WHOSE EXPERTISE COUNTS? ASSISTED MIGRATION AND THE POLITICS OF KNOWLEDGE

by

Ricardo Antonio Pelai

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Examining Committee:

Dr. Shannon Hagerman
Co-supervisor

Dr. Robert Kozak
Co-supervisor

Dr. Harry Nelson
Supervisory Committee Member

Dr. Sally Aitken
Additional Examiner

Abstract

The effects of climate change increasingly threaten forests; as a result, tree seed transfer actions - including controversial interventions like assisted migration (AM) - have adapted to facilitate trees' adaptation to future climates. In this thesis, I explore seed transfer and AM governance in British Columbia (BC) using qualitative methods. First, I present a historical profile of BC's seed transfer governance landscape, tracing decision-makers, policy instruments, rationales for seed transfer changes, risks, and knowledge used to inform policy from 1940 to 2019 based on document analysis and semi-structured interviews with key informants. Three insights relevant to understanding contemporary AM policies emerged from this analysis: i) through the opening of a policy window, a paradigmatic shift in seed transfer policy occurred with the establishment of a climate-based seed transfer system; ii) genetic knowledge produced within government ministries has been the dominant form of evidence used to inform seed transfer policy over time; and iii) governance processes, such as the disproportionately influential role of the forest industry in seed transfer policy-making, remained relatively unchanged in practice. Second, I offer a closer examination of the risks associated with and the types of knowledge that inform contemporary AM actions in BC. Based on 27 semi-structured interviews with government officials and forest industry professionals, I find that i) the type of knowledge deemed credible to inform contemporary AM decision-making is restricted to biophysical, model-based, scientific knowledge; ii) the primarily biophysical framing of AM shapes particular ways of understanding AM risks and solutions to address them; and iii) while decision-makers recognize the need to engage industry, First Nations and the general public, these groups are characterized as knowledge receivers. Interviewees also hold the view that the provision of science to different publics will prevent AM controversy. This research highlights the urgent need to meaningfully and respectfully include First Nations in AM decision-making. Overall, this thesis concludes that patrolling the types of AM expertise in informing seed transfer and AM actions serves to exclude other forms of knowledge and possibilities for shaping future forests.

Lay Summary

Human-assisted movement of trees is increasingly being used to help forests adapt to climate change. The research presented here examines who makes decisions about tree movement policies, how those decisions are made, how regulations and the objectives that drive them have changed over time, what concerns are raised, and the evidence used to inform tree movement in British Columbia, Canada. Based on interviews and documents, I find that the type of evidence considered relevant to inform tree movement is restricted to the natural sciences, especially forest genetics. This technical focus prevents the consideration of other potential concerns about tree movement. I also find that the forest industry has a highly influential role in making decisions about tree movement, whereas Indigenous Peoples and the general public have little to no input. Overall, I argue that the absence of these non-scientific voices limit the possibilities for shaping the future of our forests.

Preface

This thesis is my original, independent work. I identified the research questions, designed the methodologies, collected and analyzed the data, and wrote all four chapters. I received academic guidance and feedback from my supervisory committee at each step of the process.

A version of Chapters 2 and 3 will be submitted as research articles with myself as lead author. My research supervisors who provided support and feedback on the research design, the interpretation of the results, and writing will be included as co-authors in future publications.

The fieldwork reported in Chapter 2 and Chapter 3 was covered by the UBC Behavioral Research Ethics Board Certificate number H18-02047.

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List of Abbreviations

AAC: Annual Allowable Cut
AM: Assisted Migration
BC: British Columbia
CBST: Climate-based Seed Transfer
CCISS: Climate Change Information Species Selection
FFEI: Future Forest Ecosystem Initiative
FGC: Forest Genetics Council
FRPA: Forest and Range Practices Act
MFLNRO: Ministry of Forests, Lands, and Natural Resource Operations
MFLNRORD: Ministry of Forests, Lands, Natural Resource Operations & Rural Development
MoF: Ministry of Forests
STS: Science and Technology Studies
SPZ: Seed Planning Zones
TIC: Tree Improvement Council

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Chapter 1: Introduction

1.1 Problem context

As climate changes and trees become increasingly incompatible with the local conditions where they grow, assisted migration (AM) actions have been increasingly proposed as a means of adapting forest management to climate change (Hagerman & Pelai, 2018). There are multiple definitions of AM in the literature (Ste-Marie, Nelson, Dabros, & Bonneau, 2011), but the term AM in this thesis refers to the intentional translocation of species and/or populations within or outside their natural range to facilitate range expansion as a direct management response to climate change (Aitken & Whitlock, 2013; Vitt, Havens, Kramer, Sollenberger, & Yates, 2010). In the context of forestry specifically, AM seeks to ensure that plantations of commercially valuable tree species are established using seed sources that will be adapted to future climatic conditions (Gray, Gylander, Mbogga, Chen, & Hamann, 2011). Most AM actions and proposals in forestry have so far focused on intra-continental, single-species movements (Pedlar et al., 2012).

AM has the potential to maintain forest productivity (Gray et al., 2011), ecosystem services, and overall forest health (Kreyling et al., 2011). Yet, it remains a controversial strategy (Aubin et al., 2011) as it is at odds with the conventional forest management paradigm that assumes ecological stability (Messier et al., 2015). Forest management in western Canada in particular has been based on reforestation with native species and local seed as opposed to plantations of non-native tree species, which is done in other regions such as the Nordic countries (Kjær et al., 2014) and China (Xu, 2011). As a result, some of the most commonly cited AM risks include the potential creation of new invasive alien species, and the disruption of recipient ecological communities (Hewitt et al., 2011). Concerns with AM also include regulatory challenges, such as the lack of legislation (Camacho, 2010), public opposition to AM outside natural range (Peterson St-Laurent, Hagerman, & Kozak, 2018), and relatively low acceptability of AM actions among foresters (Moshofsky, Gilani, & Kozak, 2019). Thus, the increasing and more widespread implementation of AM actions will not only be influenced by technical and biophysical considerations, but also by societal dimensions, including history, governance and human behaviour. Despite the aforementioned biophysical and societal concerns, AM practices are

moving forward in practice with limited public debate and social science inquiry. For example, some jurisdictions have created new AM policies for specific species, such as western larch in British Columbia (BC). Other jurisdictions have modified existing seed transfer policies, including BC, Alberta, and Quebec (BC MFLNRORD, 2018; Pedlar et al., 2012).

1.2 Overview of the assisted migration literature

The fields of forest genetics, climate modelling, and forest ecology have so far provided valuable insights for understanding AM in forestry contexts. For example, studies have been conducted on the impacts of tree species range shifts, tree species suitability to AM, and species-specific capacity for adaptation (Aitken & Bemmels, 2016; Wang, Campbell, O'Neill, & Aitken, 2012; Winder, Nelson, & Beardmore, 2011). Increasingly, genomic tools have enabled scientists to detect DNA sequence differences across individuals in natural tree populations (Allendorf, Hohenlohe, & Luikart, 2010). These techniques have the potential to allow for a rapid selection of genotypes that can be spatially re-allocated to climatically suitable habitat over large areas (Sork, Aitken, & Dyer, 2013).

Insights from the social sciences and humanities to examine AM have been more limited, and have thus far focused on three main research strands: perceptions of risk, institutional and policy analysis, and ethics. Studies on perceptions of risk suggest that public support for AM in forestry is highly contested and susceptible to change in response to new information (Hajjar, McGuigan, Moshofsky, & Kozak, 2014; Peterson St-Laurent et al., 2018). There is evidence for high levels of public support for AM within natural range, but less support for AM outside of natural range (Peterson St-Laurent et al., 2018). Legal studies have examined how AM is antithetical to conventional natural resource law in the United States (Camacho, 2010). Klenk (2015) found that western larch AM policy in BC bypassed controversy by framing AM as a natural extension of reforestation standards and best practices at the time, and Klenk & Larson (2015) examined the emergence of western larch AM policy through a shift in the scientific discourse associated with forest management from an ecological to a genetic perspective. Finally, studies have explored the ethical questions of whether to deliberately manage forests or allow them to adapt on their own (Aubin et al., 2011), and the degree to which AM decision-making and actions should be a public or a professional/scientific endeavour (Minteer & Collins, 2010).

While prior AM social sciences research hints at the importance of understanding how knowledge and policy interact, key questions related to the types of knowledge deemed credible to inform AM policy, and the role of knowledge in shaping perceptions of risk and solutions to address them remain underexplored. Similarly, the historical contours of AM governance have not yet been empirically and systematically explored to understand present AM actions and proposals.

1.2.1 Objectives and research questions

In order to address the aforementioned research gaps, the overall aim of this thesis is to explore the interactions among knowledge, policy, risk and history to better understand the emergence and current implementation of AM actions. The following specific objectives and research questions are pursued within this thesis.

The first objective (Chapter 2) is to construct a historical timeline of seed transfer governance paying attention to changes in actors, policy instruments and institutions, and knowledge considered in seed transfer policy-making. Understanding this context is crucial to study the conditions for and the emergence of a contemporary climate-based seed transfer regimes that enable AM. The following research questions are addressed:

i) How has seed transfer policy changed over time in terms of actors involved, stated objectives, policy instruments and institutions, and knowledge considered?

ii) What drivers contributed to change in seed transfer policy over time?

