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People and plants in a burnt landscape: Forest fires in coastal Nunatsiavut

Par

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Ce mémoire intitulé

People and plants in a burnt landscape:
Forest fires in coastal Nunatsiavut

Présenté par

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A été évalué par un jury composé des personnes suivantes

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Résumé

Le feu est la principale perturbation naturelle dynamisant les écosystèmes du biome boréal. En ce sens, il affecte toutes les composantes de ces écosystèmes, incluant le couvert végétal, les conditions du sol, la faune et les populations humaines. Des effets complexes des changements climatiques sur les feux sont à prévoir, et la compréhension de ces effets est cruciale pour prédire le futur des écosystèmes et leur impact sur les populations locales. Ceci est d'autant plus vrai que les études portant sur l'écologie des feux sont rares pour les zones plus nordiques, comme au Nunatsiavut, la région Inuite du nord du Labrador. De plus, bien que la science occidentale puisse aider à développer cette compréhension, le savoir écologique des populations autochtones qui ont toujours cohabité avec les feux est aussi fondamental. Dans ce contexte, des entrevues semi-dirigées ont été menées dans deux communautés inuites (Nain et Postville, Nunatsiavut) pour documenter le savoir inuit local au sujet de cette perturbation et de ses impacts. Des inventaires écologiques traditionnels ont aussi été menés, complémentant les savoirs inuits. Les populations végétales au sol ont aussi été caractérisées sur le site de trois feux de forêt en régénération pour clarifier comment ces communautés végétales se rétablissent après feu dans la région, et comment certaines variables environnementales et biotiques affectent cette réponse. Comme résultats clefs, cette étude a démontré que les utilisations des sites de feux par les Inuit sont dominées par la récolte de bois brûlés, suivi d'activités généralement réalisées en parallèle comme la chasse. La relation avec le feu varie entre les deux communautés, cette relation étant plus proche à Postville qu'à Nain en lien avec des différences dans la taille et la distance des feux par rapport aux communautés, de même que différents niveaux d'hétérogénéité dans le paysage avant le passage des feux. Cette étude a démontré que le rétablissement des communautés végétales après feux en milieux côtiers au Nunatsiavut suit les patrons généraux observés ailleurs, notamment dans le sud-est et l'ouest du Labrador, tels qu'une transition des communautés muscinales de lichens, avec quelques exceptions notables, telle que des effets négatifs inattendus du feu sur *Vaccinium angustifolium*, qui devraient faire l'objet de recherches plus approfondies.

Mots-clés : Feux de forêt, Végétation au Sol, Savoir Inuit, Nunatsiavut, succession, rétablissement.

Abstract

Forest fires are the predominant natural disturbance driving ecosystem dynamics in the boreal forest. As such, fire affects all components of these ecosystems, including vegetation cover, soil condition, wildlife and human populations. As ongoing climate change is expected to have complex impacts on forest fires, notably increasing their frequency, intensity and magnitude, understanding these effects is crucial to predicting the future of ecosystems and their impacts on local human communities. This is especially true in areas where studies on forest and fire ecology have been scarce, as in Nunatsiavut, the Inuit region of northern Labrador, Canada, encompassing coastal mountainous zones. Furthermore, while Western science can help develop this understanding, the Indigenous Knowledge of populations that have always coexisted with fire, is also key to understand fire and its impacts. In this context, semi-structured interviews were conducted in two Inuit communities (Nain and Postville, Nunatsiavut) to document local Inuit Knowledge of fire and its impacts. To complement Inuit Knowledge, ecological field studies were also conducted. As part of this thesis three regenerating forest fire sites were studied to clarify how ground vegetation communities regenerate after fire in the region, and how environmental and biotic variables affect the responses. As key outcomes, this study showed that wood harvesting, followed by concomitant activities such as hunting and berry harvesting, dominated Inuit use of previously burnt sites. Inuit use and relationship with forest fires differed in the two studied communities, the more southern community of Postville had a closer relationship with fires than Nain, notably due to differences in the size of fires and their distance from the communities, as well as different levels of pre-fire landscape heterogeneity. This study also showed that the re-establishment patterns of ground vegetation communities after fire in coastal Nunatsiavut mostly follows those observed in southeast and western Labrador, which included community switches in moss species and lichens; however there were unexpected negative impacts of fire on *Vaccinium angustifolium*, which requires further investigation.

Keywords: Forest Fires, Ground Vegetation, Inuit Knowledge, Nunatsiavut, Succession, Recovery

Table of Content

Tables

Figures

Abbreviations and Acronyms

BRB. Beaver River Burn

ERT. Electrical Resistivity Tomography

IK. Inuit Knowledge

N#. Knowledge holder from Nain (See Appendix 2)

P#. Knowledge holder from Postville (See Appendix 2)

RDA. Redundancy Analysis

TBB. Tikkoatokak Bay Burn

WBB. Webb Bay Burn

Acknowledgments

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Chapter 1 – General Introduction and Foreword

1.1 Contextual Setting

In the context of climate change, the study of ecosystem dynamics is a crucial issue. Arctic and Subarctic territories, including Nunatsiavut, already experience the effects of a warming climate, which will intensify (Allard and Lemay, 2012). The impacts of this warming on Arctic ecosystems are complex, affecting simultaneously biotic, abiotic and social components of the system, from species distribution to human infrastructure and food sources, as well as permafrost dynamics and snow cover (Chapin et al., 2008).

In the boreal forest, fire is a significant large-scale natural disturbance driving ecosystem dynamics (EWSG, 1995a; Kelsall et al., 1977). This is especially true in the context of the northern coast of Labrador, where other large disturbances characteristic of the boreal forest, mainly insect outbreaks and forestry, currently have a relatively minor importance (NL Department of Fisheries and Land Resources and Nunatsiavut Government, 2017). Fire is of special interest as frequency and intensity changes are to be expected, due to the susceptibility of this disturbance to climatic conditions (Tchebakova et al., 2009).

The effects of fires in the forest-tundra and lichen woodland zones of the boreal forest affect many components of the ecosystem. First, fire affects vegetation. This effect can vary greatly depending on factors such as topography, climate, latitude, pre-fire vegetation and fire severity (Girard et al., 2008; Johnstone and Chapin, 2006; Kelsall et al., 1977; Lavoie and Sirois, 1998; Sirois and Payette, 1991). The post-fire vegetation does not always recover to pre-fire composition, and hence fire can have long-term effects on vegetation communities, mostly by impairing tree re-establishment (Sirois and Payette, 1991). For example, thinning of the forest cover in the north of the boreal forests or forest tundra, following fire, has been linked to shorter return intervals (Girard et al., 2008), high fire intensity (affecting spruce seed survival; Lavoie and Sirois, 1998), or low fire intensity (retention of a deeper organic layer affecting germination and growth; Johnstone and Chapin, 2006). Overall, post-fire spruce forest recovery depends on the rapid establishment of seedlings after the disturbance, and is thus vulnerable to many factors (Sirois and Payette, 1988). More precisely for the coastal region of northern Labrador, frequent forest fires have been associated with the change of forested stands to areas dominated by shrubs, mostly alder (*Alnus* spp.), dwarf birch (*Betula glandulosa)* and Labrador tea (*Rhododendron groenlandicum*; ESWG, 1995a). However, while these shrubs negatively affect the return of forest species, they might represent a longer successional stage rather than a permanent change (Brehaut and Brown, 2020).

As for climate change, its influence may result in a lack of post-fire tree re-establishment (Tchebakova et al., 2009), further expansion of shrubs (Myers-Smith et al., 2011), increased permafrost thaw (Loranty and Goetz, 2012) and increased fire frequency (Flannigan et al., 2009). Although uncertain and dependent on multiple factors, positive feedback loops can also stem from these relationships. For example, permafrost thaw favours shrub growth, which could influence albedo and snow accumulation, increasing permafrost thaw (Loranty and Goetz, 2012).

The complex dynamics between fire, vegetation and permafrost also has great importance to northern Indigenous populations. Indeed, fire can represent both a danger to the communities, as well as an essential factor for the renewal of various resources (Chapin et al., 2008; Natcher, 2004), that may lead to future variations in availability. For the Nunatsiavut Inuit, firewood is the most important resource harvested from burns. Indeed, dead standing burnt wood is particularly interesting as it is already dry (Lemus-Lauzon, 2016), and many Inuit rely on the dead wood for heating. Across North America, an important component of the relation between numerous Indigenous peoples and fire has been the intentional burning of the land (Stewart, 2009). However, intentional large-scale fires have not been used by Inuit for burnt wood production, possibly because of negative impacts on caribou though localized use of fire to control vegetation has been reported in Makkovik (a coastal Nunatsiavut community located close to Postville; Oberndorfer, 2016)

Another possible impact of the dynamic of fire, vegetation and permafrost on Nunatsiavut Inuit, is that shrub expansion could affect food resources, by reducing the abundance of lichens used as forage by caribou through an increase in shade and litter production (Elmendorf et al., 2012).

Caribou are an essential historical component of the Inuk diet, currently threatened and under a hunting ban (Borish et al., 2021). If Inuit and other Labrador inhabitants are affected by the dynamics of their ecosystem, they are a factor affecting it too. Through localized activities on the burns such as wood harvesting (Lemus-Lauzon, 2016) or wider land management activities such as fire suppression (NL Department of Fisheries and Land Resources and Nunatsiavut Government, 2017). The multiple interactions between fires, permafrost, vegetation, local communities and climate make predicting the evolution of northern ecosystems particularly difficult and illustrate the necessity of studying these factors in combination.

It is in this context that the research project ‘Food, Fire and Ice: Integrating local knowledge, plant response and cryosphere dynamic to predict future food and fuel’ was developed. Comprised of researchers and graduate students from various disciplines, the project aims to build an understanding of the impacts of forest fires in coastal Nunatsiavut across the ecosystems, from ground conditions and permafrost, up to shrubs, trees, wildlife and people.

Studies focusing on some of these components have already been published, on permafrost and soil (Wang, 2020), as well as arboreal regeneration (Brehaut and Brown, 2020; Brehaut, 2021). This study contributes a number of elements to this project. Chapter 3 (Burnt Woods in Nunatsiavut: Inuit Knowledge and relationship with forest fires) documents Inuit Knowledge of forest fires and their impacts. It adds to knowledge gathered through the fieldwork components of the research project in some subjects (such as forest regeneration), but also focuses on aspects not covered by fieldwork such as the effects of forest fires on fauna. This chapter also studies the relationship between fire and people in Nunatsiavut. Finally, Chapter 4 focuses on ground vegetation, and thus covers one of the ecosystem levels between the work of Wang (2020) on soil and Brehaut (2021) on trees.

1.2 Study Area

1.2.1 Region

This study is based in Nunatsiavut, the self-governed Inuit region of Northern Labrador, Canada (Figure 1). The region is home to 2560 people as of the 2016 census (Statistics Canada, 2018), living in five communities: Nain, Hopedale, Postville, Makkovik and Rigolet (Figure 1-1). The Innu community of Natuashish, although located on the coast between the communities of Nain and Hopedale, is not part of Nunatsiavut. Most of the population of Nunatsiavut identifies as Inuit (1785 or 70%) or of Inuit mixed ancestry (505 or 20%). Inuktitut is spoken by ~19% of the population, second to English (99.8%; Statistics Canada, 2018). This region is characterized by significant ecological gradients from north to south and west to east (Figure1- 2; ESWG, 1995a). In the interior, south of the rocky tundra of the Torngat Mountains in the North, is the ecoregion of the Kingurutik-Fraser Rivers, where the southern continental tundra and bare rock

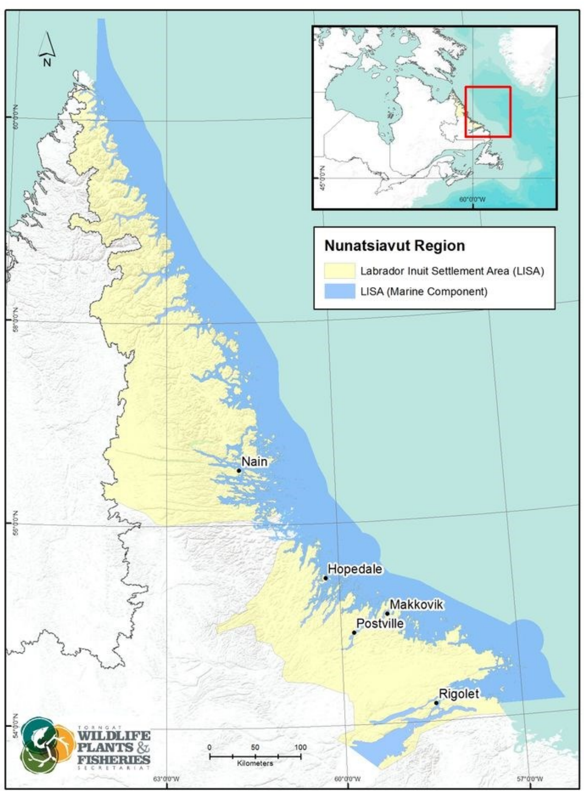

Figure 1-1 Map of the region of Nunatsiavut, including the five Inuit communities (Torngat Secretariat, 2015)

occupy the heights, and transition to birch/willow thickets and a very open spruce forest in some areas. To the south, the Smallwood Reservoir-Michikamau ecoregion forms part of the transition between the tundra and the closed boreal forest, with the dominance of open stands of lichen-black/white spruce woodlands. This transition continues in the mostly open stands of black spruce characteristics of the Mecatina River ecoregion. Finally, the typical boreal forest is reached in the ecoregion of Lake Melville, with closed and productive mixed stands of balsam fir, black spruce, white birch and trembling aspen (Figure 1-2, ESWG, 1995a).

From the Torngat Mountain south, the coast is occupied by the Coastal Barrens, where coastal heath dominates in the heights, and a variably closed white spruce forest is found on the sheltered valley slopes (Figure 1-2; ESWG, 1995a).

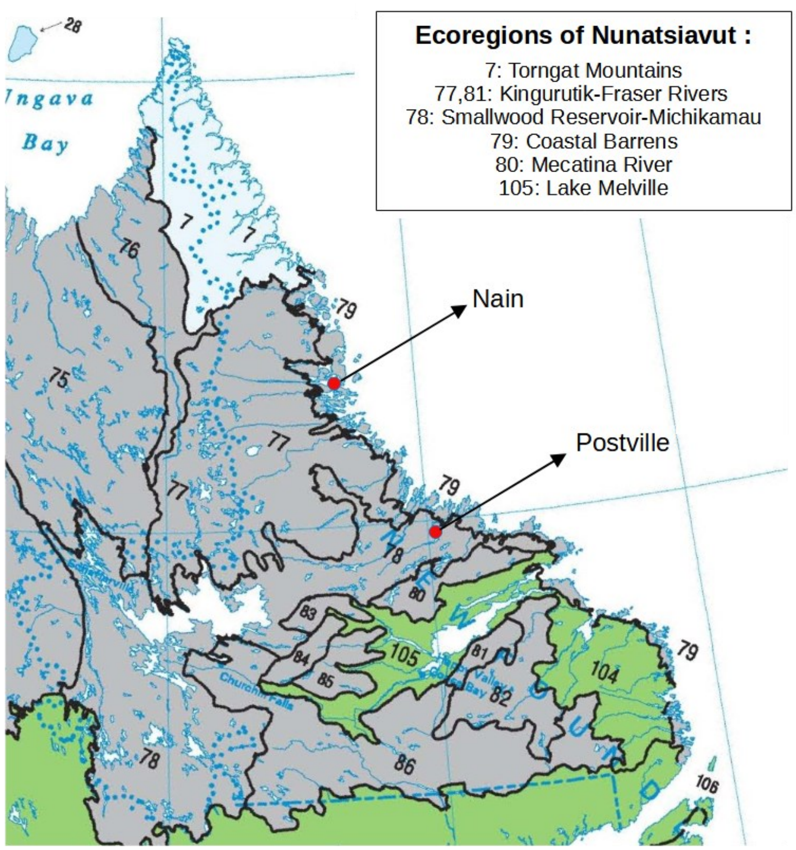

Figure 1-2 Maps of the ecoregions of Nunatsiavut, with the location of the two study communities. Adapted from ESWG, 1995b

The incidence and size of forest fires vary greatly across the region, although it is low compared with other areas of the boreal forest to the West or the South (Coops, 2018). In the ecoregions of the Kingurutik-Fraser Rivers, as well as in the coastal barrens, the fire return interval (the average time between two fires at the same location) is ~1501-5000 years. Further south, it reaches 501-1500 years in the Smallwood Reservoir-Michikamau, Mecatina River and Lake Melville Ecoregions (Coops, 2018). The location and extent of recent (1980-2016) forest fires across the region show that the interior and the North are characterized by both smaller and less frequent fires (Figure 1-3)

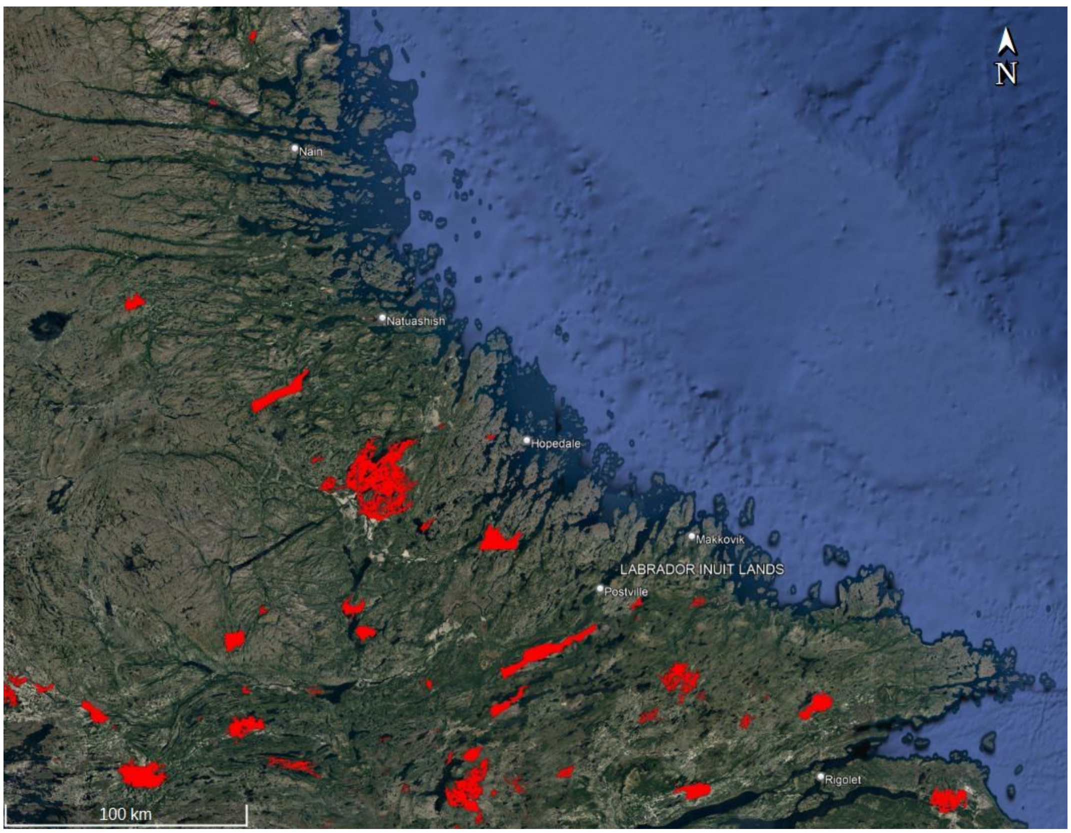

Figure 1-3 Location of forest fires (in red) in Nunatsiavut (1980-2016), in relation to Inuit Communities. Data from CFS 2021.

