		
1. Russia	3	25
2. Murmansk Oblast	1	8
3. Republic of Karelia	1	8
4. Arkhangelsk Oblast	1	8
5. Komi Republic	1	8
6. Nenets Autonomous Okrug	1	8
7. Yamalo-Nenets Autonomous Okrug	1	8
8. Krasnoyarsk Krai	1	8
9. Republic of Sakha	1	8

10. Chukotka Autonomous Okrug	1	8
Region		
1. Northwest	5	42
2. Ural	1	8
3. Siberia	1	8
4. Far East	2	17
5. N/A	3	25
Policy, Program, Project or Initiative Description (type response)		
Document Year		
1. 2008	0	0
2. 2009	0	0
3. 2010	0	0
4. 2011	1	8
5. 2012	0	0
6. 2013	0	0
7. 2014	0	0
8. 2015	0	0
9. 2016	0	0
10. 2017	2	17
11. 2018	3	25
12. 2019	6	50
13. 2020	0	0
Implementing Ministry/Department (type response)		
Policy aim		
1. Climate change adaptation	9	75
2. Vulnerability-centred adaptation	0	0
3. Resilience	0	0
4. Sustainability	0	0
5. Unclear	2	25

6. Other	0	0
Adaptation approach		
1. Stand alone	1	8
2. Mainstreamed into other programs	11	92
3. Indeterminate	0	0
Nature of climate drivers		
1. Extreme and prolonged heat	3	17
2. Changing snow and rain patterns	4	22
3. Lighting events	1	6
4. Thawing permafrost	0	0
5. Condition of fuels/vegetation/build-up index	2	11
6. Increased wind speeds	0	0
7. Unclear	4	22
8. Other	4	22
Policy/Program approach		
1. Wildfire risk reduction	11	52
2. Reduce human exposure	4	19
3. Improved fire response	6	29
4. Other	0	0
Spatial approach		
1. Yes	0	0
2. No	12	100
3. Indeterminate	0	0
Nature of the governing resource		
1. Nodality	1	8
2. Authority	11	92
3. Treasure	0	0
4. Organization	0	0

Policy goal (type response)		
Policy target (type response)		
Policy target (group)		
1. Individuals	0	0
2. Households	0	0
3. Private sector	0	0
4. Local government	9	43
5. Senior government	12	57
Consideration of vulnerable groups		
1. Yes	0	0
2. No	12	100
3. Not specified	0	0
Vulnerable populations addressed specifically in adaptation (type response)		
Climatic scenarios projected	Does the policy/program include future projections of climate change?	*6.*
Timescale of climate impacts projections		*7.*
Governance level (type response)		
1. Neighbourhood	0	0
2. City-wide	0	0
3. Metropolitan are	0	0
4. Rural area	0	0
5. Region	9	75
6. Country	3	25
7. Multiple	0	0
8. Unclear	0	0
9. Other	0	0
Policy Implementation		
1. No statement about implementation procedures found	11	92

2. *Implementation is specifically allocated to actors and rules*	1	8
3. *Only one specific actor coordinated implementation*	0	0
Administrative responsibility		
1. *Environment, natural resources, sustainability or climate change unit*	0	0
2. *Executive or legislative bodies*	1	50
3. *Planning and development department*	1	50
4. *Public works*	0	0
5. *Economic development*	0	0
6. *Emergency services*	0	0
7. *Community and Health*	0	0
8. *Energy and environment*	0	0
9. *Unclear*	0	0
10. *Other*	0	0
Budget (type response)		
Monitoring		
1. *No monitoring*	12	100
2. *Monitoring by the implementing agency*	0	0
3. *Special group/institution is established for monitoring*	0	0
URL		

Appendix B: Supplementary materials for Chapter 4

B.1. Ethics approval

The Secretariat
University of Leeds
Leeds, LS2 9JT
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

20th September 2022

Dear Ivan,

Ref no: AREA 21-166

Title: Voices from the frontline: climate change, wildfires, and adaptation in high-latitude contexts

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.