The second objective of this thesis (Chapter 3) is to examine the ways in which different types of knowledge inform current AM policy, and how they shape current perceptions of risk associated with AM. More specifically, the following research questions are addressed:

i) What types of knowledge are deemed credible for supporting contemporary AM decision-making?

ii) How do government officials and forest industry professionals perceive the benefits and risks associated with AM, and what are their proposed solutions to address such risks?

1.3 Conceptual framework

The research presented in this thesis is grounded in three bodies of literature: i) the literature of policy change over time, ii) Science and Technology Studies (STS), and iii) socio-cultural risk perceptions. Each one is discussed in turn below.

1.3.1 Theories of policy change

This literature aims to explore questions such as what causes policy change, and why policy change comes about. Various frameworks to understand drivers of policy change exist. One of them is the advocacy coalition framework, which emphasizes how belief systems affect interactions among policy coalitions (Sabatier & Weible, 2007). This framework highlights how disruptions that are exogenous to the policy systems (e.g. significant changes in public opinion) are mainly responsible for fundamental policy changes. Another framework, albeit less explanatory in nature, is the punctuated equilibrium framework, which argues that policy schemes tend to persist for long periods of policy stability, followed by short bursts of major policy changes (Baumgartner & Jones, 2010). A third framework is path dependency, developed by Pierson (2011), who argues that in order to understand policy change at a given point in time, it is vital to understand the history of preceding events. Some important features of this theory include self-reinforcement (i.e. positive feedbacks), and trajectories that become entrenched over time (Pierson, 2011). Paying attention to past events enables a more enriched understanding of complex social (and ecological) dynamics (Pierson, 2011).

A fourth and final theory of policy change is the ‘policy windows’ framework (Kingdon, 1984). Kingdon recognizes three governance streams: i) the problems (policy issues that require attention), ii) the policies (e.g. policy proposals, tools), and iii) politics (e.g. national mood, administrative turnover, interest group advocacy campaigns) (Kingdon, 1984). When these three streams converge, a ‘policy window’ may open (e.g. acceptance of a previous rejected policy proposal). Kingdon (1984) also suggests that ‘window openings’ can sometimes be triggered by

seemingly unrelated external focusing events (e.g. a crisis, such as a devastating wildfire) both within and outside of governments. Finally, Kingdon (1984) describes why 'policy windows' may close (e.g. if participants in a particular policy ecosystem feel that the problem has been addressed, or if the crisis is short-lived). This thesis utilizes the 'policy windows' framework as a lens for inquiring AM-related policy change over time. Given the controversial nature of AM actions (Aubin et al., 2011), Kingdon's framework is a good fit because it facilitates an understanding of policy-making under conditions of ambiguity (i.e. when numerous ways of thinking about an issue exist, and more information does not necessarily help to identify a straightforward solution) (Storch & Winkel, 2013). Kingdon's work also incorporates an enlarged view of policy communities relative to other frameworks (Sabatier, 2007), is empirically oriented, and has been applied in the natural resources field at different scales and in forestry contexts specifically (Kamieniecki, 2000; Nelson, 2007).

1.3.2 Science and Technology Studies (STS)

The STS literature views the relationship between knowledge and policy as mutually reinforcing (Jasanoff, 2003a), and recognizes the political nature of knowledge itself. From a STS perspective, knowledge is produced by and reinforcing of social and political contexts, meaning that knowledge is both an input to policy as well as a policy outcome (Jasanoff, 2004a; Turnhout, Dewulf, & Hulme, 2016). This perspective is encapsulated by the concept of knowledge co-production (Jasanoff, 2004a), which is often contrasted with a linear view of the relationship between knowledge and policy that assumes knowledge is apolitically translated into policy (Turnhout & Gieryn, 2019).

STS scholars also investigate the historical, political and social processes by which different forms of expertise (including scientific, local and Indigenous expertise) are validated or legitimized in the production of knowledge for environmental governance (Brand & Vadrot, 2013; Turnhout, 2018). Further, the STS literature seeks to understand how different social groups and different knowledge forms are connected with structures of power (Turnhout et al., 2015), shaping how risks and solutions to environmental problems are understood, attributed, and defined.

1.3.3 Socio-cultural risk perception

The risk perception literature highlights how individual perceptions of risk contribute to shaping patterns of human behaviour (Slovic, Finucane, Petere, & MacGregor, 2004), which in turn influence preferences for novel policies (Burgman & Yemshanov, 2013). Some relevant factors that shape individual perceptions of risk include: i) cognitive and affective factors – whereby individuals make rapid and pre-conscious judgements (role of heuristics and biases) (Leiserowitz, 2006); ii) experiential factors – whereby perceptions of risk can be influenced by past hardships (Spence, Poortinga, Butler, & Pidgeon, 2011); iii) social values and worldviews - whereby individuals may outright reject novel policies perceived as risky for values-based reasons (Hagerman & Satterfield, 2013); iv) trust - whereby people's acceptance of seemingly risky interventions are influenced by their confidence in others who can make more informed decisions (e.g. governments or practitioners) (Mcfarlane, Parkins, & Watson, 2012); and v) perceptions of novelty – whereby individuals who perceive risks as novel, uncertain, and difficult to assess are particularly prone to seeing regulatory agencies as unprepared (Beaudrie, Satterfield, Kandlikar, & Harthorn, 2013).

The risk perception scholarship also offers valuable insights on how individuals might refuse to make trade-offs linked to decisions that defy fundamentally-held protected values (Hanselmann & Tanner, 2008). In the context of AM of trees, such protected values may be 'local seed is best,' or the degree to which humans ought to (or ought not to) intervene in non-human nature. Finally, previous research in this field highlights how values-based dilemmas may present themselves as technical ones; in doing so, individuals may mention scientific uncertainty claims to avoid making trade-offs (Hagerman, Dowlatabadi, Satterfield, & McDaniels, 2010).

1.3.4 Nexus between literatures

The framing of environmental risks (and thus the solutions to solving them) is partly shaped by the types of knowledge considered (Turnhout & Gieryn, 2019). In turn, connecting insights from the 'policy windows' framework with the STS literature, the political nature of knowledge may be embedded in the way a problem stream is framed, the proposed solutions that are presented as part of the policy stream, and the nature of policy entrepreneurs who can themselves be

knowledge producers. Thus, studying how seed transfer governance has changed over time is crucial for understanding current knowledge dilemmas and risk perceptions of AM actions, which are inevitably embedded in broader social-cultural and institutional contexts (Bickerstaff, 2004) (Table 1:1).

Table 1:1:1. Summary of the three foundational literatures used in this thesis.

Research questions	Literature	Core analytics
How has seed transfer policy changed in terms of actors involved, stated objectives, policy instruments and institutions, and knowledge considered? (Chapter 2)	Theories of policy change	Policy windows, policy entrepreneurs, focusing events
	Science and Technology Studies	Knowledge co-production
What drivers contributed to change in seed transfer policy over time? (Chapter 2)	Theories of policy change	Policy windows, policy entrepreneurs, focusing events
What types of knowledge are deemed credible for supporting contemporary AM decision-making? (Chapter 3)	Science and Technology Studies	Knowledge co-production, boundary work, epistemic selectivities, technologies of humility
How do government officials and forest industry professionals perceive the benefits and risks associated with AM? (Chapter 3)	Socio-cultural risk perceptions	Upstream approach Risk governance

1.4 Methodology

1.4.1 Qualitative inquiry approach

This thesis utilizes qualitative research methodologies to address the research questions and achieve the thesis objectives. In addition to facilitating an in-depth exploration of a research problem (Creswell, 2013), a qualitative approach allows for emerging insights from the data analysis to reshape the focus and framing of the research questions as needed. Two methods of data collection were employed in this thesis: document analysis of over 1,000 pages of policy documents, and 34 in-depth semi-structured interviews. All data was collected and analyzed between November 2018 and July 2019. Concurrent analysis and data collection made it possible

for initial findings and themes to inform and improve subsequent data collection and analysis. Chapters 2 and 3 are presented as stand-alone manuscripts, and each chapter individually details the methodology utilized.

1.4.2 Philosophical worldview

The research presented in this thesis was designed, implemented, and analyzed using a pragmatic philosophical worldview and approach (Creswell, 2013). This approach focuses on the research problem (described in detail above), making it especially suitable for the objectives of this thesis given the significance of real-world solutions as opposed to theory generating (Creswell, 2013).

1.4.3 Case study approach

A case-study approach is used to set the boundaries of the investigation of this thesis. A case study approach allows for an in-depth understanding of a contemporary bounded system through detail and in-depth data collection (Creswell, 2013; Yin, 2003). Some qualitative researchers argue that a case study is merely a choice of what to study as opposed to a methodological approach (Stake, 2006). However, a case study as a methodology is useful in creating a narrative with which people can connect and from which they can gain insight and understanding into a particular problem (Thomas, 2010).