1.2.2 Communities

The ecoregion of the coastal barrens is where Nain, the northernmost community in Nunatsiavut and one of the two included in this study, is located. The administrative capital for the region, it is home to 1125 people (Statistics Canada, 2017a). While English is the first spoken language, Inuktitut is spoken by 35% of the mostly Inuit population. The town is relatively young, with an average age of 33 years (Statistics Canada, 2017a), significantly below the provincial average of 44 (Statistics Canada, 2017b). The town is located at the end of a hilly peninsula, separated from the Labrador Sea by a large number of islands (Figures 1-3 and Figure 1-4).

The second studied community is Postville, approximately 180 km south of Nain, in the Smallwood Reservoir-Michikamau ecoregion. A significantly smaller town, with a population of only 177 people (Statistics Canada, 2017c), it sits on the shores of Kaikopok Bay about 40 km inland from the mouth of the bay (Figure 1-5). Population is older, an average of 39.5 years old, and is mostly Inuit, although Inuktitut is not commonly spoken (no speakers reported in the 2016 census; Statistics Canada, 2017c).

Figure 1-4 Location of forest fires (in red) near the community of Nain, with identification of the two study sites: the Tikkoatokak Bay Burn (TBB) (left) and the Webb Bay Burn (WBB) (right). Data from CFS 2021.

1.2.3 Forest Fire Sites

Tikkoatokak Bay Burn (TBB)

Tikkoatokak is a saltwater bay located northwest from the community of Nain, and extending inland for about 40 km, to the outlet of Kingurutik Lake. The Tikkoatokak Bay Burn, also called the Burn Woods locally, is located on the north side of the bay, about 20 km from its mouth (Figure 1-4). It burnt in the summer of 2001, and was thus inventoried approximately 17 years after. It has a surface area of ~3.5 km^2. Pre-fire stand density, as measured in the unburnt forest, was 2.38 stems/m^2 and *Picea mariana* was the dominant species, accompanied by *Larix laricina* and *Abies balsamea* (Brehaut and Brown, 2020). Dendrochronology analyses showed this site had the youngest forest of the three, with a mean tree age of 112 years. The survey site was located on the eastern end burn.

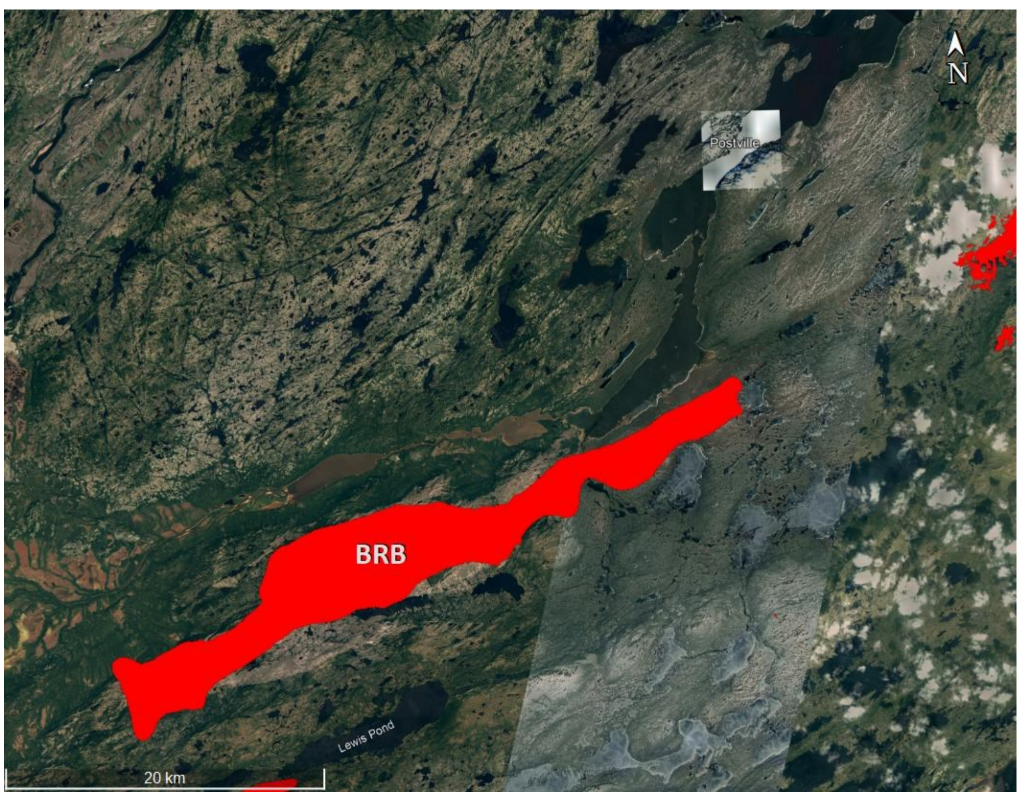

Figure 1-5 Location of forest fires (in red) near the community of Postville, with identification of the study site, the Beaver River Burn. Data from CFS 2021.

Webb Bay Burn (WBB)

The burn in Webb Bay, also called Sandy Point, is located on a peninsula that forms the south side of the bay, close to its western end. The bay is open to the North and the South at its eastern end, but is separated from the Labrador Sea by the vast South Aulatsivik Island (Figure 1-4). The fire there is the smallest and youngest of the three studied, at only 0.5km^2 and 14 years old at the time of inventory, having burnt in 2004. Its forest was the less dense at 0.86 stems/m^2, and was composed of mainly of *P. glauca,* accompanied by *L. laricina (*Brehaut and Brown, 2020). It was, however, the oldest forest at an average age of 227 years old (Brehaut and Brown, 2020). Transects were located along the western border of the burn.

Beaver River Burn (BRB)

The Beaver River Burn, simply known as 'the fire up the bay' in Postville, is respectively tens and hundreds of times larger than the Tikkoatokak and Webb Bay burns, at around 150 km^2 (Figure 1-5). It starts on the south side of Kaikopok Bay, by the mouth of the Beaver River, less than 15 km from Postville. It follows the bay to its end, and extends another 30 km inland, to the southwest. Pre-fire stand density at the site of surveys is the greatest of the three sites (2.48 stems/km^2), while stand age is between both Nain sites (170 years +- 43; Brehaut and Brown, 2020). Tree species present in the residual forest were *P. mariana* and *A. balsamea* (Brehaut and Brown, 2020). The survey site was located on the southeast side of a residual forest island near the mouth of the Beaver River.

1.3 Methods

1.3.1 Site Selection

Several factors affected the selection of study sites. Burnt sites needed to be from fairly recent forest fires where the forest had not grown back, to represent regenerating sites. They needed to be accessible by boat during the summer and snowmobile in the winter for the fieldwork to be conducted. Thus, they needed to be located close to communities. The identification of potential sites was based on previous knowledge of members of the research team (who have been active in the region for more than 15 years) as well as on a preliminary visit to the communities in 2017.

In the burns, sites and transects needed to be suitable for all aspects of the larger research project, and the main limiting factor was the requirements of the Electrical Resistivity Tomography (ERT) surveys, used for permafrost investigation (Wang, 2020). The weight of the equipment limited the distance inside the burns that could be travelled and required transects to be located relatively close to the shore. It also restrained the length of the survey transects: while the full length could be attained in WBB and TBB, the more complex geography of the burn up the bay from Postville (BRB), leads to a longer distance to get to the transects location, and only half the cabling could be transported, restricting the transects to 40 m.

1.3.2 Inuit Knowledge and Interviews (Chapter 3)

1.3.1.1 Preliminary Meetings

Two meetings were held at the end of March 2018, one in each community, to present the project to community members, and to gather comments and concerns ahead of the start of the research (ITK and NRI, 2007). The comments gathered allowed readjustment of the study, mostly the interview plan. Notably, new areas of enquiry were added or emphasized (patterns of harvesting and rules of territory sharing, trapping and hunting, etc.).

1.3.1.2 Interviews

Semi-structured individual interviews were the main methodological tool used in this study to record Inuit knowledge, as they allow for participants to partially control the content of the interviews (Huntington, 1998). They avoid restricting the interviews to areas of enquiries identified by the researcher prior to fieldwork, and for local interest and priorities to be explored (Huntington, 1998). If requested, couples were interviewed together.

The selection of participants was based on a mixed selection method. First with a purposive strategy where potential knowledge holders familiar with or interested in forest fires were identified from experience and previous studies by members of the research team as well as with the help of community members and local research assistants. These participants then served as starting points for snowball sampling, identifying other relevant participants for the researcher to contact (Bernard, 2000).

Semi-structured interviews were held at the location most convenient to knowledge holders (either their home, workplace or the accommodations of the researchers), and conducted according to the interview guide in Appendix 1. They were conducted in English or in Inuktitut, with the help of a local translator.

Printed laminated maps and dry erase markers where available to participants, to guide the discussions and help identify locations described in the discussions.

No interview was held before obtaining prior and informed consent from the participants. Consent forms were explained to participants before the interview, and they were given as much time as they required to read and review. For participants preferring oral consent and for Inuktitut speakers, the form was read to the participant by the interviewer or the interpreter. Interviews were recorded if the participant agreed. Interviews were anonymous unless participants indicated on the form they agreed to the use of their name in publications and presentations. Participants were offered a financial compensation (ITK and NRI, 2007) of 25$/hour.

This study was granted an ethics certificate for research involving humans by the arts and sciences research ethics board of the *Université de Montréal* (*Comité d'éthique de la recherche en arts et en sciences* ; CERAS-2017-18-251-D).

1.3.1.3 Review meetings

Follow-up discussions were held in both communities to review the preliminary analyses of the interview data. They allowed knowledge holders to comment, correct, or add information to be incorporated back into the analyses. Holding group reviews allows for participants to discuss and encourage each other, and can minimize the role of the researcher in analyses and in resolving potentially conflicting observations (Huntington, 1998; 2000)

Three meetings were held, at times most convenient for the participants, one in Nain in the Nunatsiavut Government building's main boardroom, and two in Postville in the researcher's accommodations. A summary of the results of preliminary analyses was presented by the researcher, and followed by a discussion with participants.

A second consent form was required for participants, and meetings were recorded only if all participants present agreed. Food and beverages (tea and coffee) were offered to participants during the review meetings.

1.3.3 Vegetation Inventories (Chapter 4)

Inventories were conducted at one site for each burn. Two transects of 40 m in BRB or 80 m in WBB and TBB were established at each site, extending across the forest border with one half in the burn and the other in the residual forest. Transect length was constrained by the logistics of carrying ERT equipment to the different study sites. 40 plots of $1m^2$ were inventoried on each transects with the help of metre sticks, 20 plots in the burn and 20 plots in the forest. They were located on alternating sides of the transect line. In the 80m transects of WBB and TBB, plots were spaced one metre apart. Percent cover was estimated for shrubs, ground vegetation, mosses and lichens in 5% classes and to the percent between 0 and 10%. Specimens were identified at the species level, with a few exceptions such as lichens that were identified at the genus level.

1.3.4 Statistical Analyses

The main statistical tool used for the analyses of ground vegetation community structure was the transformation based redundancy analysis (TB-RDA). Canonical ordination methods such as the RDA allows for the representation of sites or plots in a multivariate space according to community composition data, where each variable (here, each species) is one dimension (Borcard et al., 2011). Redundancy analyses are an extension of the multiple regression and allow for the examination of the role of a set of explanatory variables on the ordination of sites and to test the significance of these relations through permutation testing (Borcard et al., 2011). In the context of community composition data, the use of the Hellinger transformation and the RDA allows for an ordination that focuses on higher-level community differences, preserving the weight of abundant species without overestimating the importance of rare taxa (Legendre and Legendre, 2012; Legendre and Gallagher, 2001). Analyses produced are also more robust to small sample sizes that can lead to issues with rare species (Borcard et al., 2011) and have been used in similar studies (Boiffin et al., 2015). Preliminary analyses were conducted with another commonly used distance appropriate for community analyses (Bray-Curtis). However, they explained a smaller portion of variance, and the distance might not necessarily be well suited to produce triplots for interpretation (Legendre and Gallagher, 2001). For general analyses, the specific effect of the sites was partialed out (Borcard et al., 2011).

Explanatory variables used were the fire status of the plot (categorical, burnt or not), Soil Temperature (ST, °C), Soil Moisture (SM, vol cm^3/cm^3), Organic Layer Depth (OLD, cm) as well as the cover of taller shrub species. Shrub species considered as explanatory variables included 'Tall Shrub' species (~50 cm or greater, Myers-Smith et al., 2015) as well as two species of shorter shrubs still found to have localized dominance in plots (*Rhododendron groenlandicum* and *Betula glandulosa*). In the regenerating burns and in the absence of significant tree cover (Brehaut and Brown, 2020), taller shrubs where the canopy-forming species at the sites. Smaller 'Low Shrubs' as well as 'Dwarf Shrubs' (less than ~20 cm; Myers-Smith et al., 2015) were considered with ground vegetation.

Chapter 2 – Objectives and Hypotheses

2.1 Objectives

Chapter 3: Document local Inuit Knowledge of the disturbance and its impact on life in two communities: Nain and Postville.

Chapter 4: Clarify how ground vegetation communities regenerate after fire in coastal Nunatsiavut and how environmental variables affect this response.

2.2 Hypotheses and predictions

Chapter 3: Inuit relationship with fire will vary amongst individuals, according to their actual use of burnt sites. Wood harvesting will be the most important activity in burns, being relatively specific to those sites and with high socio-economic significance, followed by hunting and berry picking. Usefulness of fires will lead to a more favourable attitude towards the disturbance, outweighing the possible risks to villages and cabins.

Chapter 4: Ground vegetation communities in burnt and unburnt sections of the study transects will be similar with some exceptions, including an increased presence of open habitat species such as *Chamaenerion angustifolium* and some *Carex* spp. in the burnt sections. However, mosses and, above all, lichens communities will not have recovered, and composition will differ between burnt and unburnt sections.

Chapter 3 – Burnt Woods in Nunatsiavut: Inuit Knowledge and Relationship With Forest Fires

Destination publication: Arctic Science

Status: In preparation

Authors: Dwyer-Samuel, Frédéric ; Luise Hermanutz and Alain Cuerrier

3.1 Introduction

Fire is an important large-scale natural disturbance in the boreal forest, and an important driver of ecosystem dynamics (Ecological Stratification Working Group [ESWG], 1995; Kelsall et al., 1977). Fire has significant impacts, not only on the vegetation cover, but also on duff and soil conditions, and biodiversity (Rowe and Scotter, 1973; Brehaut and Brown, 2020). Indigenous groups inhabiting ecosystems impacted by fire regimes have also developed important relationships with fires, using resources they provide and landscapes created, and often using fire to modify their environment (Chapin et al., 2008; Natcher, 2004; Pyne, 2007). Although Inuit might not be readily associated with forests, all current communities in Nunatsiavut (the Inuit region in northern Labrador) are located in the Taiga Shield ecozone, below the latitudinal treeline (ESWG, 1995a).

The relationship of *Nunatsiavummiut* (people living in Nunatsiavut) with fire has been explored in a limited number of publications. Most notably, Oberndorfer (2016, 2020) studied the historical Indigenous Inuit's relationship with fire (in both natural and human-made settings) in Labrador, as well as current relationships within the community of Makkovik. Oberndorfer has shown that the relationship between taiga fires and Inuit revolves predominantly around the harvest of burnt wood for firewood after natural fires. She also documented harvest of trembling aspen (*Populus tremuloides*) in regenerating burns for carving material; the use of controlled burns around cabins; the historical use of fires to direct caribou migrations for hunting; and the potential negative impacts of fire, notably the danger it could pose to communities and cabins. Although focusing on travel, Riedlsperger (2014) also identified the importance of burns for firewood harvesting in Postville and Makkovik, and highlighted the susceptibility of this harvest to changing ice conditions related to climate change. Further north, in Nain, Lemus-Lauzon (2012) documented similar firewood harvesting practices. Finally, the use of a specific old forest fire site near Postville for caribou hunting was noted by Brice-Bennet (1977).