I am pleased to inform you that the above research ethics application has been reviewed by the School of Business, Environment and Social Services (AREA) Committee and on behalf of the Chair, I can confirm a conditional favourable ethical opinion based on the documentation received at date of this email and *subject to the following condition/s which must be fulfilled prior to the study commencing:*

1. Applicant to check with the contracts / data protection team if a data sharing agreement is required or if the NDA is sufficient – written confirmation (email is fine) and data sharing agreement (if applicable) to be submitted for records

The study documentation must be amended where required to meet the above conditions and submitted for file and possible future audit.

Once you have addressed the conditions and submitted for file/future audit, you may commence the study and further confirmation of approval is not provided.

Please note, failure to comply with the above conditions will be considered a breach of ethics approval and may result in disciplinary action.

Please retain this email as evidence of conditional approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/ or contact the Research Ethics & Governance Administrator for further information on researchethics@leeds.ac.uk if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.
Best regards
Sou
On behalf of Dr Judith Hanks, AREA FREC CHAIR

B.2. Interview guide

Q#	Questions	Possible answers
N/A	ID #	OPEN
N/A	Interview #	OPEN
N/A	Date	OPEN
N/A	Name (if consent given)	OPEN
N/A	Consent	Yes or No Answer
1. Socio-demographic data & basic information		
1	Gender	M/F
2	Age	OPEN
3	Livelihood activities (main occupation)	OPEN
4	How long have you lived in Valemount?	OPEN
5	What type/level of education have you received?	1. Elementary
		2. Secondary
		3. Post-secondary
2. Risk perception and ex-ante risk and resilience		
6	How (un)likely do you think a wildfire will impact your community within the time period you expect to live here? Why do you think that?	OPEN
7	Are you prepared in the event of a wildfire? If yes, how did you prepare for it? *If participant is not prepared for a wildfire, refer to section 4 (question 10 onwards)*	Yes and No answer OPEN
3. Constraints & facilitators of adaptation, vulnerability, and resilience		
8	What factors help(ed) you prepare for and respond to wildfires?	1. Economic/financial
		2. Social/cultural
		3. Governance, institutions, policy
		4. Physical, biological
		5. Other
9	What factors limit(ed) your ability to prepare for and respond to wildfires?	OPEN

4. Fire management & public perceptions and attitudes		
10	To what extent are you displeased or pleased with the way wildfire are currently managed by fire and forest ministries/departments?	OPEN
5. Changes in wildfire activity		
11	Have you seen any changes in the frequency and severity of wildfires over the last 30 years? Has wildfire activity increased, decreased, or stayed the same? If yes, ask questions below:	OPEN
11.5	Have such changes affected your life? If yes, how?	OPEN
11.6	What do you think is driving changing wildfire activity?	OPEN
6. Cascading impacts and effect on vulnerability, resilience, and adaptation		
12	Are there other hazards and events that affect your ability to prepare for, cope, and respond to wildfires? If yes, how have they affected you? How have you responded to them?	OPEN *But mention examples such as heat waves, permafrost thaw, COVID-19, water runoff, water pollution, etc.*
7. During and ex-post a wildfire risk and resilience		
This section includes questions related to experienced/observed wildfires and associated impacts and the nature of adaptation actions used.		
13	Did you experience a wildfire before? If yes, how did wildfires impact you? If yes, keep asking following questions. *By experience I mean having directly suffered the impacts of a wildfire, either through, for instance, health impacts or disruptions to livelihoods, etc.*	Yes or No answer. *Options could include: loss of income, health discomfort/damage/problems, death of animals, livestock, pets, home and property damages, prevented from engaging in traditional activities, etc.*
14	What did you do during a wildfire? What actions/measures did you adopt during a wildfire?	OPEN
15	What action(s) did you adopt after a wildfire?	OPEN. *Options could include: installed fire infrastructure (e.g. fire resistant roofs); landscape management (e.g. pruned limbs and/or removed dead/overhanging branches within a distance from the community), etc.*
END OF INTERVIEW GUIDE		
Do you know anyone else who you think I can contact?		