1.4.4 Case study selection

The case of tree seed transfer in BC was selected as the focus of this thesis. BC is a pioneer in AM actions and policy development in its forest sector. For example, BC was the first jurisdiction in Canada to explicitly develop an AM pilot policy to enable the movement of western larch from southern BC to northern parts of the province (Klenk & Larson, 2015). Moreover, the BC government has adopted a more widespread and legislated AM framework as a means of adapting trees to climate change (BC Chief Forester, 2018), which is expected to be mandatory for reforestation practices by 2021 (BC Chief Forester, 2019). All of these factors make tree seed transfer in BC an ideal case to study AM governance. Seed transfer in BC is a well-bounded case with unique governance characteristics, making it an intrinsic case – a case

representing an unusual condition (Creswell, 2013), and is not necessarily representative of forest sectors in other regions.

1.4.5 Validity, positionality and generalizability

The validity of this research was ensured through using multiple sources (i.e. documents and interviews) to corroborate evidence (Creswell, 2013), peer-review and debriefing with research advisors who often challenged the interpretation of this thesis, member-checks and confirmations, piloting of semi-structured interviews, and in-depth reflections of positionality throughout the research process.

The research presented in this thesis necessitates the acknowledgment and consideration of the researcher's biases as a key tool in conducting effective qualitative research (Maxwell, 2013). In this thesis, the author is a person of colour not originally from Canada, has a BSc in Natural Resources Conservation, and does not have a long-term attachment to the forested lands where AM actions take place. The research presented in this thesis is part of a larger project (CoAdapTree) that has the overall objective of providing recommendations for the AM of trees. CoAdapTree is funded by Genome Canada, a non-profit organization funded by the Canadian government.

Given the case study methodology of this thesis, the work presented here does not seek to externally generalize the results into theoretical insights beyond the case of AM governance in BC. Rather, only internal generalizability (i.e. generalizability of results within this case study) is pursued (Maxwell, 2013). Nevertheless, although not all jurisdictions will encounter the same contextual challenges in implementing and governing novel forest management initiatives in light of climate change (such as AM), the lessons arising from this thesis raise pivotal governance questions serving as a departure point for other forest sectors considering AM actions in the future.

1.4.6 Research ethics

This research was conducted with approval from the UBC Behavioural Research Ethics Board to ensure free, prior and informed consent, confidentiality, and proper data storage procedures. No information that can be used to identify specific individuals was included in this thesis. All interviewees were notified if their quotes were used prior to publishing. Participant consent forms as well as all interview schedules can be found in the Appendices.

1.5 Study context

This thesis focuses on AM governance in the province of BC, Canada. Provincial governments are responsible for the management, development and conservation of most of Canada's forests. In BC, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) manages the province's vast forests. 95% of the 55 million hectares of forested land in BC is owned by the provincial government as 'Crown land' (BC MFLNRO, 2013). Land ownership, however, is contested as most land in BC was never formally ceded by First Nations (Low & Shaw, 2009).

Rights to harvest timber occurs through a complex system of tenures allocated to licensees, which includes private forest companies, and increasingly local communities and First Nations (Nikolakis & Nelson, 2015). Licensees are responsible for reforestation after logging until trees reach free growing (usually 20 years following harvest), and they must ensure that seed used to reforest conforms to prescribed requirements (Government of BC, 2002). Once trees reach free growing, management responsibilities for the area go back to the provincial government. The Chief Forester is authorized to determine the Annual Allowable Cut, and is also responsible for leading research and development in tree improvement, and regulating seed use through the *Chief Forester's Standards for Seed Use*. These standards presently establish the rules governing the registration, storage, selection and transfer of tree seed to reforest 'Crown' land in BC.

Like other Canadian provinces, forestry in BC has historically been driven by a need to support an industrial model of forest management (Howlett, 2001). Forestry in BC has gradually moved from a close and rather exclusive partnership between government and the forest industry towards increasingly considering the interests of a broader range of actors, including

environmental groups, First Nations, and the general public (Howlett, Rayner, & Tollefson, 2009).

Climate change is increasingly threatening the health and productivity of BC's forests (Fettig et al., 2013; Winder et al., 2011). There is abundant evidence linking climate change in BC to drought events, forest fires, and pest outbreaks such as the mountain pine beetle, all of which are expected to increase in the decades to come (Kurz, Stinson, Rampley, Dymond, & Neilson, 2008). As a result, BC has moved forward with various climate change mitigation and adaptation measures, including AM (BC Chief Forester, 2018).

1.6 Thesis organization

This thesis is divided into four chapters, including this introductory chapter. Two research papers are written and presented as individual empirical contributions (Chapters 2 and 3), both of which delve further into more specific analytics, methods, and analysis relevant to each individual contribution. Chapter 2 explores the history of over 80 years of seed transfer policies in BC to examine the drivers of change resulting in the emergence of a climate-based seed transfer system that facilitates AM. Chapter 3 delves into the specifics of contemporary AM policy in BC by examining the types of knowledge deemed credible to inform AM policy, and how this may shape AM risks and solutions to address them. The final chapter offers conclusions and contributions of this work as well as its limitations.

Chapter 2: Seeds of change? Seed transfer governance in British Columbia: Insights from history

2.1 Summary

Tree seed transfer practices are key for effective reforestation programs. Although a lot is known about the biophysical aspects of seed transfer, its governance dimensions remain under-examined. Exploring the roots of seed transfer policies provides important insights to understand future, and potentially controversial seed transfer actions like assisted migration (AM). This article offers a historical analysis of seed transfer governance in British Columbia, Canada by applying analytics from the policy change literature, and Science & Technology Studies. Based on document analysis and semi-structured interviews with key informants, we trace a set of governance attributes for an 80-year period, and examine how and why they have changed (or not) over time. Through this analysis, we delineate four governance eras: i) limited seed transfer regulation and explicit emphasis on forest productivity (1940-1995), ii) mandated geographic-based seed transfer regulation (1995-2005), iii) interim standards for seed use amendments and emergence of climate objectives (2005-2012), and iv) climate-based seed transfer (CBST) and AM implementation (2012-2019). This study reveals a paradigmatic shift in the way seed transfer is based on, culminating in a CBST system that emerged through the opening of a policy window. Genetic knowledge produced within government ministries has been the dominant evidence used to inform seed transfer policy. In contrast, governance processes, including the disproportionately influential role of the forest industry in seed transfer policy-making, remained relatively unchanged in practice. These insights shed light to the legacies of a strong government-industry forest policy coalition that have influenced underlying seed transfer objectives (i.e. forest productivity), and help explain the ongoing dominance of particular forms of knowledge used to inform seed transfer policy. We highlight the need for increased contributions from a wider range of expertise, stakeholders, and rights holders in developing seed transfer policies for the future of BC's forests.

2.2 Introduction

As climate changes and threatens the productivity and overall health of forests, tree seed transfer regulations, essential for effective reforestation programs, have been increasingly modified in some form as a climate change adaptation strategy (Hagerman & Pelai, 2018). Usually, this entails facilitating the movement of tree seed within, or just beyond, the natural range a particular species (Pedlar et al, 2012). Seed transfer is often informed by tree improvement endeavours such as tree breeding, which is used to select, test, breed, and produce trees with desirable characteristics (Ying & Yanchuk, 2006). While there is extensive research on the biophysical aspects that drive seed transfer and tree improvement policies (e.g. Ukrainetz, O'Neill, & Jaquish, 2011), social sciences research in this domain remains sparse. Some notable exceptions include studies on the framing of seed transfer policies (Klenk & Larson, 2015; Klenk, 2015), and research on public perceptions of risk in relation to movement of tree seed for the purposes of reforestation (Hajjar et al., 2014; Peterson St-Laurent et al., 2018).

Future implementation of seed transfer policy changes will be influenced not only by biophysical considerations, but also by the way seed transfer is governed. Yet, in order to understand policy change at a given point in time, it is vital to understand the history of preceding events and processes that led to that particular point in time (Pierson, 2011). Considering moments of policy change and policy development processes over time, as they shape the circumstances under which institutions change, enables a more enriched understanding of complex social-ecological dynamics (Pierson, 2011). From an applied point of view, taking a historical approach can also facilitate the distillation of insights into potential future iterations of seed transfer policy change.

In the western Canadian province of British Columbia (BC), its 55 million hectares of forests are increasingly threatened by climate change (Fettig et al., 2013). BC has a long history of restricting tree seed movement, voluntarily or through regulations (Ying & Yanchuk, 2006), and was the first jurisdiction in Canada to explicitly develop a pilot policy to enable the movement of western larch seed from southern BC to northern parts of the province (Klenk, 2015). Moreover, BC has moved forward with preliminary policies and actions to modify seed transfer as a climate change adaptation strategy (BC MFLNRORD, 2018b). Specifically, BC has put in place a Climate-Based Seed Transfer (CBST) system, which matches seedlings/seedlots to future

(projected) planting site climates. This system will eventually replace BC's geographic-based seed movement (BC Chief Forester, 2019). For these reasons, BC constitutes an ideal case to study changes in seed transfer policy over time.