As for other indigenous groups, the close relationship between Inuit and their environment allows them to develop extensive knowledge and understanding of the ecosystem. This knowledge system, acquired through observations or passed down and shared, is called Traditional Ecological Knowledge (Huntington,2000), or simply Inuit Knowledge. If a number of studies have worked to document Inuit Knowledge, notably related to climate change (Cuerrier et al., 2015; Furgal et al., 2002) subjects such as fire or ecosystem dynamics in general have seldom been studied in Nunatsiavut, with the exception of the studies cited above. As the burns are actively visited and used by *Nunatsiavummiut* (see paragraph above), it is likely that their knowledge of the disturbance and its impacts is significant.

Thus, this paper aims to document Inuit Knowledge of forest fires in Nunatsiavut, and to examine more closely the current relationship with burnt landscapes and their impacts on life in two Nunatsiavut communities, Nain and Postville.

3.2 Methods

3.2.1 Study Location

Two communities were visited for this study. The larger of the two, Nain, is the northernmost permanent community in Nunatsiavut, as well as the administrative capital for the regional government (Nunatsiavut Government). It is home to 1125 people (Statistics Canada, 2017a) and is located in the Coastal Barrens and Kingurutik-Fraser Rivers Ecoregions (ESWG, 1995a; Figure 1-2). Forests are mostly relegated to the valleys, while shrubs and lichen tundra occupy the high points as well as the islands and the coast (ESWG, 1995a). Forest fires are rare and of a relatively small size (Figure 1-3), with a fire return interval (the average time between fires at a single location) of 1501–5000 years (Coops et al., 2018).

Postville is a smaller community (177 people; Statistics Canada, 2017c) located approximately 180 km further south (Figure 1-1). It sits in the boreal forest, in the ecoregion Smallwood Reservoir-Michikamau (ESWG, 1995a), although Coastal Barrens occupy the coastline out of Kaikopok Bay. Forests are more developed, reaching commercial size and density, and forestry operations have been active near the community (NL Department of Fisheries and Land Resources, and Nunatsiavut Government, 2017). Fires in the area are significantly larger than around Nain (Figure 1-3) and the fire return interval, although still low in comparison to many other places in boreal Canada, reaches 501-1500 years (Coops et al., 2018).

3.2.2 Engaging Target Communities

As advised by Inuit Tapiriit Kanatami (the national representational organization for Inuit in Canada) in its guide regarding research relationships with communities (ITK and NRI, 2007), consultation prior to research commencement was carried out in each community. A meeting was held in each community in 2018 (Nain—March 26; Postville—March 28), to discuss the project with community members, and to gather comments and concerns about the proposed study. The comments gathered were used to refine the study, adding new areas of enquiry, such as patterns of harvesting and rules of territory sharing, trapping and hunting.

3.2.3 Interviews

Forty semi-structured interviews with Inuit knowledge holders were conducted in both communities (25 in Nain, 15 in Postville) in August and September 2018. Participants were mostly men (65%) with an average age of 55 years. Most interviews were conducted individually, with the exception of five couples who chose to be interviewed together. The selection of participants was aimed at individuals holding knowledge of forest fires or experience in the burns, with a mixed selection method: potential participants were identified by community members, local research assistants, or from previous studies, and served as starting points for snowball sampling.

A research assistant was hired in each community to help contact knowledge holders and conduct interviews. In Nain, the research assistant was also the Inuktitut interpreter but no interpreter was needed in Postville

Interviews were conducted in English or Inuktitut (with the help of an interpreter) according to the participant's preference, and were held either at their home or workplace, or in the researcher's accommodation. They included a mapping section, for the localization of sites of interest and to help guide discussion. Participants were offered a compensation for their time and knowledge (ITK and NRI, 2007) of 25$/hr. Interviews were analyzed using the software NVIVO (QSR International).

The project was approved by the *Comité d'éthique de la recherche en arts et en sciences de l'Université de Montréa*l (Arts and Science Research Ethics Committee - CERAS-2017-18-251-D) and by the Nunatsiavut Government Research Advisory Committee.

3.2.3 Review Meetings

After the interviews, both communities were revisited in July and August 2019, and discussions were held following preliminary data analysis. The meetings consisted in a review of the preliminary data analysis and results, followed by a discussion allowing knowledge holders to comment, correct, or add information to be incorporated into the final results. Inuktitut-English interpretation was offered in Nain. Meetings were advertised in the community Facebook groups, and interview participants that had expressed interest in participating in follow-up meetings the year before were directly contacted (called or visited). Three meetings were held to accommodate participants, one in Nain and two in Postville. Four people attended the meeting in Nain. In Postville, the first meeting had three participants, and the second only one.

3.3 Results

3.3.1 *Nunatsiavummiut* Relationship with Fires

Residents of Postville and Nain reported four general types of activities practised in the burns: Wood harvesting, hunting and trapping, travel, and boil ups.

Wood harvesting

Firewood harvesting is, by far, the main use reported in both communities. Indeed, only one household out of the 36 that reported some activities in the burnt areas did not mention harvesting firewood, with the majority reporting it either as their only use, or only paired with other opportunistic activities, mainly hunting (N5, P9[1], see below).

> "I don't do anything than cut trees, in the burn areas. I think people just goes wooding and haul out their wood" N2, Nain

Wood is a major source of heat for households in Nunatsiavut, with 55% of residents relying on wood as the first source of heating (Nunatsiavut Government, 2016). Wood is often preferred over oil and electricity, for several reasons: 1) It is considered cheaper than the alternatives by most (P5, N6, N7, N8, N9, N10), even factoring in the costs of fuel and maintenance for snowmobiles and other equipment needed for harvesting the wood; 2) It provides heat that is more appreciated, and considered to be "better" (N11), "more comfortable" (P5) and "less dry" (N6, N5). The heat produced also last longer than with oil, where cold comes back quickly when the furnaces are turned off or the power is lost (N7, N1, N5); 3) The act of wood gathering or "wooding" is also valued as an important cultural activity. Learning to go wooding in the burnt forest has been described in Postville as an important part of becoming an adult, associated with a kind of "social obligation" for boys and young men (P9) and a source of pride (P1). Families taking boys wooding is also important in Nain, though not as focused on burn woods (N12); and 4) Wooding is also a good way to exercise (P9, N13, P10, P11) and a family activity (N12, P2).

Using other sources of heat was once limited to outsiders of the communities (P9), or associated with laziness (P10), although it is now more common and accepted. Oil and electricity, in a more limited capacity, are generally chosen for their convenience as they provide quick and automatic heating that doesn't need to be tended to, or preferred by people without the means or the time to go wooding (P9, N4, P3).

> "It's a lot better heat too, the wood. Than the oil. The oil, when it cuts off you can feel the cold, but with the wood it's steady, steady heat" N13, Nain

1 Key knowledge holders are identified in the text by the initial of their community (P for Postville, N for Nain) and a number. Names of participants who agreed to be named are listed in Appendix 2.

In terms of wood quality, not all sources are valued equally. Green wood (trees harvested alive in the forest) is considered more "dirty" than dry wood, increasing risk of soot build ups and potential chimney fires (N6, N1). In addition, it needs to be seasoned over the summer, for use in the subsequent winter (P1, N7, N13). However, it is still used due to its abundance and proximity and can be used mixed with dry wood to increase burn time, as dry wood burns too fast for some people (N14, P12).

Dry wood is thus a valued commodity, and though "natural dry" wood (standing dead trees, killed by sickness or porcupines, for example), is also harvested by most, especially in early winter before sea ice travels becomes possible (P5), or due to the longer travel required to reach the burns (N1, P13), the process of roaming around searching for the dead sticks can be time consuming (N6).

> "Before that burnt, I used to go for natural dry. But you need to look, right? But now you just go to burn wood and cut whatever you want" N6, Nain

Burnt wood, however, provide a convenient and reliable source of dry wood in a single location (N6, P4). This leads some residents from both communities to talk about how it would be positive for a fire to burn a patch of forest conveniently distanced from their own town, either to make it more accessible or to provide for a continuous supply once the currently harvested burns grow too old (P9, N15).

In Postville, in the burn known as Gulu, dating from 1967, regeneration is variable, but new patches of deciduous trees can be found (mostly poplar—*Populus tremuloides*—and birch—*Betula papyrifera;* P8, P10, P3). Birch is harvested as firewood and sought after as it burns slowly yielding a lot of heat compared to other species. It is only harvested green, rotting quickly after it dies (P9, P4, P6, P11).

Firewood is currently harvested in winter and spring, using a snowmobile and a *Kamutik,* a type of wooden sled that can either be flat to haul sticks (tree trunks de-limbed but whole) or have a box to bring logs cut up on-site. Harvesting happens at the burns throughout the season, when ice is reliable for travel (as early as January; P6, N1) until it starts melting, usually in April or May (DD, P11, P8). Springtime, with long days and warmer temperatures, is generally the prime time for wooding at the burns (P9, N11, P7). There are three burns currently harvested for dry wood by community members in Nain: Tikkoatokak, generally referred to as the “Burn Woods” is used by most (N16, N14, N7); Sandy Point, in Webb Bay, mostly harvested by the Webb families (N5, N13); and Frank’s Brook, near Voisey’s bay (N16). In Postville, the burn up the bay (sometimes referred to as Beaver River Burn in this thesis) is the only one currently harvested, as burnt trees in the older site of Gulu have rotted and fallen (P8, P5).

Prescriptive customs regarding uses of wood-cutting paths and areas were described in Postville. Areas and trails are generally only shared within close family groups, or sometime friends, and cutting wood in somebody else trail is viewed very negatively (P9, P1, P4). Snowmobile harvesting trails lead into the burnt woods from the shore or branch off from the main trail to Goose Bay (that crosses through the fire up the bay). When starting a trail, it is acceptable to follow someone else’s trail for a short distance before branching out, generally a kilometre or two (P9), but it is important to stay away from the area where the person who established the trail is harvesting (P9). Sharing trails still happens, though it is considered necessary to ask for permission (P9, P1, P11).

> “Certainly there’s still sharing happens, and lots of times if you are reassured that you have your wood people will say ‘you can cut in my path’ or ‘I’ll haul you a few loads’ but if you have no wood at the time, and obviously the urgency is there to get your wood out and to not have other people access your wood path, right.” P1, Postville

On the contrary, trails in the burnt areas near Nain are used communally, with no apparent restrictions (N3, N13, N11, N6). Some of the harvesters interviewed mentioned knowing of people who are protective of their trail, but it is viewed negatively (N5, N15).

> “Once you make the path, everybody uses it. But it’s the worst thing. To make the path when the powder, all the powdery snow. You get stuck quite a bit. But then you can use that path all winter once you gets it made.” N13, Nain

Though firewood is by far the main use of wood harvested in the burnt areas, a marginal use of burnt wood as lumber has been reported in Postville (P7 and P8), notably for repairing a dock, where wood quality is not important. One person in Postville also reported harvesting burnt wood for carvings (P12).

Hunting/Trapping

Hunting is a common activity in the burn, reported in half the interviews (20). The animals most commonly hunted in the burns are partridge species; white partridge (ptarmigan, *Lagopus* spp.) and spruce partridge (*Canachites canadensis)* (N17, P10, P5, N7, P14, N1). The other hunted species mentioned were food species such as moose (*Alces alces*; P1), caribou (*Rangifer tarandu*; P13), geese (*Branta canadensis;* BM, P12), porcupine (*Erethizon dorsatum*; N5), and hare (L*epus spp;* P4), as well as animals trapped for their fur: lynx (*Lynx canadensis*; P13), marten (*Martes americana),* fox (*Vulpes spp*.) and mink (*Neogale vison ;* P12).

Hunting in the burn is often an opportunistic activity, concomitant to wood harvesting. Patterns of use, however, differ between communities. In Nain, only two hunters reported specific hunting trips to the burns (P10, N7) although opportunistic hunting is common, whether during wood harvesting (P9, N1) or in passing during larger hunting trips (N13, N11).

> “[When] I go get firewood, I take a .22 just in case I see a partridge. You see partridges when you don’t have no gun” N10, Nain

In Postville, if hunting often goes with wooding, it is also more frequently a specific activity on the burnt woods, reported by nine hunters. Specific hunting was mentioned for partridge (P10, P9), moose (P1) and geese (P12, P1). An old burn north of town was also used for caribou hunting (P13).

Not all species hunted in the burns are species that benefit from the fire. Caribou, marten and spruce partridge are amongst the species harvested from the burns that have been known to be negatively impacted by fires (See 3.3.2 Inuit Knowledge). For these species, as well as species for which the impact of fire is ambiguous, convenience seems to be the reason for the hunt; either because hunters are passing through the burns for wood harvesting or as part of a longer hunting trip, because travel is easier through the burns than the adjacent forest (see below), or because it is easier to see animals and their tracks in the open landscape of the burns (P1, P13, P6).

However, even if access can be increased, when species are driven away in the long term by the loss of habitat or food source, hunting and trapping can be negatively affected. Notably, the forest fire up Kaikopok Bay burnt through trap lines, in an area that used to be good for marten (P13, P8).

Travel

The ease of travelling on snowmobiles is an important advantage stemming from fire, especially mentioned in Postville. Harder, wind-packed snow in the open burns is more stable and the snowmobiles sink less than in the wooded areas (P12, P9, P6, P5, P10). Long-distance travel towards Happy Valley-Goose Bay was also facilitated by the forest fire up the bay, as the removal of the forest cover allowed people to adopt a more direct route travelling up the hill rather than the previous way going up the ponds and brooks (P12). Past the recent burn, starting at Burnt Lake, the trail also runs on relatively open terrain, due to an older fire (P12).

It has been mentioned, however, that some areas of the burn up Kaikopok Bay have gotten harder to travel. As the burn ages and dead trees are harvested, the number of stumps and deadfall increases. With a snowfall now less reliable and quicker to melt than in the past, hilly and rocky areas that don't accumulate a lot of snow can become treacherous in the spring (P1, P2).

Boil Up

Boil ups are a common activity enjoyed in Nunatsiavut. It consists of "hanging out" with snacks and tea around a campfire, generally in the springtime when the weather warms up (P9). Though boil ups can be held anywhere, the abundance of easily accessible fuel as well as the proximity with popular fishing areas of both the burns in Tikkoatakok and up Kaipokok Bay make them convenient locations (P9, N13).

Negative Impacts

While the production of firewood makes forest fires important for community members, they are not without significant negative impacts. Forest fires can pose a risk for people and communities (P5, N6, N16, P6, N3). Even though firebreaks were built to protect both communities, these are not infallible (P10), and do not protect cabins and homesteads that are away from the communities (P6, N10). Furthermore, water bombers are not stationed close to the communities, and cannot be refuelled in Postville, limiting their capacity to intervene (N3). The destructive capacity of forest fires also negatively affects plants and animals (See IK section). As mentioned above, this also leads to negative impacts for hunters and trappers.

3.3.2 Inuit Knowledge

Due to their practical and cultural significance, Inuit hold extensive knowledge on forest fires and their impact in Nunatsiavut. The coverage of this knowledge, however, is affected by the patterns, notably seasonal, in Inuit use of the burnt sites. Indeed, a number of knowledge holders have not or rarely visited burns outside of winter and spring, when snow covers the ground and vegetation. In Postville, people visit the burns to pick berries in the fall, but harvesters stay close to the shore (P1). Only people heading to specific goose hunting areas travel significant distances in the burns during the snow-free seasons (P1). Other than the lack of specific activities visits to burn woods in the summer are also limited by an increase in the number of black flies (P4, N14, N3).

Fire Source

The cause for most fires identified by knowledge holders was unknown. However, when a cause can be attributed, fires are generally identified as natural, with lightning as the cause of ignition. Although several harvesters spoke about their wish for a new fire to occur within a convenient distance from communities, none confirmed intentional burns for the sake of firewood production, although there is some speculation about a small fire on Paul Island (N15). The only intentional fires described where those set to burn old grass around cabins or in communities, though it was only mentioned as a practice of the past, with current laws banning it (N5, N18, N3). One fire, near the community of Nain, was identified as accidental, caused by a boil up fire (N5).

Vegetation

By definition, forest fires affect the vegetation, burning plants and trees, and changing habitats for animals. In coastal Nunatsiavut, fires have long-term impacts on tree cover. Even the oldest fires described by knowledge holders have not yet recovered to their previous level of forest cover; for example, a fire probably dating from the beginning of the 1900s near Okak still shows more openings and smaller trees than the surrounding forest (N19), and the old fire behind Postville, that is maybe 70–80 years old (P13), is still largely open, with only patches of trees (P13, P9).

> “There’s a place here to the north of here that’s been burnt before I was born. I go there the day, hunting partridges in the winter. And the land is so barren. I go there today and I can sit on my snowmobile on a peak and look for miles on barren country. I’ve asked elderly people here, ‘Was this always barren like it is growing up since the fire?’ and they says no this was lot heavy green woods. But since the fire it’s... Yeah. There’s spots growing up here, another over there, but you can drive through. It’s not grown back how it originally was.” P13, Postville

In general, the forest growing back after fires remains sparse for a significant amount of time (P10, N18, P5, N7, P1), with shrubs such as willows (*Salix* spp.), alders (*Alnus* spp.) and Labrador tea (*Rhododendron groenlandicum*) replacing some of the forest cover (P5, P6, N10, P12). The burnt woods in Gulu stand apart from other burns in the region, with areas of forest cover re-establishing with deciduous trees, mainly poplar (*Populus tremuloides*) and birch (*Betula papyrifera*; P10, P3, P12).

Some knowledge holders have reported that burns would eventually grow back, notably because the forest is still present in the landscape (N11, N3), but the absence of known fully recovered regrowth after fire seems to indicate that this happens at least at the scale of several human generations.

In terms of ground vegetation, precise observations are limited, probably due in part to the seasonal uses of the sites. Positive impacts on berry-producing species are the main observation reported, with redberry (*Vaccinium vitis-idaea*) particularly benefiting from the burns (P10, N12, P1), followed by blueberries (*V. uliginosum* in Nain and either *V. boreale* or *V. angustifolium* in Postville) and blackberry (*Empetrum nigrum*, N7, P5, N6).

> “Ever since I was a kid, you know, we would get into the burnt land to get redberries. That’s what I can remember most vividly, and most people too. It’s probably the first vegetation that came back” P1, Postville

Fires also favours the growth of grasses (N4, DD, P10). Mosses and lichens are growing back on the burns (N3, RP, P1, N13, P12), although details on species and composition are limited. One observer did report that, in the burns north of Postville and another towards Burnt Lake, "caribou moss" (*Cladonia* spp.) was not growing back as much as another type of brown moss (P10).

Animals

Knowledge holders report a number of impacts of forest fires on animals frequenting the areas. In general, this impact is described as negative, with the fire driving wildlife temporarily away from the area (N4, P4, P5). In the long term, with burns growing back, species return (P4) even if some will not reach the same numbers as before the disturbance. The relatively small size several burns (N13), as well as the number of adjacent intact forested islands, providing habitat and cover (P13, P4), can explain the return of species that are overall negatively affected by the burns.

Observations regarding the effects of burns on animals are summarized in Table 3.1. Spruce partridge is the species most often noted as being negatively impacted by burns. Most other species negatively affected are animals trapped for their fur: marten, otter, beaver, mink (Table 3.1). Caribou can also be considered negatively impacted, with the only observation of "no change" still associated with years of absence before an eventual return (N15).

> "Years ago, my father and me used to go to Goose Lake hunting caribou. But there was a fire, and it drove the caribou from there. Last time I saw caribou there, there were thousands of them. Lots. But now they're all gone." P3, Postville

A few animals have been described as benefiting from burns, with the white partridge or ptarmigan by far the most frequently mentioned (Table 3.1). Geese and black bears are also reported as having an increased presence in the burnt areas, but there are conflicting observations. The case of the moose remains unclear, but a recent decline related to hunting pressure in Gulu (P12, P7) might have clouded the picture.

The main driver of the initial impact of forest fires on wildlife would be the disturbance itself, followed by differences in habitat and food availability driving the different rate of return to the area for different species. Food abundance has been identified as the cause for the presence of moose (new saplings; P3), white partridge (willows, berry and new growth; N7, P7, P12) and bears (berries; N19). The quality of post-fire habitat resulting in open areas but with an abundance of shrubs is also more suited for white partridges, often found in the barrens rather than the closed forest (N13). The loss of this closed forest cover is associated with the decline of marten, mink and otters (P13).

Table 3-1 Animal species reportedly impacted by fire, with the number of mentions (positive or negative) during interviews.

Local English name	Latin name	Positive	Negative	No Change*
Marten	*Martes americana*	—	**3**	—
Fox	*Vulpes vulpes, V. lagopus*	1	1	3
Beaver	*Castor canadensis*	—	**1**	—
Otter	*Lutra canadensis*	—	**2**	—
White Partridge/Ptarmigan	*Lagopus lagopus, L. muta*	**14**	—	2
Spruce Partridge	*Canachites canadensis*	1	**8**	1
Caribou	*Rangifer tarandu*	—	**2**	1
Moose	*Alces alces*	4	2	3
Goose	*Branta canadensis*	**5**	—	3
Linx	*Lynx canadensis*	1	1	**4**
Mink	*Neogale vison*	—	1	—
Porcupine	*Erethizon dorsatum*	—	2	2
Black Bear	*Ursus americanus*	**4**	1	1
Rabbit/Hare	*Lepus arcticus, L. americanus*	—	1	**3**

*Does not include absence of observations, or notes of presence without indications of abundance. Observations of a decline followed by a timely return were classified as "no change" as all species are temporarily driven away (N4, P4).

Snow Cover

Local observations of snow cover between the burns and the unburnt forest reveal consistent differences in snow density. The snow in the burnt landscapes is windblown without the shelter of trees, leading to a potentially thinner, but mostly more densely packed snow cover (P5, P3, N7, N1, N12, N3).

3.4 Discussion

3.4.1 Burnt Wood Harvesting Versus Salvage logging

An important element to note regarding burnt wood harvesting in Nunatsiavut is that it differs significantly from the practice of salvage logging, common in western forest management, both in practice and in values. Western salvage logging consists of often clear-cut harvesting of burnt wood following forest fires using heavy equipment, to salvage the wood resource before it loses its value (Lindenmayer et al., 2008). Salvage logging generally happens quickly after the disturbance (around a year) and with a high harvest intensity, averaging 80% but often above 90% (Leverkus et al., 2018). On the contrary, in Nunatsiavut burnt woods, harvesting is in itself a highly valued activity: burnt wood sought after is regarded as the main positive impact of forest fires. In practice, burnt wood harvesting is also a long-term process using only snowmobiles and chain saws. Even small burns are still harvested over a number of years (N2, N13, N5), as opposed to a single harvesting event. Small scale snowmobile harvesting is also selective, leaving smaller sticks to naturally decay and fall (P1). Furthermore, manual harvesting above the snow in winter, on snowmobiles, minimizes potential detrimental impacts on regeneration, ground vegetation, and soil that can be associated with salvage logging and heavy machinery (Lidenmayer et al., 2008).

3.4.2 Differences Between Communities

There appears to be major differences in use and general relationship with forest fires between Postville and Nain. First, the variety of activities frequently practised in the burnt woods is higher in Postville, where berry picking, hunting, trapping and firewood harvesting regularly bring community members to these areas, as well as some instances of green wood harvesting in the new growth, timber harvesting, and boil ups reported. This contrasts with Nain where firewood harvesting is often the only reason to travel to the burns, as hunting is generally opportunistic during wood harvesting and only isolated instances of berry picking, boil ups and specific hunting are reported.

The importance of burnt woods as a source of firewood is also significantly greater in Postville, where it is the main, if not the only source of wood for most interviewees, whereas sources are more diverse in Nain, including some not reported in Postville, such as the retrieval of trees cut by the mine in Voisey's Bay or the salvage of wood discarded to the municipal landfill (ES, N16). The practice of wood harvesting in the burns also has a particular place in Postville, as evidenced by its status as a kind of rite of passage to adulthood, and in the pride it instills. Talking about harvesting on the burns, one community members mentioned: "We grew up with our fathers hauling wood. Everyone in Postville loves to haul dry wood. It's one of the bigger thing people associate with our community, it's harvesting the dry wood. It's really coveted." Anonymous 1, Postville. Similarly, another answered, when asked if he harvested green wood: "No. Absolutely not. (…) I'm from a generation that all I've known is burnt wood. I have that preconceived notion that if I cut green wood it's below my status." P9, Postville.

One of the factors that can explain these differences is undoubtedly the proximity of fires and their prominence in the landscape (Figure 1-3). In Nain, the currently harvested burns are all located relatively far from the community (travel distance to both burns in Tikkoatokak and Webb Bay is around 40 km), and although their convenience for firewood still leads to their widespread use, that distance was a reason cited by some community members to explain their greater reliance on other sources of wood, at least for part of the year (ML, N16, P19). Fires are also relatively small (Figure 1-3). In contrast, both the fire up Kaikopok Bay (starting around 17 km from town) and the previous one in Gulu (right across the bay) are easily accessible from Postville. With the Gulu fire dating from 1967, a significant portion of people living in Postville have lived their whole lives with burns as an important part of their physical and cultural landscape.

The environmental differences between the two communities also need to be taken into account. In the boreal forest, the capacities of forest fires to open the forest cover, to create or maintain open areas, increasing landscape heterogeneity and establishing a mosaic of habitats are significant advantages that lead to the close relationship between indigenous groups and the disturbance, notably with intentional fires (Pyne, 2007; Lewis and Ferguson, 1988). In the relatively dense forests of the Postville area (NL Department of Fisheries and Land Resources, and Nunatsiavut Government, 2017), open areas that fires create are well-suited habitat for different animals and plants, and open travel routes through otherwise forested landscape. Nain, however, is not located in continuous boreal forest. The coastal barrens and forest tundra surrounding the community already provides fragmented forest cover and a mosaic of different open habitats (ESWG, 1995a). Sought after berries that thrive in open habitats, such as redberries, are found near the community in the hills and offshore islands without requiring travel to the burnt woods (N1). All in all, the benefits that forest fires can provide to community members in Nain are, simply put, less significant than in Postville.

Another important difference between both communities is the customs surrounding wooding paths; areas that are communal in Nain and relatively private in Postville. It has been hypothesized in Nain (N5) that the difficulty to access the burns that are far away from the community could have encouraged co-operation in creating wooding paths. However, in Postville, the longer distance people have to travel to find wood in the increasingly cut out burn was reported as strengthening the social pressure against the use of other people's trails (P1). Faced with conflicting explanation, some clues might be found in past customs. Brice-Bennet (1977), while studying land use in the Labrador Inuit communities, identifies examples of somewhat private areas in both communities, where families have reserved hunting and trapping areas surrounding cabins and houses that ensured they would be able to harvest enough to satisfy their needs. She also describes practices around sharing of other resources harvesting, such as fish netting areas in Postville, and the rationale behind these could also explain differences in wood harvesting customs. At least in Postville, netting areas where not strictly private, and although families had designated spots, they could not prevent others from setting a net nearby. This was, in part, because good netting areas where few, and yield could vary greatly. Thus, fully private netting areas would result in some families lacking access to resources such as fish and seal that were essential. These sets of customs aimed to ensure fair distribution of locally available resources (Brice-Bennet, 1977).

Parallels can possibly be drawn with the current situation of burnt wood harvesting in the two communities: in Postville, where burns are much larger, separate wooding areas would allow each family to plan harvest, investing time and energy in preparing a wood path in a zone that they know will provide them with the wood they need for the year. On the other hand, in Nain where burns are farther from the community and smaller than in Postville, the best way to ensure access to the resource for everyone would have to be the common use of areas and paths, as the burns wouldn't be large enough to divide in a sufficient number of similarly accessible and large enough harvesting areas, considering the size of the community.

This interpretation would also be consistent with the fact that practices similar to the ones reported here in Postville around the use of wood harvesting paths were reported in Makkovik, although not specifically linked to harvest of burnt woods (Oberndorfer, 2016). Makkovik is the community closest to Postville, and wood is also not considered scarce there, compared to further north (Oberndorfer, 2016)

3.4.3 Future Perspective

Two main factors have been highlighted by knowledge holders that can forecast changes in the relationship between the communities and forest fires. The first is climate change. As previously reported by Riedlsperger (2014), changes in ice conditions can impede access to wood harvesting areas. Members of both communities have observed the sea ice forming later and disappearing earlier (AL, P10, P5, P4, N11). This can be an issue, as waiting for the ideal spring days to build reserves for the year can carry the risk of an early break up leaving people without sufficient wood to heat their homes (P13). The late freeze up can also be problematic, as people might need to store more wood in the already shorter season to be able to last long enough, or increase their reliance on green or naturally dry wood (P5).

The other issue that cannot be considered separately from the first as their impacts might interact is the fact that good firewood is becoming scarce. The burnt woods near both communities are being cut down, with harvesters having to travel further and further in the burns to find firewood, as well as harvesting increasingly smaller trees (P1, N20, N18, P14). It is hard to estimate the number of years left of the harvest in the burns (P5, N3), but it is a possibility that burnt woods could be depleted of harvestable wood before new fires replenish the resource. Problematically, natural dry wood is also getting scarcer in the vicinity of Postville and Nain (N13, P9).

The level of concern over these issues is, however, variable. Some people are comforted by the fact that modern firewood harvesting practices are fairly recent (P4). Indeed, before the advent of the snowmobile, harvesting used to happen near the communities, notably by dog team, or by boat in the fall. Community members in Postville still recall harvesting from motorboats, or floating logs with the tide (P11, P4). While trying to carry wood in the speedboats that are now common in the communities is not practical, it has been done (N13). Furthermore, before the Gulu fire, there were simply no burnt woods to harvest near Postville (P4). People relied on natural dry wood, as well as green wood either by cutting and "seasoning" (leaving the wood to dry over the summer), or by stripping bark to create standing dead wood (P4).

However, the difference in forest cover between Nain and Postville is, again, important. If a strategic retreat towards green wood harvesting can be seen as sustainable in Postville, the amount of available wood in general is limited around Nain. Although climate change could potentially increase forest cover in this type of environment (Gamache and Payette, 2005), for the Nain region the opposite has been noted by community members (N5, N12) and highlighted by historical studies (Lemus-Lauzon, 2016). Proposed solutions to these issues, however, are not in short supply. Although the interviews plan for this project did not officially cover that subject, a number were still brought forward, such as an expansion of the Nain Inuit Community Government program of importing wood from Happy Valley-Goose Bay, wood plantations, high efficiency wood stoves or larger scale organized logging for firewood (N13, N12, N3).

Chapter 4 – Post-fire Ground Vegetation Communities in Harvested Burnt Woods of Coastal Nunatsiavut (Labrador)

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4.1 Introduction

In most of the boreal forest, fire is the main large-scale natural disturbance driving ecosystem dynamics (ESWG, 1995a; Kelsall et al., 1977). In these regions, forest fires are a stand-replacing disturbance, destroying a significant portion of the canopy-forming trees in addition to the understory vegetation, allowing the establishment of a new regenerating community (Franklin et al., 2007; Perron et al., 2008). Plant species have developed various strategies in response to this dynamic. *Picea mariana*, for example, relies on a fire-resistant aerial seed bank of serotinous cones (USFS, 2021). Resprouting from underground rootstock is also a popular strategy used by numerous trees and shrubs such as *Populus* spp. and *Rhododendron groenlandicum* (USFS, 2021; Schimmel and Granström, 1996). Ground vegetation also relies on similar strategies, with species using seeds and spores dispersed or preserved in the soil seed bank (many bryophytes, *Chamaenerion angustifolium*), as well as benefiting from underground rhizomes (*Deschampsia, Cornus canadensis;* USFS, 2021; Schimmel and Granström, 1996) to recolonize burnt sites.

Forest fire impacts on plant communities can vary greatly depending on a number of geographic, climatic or biotic factors, such as temperature, latitude, pre-fire vegetation and fire severity (Girard et al., 2008; Johnstone and Chapin, 2006; Kelsall et al., 1977; Lavoie and Sirois, 1998; Sirois and Payette, 1991). While post-fire vegetation generally recovers to pre-fire composition, fire can have long-term effects on the composition of vegetation communities, notably by impairing tree re-establishment (Sirois and Payette, 1991).

Studies of ecosystem disturbance dynamics, especially related to forest fire, is a crucial issue in the context of climate change. Arctic and Subarctic territories, including Nunatsiavut (Canada), are experiencing the effects of a warming climate that will likely intensify (Allard and Lemay, 2012; IPCC, 2023). Due to their relationship with climatic conditions, forest fires are particularly susceptible to the impacts of climate change. Variations are expected in terms of increased fire intensity and frequency (Tchebakova et al., 2009, Flannigan et al., 2009), as well as impacts to biotic factors such as tree re-establishment failure (Tchebakova et al., 2009) and further expansion of shrubs (Myers-Smith et al., 2011). In terms of ground vegetation, in addition to the effects of climate change on fire characteristics, it can also directly influence post-fire ground vegetation through environmental conditions, notably the climate and microclimatic conditions (Boiffin et al., 2014). Furthermore, in coastal regions of Nunatsiavut, frequent forest fires have been associated with the transition of forested stands to areas dominated by shrubs, mostly *Alnus* species, *Betula glandulosa* and *Rhododendron groenlandicum* (ESWG, 1995a). This could indicate that the resilience of Nunatsiavut forests to the existing fire regime, their capacity to return to their original conditions after burning, is already limited. A further loss of resilience associated with climate change and modified disturbance regimes could favour this (or other) alternate recovery trajectories (Johnstone et al., 2016).

While numerous studies have looked at post-fire ground vegetation regeneration across the North American boreal forest (Boiffin et al., 2015; White, 2018; Simon, 2005), research efforts have been focused on continental forests, notably in the western boreal forest or further south in the east (Whitman et al., 2018; Bernhardt et al., 2011; De Granpré et al., 1993; Day et al., 2017, etc.) In Northern Labrador, Nunatsiavut-specific studies on fire ecology are few (Oberndorfer, 2020) and, to our knowledge, no studies on post-fire ground vegetation communities have been conducted in the region.

This is an especially important research gap considering the cultural and economic importance of forests and burns for *Nunatsiavummiut* (Lemus-Lauzon, 2016; Obendorfer, 2020; Chapter 3), as well as the important differences in fire regimes and impacts across the North American boreal forest. For example, fire frequency is highly variable with return intervals ranging from 50 to more than 5000 years (500-5000 in Nunatsiavut; Coops et al., 2018). Pre-fire overstory and understory composition are also important drivers of post-fire communities (Whitman et al., 2018; Boiffin et al., 2015), with a definitive regional importance as species change across the vast range of the boreal forest.

Therefore, this study is aiming to clarify how ground vegetation communities regenerate after fire in coastal Nunatsiavut. In the context of climate change, it will also investigate the effects of climate-affected variables potentially influencing post-fire vegetation communities such as shrub cover (Myers-Smith et al., 2011; Hart and Chen, 2006), ground conditions (Whitman et al., 2018) and fire intensity (Bernhardt et al., 2011).