Following this line of reasoning, shifts towards new seed transfer systems in BC can be best understood not as an isolated process, but as embedded within, and produced by, broader social and political contexts operating across time. Yet, the historical contours of seed transfer governance have not yet been empirically and systematically explored to identify key drivers of change over time. To address this gap, we examine changes of seed transfer governance in terms of actors involved, desired objectives and policy tools, risks considered, and knowledge used to justify policy changes over time. We pay especial attention to key drivers that influence change in provincial seed transfer policy, and the role of knowledge (and types of knowledge) throughout these policy changes. We address the following research questions: i) How has seed transfer policy changed in BC over the past 80 years in terms of actors involved, stated objectives, policy instruments, risks considered, and knowledge? And ii) What drivers contributed to change in seed transfer policy in BC for the past 80 years?

2.2.1 Conceptual foundations

In order to address our research questions, this study draws from two bodies of literature: i) theories of policy change over time, and ii) Science and Technology Studies (STS). The policy change literature allows for an exploration of what causes policy change, and why policy change occurs. Various frameworks to understand drivers of policy change exist, including the advocacy coalition framework, which emphasizes how shared belief systems (i.e. value priorities and perceptions of what matters), and policy-oriented learning are key factors that affect policy change (Sabatier & Jenkins-Smith, 1993). The punctuated equilibrium framework argues that policy schemes tend to persist for long periods of policy stability, followed by short bursts of major policy changes (Baumgartner & Jones, 2010). A third theory of policy change is the 'policy windows' framework developed by Kingdon (1984), which recognizes three main streams in governance: i) the problems (policy issues which are deemed to require attention), ii) the policies (e.g. policy proposals, tools), and iii) politics (e.g. provincial mood, administrative

turnover, interest group advocacy campaigns) (Kingdon, 1984). When these three streams converge, a 'policy window' may open, often for a short period of time. Kingdon (1984) further describes the need for policy entrepreneurs in order to facilitate the opening of policy windows. Policy entrepreneurs are individuals or corporate actors who are willing to invest time, energy, reputation (and occasionally even financial resources) in attempting to couple the three governance streams (Kingdon, 1984).

In this study, we utilize the 'policy windows' framework as a lens for our inquiry. Kingdon's work fits well with BC's seed transfer governance landscape as it is applicable to policy formation under conditions of ambiguity (i.e. when there are various ways of thinking about an issue, and more information does not help to identify a straight-forward technical solution) (Storch & Winkel, 2013). This is particularly important given that BC has implemented assisted migration actions (further described below), which are considered controversial (Aubin et al., 2011). Moreover, the policy windows framework has important implications for claims concerning the role of individuals and institutions in policy-making as it subscribes to the notion that institutions make things possible, but people make things happen (Zahariadis, 2007). Finally, Kingdon's work incorporates an enlarged view of policy communities relative to other frameworks (Cairney & Heikkila, 2007), is empirically oriented, and has been applied in the environmental field in subnational, national and global contexts as well as in BC forestry contexts specifically (e.g. Kamieniecki, 2000; Nelson, 2007).

Insights from STS scholarship help to understand the roles of (scientific) knowledge and knowledge-related debates in decision-making, including knowledge as a source of policy change (Jasanoff, 2004a; Turnhout & Gieryn, 2019). Decades of research in this field have shown the relationship between knowledge and policy as mutually reinforcing (Jasanoff, 2003a) as opposed to linear, recognizing the political nature of knowledge itself (Turnhout et al., 2016). These ideas are encapsulated by the concept of knowledge co-production. STS scholarship also investigates the mechanisms by which different forms of expertise (including scientific, local and Indigenous expertise) are included or excluded in the production of environmental knowledge (Turnhout, 2018; Brand & Vadrot 2013). Linking insights from the policy change and STS

literatures, the political nature of knowledge may be embedded in the way a problem stream is framed, the proposed solutions that are presented as part of the policy stream, and the nature of policy entrepreneurs who can themselves be knowledge producers.

2.2.2 Background: seed transfer and tree improvement governance in BC

Responsibility for the management, development and conservation of most of Canada's forests is vested with the provincial governments. Specifically, the responsibility for managing BC's forest is assigned to the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD). Approximately 95% of BC's forests are owned by the provincial government as 'Crown' land (MFLNRORD, 2013). Rights to harvest portions of the annual allowable cut (AAC) are allocated to forest companies, communities, First Nations, and individuals under agreements (i.e. licenses). BC's Chief Forester (appointed by the elected Minister of Forests, Lands, Natural Resource Operations and Rural Development) is authorized to determine the AAC, and leads initiatives related to research and development in tree improvement. The Chief Forester is also responsible for regulating tree seed use through the *Chief Forester's Standards for Seed Use*, which currently establish the rules governing the registration, storage, selection and transfer of tree seed to reforest 'Crown' land. Licensees are responsible for reforestation after logging until trees reach free growing (usually 20 years following harvest), and they must ensure that seed used to reforest conforms to prescribed requirements (Government of British Columbia, 2002). Once free growing status has been achieved, management responsibilities for the area go back to the BC government.

2.3 Methodology

2.3.1 Approach and data collection

Using a case study approach (Creswell, 2013), we focus on tree seed transfer governance in BC. This study is based on document analysis of all publicly available policy documents on the topics of seed transfer, tree improvement (including tree breeding and genetic resource management), and climate change adaptation published by the BC MFLNRORD. Documents analyzed included Ministry annual reports (1920s – 2018), Forest Genetic Council of BC annual reports (2000 – 2018), forest-related regulations (including BC's *Seed and Vegetative Material Guidebook* and

all its updates, as well as BC's *Chief Forester's Standards for Seed Use* and all its amendments to date), forest-related legislation (including experts from the *Forest Act*, the *Forest Practices Code of British Columbia Act*, and *Forest and Range Practices Act)*, CBST's project charter and updates, technical reports and research notes prepared by the MFLNRORD, and many others.

Document analysis was supplemented by in-depth semi-structured interviews (n = 7) with key informants within the BC government, including tree breeding managers and government scientists. Interviewees were identified using a purposeful sampling strategy (Creswell, 2013) to identify individuals responsible for tree improvement and seed transfer, and/or reforestation policies and practices in BC. Individual participants were selected based on having a minimum of 15 years of work experience in the BC forest sector, and a portfolio related to tree improvement and/or seed transfer. The rather stringent inclusion criteria resulted in a small sampling pool of potential participants. However, seven interviews represent an exhaustive list of the potential participants for this study. Participants were identified online using the BC government directory, in consultation with government informants, and from interviewees themselves who recommended key individuals to speak with. Interviewees were asked about the objectives guiding seed transfer and tree improvement over time, the types of evidence used to inform changes in seed transfer and tree improvement priorities, as well their views on the current CBST system in BC. Interview protocols can be found in the Appendices.

2.3.2 Analysis

Documents were systematically analyzed using content analysis (Hsieh & Shannon, 2005). We developed and applied a set of coding categories based on key governance attributes that derive from the theoretical foundations descried above, and that are often included in policy-oriented historical analyses of socio-ecological systems (e.g. Hagerman, Dowlatabadi, & Satterfield, 2010). We examine changes in knowledge, institutions, policy instruments, and actors alongside their stated objectives in relation to tree seed transfer and tree improvement governance in BC from the early 1940s to 2019 (Table 2:1). Each document was added to NVivo (NVivo qualitative data analysis software for Windows; Version 11, 2016), and the full text of each document was coded line by line following the typology described above. In total, 144 individual

documents and 1,000+ pages were analyzed. The first author conducted all interviews as well as all the coding and analysis. Interviews were audio-recorded, transcribed verbatim, and analyzed in NVivo. Text was coded line-by-line, and systematically analyzed using a combination of a deductive and inductive approach to identify recurrent concepts and ideas, and subsequent analytical themes (Charmaz, 2006). Insights from the seven semi-structured interviews provided a means to confirm the analytical interpretations arising from the document analysis.

Table 2:1 List of governance attributes investigated through time.

Governance attribute category	Specific governance attribute investigated
Actors and institutions involved	Who makes decisions? Who is consulted? Stated objectives and desired outcomes
Policy instruments and processes	Regulations and guidelines Enforcement mechanisms Decision-making processes
Risks	Risks and concerns identified
Knowledge	Whose knowledge is used? What type of knowledge is used? How is that knowledge used?

2.4 Results: A historical profile of seed transfer governance in BC (1940-2019)

In this section, we present a historical profile of BC's seed transfer governance over time. Through this analysis, we identify four distinct eras distinguished by changes in governance and overarching seed transfer objectives. The first era begins with little to no seed transfer regulations, and an explicit focus on forest productivity (early 1940s – 1995). The second era starts with the first set of mandated and legislated regulations of seed movement in BC (1995-2005). The third era begins with the inception of interim standards for seed use amendments in response to climate change adaptation objectives, and culminates with changes to western larch

seed transfer limits (2005-2012). The fourth and final era (2012-2019) begins with the inception of the CBST project, and continues into the transition towards a seed transfer regime based on climate as opposed to geography, and an increasingly diverse set of objectives driving seed transfer policy (in addition to forest productivity). Tables 2:3 and 2:4 offer an overview and summary of these four eras.