For the most part, plant communities response to forest fires is expected to follow the general trends observed elsewhere in the boreal forest. However, the instances of long-term loss of forest cover in the region (Chapter 3), the slow regeneration observed in similar study in southern Labrador (Foster, 1985), as well as a potential reduction in forest resilience linked to climate change (Johnstone et al., 2016), suggest that characteristic post-fire communities might subsist longer in the landscape than seen in southern or western forests.

4.2 Methods

4.2.1 Study Area

Fieldwork was conducted on the site of three forest fires in coastal Nunatsiavut in the summer of 2018. Sites were selected due to their proximity to communities, to allow access by boat and snowmobile, as well as for the fact that they were still regenerating from the fires and relatively close in age for comparison.

Two sites were located near the community of Nain (in Tikkoatokak Bay and Webb Bay), and one near Postville (up Kaikopok Bay; Figure 1-3). The main ecoregion around Nain is the Coastal Barrens (ESWG, 1995b). Climate is characterized by cool and moist summers (average temperature of 7^{o}C) and cold winters (-13.5^{o}C), for an average annual temperature of -3.5^{o}C. Forests in this ecoregion are generally relegated to moist sheltered areas, and generally characterized by variably dense (from closed canopy to open forest) white spruce dominated stands with moss understory. Open areas of coastal heath, scrubland, bogs and exposed bedrock characterize the rest of the landscape (ESWG, 1995a). Both sites are located in this ecoregion according to the Ecological Stratification Working Group (1995b),

The 2001 burn at Tikkoatokak (TBB) is located approximately 40 km northwest of Nain and covers approximately 3.5km^2. The fire in Webb Bay (WBB), 25 km north of Nain, is smaller and younger, with 0.5km^2 burnt in 2004. Pre-fire stand density was higher in TBB (2.38 stems/m^2) than WBB (0.86 stems/m^2, Brehaut and Brown, 2020). *Picea mariana* was the dominant tree species in the unburnt forest in TBB, and *P. glauca* in WBB. The dominant spruce species was accompanied by *Larix laricina and Abies balsamea in TBB, and by L. laricina and by P. mariana in WBB* (Brehaut and Brown, 2020; Brehaut, unpublished data). Dendrochronology analyses showed wide variation in stand age for the unburnt forest, with TBB younger than WBB (112 years +- 27 vs. 227 years +- 53 respectively; Brehaut and Brown, 2020). While both sites are located near the shorelines, they are separated from the ocean by a large number of islands (Figure 1-1). Both fires around Nain, as well as the Beaver River burn, were characterized as low intensity fire or light surface burn (Brehaut and Brown, 2020; Turner, 1994)

The region of Postville, further south, is in the ecoregion of the Smallwood Reservoir-Michikamau (High Subarctic Forest) (ESWG, 1995a; Roberts et al., 2006), whereas Coastal Barrens occupy the coastline. Average annual temperature is similar to Coastal Barrens (-3.5^{o}C), but with warmer summers (7^{o}C) and colder winters (-16^{o}C). Landscape is predominantly forested, mainly by open stands of lichen-spruce woodlands with an understory of feather mosses. Forests are more productive than in the Nain area, with a history of small-scale commercial forestry (NL Department of Fisheries and Land Resources and Nunatsiavut Government, 2017). The Beaver River Burn (BRB), dating from 1996, is located more than 55 km inland up Kaikopok Bay, starting less than 15 km from the community (Figure 1-1), but covering ~150 km^2. Pre-fire stand density at the site of surveys is the greatest of the three sites (2.48 stems/km^2), while stand age is between both Nain sites (170 years +- 43; Brehaut and Brown, 2020).

All sites were actively visited and used by Inuit from the nearby communities, mainly for harvesting of standing dead trees for firewood (see Chapter 3).

4.2.1 Species Inventories and Environmental Variables

Vegetation communities were characterized along transects extending from the burnt to the unburnt forest, perpendicularly to the forest border. Inventories were conducted from mid-July to mid-August 2018. Transects measured 40 m in BR and 80 m in TBB and WBB. Vegetation was assessed in 1m^2 plots using metre sticks as guides, on alternating sides of the transect. Plots were contiguous in BRB and spaced one metre apart in the 80m transects, for a total of 20 plots in the burns and 20 plots in the forest, regardless of the transect length. Vegetation transects were selected to coincide with the Electric Resistivity Tomography transects (ERT, used for permafrost detection; Wang, 2020), which required continuous measurements from the forest to the burns, rather than separate transects in the burns and the forest. Access constraints linked to the difficult transport of ERT equipment dictated the length of the transects, especially for the BR site where the long travel distance from one of the shore drop-off points restricted that length to 40 m. Percent cover (in 5% classes except for 0-10%) was estimated for shrubs, ground vegetation, mosses and lichens. Samples were collected when identification on the field was not possible. Specimens were identified at the species level, with the notable exception of lichens, which were identified at the genus level.

Cover estimates were made by the same person to control for observer bias, but a second observer was present whenever possible for note taking and confirmation of identification and to crosscheck cover estimates.

Organic layer depth was measured in each plot using a 50 cm rod, that was inserted down to the mineral soil, until resistance was felt (Wang, 2020). Estimates were confirmed in several test pits at each location.

Soil temperature and moisture were measured at three locations in each plot and averaged. Instantaneous measurements were obtained with the Delta-T HH2 Moisture meter and WET Sensor.

A number of guides and reference books were used to make or confirm identifications. Main field guides were Pope (2016), Johnson et al. (1995), Cuerrier and Hermanutz (2012), and

Blondeau et al. (2010). Main reference books were Marie-Victorin (2002), Payette (2013, 2015, 2018) and Brodo et al. (2001).

4.2.1 Analyses

Community composition analyses were conducted in R (R Core Team) and consisted in partial distance based-redundancy analyses (with community data Hellinger-transformed and a control for transects in the permutation tests) to examine the impact of fire on community composition and the effects of environmental variables potentially affected by climate change. Variation partitioning (Legendre and Legendre, 2012; Borcard et al., 2011) using the community ecology package ‘vegan’ (Oksanen et al., 2020) was also conducted to investigates the relationships between the effect of the forest fire itself on ground vegetation and those of selected environmental variables. Explanatory variables used were the fire status of the plot (burnt or not), Soil Temperature (ST) and Soil Moisture (SM) for ground conditions, Organic Layer Depth (OLD as indicator of fire severity) as well as the presence of taller shrub species. Shrub species considered as explanatory variables included ‘Tall Shrub’ species (Myers-Smith et al., 2015) as well as two species of lower shrubs found to have localized dominance in plots (*Rhododendron groenlandicum* and *Betula glandulosa*). Smaller ‘Low Shrubs’ as well as ‘Dwarf Shrubs’ were considered with ground vegetation. Variables were tested for collinearity with a correlation matrix and the variance inflation factors.

4.3 Results

4.3.1 Community Composition

The Hellinger-based RDAs of community structure constrained by fire (Burnt/Unburnt, Figure 4-1) shows that the proportion of the variance in community structure explained by this variable is low, at only 0.15, with most of the variance unexplained, although the influence of fire remains statistically significant (Figure 4-1). Species more strongly associated with burnt sites include lichens (*Cladina*), horsetails (*Equisetum sylvaticum*), mosses (*Polytrichum juniperinum*), ground plants (*Chamaenerion angustifolium, Cornus canadensis*) and shrubs (*Vaccinium uliginosum, V. boreale*). Strong negative associations with fire appear less straightforward, though species clearly negatively associated include *Empetrum nigrum and Dicranum scoparium*. However, some species whose distribution is highly influenced by factors other than

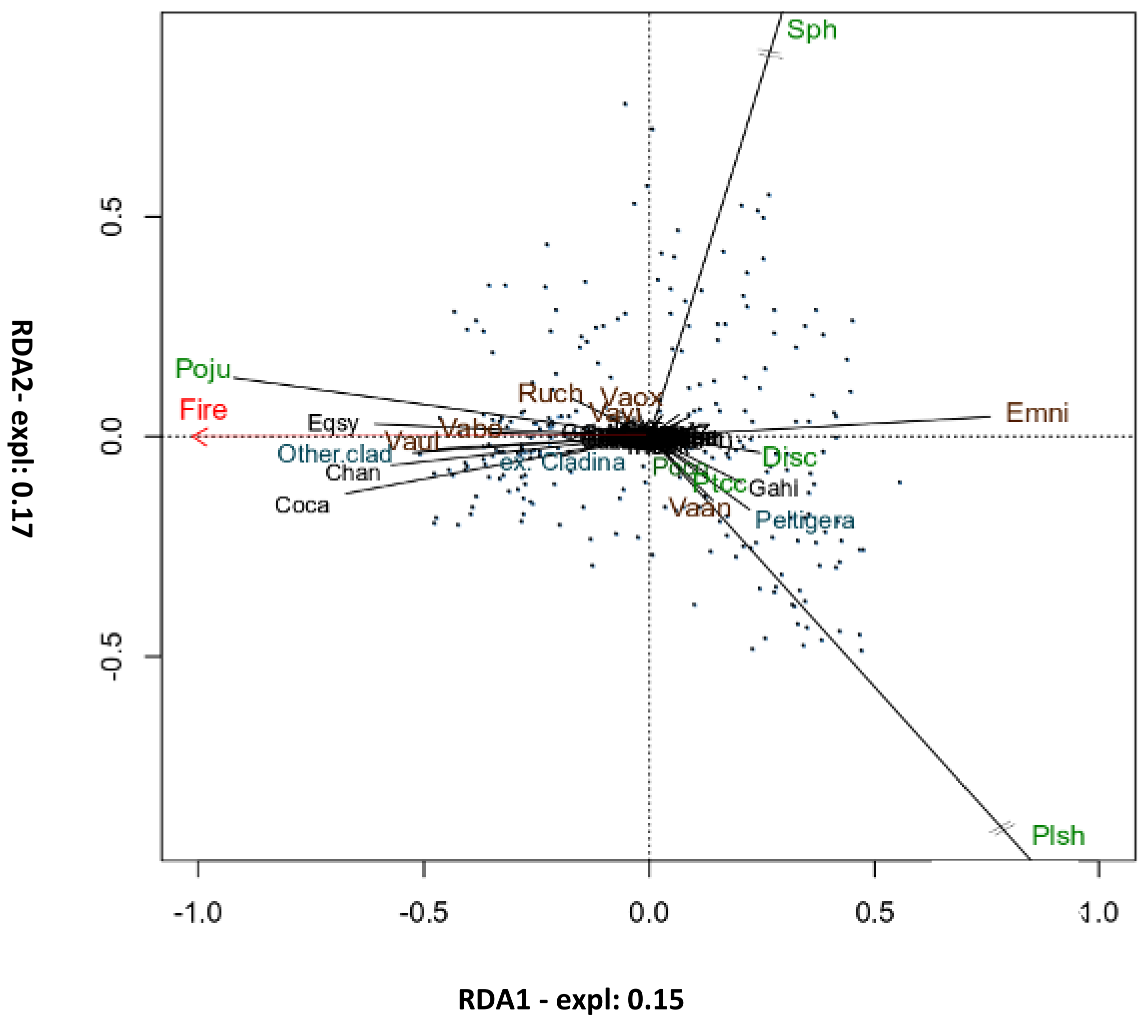

Figure 4-1 RDA of Hellinger-transformed species data with fire (burnt, unburnt) as a constraint. Plots are represented as points. Vectors are species (see list in Appendix 3), with berry-producing species in brown, lichens in blue, mosses in green and other species in black. The effect of the factor is significant (p=0.001). Adjusted R-squared: 0.12. Redundancy Analysis axes (RDA1-2).

fire (high projection on PC1) still have a large importance on the ordination along that axis, most importantly *Pleurozium schreberi* and Sphagnum species. Most other mosses are also slightly associated with the unburnt plots, with the exception of *Aulacomnium palustre and P. juniperinum*. These trends are also discernible in average cover and differences between burnt and forest plots for most common species (Figure 4-2).

With the importance of moss species on the ordination along the fire-constrained axis, as well as the large numbers of species associated with the forests (Figure 4-1), and their important cover (Figure 4-2), the switch from pre-fire moss communities characterized by either *Sphagnum* or *Pleurozium* to post-fire communities characterized by *Polytrichum* is the most characteristic impact of fires on ground vegetation detected (Figures 4-1, 4-2).

The majority of berry-producing species are associated with the burns, most importantly blueberry species *Vaccinium boreale* and *V. uliginosum*, and to a lesser extent *Rubus chamaemorus* and *V. vitis-idaea*. In addition to *Empetrum nigrum* mentioned above, *V. angustifolium* is also associated with the unburnt forest. Graminoids are either somewhat associated with post-fire communities or mostly independent, except for *Carex bigelowii*, which was associated with the forest (Figure 4-1).

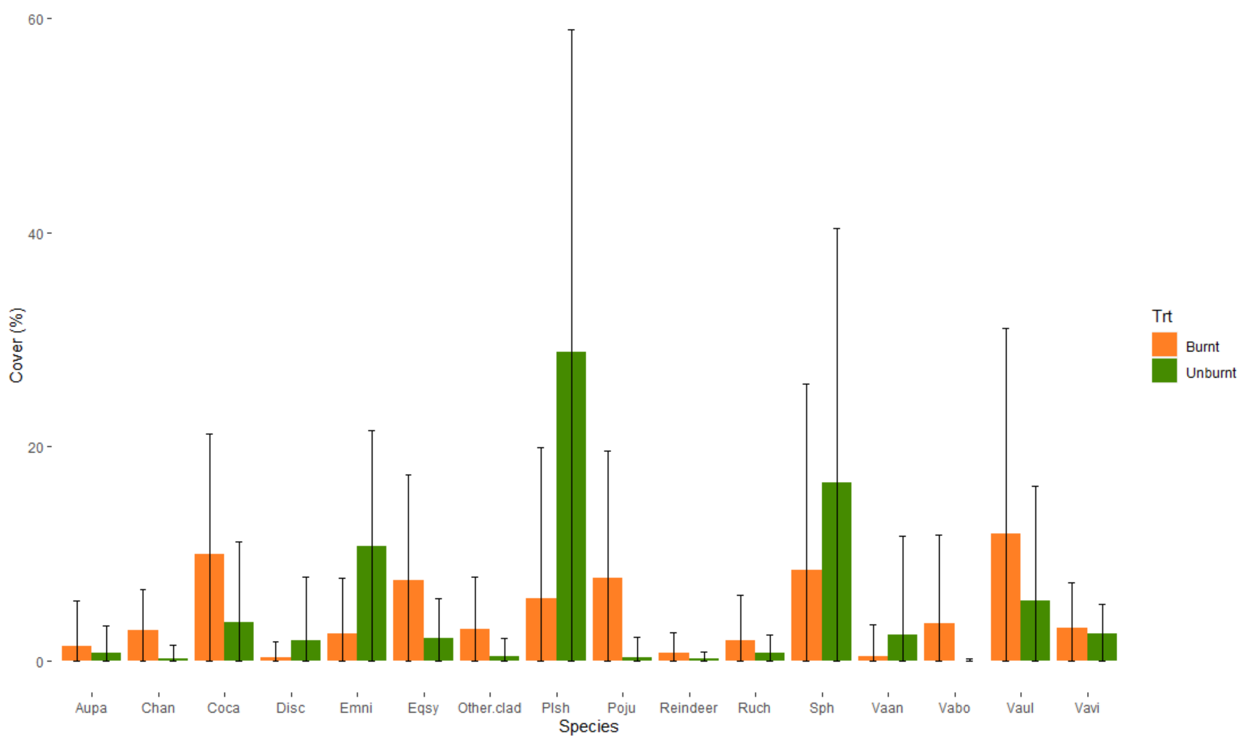

Figure 4-2 Average Cover of key species (%) for the burnt and forested plots. Species listed in Appendix 3. Negative portion of error bars not shown.

Results vary at the site-specific level (Figure 4-3), though most trends visible in the overall data are still present. Important differences include, in BRB, the importance of species unique to the

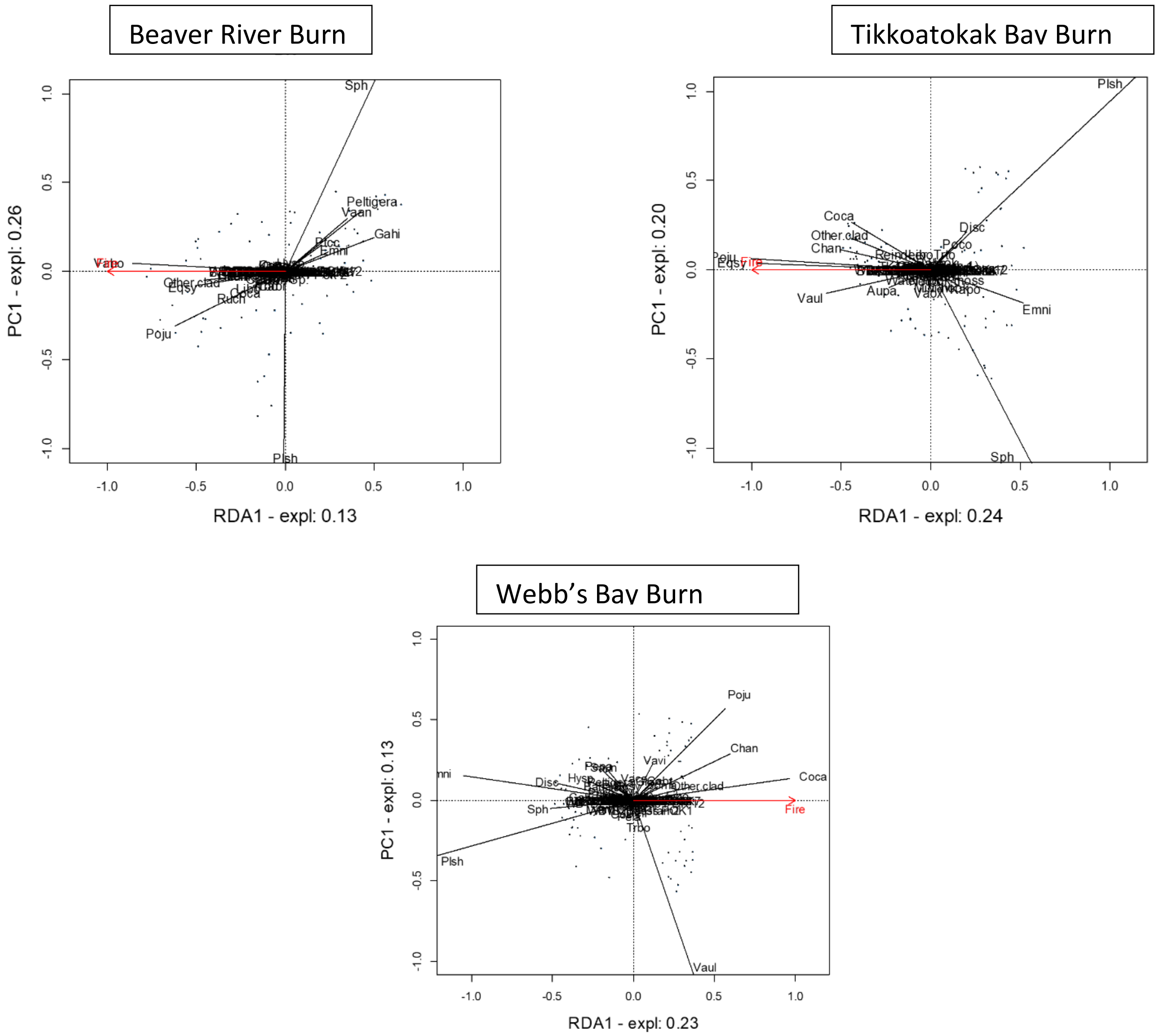

Figure 4-3. RDA of Hellinger-transformed species data with fire (burnt, unburnt) as constraint, separated by sites: Beaver River Burn (BRB), Tikkoatokak Bay Burn (TBB) and Webb Bay Burn (WBB). Plots are represented as points. Vectors are species (see list in Appendix 3).

site such as *V. boreale* being strongly associated with the burns, or *Gaultheria hispidula* associated with the residual forest, as well as the almost complete absence of correlation between the disturbance and *P. schreberi* cover. Importantly, the proportion of variance in communities explained by the fire is lower in BRB (0.13) than in the two younger burns (0.24 in TBB and 0.23 in WBB).

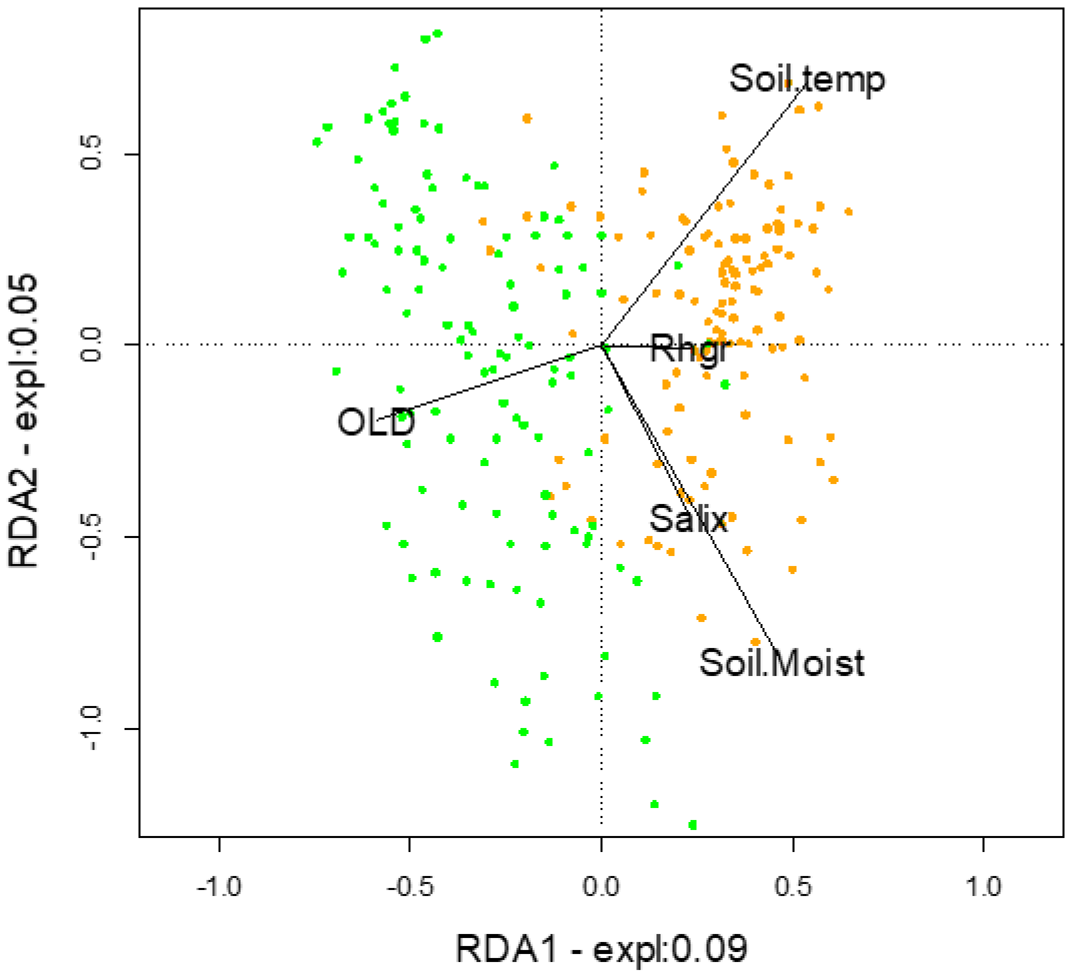

Figure 4-4. RDA of Hellinger-transformed species data with environmental variables as constraints (Soil Temperature [Soil.temp], Soil Moisture [Soil. Moist], Organic Layer Depth [OLD], *Rhododendron groenlandicum* presence [Rhgr] and *Salix* spp. Presence [Salix]). Burnt plots are shown in orange, forested in green.

4.3.1 Environmental and Biotic Variables

The effects of environmental variables (shrub cover and ground conditions) are shown in Figure 4-4. The significant environmental variables explaining vegetation community structure are Soil Temperature, Soil Moisture, Organic Layer Depth (OLD) as well as the cover of *Salix* spp. and *R. groenlandicum*, with an adjusted R-squared of 0.1. While greater Organic Layer depth is associated with the Forest sites, the other variables are positively associated with fire. Soil Moisture and Soil Temperature have mostly opposite impacts, while *Salix* cover is strongly linked with soil moisture. In both the ordination (Figure 4-4) and averages measures (Figures 4-6, 4-7), higher soil temperature and moisture are associated with the burn, while the opposite is true for the OLD (Figures 4-4, 4-5) Some of the organic layer remained at each site after fires (Figure 4-5).

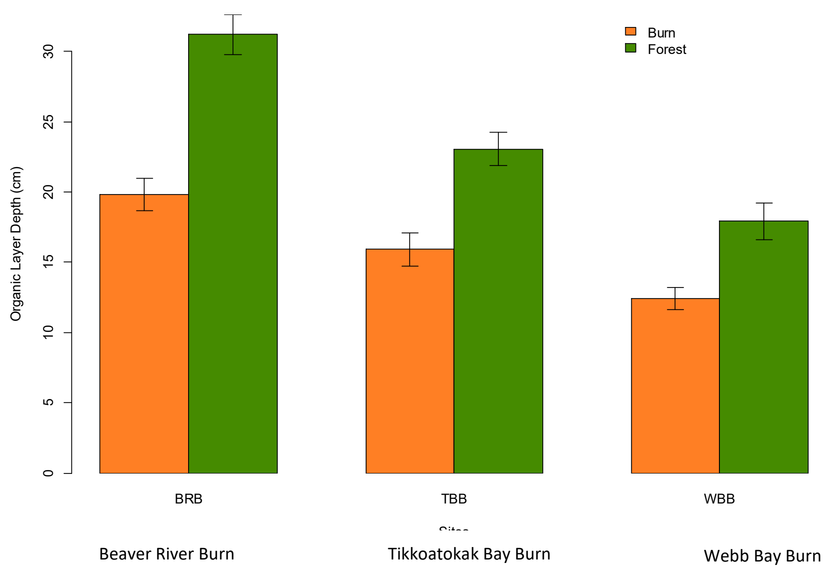

Figure 4-5 Comparison of average Organic Layer Depth (cm) in the Forested and Burnt plots of each site.

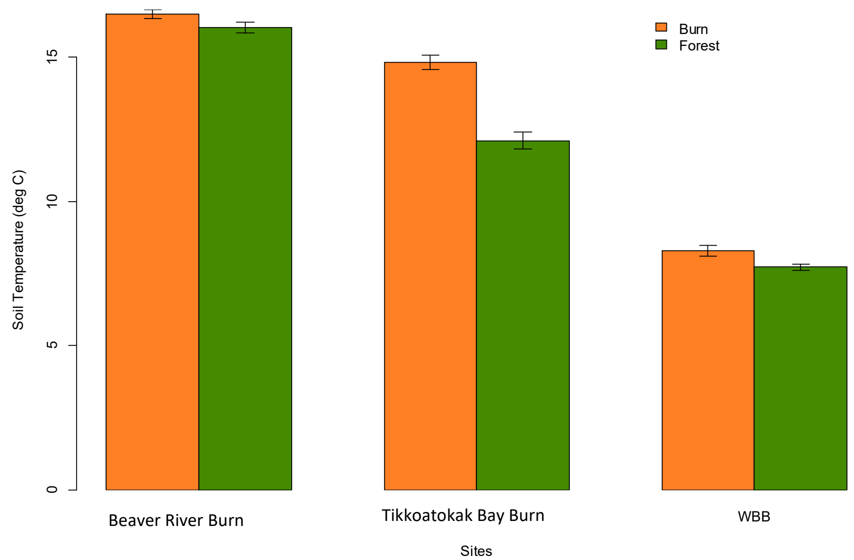

Figure 4-6 Comparison of average Soil Temperature (°C) in the Forested and Burnt plots of each site.

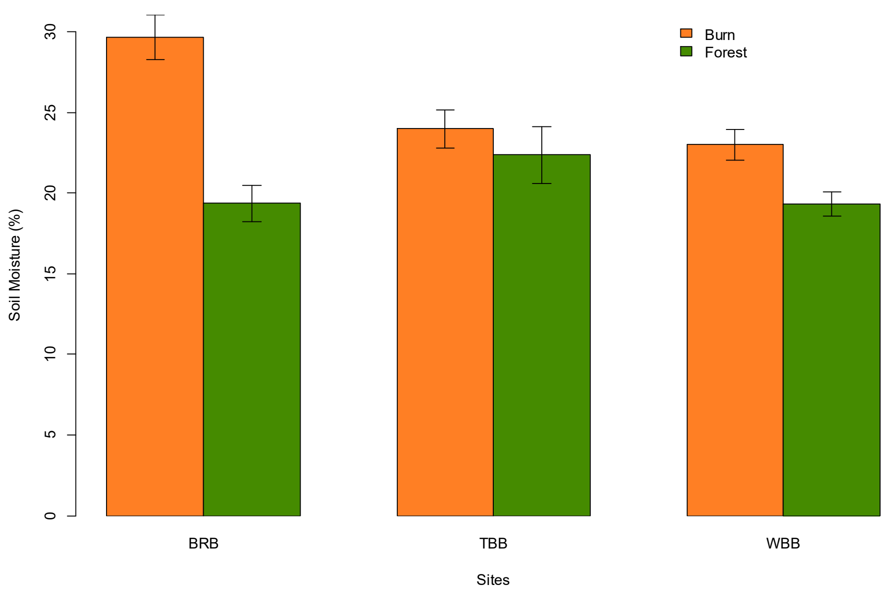

Figure 4-7 Comparison of average Soil Moisture (%) in the Forested and Burnt plots of each site.

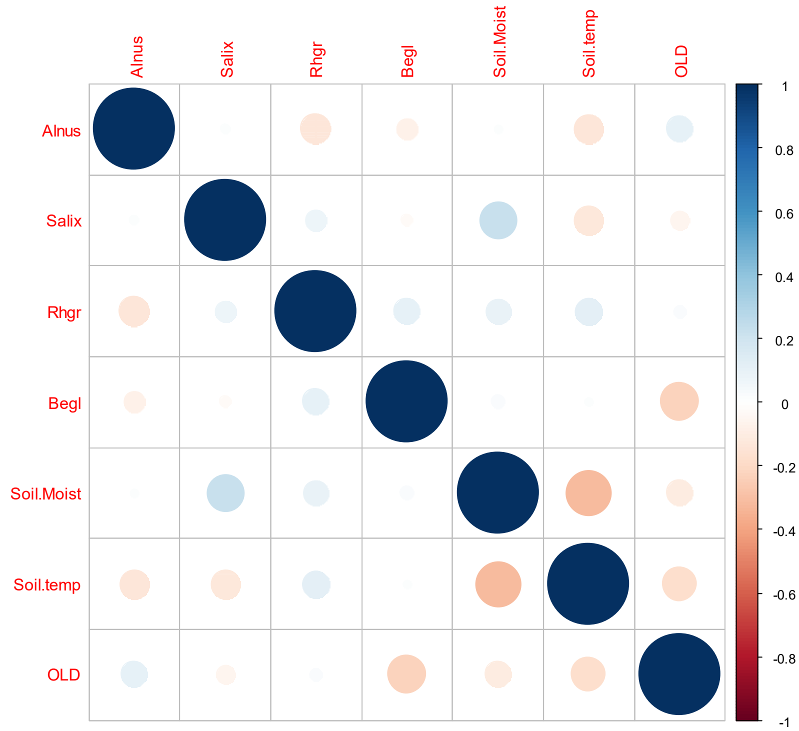

Figure 4-8 Correlation matrix of environmental variables: presence/absence of Alnus spp, Salix spp, Rhododendron groenlandicum, Betula glandulosa, Soil moisture (%), Soil temperature (°C) and Organic Layer Depth. Multicollinearity was also tested with Variance Inflation Factor.

Variation partitioning shows that most of the variation of community structure explained by Fire is unique to this variable (0.075, Figure 4-9) and not explained by measured environmental and biotic variables. However, about a third of the variation explained by Fire is also shared with ground conditions. The impact of Fire and Shrubs are mostly independent.

In the burnt plots (Figure 4-10), the explanation power of measured environmental variables is limited, with an adjusted R-squared of only 0.05, and similar value for the variance explained by the constrained RDA axes (Figure 4-10). Significant variables selected are Soil temperature, Organic layer depth, *R. groenlandicum* and *Salix* spp. cover. *R. groenlandicum* cover and organic layer depth are positively associated, while the effect of both shrub variables are negatively associated, as for both soil condition variables.

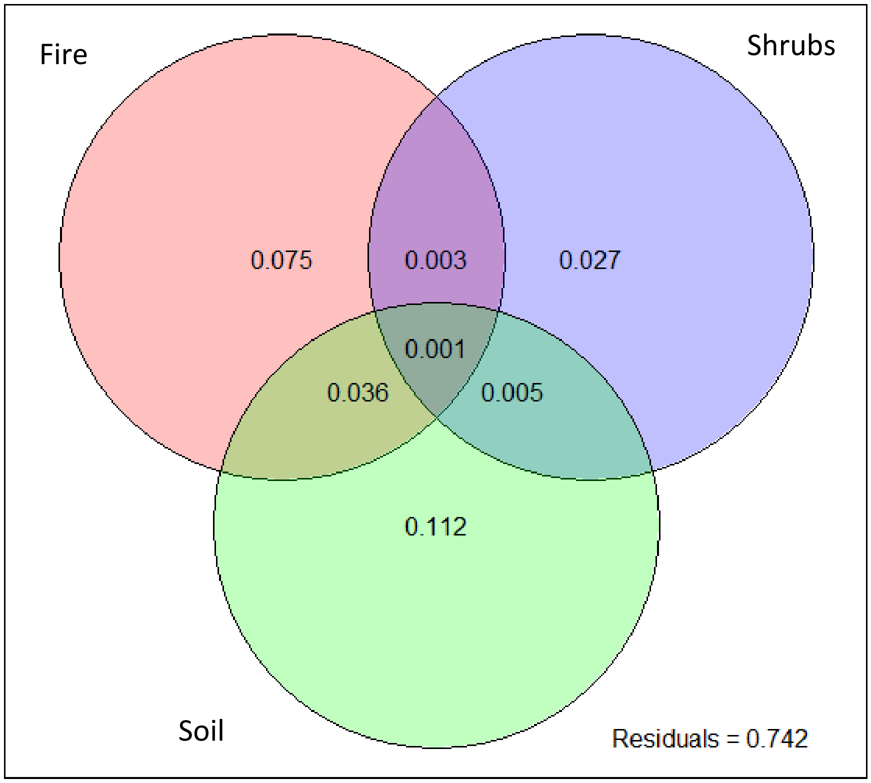

Figure 4-9. Venn Diagram of the variation partitioning of the RDA of Hellinger-transformed species data with environmental variables as constraints, showing portion of total variance explained by each group of variables as well as shared variance. Fire, Shrubs (R. groenlandicum and Salix spp.), Soil (Soil temperature, Soil Moisture, Organic Layer Depth).