2.4.1 Limited seed transfer regulation and explicit emphasis on productivity (1940-1995)

There were no seed transfer practices in BC prior to the 1940s. Before then, most reforestation endeavours occurred via natural regeneration. Whenever seed was collected, local seed was considered "safest" (BC Ministry of Forests, 1987). According to government records, the first seed zones in BC were drafted in 1946 for Vancouver Island and the south coast mainland, and re-drafted in 1962 to include the interior of the province (BC Forest Service, 1946). In 1962, a seed collection zone map for Douglas-fir (*Pseudotsuga menziesii*) was recommended by a University of British Columbia professor (Haddock, 1962), enabling the creation of a seed collection zone map for Douglas-fir.

As reforestation actions expanded into the interior of BC, 67 Forest Tree Seed Zones were created for the province in 1974 in order to guide seed collections. The transfer of seedlots beyond zone boundaries was allowed as long as it was within its 'adaptive limit' (Ying & Yanchuk, 2006). In 1986, seed planning zones in the interior of BC were consolidated into 21 zones. These changes were led by a government-mandated review task force that consisted of seed orchard managers, forest geneticists, ecologists, and silviculturists from both the forest industry and government (Ying & Yanchuk, 2006). In terms of knowledge, the delineation of these early seed zones was primarily based on field experiments (provenance trials) by government scientists (specifically forest geneticists), and by regression models relating provenance geographic variables to provenance growth whenever this data was available (Ying & Yanchuk, 2006). A memorandum released to staff in the BC Ministry of Forests on coastal Douglas-fir seed zones and seed transfer rules describes the role of provenance data and forest scientists in making seed transfer changes:

> "Research Branch provenance test data was invaluable in arriving at the recommendations of this task group […] Comment on the preliminary

> recommendation (November, 1985) was solicited, and received from scientists at the Pacific Forestry Centre and from selected operational users of Douglas fir seed." (BC Ministry of Forests - Seed Zone and Transfer Rules Task Group, 1986 - *Memorandum released to staff in the BC Ministry of Forests on Coastal Douglas-fir Seed Zones and Seed Transfer Rules*)

These new seed transfer recommendations were implemented, and transfer of seed from superior Washington state provenances was allowed for operational trials only. The main objectives of modifying seed transfer guidelines during this time were to "help ensure adaptability and optimum utilization of the site's growth potential" (BC Ministry of Forests, 1987). Seed movement was not mandated during this period (1940s – 1995). Similar to various silvicultural regulations at the time, seed zones in BC were used as references to help foresters make decisions on the use of seed sources (Ying & Yanchuk, 2006). During this era, research reports on government-run provenance tests recommended less restrictive movement of seed:

> "The local provenance is not always the best in terms of growth […] and Interior spruce and Lodgepole pine seed could be safely transferred beyond the limits previously recognized" (BC Ministry of Forests, 1987 - *Seed Planning Zones and Transfer Guidelines for Interior Spruce and Lodgepole Pine*)

A few years later, the BC Ministry of Forests recommended even fewer restrictions on seed transfer, with an ongoing emphasis on maximizing volume gains via "superior" provenances:

> "The transfer guidelines given here are based largely on early results from the provenance and progeny tests established by the Research Branch […] Less restrictive movement of superior provenance seed, over other natural stand provenances, is recommended because of demonstrated top performances in wide-ranging field tests […] It is important that emphasis be given on the use of seed from seed orchards and superior provenances sources when available to achieve genetic gains as soon as possible through planting programs. In both cases estimates of volume gains are significant." (BC Ministry of Forests, 1989 - *Interior Seed Transfer Guidelines for Cone Collection Planning and Seedlot Selection*)

In addition to provenance data, other forms of evidence were sometimes used to modify seed transfer guidelines, including biogeoclimatic data and "practical knowledge" (BC Ministry of Forests, 1990). The role of universities is salient in this process as well:

> "These guidelines given here for natural stand seed are based on information drawn from provenance and progeny testing in B.C. and elsewhere, the biogeoclimatic (BGC) classification system and practical knowledge. They have been approved by the Coastal Seed Transfer Task Group which consists of Ministry of Forests, industry and

> university representatives." (BC Ministry of Forests, 1990 - *Coastal Seed Transfer Guidelines*)

Notably, exotic seed sources (including noble fir and hybrid poplar) for coastal BC were allowed as part of the 1990 Coastal Seed Transfer Guidelines but on an experimental basis only (BC Ministry of Forests, 1990).

Seed transfer and forest genetics research have been inextricably linked over time. As per the previous examples, provenance tests based on forest genetics provided a wealth of information to continually refine seed transfer guidelines. Forest genetics research in BC started by government scientists at the BC Forest Service in the 1950s at the Cowichan Lake Research Station on Vancouver Island, and mainly focused on Douglas-fir (Schmidt, 1992). The shortage of high elevation Douglas-fir seed in the 1950s was causing the BC Forest Service's Reforestation Division some concern (BC Forest Service, 1967).

In terms of actors involved, forest genetic research management activities in BC (including tree improvement and tree breeding programs) were planned and coordinated by the Plus Tree Board in the 1960s. The forest industry at the time was interested in these endeavours, and participated in tree selection research:

> "It was clear that progress in [tree] selection would be too slow if the Forest Service effort was not augmented in some way and that it would be difficult to build up an adequate breeding population for the programme especially when the widespread distribution of Douglas-fir was considered. However, by 1959 the forest industry showed an increasing interest in tree improvement work and the Plus Tree Board […], which is an organization of companies holding Tree Farm Licences on the coast, and members of the Federal and Provincial Forest Services and the University of British Columbia." (BC Forest Service, 1967 - *A Review of the Plus Tree Selection Programme for Douglas-fir in Coastal British Columbia*)

The forest industry at the time also participated in the development of seed orchards (Woods, 2012). Similar to seed transfer guidelines, objectives of BC's tree improvement program in this era put an emphasis on growth:

> "What is required above all is a more efficient tree, a tree which will reach a given size on a given site in a shorter time than a normal seedling and a tree which has characteristics better suited to its eventual utilization." (BC Forest Service, 1967 - *A Review of the Plus Tree Selection Programme for Douglas-fir in Coastal British Columbia*)

While early tree improvement efforts focused on Douglas-fir, BC's forest genetics program expanded in the sixties and seventies to include other species and extensive research on provenance variation in several native tree species (e.g. spruces). The establishment of lodgepole pine (*Pinus contorta*) provenance trials in the 1970s stands out as it became the world's largest conifer genecology field trial (Woods, 2012).

Since the late 1950s, BC's provincial government also established numerous plantations of native and exotic tree species to test their growth and vigor in areas where these trees were not considered native species. As alluded to above, these trials included plantations of noble fir (*Abies procera*), whose northernmost natural range is one degree south of the Canada-U.S. border (BC Ministry of Forests, 1998). The following research report by a government scientist describes how the introduction of noble fir gained interest given the potential for a higher volume of wood:

> "Noble fir is able to sustain good growth for over 1 or 2 centuries, and it produces a higher volume of wood than most other conifers at the same height because of its columnar stem form and thin bark. It also has strong wood and is relatively free of insects and diseases (Franklin 1982). Because of these attractive silvicultural characteristics, foresters in British Columbia have long been interested in noble fir's introduction. It was first planted at Agassiz Agricultural Experimental Station in the Fraser Valley in 1893, and is still being operationally planted along the lower coast of British Columbia, although in small scale" (Ying, 1990 - *Research Report from the Research Branch of the BC Ministry of Forests*)

In addition to noble fir, Siberian larch (*Larix sibirica*) plantation trials also took place in the 1990s, where government-run experimental projects suggest that it can successfully be grown in interior BC (BC Ministry of Forests, 1993).

After the Plus Tree Board Forest was dissolved, genetic research management was managed by the Coast and Interior Tree Improvement Councils from the late 1970s until 1997. When these councils were established, the majority of forest genetic management activities on BC 'Crown' land were conducted cooperatively by the forest industry and government (FGC, 1998). Funding provided via the *Forest Act* included capital and operating costs for industry orchards and for government-led genetic testing (Government of British Columbia, 1996). Significant development of seed orchards also took place during this period (Woods, 2012). As part of this industry-government cooperative, BC's Ministry of Forests and Range at the time owned and operated orchards, and provided a planning and regulatory role (FGC, 1998). In 1987, changes in legislation shifted reforestation costs (including the cost of seed) to forestry companies, which discontinued the funding mechanism and cooperative structure that had been in place to coordinate improved seed supply (FGC, 1998).

2.4.2 Mandated geographic-based seed transfer regulation (1995-2005)

This period is characterized by mandated and legislated regulation of seed movement (as opposed to guidelines), starting in 1995 with the creation of fixed seed planning zones, together with geographic transfer limits as described in the Seed and Vegetative Material Guidebook:

> "The regulation of seed and vegetative material collection, registration and use is governed by two acts (the *Forest Practices Code* of British Columbia Act and the *Forest Act*) and their respective regulations. Regulations governing the collection, registration, processing and disposition of seed and vegetative material are in the Tree Cone, Seed and Vegetative Material Regulation, attached to the *Forest Act*. Regulations governing the use of seed and vegetative material are in the Silviculture Practices Regulation, attached to the *Forest Practices Code of British Columbia Act*." (B.C. Ministry of Forests, 1995 - *Seed and Vegetative Material Guidebook*).