These variables explain a larger proportion of community structure at the site level, with a proportion of variance constrained ranging from 0.27 (WBB) to 0.14 (TBB) and 0.18 (BRB). However, the environmental and biotic variables measured explain more of the community structure variation in the forested transect section than in the burns, except in WBB: 0.12 total, 0.27 BRB, 0.30 TBB, 0.19 WBB. Other RDA plots are shown in Appendix 4.

4.4 Discussion

Results show that the re-establishment of ground vegetation communities after fire in coastal Nunatsiavut follows identified patterns, notably those found in previous studies in Labrador, as well as the major trend in the wider Boreal Forest, with some important exceptions. These results also indicate that specific impacts of climate change on post-fire ground vegetation communities' composition could be limited.

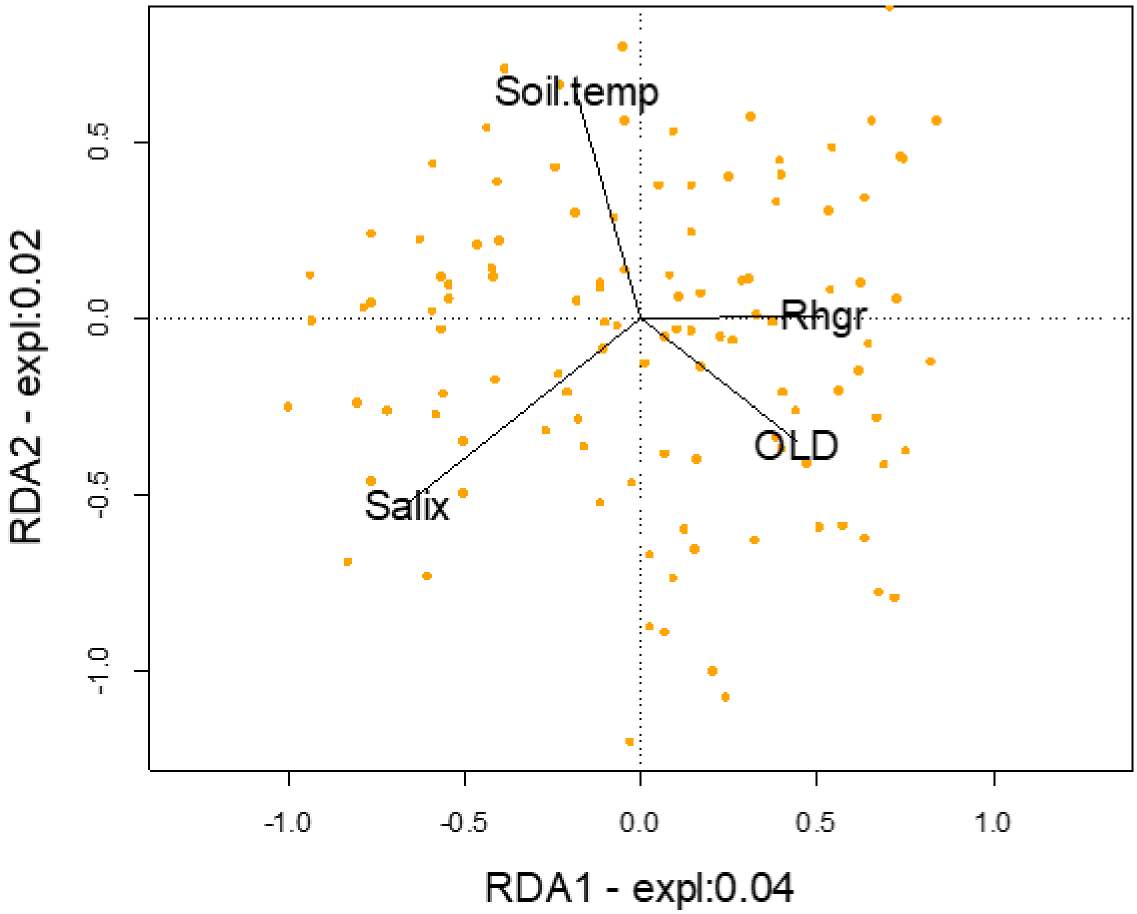

Figure 4-10. RDA of Hellinger-transformed species data with environmental variables as a constraint for the burnt plots. The effect of the variables shown is significant (p <0.01). Adjusted R-squared: 0.05. Constraint variance: 0.05. Variables are Soil temperature (Soil.temp), Organic Layer Depth (OLD), presence of *Salix* species (Salix) and presence of *Rhododendron groenlandicum* (RHGR).

4.4.1 Community Composition

In terms of species association with fire, results are for the most part similar to those reported in other studies, notably in Southeastern (Foster, 1985) and Western Labrador (Simon and Schwab, 2005), as well as for the boreal forest at large (US Forest Service, 2021). Notably, similar shifts in moss communities have been reported in Labrador and other regions (Simon and Schwab, 2005; Marozas et al., 2007) and can be linked to moss species, including *Dicranum scoparium* and especially feather mosses such as *Pleurozium schreberi*, being often late succession species requiring the return of pre-fire soil condition and closed canopy cover to successfully recover (US Forest Service, 2021), and lack fire-adaptive strategies to quickly recolonize burnt sites.

Polytrichum juniperinum, however, possesses rhizoids able to penetrate mineral soil, as well as wind dispersed spores for off-site colonization, while *Aulacomnium palustris* relies on wind-dispersed spores, in addition to potential unburnt fragments or gemmae after low-severity fires (US Forest Service, 2021) to quickly recolonize after forest fires.

Cladonia species are generally negatively affected by fire, as individuals are easily killed by fire and populations can take decades to recover to pre-fire levels (US Forest Service, 2021). However, this can vary depending on regions and forest types, as Simon and Schwab (2005) have reported results congruent to those seen here, with an increase in *Cladonia* species in the first decades following fire, followed by a replacement with mosses. Foster (1985) observes a similar scenario, with *Cladonia* lichen woodlands as a transitionary stage, and feather mosses (such as *P. schreberi) and Sphagnum* species taking over as the canopy closes, likely due to the fact that increased shade and litter negatively affect lichens (Elmendorf et al., 2023).

Results on the association of *E. nigrum* with unburnt sites were also predicted (Foster, 1985). The species is reportedly negatively impacted by burns due to its shallow underground parts that are very susceptible to fire, and the fact that it rarely recolonizes from seeds (US Forest Service, 2021). However, Inuit Knowledge from Nunatsiavut indicates an opposite relationship, with an increase in *E. nigrum* presence after forest fires (see Chapter 3). A potential explanation for this discrepancy validated by knowledge holders is a spatial variation in both *E. nigrum* response to fire and sites of interest for either knowledge systems. The burnt sites frequently visited by *Nunatsiavummiut* are along the coasts, and are accessed by boat during the open-water season (see Chapter 3). For that reason, travelling inland on the burns is generally limited in summer and fall, with observations of vegetation concentrated along the shorelines. In contrast, scientific studies on forest fires occur in variety of locations, and (as exemplified by this study) surveys are not conducted right on the shores even when the burns are in coastal locations. The proximity with bodies of water can have complex effects on fire frequency and intensity (Nielsen et al., 2016; Rothermel, 1983). Most importantly, proximity with water can reduce fire intensity through impacts on the microclimate. Large lakes have been reported as decreasing air temperature and increasing humidity on a relatively small scale (Nielsen et al., 2016; Newas et al., 2020). It is thus possible that along shorelines fire intensity can decrease and reach levels where rhizomes or even above ground parts of *E. nigrum* survive and later benefit from competition reduction and/or nutrient availability. While not reported following natural disturbances, a similar scenario has been described in Britain, where *E. nigrum* could have a temporary increased abundance following low intensity controlled burning of *Calluna* heath (Ratcliffe, 1959; Bell and Tallis, 1973).

Vaccinium angustifolium, which is known to quickly recover and generally benefit from fire (US Forest Service, 2021; Simon and Schwab, 2005), responded very differently in this study. Found only at the BRB site, *V. angustifolium* was associated with the unburnt forest (Figure 4.1, 4.2). The species was almost completely absent from the burn, observed in only four plots in the two burnt sections of transect. A number of factors could have affected *V. angustifolium* regeneration success. Fire intensity is known to affect *V. angustifolium* regeneration success, with a better response to low intensity fires (Duschesne and Wetzel, 2004; US Forest Service [2021]. However, the fire at the BRB site was of low intensity [Brehaut and Brown, 2020], and the species is known to still successfully colonize after high intensity fires [Payette, 2018]. Thus, potential direct negative impacts of fire would not explain an almost complete lack of recolonization. Furthermore, the effects of more severe fires on *V. angustifolium* are linked to damage to the underground root system [Duschesne and Wetzel, 2004], and the closely related species *V. boreale* [whose root system is shallower than *V. angustifolium's*; Kloet, 1977] did not show the same unexpected negative association with the burn. Interspecies competition could also be in cause. *Rhododendron groenlandicum*, the dominant species in the burns [average cover of 27.5% in BRB] is known to compete with *V. angustifolium* and to affect size and yield in some settings [Lavoie, 1968; Marty et al., 2019]. *V. angustifolium's* size is similar to that of *R. groenlandicum* while *V. boreale* is significantly smaller [Payette, 2018], and competition with *R. groenlandicum* might affect both species differently. However, as both *V. angustifolium* and *R. groenlandicum* resprout from deep fire-resistant root systems [US Forest Service, 2021], and without indication that *R. groenlandicum* resprouts faster than *V. angustifolium* following fire

[Simon and Schwab, 2005], this competition would be unlikely to lead by itself to a near exclusion of *V. angustifolium* from the burns. It is possible that, rather than an impact of fire, some of the post-fire distribution of *V. angustifolium* observed here represents a legacy of its pre-fire distribution, potentially driven by competition with *R. groenlandicum*. Indeed, the species is observed in significant number in only one section of one transect [the forest section of the first BRB transect], and is only present in four plots in the second BRB transect), hence perhaps limiting the ability to recolonize. Further replication, and examination of the competitive relationship between the three species (*V. angustifolium, R. groenlandicum* and *V. boreale*) would be warranted.

Comparing site-specific results, a clear impact of latitude/ecoregion can be seen. For example, *Gaultheria hispidula* reaches the northern limit of its distribution between Postville and Nain (Payette, 2018), whereas *V. boreale* and *V. angustifolium* are absent from the Labrador Coast north of Hopedale although they reach higher latitudes in the interior (Payette, 2018). An effect of age is also likely: the decreasing association of *P. schreberi* with forests at the older BRB site corresponds to what has been recorded in Western Labrador (Simon and Schwab, 2005) and elsewhere in the boreal forest (Hart and Chen, 2007). However, untangling potential sources for the between-site variation is complicated by the co-variability of several elements, due to the limited number of study sites. For example, compared to the burn near Postville, the two burns around Nain are both younger and closer in age, further north, and in a different ecoregion. WBB and TKB are also separated by only about 20 km, whereas BRB is located approximately 250 km southeast of the two (Figures 1.3-1.5).

The main recolonization strategy of species characteristic of the post-fire communities in our sites is by far resprouting from underground parts such as rhizomes or root crowns. *E. sylvestris, C. angustifolium, P. juniperinum, Cornus canadensis, V. uliginosum* all use this strategy to quickly recolonize burnt sites (US Forest Service, 2021). Other strategies are less frequent, with wind-dispersed seeds for the two fire-associated mosses (as described above) as well as regeneration from fragments reported for both mosses and some *Cladonia* species (Schimmel and Granstrom, 1996). *Cornus canadensis* might also recolonize from seed banks in the soil (US Forest Service, 2021).

Overall, even shortly after the fires, and while tree regeneration is still minimal (Brehaut and Brown, 2020), the proportion of ground vegetation community variation between study plots that is explained by the impact of fire is limited (0.15, Figure 4-1). This suggests that the ground vegetation recovery is partly independent from forest cover re-establishment, and that even forest-associated species start recolonization in the still-open landscape. However, it could indicate that recovery likely progresses quickly at first, before stalling due to the fact that some species (such as feather mosses) do need forest cover to reach pre-fire abundance (US Forest Service, 2021). Previously cited studies in the region with similar results but wider range of fire age (Foster, 1985; Simon and Schwab, 2005), have concluded that it is a transitional stage, with vegetation recovering to pre-fire community composition after the re-establishment of the forest cover, baring a new fire. Follow-up studies including sites of a higher burn age diversity would be able to confirm whether the same phenomenon is observed.

4.4.1 Environmental Variables and Relationship with Climate Change

An increase in fire frequency is predicted with climate change and will cause direct impacts on ground vegetation communities at the regional scale, as it would directly affect the proportion of recently burnt areas. With an increase in frequency, fire-adapted species assemblages could see their presence in the landscape increase, to the detriment of closed canopy dependent forest species. At this time, however, an increase in fire frequency has not been detected within the Taiga Shield East Ecozone, with no trend in area burnt between 1985 and 2015, and even a potential slight decrease during the 1996–2015 period (Coops et al., 2018). Furthermore, the fire return interval is long in the regions of both Nain (1501–5000 years) and Postville (501-1500 years) (Coops et al., 2018), and the variation in vegetation community structure explained by fires is reduced even before the return of forest cover (Figure 4-1). This indicates that changes in fire frequency would have to be large before impacts might be felt at the regional and community level due to ground vegetation resiliency to disturbance.

A portion of the variation in community structure explained by fire is linked with ground conditions potentially affected by climate change (Soil temperature, soil moisture, and organic layer depth as an imperfect proxy for fire intensity). This hints to another mechanism through which climate change could affect post-fire vegetation: changing recovery patterns. Analyses of the impacts of environmental variables on vegetation in the burnt plots both show soil temperature and organic layer depth have a significant impact on community structure (Figure 4-2). However, if the portion of community structure variation explained by these variables is not negligible, it is not higher in the burns than in the unburnt forest. This suggests that, based on the limited variables included here, potential effects would not be specific to sites of forest fires but reflect general impacts of climate change in the landscape.

4.5 Conclusion

With very limited infrastructure, lack of roads outside of communities and huge landscapes, forest fires in Northern Labrador are, for the most part, very difficult to access. Research is, without expensive helicopter support, limited to areas around the few communities along the coast that are accessible by boat or snowmobile. Furthermore, with the low fire frequency, especially around Nain and further north, the number of potential study sites is limited.

Despite these constraints, this study (as well as the other projects of the Food, Fire and Ice collaboration, Brehaut and Brown 2020; Wang, 2020) identified important characteristics of post-fire regeneration in the region that will require further study. As the region significantly differs from areas where the majority of forest fire research is conducted and considering the importance of the disturbance for local Inuit as well as the uncertainty around the potential impacts of future climate change, it is crucial that efforts to fill the research gap in forest and fire ecology in Nunatsiavut continue.

Chapter 5 – General Conclusion

This study achieved both its objectives; 1) characterizing the ground vegetation response to forest fires, and the impact of environmental variables, as well as 2) documenting the relationship with, and knowledge of forest fires by *Nunatsiavummiut*. It showed that the re-establishment of ground vegetation communities after fire in coastal Nunatsiavut is comparable to other studies, notably those found in previous studies in Southeastern and Western Labrador. This study found that the impacts of climate change on post-fire ground vegetation communities' composition and importance in the landscape are likely to be limited considering the trajectories of communities returning to pre-fire conditions and the low level of fire activity. It also showed that Inuit use of burns was dominated by wood harvesting, followed by concomitant activities such as hunting in winter. Use during the snow-free months is limited, with berry-picking the most important activity. Inuit use and relationship with forest fires differed in the two studied communities; the more southern community of Postville having a closer relationship with fires than Nain. The differences are linked to the size and proximity of fires to these communities, as well as different levels of pre-fire landscape heterogeneity. These differences would notably lead to different strategies to ensure equitable sharing of resources.

However, this study suggests interesting future research questions. Concerning ground vegetation, the source of inter-site differences would require increasing the study scale to include fires of a wider range of age across the landscape of Nunatsiavut. Similarly, the spatial variability of *E. nigrum* regeneration, hypothesized as the source of a discrepancy between Inuit and Western scientific knowledge would need to be studied further, addressing both knowledge systems. The analysis of differences in relationship with fire between the two Inuit communities should be expanded to include the other Inuit communities and confirm if the explanations proposed are applicable to the wider human and natural landscape.

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Appendices

Appendix 1 Interview Guide

Section 1. Fire, plants and permafrost

<table>
<tr><td colspan="2">Personal information</td></tr>
<tr><td colspan="2">Name
Date of birth/age
Place of birth</td></tr>
<tr><td>Themes</td><td>Main subjects</td></tr>
<tr><td>Land use</td><td>-Activities the participant does (or used to do) on the land
-Important places on the land. Cultural, personal, places he/she connects with

(mapping)
-Localizing important site, what they are used for/what is their importance.</td></tr>
<tr><td>Fire</td><td>-Impact of fire on vegetation
-Vegetation impact on fires
- Impact of fire on animals
- Impact of fire on the use of a site
-Effect of fire on snow accumulation in winter, wind, dust in the summer.