Although the language of "guidelines" persisted, the Seed and Vegetative Material Guidebook was put in place to "help forestry practitioners meet the requirements of the *Forest Practices Code* with respect to planning, collecting, registering and using seed and vegetative material" (BC Ministry of Forests, 1995). The reliance on provenance data and the influential role of government-industry task forces remained prevalent in the era:

> "These guidelines are based on results from the ministry's provenance and progeny tests or observations of general patterns of adaptive genetic variation. These guidelines

> are updated whenever significant test information has been collected, analyzed and fully reviewed (approximately every five years). Seed transfer review task groups of ministry and industry personnel, review the guidelines of coast and interior species and recommend any changes to the chief forester. The information in these guidelines therefore represents the best available knowledge of seed and vegetative material transfer in the province." (B.C. Ministry of Forests, 1995 - *Seed and Vegetative Material Guidebook*).

In terms of risks considered, a salient feature of this period includes increasing concerns about maladaptation risks (and subsequent growth losses) associated with seed transfer:

> "Transfer guidelines minimize the risks of maladaptation or growth loss associated with moving seed or vegetative material from its source to another location. Exceeding the transfer limits may decrease productivity or increase susceptibility to frost, insects or disease. Poor survival or outright mortality may occur when seed is transferred past its ecological tolerance; however, losses in productivity can be substantial even over relatively short distances, particularly where elevation is concerned." (B.C. Ministry of Forests, 1995 - *Seed and Vegetative Material Guidebook*).

According to the Seed and Vegetative Material Guidebook, five provenances considered exotic were allowed to be planted in BC, but regulations on where they could be planted were very specific:

> "Noble fir seed can be transferred to the coast of British Columbia, provided that collections are restricted to natural stands north of 45° latitude and above 1,000 m. Use of noble fir provenances must be restricted to maritime sites on Vancouver Island and south of 50° latitude on the mainland" (BC Ministry of Forests, 1995).

In addition to noble fir, interior spruce (*Picea engelmannii* × *glauca*) seed could be transferred from the western limit of the species' natural range to the maritime seed planning zone (slightly outside of the species' natural range) (BC Ministry of Forests, 1995). Idaho western white pine (*Pinus monticola*), bred for disease (white pine blister rust) resistance, could be transferred to the interior seed planning zones of B.C., provided it was used south of 52° latitude and below 1,450 meters (BC Ministry of Forests, 1995). Finally, Sitka spruce (*Picea sitchensis*) seed from Oregon and Washington states could be transferred to the BC coast, provided that collections were "from within 30 km of the coast and below 200 m. Their northward transfer should not be more than 4° of latitude and 300 m above the source of origin" (BC Ministry of Forests, 1995). The examples

above show how seed transfer policy in this era focused almost exclusively on seed planning zone–specific geographic features (e.g. latitude, longitude, elevation) to regulate seed transfer.

Since its establishment in 1995, BC's Seed and Vegetative Material Guidebook has been updated five times, all of which were primarily based on progeny and provenance testing programs. A notable change came after an extensive review of interior seed planning zones for seed produced in orchards in 1998:

> "The objectives of the Interior Seed Planning Zone (SPZ) Review were to 1) update interior seed zone's in order to incorporate recent biological information and interpretation, 2) to make better use of the biogeoclimatic ecological classification system (BEC) mapping tools, and 3) to increase administrative efficiencies […] Input included representation from both ministry and industry clients involved in planning, tree breeding, orchard management and silvicultural activities." (BC Ministry of Forests, 1998)

The Interior Seed Planning Zone Review exemplifies an increasing use of non-genetic (e.g. ecological) knowledge to inform seed transfer, but shows a continuing prevalent role of forest industry and government in making seed transfer decisions. The Interior Seed Planning Zone Review, and associated updates to the Seed and Vegetative Material Guidebook made small, incremental changes in seed transfer rules, allowing for increased transfer distances:

> "The new SPZ's represent expanded areas of intended use for Class A seed. Genetic and provenance test results indicate that Class A seed can be moved safely within much broader areas than originally planned and that greater flexibility can be accommodated through the use of overlap zones." (BC Ministry of Forests, 1998)

In 1997, BC's Chief Forester combined the Tree Improvement Councils, and appointed a transitional Tree Improvement Council (TIC) of British Columbia, whose mandate was to:

> "Develop and recommend an organizational structure among government, industry, Forest Renewal BC [Crown corporation], and universities that will result in the efficient delivery of a forest genetics program in British Columbia" (Forest Genetics Council of BC, 1998).

The TIC recommended the name "Forest Genetics Council of British Columbia" for the permanent multi-stakeholder council that would set provincial objectives related to forest genetic management, which was later endorsed by BC's Chief Forester at the time (FGC, 1998). Thus,

starting in 1997, forest genetic research management activities in BC were planned and coordinated by the Forest Genetics Council (FGC) of BC. As set out in its 1998 Strategic Plan, the FGC's goal was to:

> "To maximize the economic benefits from tree improvement investments for gains in wood quality, quantity, and pest tolerance consistent with strategic land use planning." (Forest Genetics Council of BC, 1998).

In subsequent years, the mandate of the FGC shifted towards cooperative management and signaled a scientific basis:

> "Lead the cooperative management of tree gene resources in British Columbia consistent with scientific and conservation principles." (Forest Genetics Council of BC, 2004)

The mandate of the FGC also expanded to "coordinating stakeholder activities and securing resources to meet [FGC's] Business Plan priorities" (FGC, 2004). The role of the FGC consolidated as an advisory body appointed by the Provincial Chief Forester. This multi-stakeholder council advises the Chief Forester on related policy issues and allocates provincial funds to forest genetics programs (FGC, 2002). The FGC and its technical advisory committees consist of representatives of provincial and federal governments, forest companies, woodlots, seed orchards, nurseries, universities, and other agencies (FGC, 2015).

2.4.3 Interim standards for seed use amendments and emergence of climate objectives (2005-2012)

During this period, the *Forest and Range Practices Act* (FRPA) was introduced in 2004, replacing the *Forest Practices Code of British Columbia Act* in order to increase efficiency for both government and industry while still maintaining high environmental standards (Government of BC, 2002). FRPA focuses on results as opposed to methods, meaning that it has fewer prescriptive rules than the *Forest Practices Code*, providing licensees with more operational flexibility and opportunities to potentially carry out innovative forest practices.

In 2005, seed transfer limits in the Seed and Vegetative Material Guidebook and updates were all repealed and replaced with the transfer limits in the *Chief Forester's Standards for Seed Use.* These standards currently establish the rules governing the registration, storage, selection and

transfer of tree seed to reforest 'Crown' land. The objective of these seed standards continue to mention seed adaptability and productivity, but also highlight genetic diversity:

> "The purpose of these standards is to maintain the identity, adaptability, diversity and productivity of the Province's tree gene resources by a) establishing criteria for the registration of seedlots and vegetative lots used to establish a stand under section 29 of the [FRPA] Act, and b) regulating the storage, selection, use and transfer of registered lots." (BC Ministry of Forests, 2004 - *Chief Forester's Standards for Seed Use*)

As exemplified above, tree seed use in this era remains a prescribed (i.e. non-results-based) practice, and the Chief Forester's Standards for Seed Use are among the few legally enforceable standards under the FRPA (Government of BC, 2002). Licensees who plant trees to establish a free growing stand must use seed that has been registered, stored, selected and transferred in accordance with the Chief Forester's Standards for Seed Use (BC Ministry of Forests, 2004), or an alternative to the standards approved by the Chief Forester. Furthermore, BC's seed transfer rules for seed in this era continue to be geographically-based, meaning that seedlots must be used within the seed planning zone (SPZ) in which they are collected, and within elevational, latitudinal and longitudinal limits specific to the tree species. These seedlots may, however, be transferred outside their SPZ of origin if used within the same BEC zone. Seed collected from superior provenances (i.e. improved or selectively bred trees) continue to have broader transfer limits than untested or average performing wild provenances. Seed derived from seed orchards must be used within SPZs and in an elevation range where the parent trees in the orchard have been tested (BC Ministry of Forests, 2004).

As per the Chief Forester's Standards for Seed Use, all tree seed in BC must be registered and stored at the ministry's Tree Seed Centre located in Surrey, BC. Tree seed must meet specific collection, genetic diversity, and physical quality requirements to be able to be registered (BC Ministry of Forests, 2004). The standards for seed use restrict the registration of seed and subsequently the use of tree species from non-BC sources. The only non-native tree species that can be registered for use under the standards are noble fir and tested hybrid poplars (BC Ministry of Forests, 2004). Registration of seed collected from trees that are part of a breeding program requires recording of information on the parent trees and the breeding process. Seed that has

been genetically engineered cannot be registered or used for ‘Crown’ land reforestation (MFLNRORD, 2019a).

Compared to the Seed and Vegetative Material Guidebook, the Chief Forester’s Standards for Seed Use language changed from “exotic provenances” to “non-BC seed sources” (BC Ministry of Forests, 2004). In this new iteration of seed transfer regulations, standards on non-BC seed sources were more specific, but remained almost unchanged for the first decade. Interior spruce was no longer listed as a non-BC provenance (BC Ministry of Forests, 2004). Table 2:2 describes the specific geographical requirements to collect and transfer non-BC seed:

Table 2:2 List of standards on non-BC seed sources as part of the Chief Forester’s Standards for Seed Use published in 2004.

APPENDIX 6 – NON-BC SEED SOURCES

Table 6.1 Non-BC Natural Stands

Species		Collection Area Criteria Section 5.2.3.1 (b)			Transfer Limits Section 8.7 (a)		
Code	**Common name**	**Elevation limits** *(metres)*	**Maximum range between lowest and highest elevation** *(metres)*	**Additional criteria**	**May be used within the following natural stand seed planning zones**	**May be used within the following range (up/down) from mean elevation of origin** *(metres)*	**May be used within the following latitude range** *(degrees)*
Bp (Bn)	Noble fir	≥ 700	300	Within natural stands located north of 45° in Washington or Oregon, USA	M, SM	+300 / -400	48° – 52°
Fdc	Coastal Douglas-fir	No limit	350	Within natural stands located north of 46° in Washington or Oregon, USA	GL, M	+350 / -350	48° – 52°
Ss	Sitka spruce	≤ 200	250	Within natural stands located within 30 km of Pacific Ocean in Washington or Oregon, USA	M Queen Charlotte Islands only	+300 / no limit down	No limit

After the Chief Forester’s Standards for Seed Use were established, BC has gradually modified these standards to allow for more flexible seed transfer. In 2008, for example, species movement was expanded +200 meters north of their current ranges. Target transfer distances were identified for suitable movement for species and a transfer range was created around the distance that would maintain acceptable productivity, but introduces considerations of forest health and climate change adaptation as well:

> “The purpose of these amendments is to address potential forest health and productivity impacts associated with climate and to guide the appropriate selection

> and deployment of tree seed. The recommended changes are based upon a report by G. A. O'Neill et al, 'Assisted migration to address climate change in BC: recommendations for interim seed transfer standards' […] Overall, these interim changes increase seed deployment options – not restrict them." (BC Chief Forester, 2008 - *Amendments to the Standards for Seed Use*)

The report cited above was led by a forest geneticist within BC the Ministry of Forests, who used a combination of Geographic Information Systems and modelling to make its recommendations (O'Neill et al., 2008). The 2008 amendments to the standards introduce for the first time in BC's seed transfer policy the concept of assisted migration (AM) as a tactic to address climate change. Although AM is not defined in official policy documents, it is defined in government-led technical reports used to inform seed transfer policy:

> "Climate change is expected to result in trees in most regions of British Columbia becoming increasingly maladapted to the climates in which they are planted. Consequently, planting seedlings adapted to future climates (assisted migration) is recognized as a key strategy to address climate change, as it will help maintain healthy, productive forests, and ensure capture of gains obtained from decades of selective breeding." (O'Neill et al., 2008 - *Technical report as part of BC's Ministry of Forests and Range Forest Science Program*).

Yet, the most notable amendment to the standards in this era is the AM of western larch (*Larix occidentalis).* Western larch is one of the most productive interior conifer species in BC (BC MFLNRO, 2000). The objectives of these changes were similar to the ones in 2008, but focused more heavily on climate:

> "The purpose of these amendments are to expand the seed transfer limits of western larch to increase species diversity, and address the potential forest health and productivity impacts associated with a changing climate. Specifically, this amendment provides for the range and population expansion of Western larch (Lw) beyond its contemporary range (historical and current climate envelope) in areas projected to be climatically suitable in the year 2030." (BC Chief Forester, 2010 - *Amendments to the standards for seed use*).

In terms of additional objectives, the BC MFLRO hoped that the availability of western larch as a planting option at the time would reduce the dominance of lodgepole pine as the regeneration species of choice, which would increase diversity and potentially improve forest health at stand

and landscape scales (Newsome et al., 2016). In addition to in-house scientific knowledge, the 2010 amendments to the standards mention stakeholder consultations for the first time:

> These amendments are based on recent scientific research and analysis conducted by Dr. Gerald E. Rehfeldt (USDA Forest Service, retired) and Dr. Barry Jaquish (MFR, Research and Knowledge Management Branch), as reported in their publication, "Ecological impacts and management strategies for western larch in the face of climate change" (March, 2010, […]); feedback solicited through stakeholder consultation; and analysis undertaken by ministry staff." (BC Chief Forester, 2010 - *Amendments to the standards for Seed Use*).

To put the quote above in perspective, western larch's natural distribution in BC at the time was restricted to the southeastern portion of the province. However, key in-depth modelling work done by Rehfeldt and Jaquish (2010), combined with field trials of western larch outside of its natural range, suggested that the potential niche of western larch extended considerably further north. Rehfeldt and Jaquish (2010) provided climate projections for the movement of western larch at high levels of spatially explicit accuracy. By combining forest inventory plots, field trials, ecological plots and genetic variation alongside climate variables, the presence and absence of western larch under future climate projections was determined, enabling pinpointing to specific areas for transfer (Rehfeldt & Jaquish, 2010). Using this evidence, three new seed planning zones were developed that allowed for the long distance dispersal of western larch into areas that are both suitable in today's conditions as well as future climatic conditions. The species could account for a maximum of 10% of the planting mixture used by licensees (BC Chief Forester, 2010).

The changes to seed transfer policy in this era are notable. When the climate seed planning zones for western larch were introduced, long distance dispersal was incorporated into BC's Chief Forester's Standards for Seed Use for the first time. This was also the first time policy explicitly allowed for the assisted migration of commercially valuable tree species in Canada (Klenk, 2015).

2.4.4 Climate-based seed transfer and assisted migration implementation (2012-2019)

This period is characterized by an increased emphasis on climate change adaptation and forest health as drivers of seed transfer and tree improvement policy. In this era, the first official climate change strategy is presented by the BC Ministry of Forests Lands and Natural Resources. Several report during this time signaled urgency in relation to climate change-related risks affecting BC forests.

> "British Columbia's climate is changing: Climatologists have documented significant temperature and precipitation changes over the past several decades. The impacts of climate change, such as the mountain pine beetle epidemic and 2015 droughts, are already been seen in B.C. In the decades ahead, temperatures are projected to be higher and precipitation patterns will be more variable causing major changes to both human and ecological systems." (BC Ministry of Forests Lands and Natural Resources, 2015 - *Climate Change Strategy 2015-2020*).

To better address the impacts of climate change, BC's provincial government developed a Forest Stewardship Action Plan for Climate Change Adaptation, with the overarching goal of accounting for a changing climate in BC's forest management policy framework (MFLNRO, 2012b). As part of this plan, the first objective was to foster forest resilience. Action items to meet this objective included developing a climate-based seed transfer (CBST) system that would allow for adjustments to the forest regeneration framework to make it suitable for changing climates (MFLNRO, 2012). More concretely, CBST would convert BC's geographically-based system of seed selection, transfer and deployment to a climate-based system:

> "The aim of this forest stewardship climate change adaptation initiative and project [CBST] is to transition British Columbia's genetic resource management seed transfer system from a geographically-based science, policy and decision support framework to one that is climate based." (BC Ministry of Forests, Lands and Natural Resource Operations, 2012 - *CBST Project Charter*)

Furthermore, the CBST project explicitly references assisted migration of trees as a key strategy to combat climate change in the forest sector, which the system would enable:

> "Among management strategies proposed to mitigate the negative impacts of climate change in forests, climate-based seed selection, transfer, and deployment, together with climate change adaptation strategies such as assisted migration, offers a key solution." (BC Ministry of Forests, Lands and Natural Resource Operations, 2012 - *CBST Project Charter*)

The rationale for developing a CBST system includes the need for trees to adapt to climate change and associated droughts and pests, but reveal the underlying reason to ensure climate change adaptation: forest productivity and growth. The following text delineates the link between CBST's objectives:

> "A key goal of sustainable forest management in BC is the reforestation of forest stands and landscapes that are productive, healthy and resilient. Forest management objectives that support this goal require the establishment of plantations that can yield their optimum potential for forest productivity and growth, while still maintaining their genetic capacity to evolve and adapt to changing conditions and the environmental limits set by climate, weather and soil. To achieve this objective, we must ensure a 'match' of planting stock with environments where the trees will thrive, be well adapted, and able to respond to periodic and catastrophic abiotic and biotic disturbance events such as drought, wildfire, pests and disease infestations." (BC Ministry of Forests, Lands and Natural Resource Operations, 2012 - *CBST Project Charter*)

The underlying focus on growth and productivity was corroborated by interviewees. As one government informant expressed when talking about benefits of AM in the CBST context:

> "When we move, when we restore populations of trees back to their ancestral climates, they are much happier. They are adapted to the pests, the diseases, and the climate of those ancestral locations, and consequently, they are more productive and healthier." [I1 - *Government*]

Although the implementation of a CBST system started in 2012, the scientific foundation of a CBST model started developing over years before under the Research Branch (now called the Forest Improvement and Research Management Branch) of the B.C. Ministry of Forests and Range (O'Neill et al., 2008). CBST is based on the increased knowledge and growing information around genecological research, provenance trial data, fine-scale climate mapping, improved General Circulation Models, and to a lesser extent genomic tools that assess seed source climate adaptation (O'Neill et al., 2017). Moreover, as part of the MFLNRO's climate change strategy during this time, the importance of internal expertise remains pivotal as described by the following strategic objective:

> "Climate Science: The ministry retains internal climate change adaptation and mitigation science expertise to ensure that British Columbia is progressive and informed to the extent of other comparable jurisdictions and institutions in North America." (BC Ministry of Forests, Lands and Natural Resources, 2015 - *Climate Change Strategy 2015-2020*).