(mapping)
-Sites and dates of forest or tundra fires</td></tr>
<tr><td>Wood harvesting</td><td>-Reasons for harvesting burnt wood
-Size, choice of harvest: bigger or closed
-Method of harvest and ethics
-Proportion of wood used harvested in burns
-Selection of species for harvesting and differences between burnt wood/ other standing dead wood/ living trees
-Wood commerce

(mapping)
-Burns where they harvest wood
-Other sites of wood harvest</td></tr>
<tr><td>Permafrost</td><td>Impact of fire on permafrost

Impact of permafrost on vegetation
Impact of vegetation on permafrost

(mapping)
-Sites where signs of permafrost is visible.</td></tr>
</table>

	-Sites of visible changes
Vegetation	- Climate change: changes in vegetation cover -Useful wild plants. Plants he/she likes or connects with or uses. (mapping) -Presence of important plants -Sites of observed vegetation change
Animals	-Useful wild animals. Animals he/she likes or connects with (mapping) -Sites of sightings
Interactions	-What else can you tell me about the interactions between fires, plants and permafrost?
Conclusion	-Is there something else you would like to add? -Do you have any concerns or comments about the study or this interview? -Would you be interested in taking part in a group discussion after the interview process, to review and corroborate preliminary findings?

Section 2. Climate Change

Themes	Main subjects / sub-questions examples
Fire	-Climate change: Changes in the incidence of fires
Permafrost	-Climate change: Changes in the extent of permafrost (mapping) -Sites where signs of permafrost is visible. -Sites of visible changes
Vegetation	- Climate change: changes in vegetation cover (mapping) -Sites of observed vegetation change
Animals	- Climate change: changes in animal populations, movement or behavior. (mapping) -Sites of observations relating to changes
Conclusion	-Is there something else you would like to add? -Do you have any concerns or comments about the study or this interview? -Would you be interested in taking part in a group discussion after the interview process, to review and corroborate preliminary findings?

Appendix 2. Knowledge holders

Nain	
N1	Manasse Pijogge
N2	Anonymous
N3	Anonymous
N4	Abia Obed
N5	Ronald Webb
N6	Jerry Tuglavina
N7	Joe Atsatata
N8	Wilson Semigak
N9	Jennifer Semigak
N10	Jacko D Merkuratsuk
N11	Edna Winter
N12	Liz Pijogge
N13	Joe Webb
N14	Edward Sillit
N15	Richard Leo
N16	Mark Saksagiak
N17	Adam Lidd
N18	Don Dicker
N19	Joseph (Buddy) Merkuratsuk
N20	Anonymous
N21	Jenny Merkuratusk
N22	Robina Pijogge
N23	Maria Merkurastuk
N24	Sarah Semigak-lidd
N25	Alice Pilgrim
N26	Christine Baikie

N27	Isabel Ittulak
N28	Anonymous
Postville	
P1	Anonymous
P2	Gillian Gear (Edmunds)
P3	Anonymous
P4	Anonymous
P5	Anonymous
P6	Anonymous
P7	Anonymous
P8	Maurice Jacque
P9	Jim Goudie
P10	Brian Jacque
P11	Harold Goudie
P12	Jason Jacque
P13	Glen Sheppard
P14	John Rose
P15	Shirley Goudie
P16	Harold Jacque
P17	Josephine Jacque

Appendix 3. Species List and Coordinates Along the First RDA Axis (Fire) of the RDA of Hellinger-Transformed Species Data with Fire (Burnt, Unburnt) as Constraint Variable (See Figure 4-1).

Genus	Species	Code	RDA1 coordinates
Polytrichum	*juniperinum*	Poju	-0.4601199
Cornus	*canadensis*	Coca	-0.3356069
Equisetum	*sylvaticum*	Eqsy	-0.3047515
Chamaenerion	*angustifolium*	Chan	-0.2852638
Cladonia	other	Other.clad	-0.261006
Vaccinium	*uliginosum*	Vaul	-0.2336023
Vaccinium	*boreale*	Vabo	-0.1774757
Cladonia	Ex-*cladina*	Ex.Clad	-0.0973466
Linnaea	*borealis*	Libo	-0.0969673
Rubus	*chamaemorus*	Ruch	-0.0834204
Carex	*brunescens*	Cabr	-0.0594875
Aulacomnium	*palustre*	Aupa	-0.0412611
Solidago	*macrophylla*	Soma	-0.0338296
Vaccinium	*vitis-idaea*	Vavi	-0.0322725
Trientalis	*borealis*	Trbo	-0.0259985
Luzula	*parviflora*	Lupa	-0.0143607
Vaccinium	*oxycoccus*	Vaox	-0.0128117
Poa	*spp*	Poa sp	-0.0085837
Calamagrostis	*spp*	Calam. Sp.	-0.0075391
Maianthemum	*trifolium*	Mapo	-0.0059614
Cinna	*latifolia*	Cila	-0.0055351
Stellaria	*borealis*	Stbo	-0.0053588
Eriophorum	*brachyantherum*	Erbr	-0.0040151
Viola	*labradorica*	Vila	-0.0034618
Carex	*canescens*	Caca	-0.0029935
Orthilia	*secunda*	Orse	-0.002679

Flavocetraria	*cucullata*	Flcu	-0.0025012
Cersatium	*alpinum*	Cela	-0.001698
Lycopodium	*clavatum*	Lycl	-0.001698
Bistorta	*vivipara*	Bivi	-0.0003635
Dicranum	*majus*	Dima	0.0033025
Ptilidium	*ciliare*	Ptci	0.0043736
Orthotrichum	spp	Orthotrichum sp.	0.0054901
Coptis	*trifolia*	Cotr	0.0113544
Ptilium	*pulcherinum*	Ptpu	0.0122622
Neottia	*cordata*	Neco	0.0129493
Lycopodium	*annotinum*	Lyan	0.013072
Trichocolea	*tomentella*	Trto	0.0149333
Rhizomnium	*pseudopunctatum*	Rhps	0.0155048
Pyrola	*minor*	Pymi	0.0170953
Tomenthypnum	*nitens*	Toni	0.0218225
Polytrichum	*commune*	Poco	0.0277961
Sanionia	*uncinata*	Saun	0.0322597
Kalmia	*polifolia*	Kapo	0.0330132
Petasites	*frigidus var. palmatus*	Pepa	0.0391762
Barbilophozia	*barbata*	Baba	0.0409751
Phyllodoce	*caerulea*	Phca	0.0456745
Carex	*bigelowii*	Cabi	0.0577911
Hylocomium	*splendens*	Hysp	0.0642635
Ptilium	*crista-castrensis*	Ptcc	0.0644399
Vaccinium	*angustifolium*	Vaan	0.0721683
Gaultheria	*hispidula*	Gahi	0.1037549
Peltigera	*aphthosa*	Peltigera	0.1116213
Dicranum	*scoparium*	Disc	0.1233285
Sphagnum	*spp.*	Sph	0.306953
Empetrum	*nigrum*	Emni	0.3782456
Pleurozium	*schreberi*	Plsh	0.6986877

Appendix 4. Site-Specific RDAs with Environmental and Biotic Variables, for Burnt and Forested Plots.

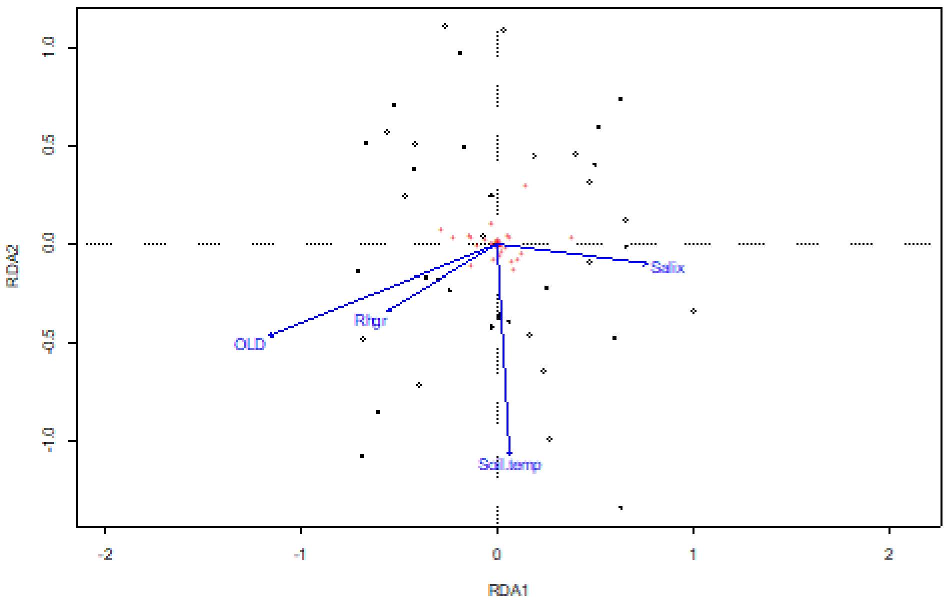

Figure A-1. RDA of Hellinger-transformed data with environmental variables as constraint for the burnt plots of BRB. Constraint variance: 0.18

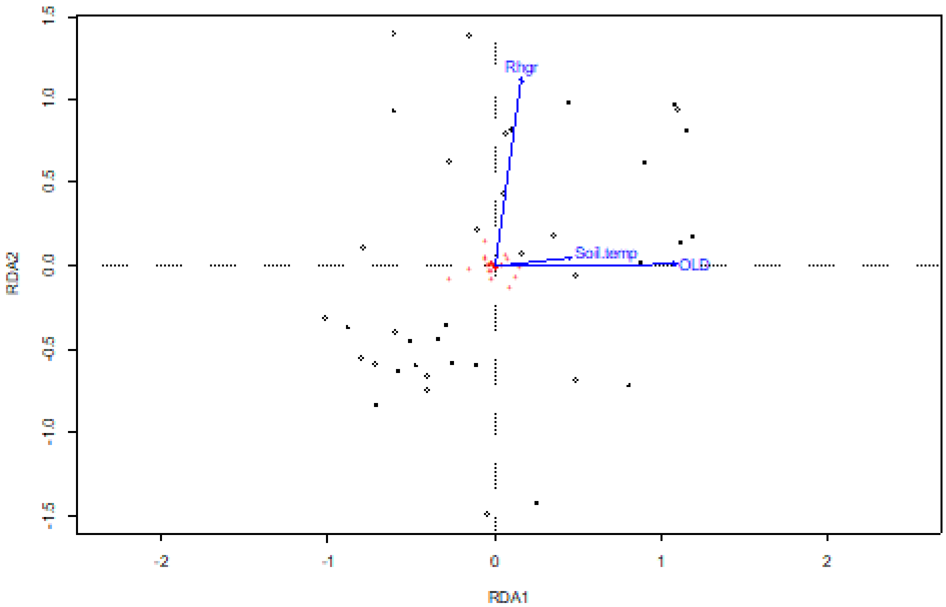

Figure A-2. RDA of Hellinger-transformed data with environmental variables as constraints for the forested plots of BRB. Constraint variance: 0.27. Salix not shown here as it is absent from the plots.

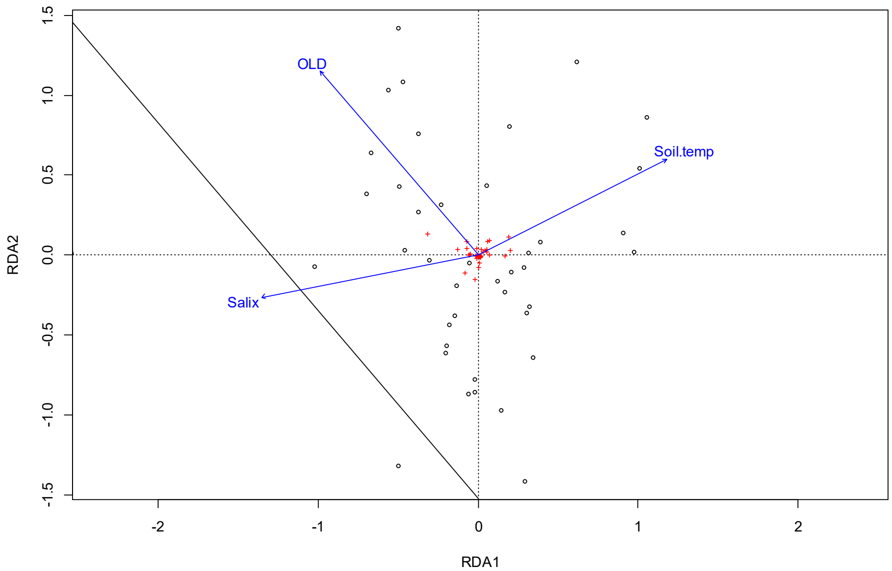

Figure A-3. RDA of Hellinger-transformed data with environmental variables as constraints for the burnt plots of TBB. Constraint variance: 0.14. RHGR is not visible as it was present in all plots.

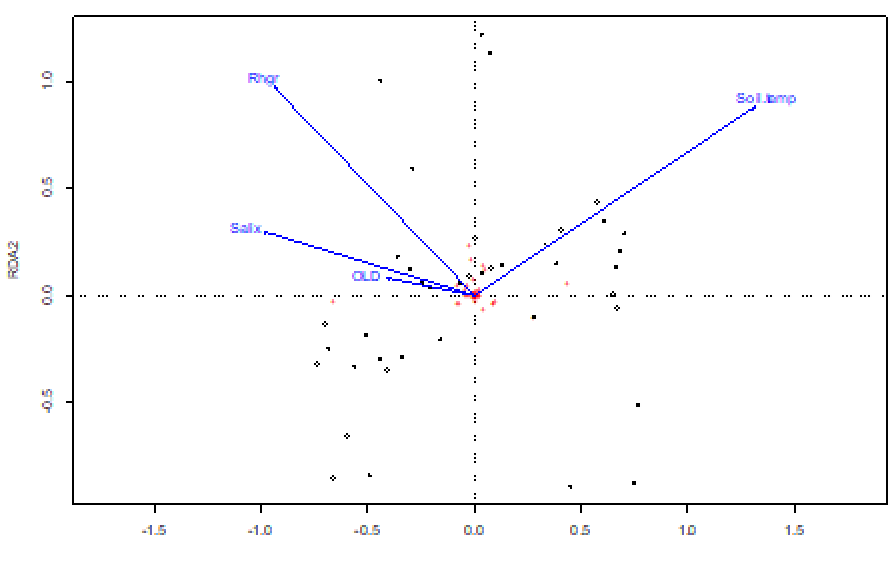

Figure A-4. RDA of Hellinger-transformed data with environmental variables as constraints for the forested plots of TBB. Constraint variance: 0.30

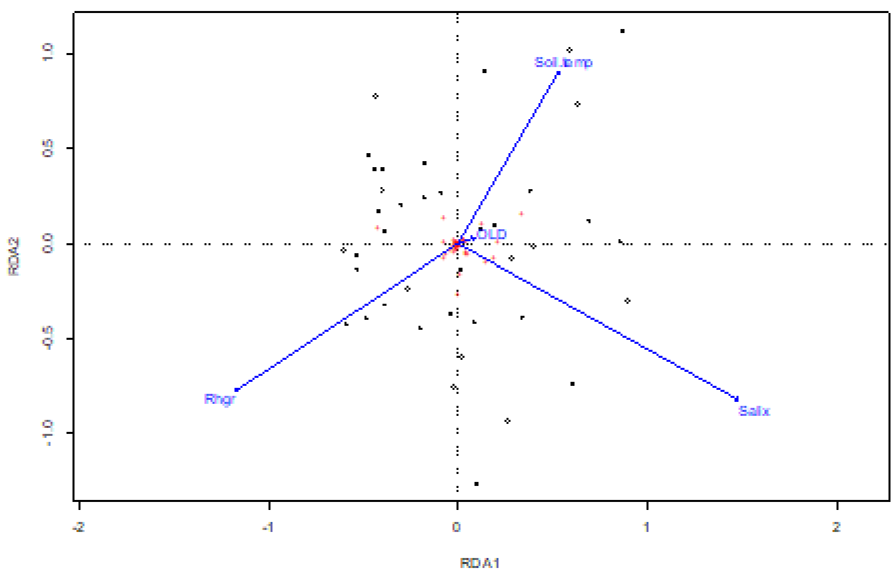

Figure A-5. RDA of Hellinger-transformed data with environmental variables as constraints for the burnt plots of WBB. Constraint variance: 0.27

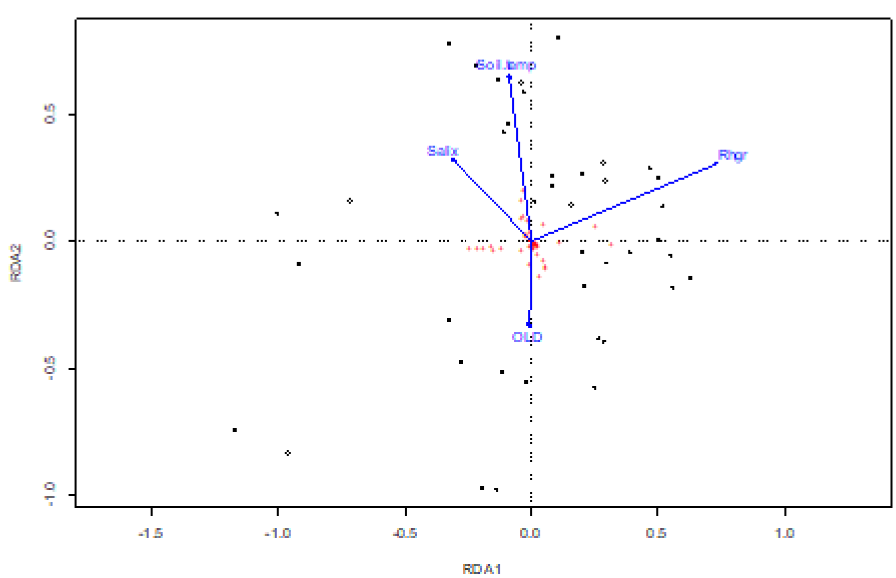

Figure A-6 RDA of Hellinger-transformed data with environmental variables as constraints for the forested plots of WBB. Constraint variance: 0.19. RHGR is not visible as it was present in all plots.