Interviewees echoed the historical reliance on (internal) experts to inform actions by BC's MFLNRO. When asked about assisted migration governance in particular, a government informant expressed the following:

> "We have a decision making system historically whereby experts have been hired to make decisions for the benefit of society […] This is a science-led decision making process, and I think it needs to remain that way." [I7 - Government]

The role of the FGC in facilitating and generating genetic knowledge to inform CBST becomes evident during this time. The FGC set the following objective in its five-year Strategic Plan:

> "By 2020, high-quality genecology research information will guide operationally efficient climate-based seed transfer policy and practice for all trees planted in BC." (Forest Genetics Council of BC, 2009 - *2009-2014 Strategic Plan*)

Similar to seed transfer, tree improvement objectives shifted towards a more explicit emphasis on forest health, as described by a government scientist:

> "About four years ago [~2014], the Forest Genetics Council recommended to the Chief Forester that we ought to place greater emphasis on selecting and breeding for pest and disease resistance. So my colleagues have shifted the focus of tree breeding objectives to more heavily weight those forest health traits in their selections. It's not that we weren't doing it previously, but now it's a more explicit endeavor […] The objective prior to four years ago for most species was primarily growth." [I3 - Government]

It is noteworthy to mention that the most recent objectives of the FGC reference non-timber economic value of forests (in addition to timber) for the first time, and emphasize native species:

> "1) Conservation – the maintenance of natural levels of genetic diversity for all tree species indigenous to BC. 2) Resilience – matching seed (genotypes) to planted sites (environments) and maintaining natural genetic diversity in planted populations of trees. 3) Value – increasing the timber and non-timber economic value of planted forests." (Forest Genetics Council of BC, 2019 - *2018/2019 Annual Report*).

In terms of policy instruments, the Chief Forester's Standards for Seed Use were amended in 2018 (six years after the project charter was published) to legislate and enforce a CBST system in BC, mirroring the objectives of the CBST project charter:

> "CBST promotes healthy, resilient and productive forests and ecosystems through the matching of seed sources (seedlots) to climatically suitable planting sites. Introduction

> of CBST is one of the ministry's first climate change adaptation policies to mitigate the impacts of climate change." (BC's Chief Forester, 2018 - *Amendments to the Standards for Seed Use*)

The 2018 amendments made it optional for licensees to use CBST (although geographically-based seed transfer can still be used as of September, 2019) (BC Chief Forester, 2018). Seed users can currently use the geographically based transfer standards, the CBST standards, or a mix of both. BC's Standards for Seed Use were amended again in 2019 anticipating that by 2021, CBST will become mandatory (BC Chief Forester, 2019). As of 2018, almost a year after the Chief Forester Standards of Seed Use were amended to enable CBST, 33% of seedlings requested by licensees for reforestation obligations were CBST-based (BC MFLNRO, 2018a) (Figure 2:1).

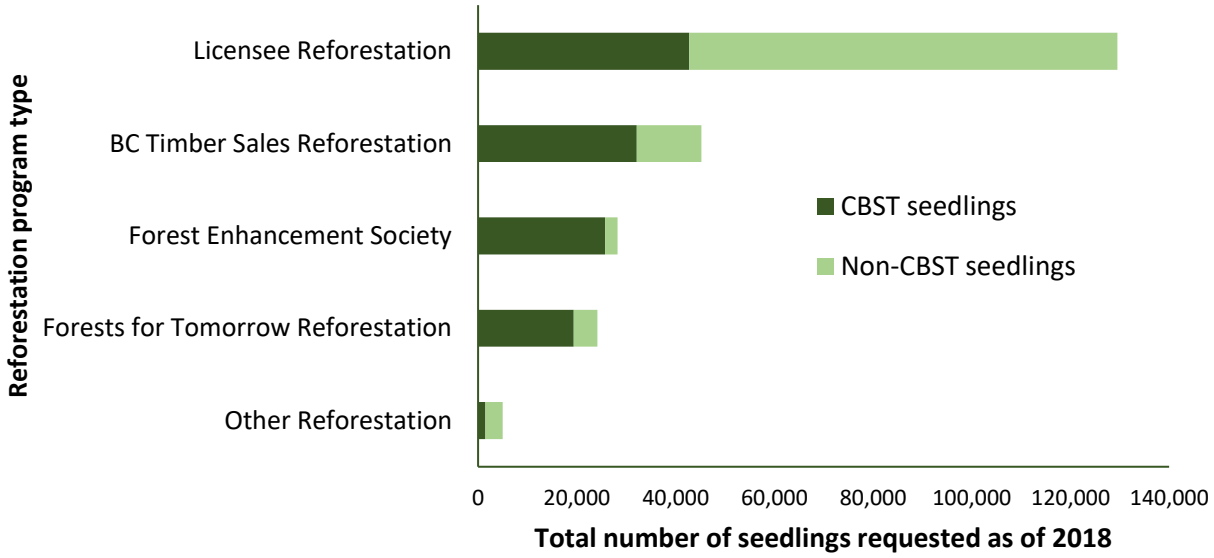

Figure 2:1 Initial uptake of CBST after amendments to standards (2018). Source: Annual Report by the Forest Improvement and Research Management Branch - BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

A shift towards a climate-based seed transfer and deployment system inevitably brought changes to reforestation practices in BC, affecting a number of groups including the forest industry and First Nations. The CBST Project Charter touches on the need to manage and minimize such changes:

> "Changes will be managed through a phased approach to minimize impacts to GRM [genetic resource management] clients, stakeholders, First Nations and the broader GRM community. Projects to address GRM and climate change adaptation are expected to evolve over time as science and new information becomes available." (BC Ministry of Forests, Lands and Natural Resource Operations, 2012 - *CBST Project Charter*)

Similarly, although not mentioning CBST directly, MFLNRO's latest climate change strategy highlights the need for collaboration with a range of actors:

> "Collaboration: Climate change actions taken by the ministry are planned and executed in the public interest. Collaboration with external partners, including First Nations, government agencies, industry, academia, related institutions and communities help to shape enduring project outcomes." (BC Ministry of Forests, Lands and Natural Resources, 2015 - *Climate Change Strategy 2015-2020*).

Yet, CBST's communication, extension and training efforts have focused almost exclusively on the forest industry. The Forest Improvement and Research Management Branch reported in 2018 that the CBST project conducted webinars and tutorials to the forest industry, publications on the Forest Professional and the Commonwealth Forestry Newsletter (forest industry practitioner literature), regional Wild Stand Cone Collection workshops, presentations to BC's Coastal Silviculture Committee, presentation to foresters working for Interfor and Western Forest Products (private forestry companies), and presentations to the Forest Genetics Council (BC MFLNRO, 2018a). Similarly, part of the FGC's mandate involves coordinating stakeholder activities for the "efficient delivery of a province-wide genetic resource management program" (Woods, 2012).

Table 2:3 Overview of seed transfer policy in British Columbia from the early 1940s until 2005.

Era	Timeframe	Governance attributes						
		Significant events	**Policy instrument**	**Enforcement mechanism**	**Seed transfer objectives**	**Actors involved in decision-making**	**Knowledge used**	**Risks considered**
No seed transfer	Pre-1940s	No records of seed transfer. Reforestation occurred via natural regeneration and whenever seed was collected, local seed was considered "safest"						
Limited seed transfer regulation and explicit emphasis on productivity	1940s – 1995	1946 - first seed zones drafted for Vancouver Island and the south coast mainland 1974 - 67 Forest Tree Seed Zones created to guide seed collections 1986 - seed planning zones in the interior consolidated into 21 zones	Delineation of seed zones	Seed movement not mandated Seed zones were used as references to help foresters make decisions on the use of seed sources Fewer seed transfer restrictions recommended	To help ensure adaptability and optimum utilization of the site's growth potential	Government-mandated review task force consisting of seed orchard managers, forest geneticists, ecologists, and silviculturists from both industry and government Plus Tree Board - Coast and Interior Tree Improvement Councils (forest companies, federal and provincial government and UBC) managed forest genetic research	First seed zone based on a seed collection zone map produced by UBC researchers Field observations by government scientists (forest geneticists) and by regression models relating provenance geographic variables to provenance growth To a lesser extent, biogeoclimatic data and "practical knowledge"	Seed availability for reforestation actions
Mandated geographic-based seed transfer regulation	1995-2005	1995 - creation of fixed seed planning zones and geographic transfer limits 1998 - Interior Seed Planning Zone Review 1998 - Tree Improvement Councils combined and renamed Forest Genetics Council	Forest Practices Code Forest Act - Tree Cone, Seed and Vegetative Material Regulation, Seed and Vegetative Material Guidebook	Mandated and legislated regulation of seed movement	To help ensure adaptability and optimum utilization of the site's growth potential	BC Chief Forester makes seed transfer decisions. Government-industry task forces make recommendations Interior Seed Planning Zone Review included input from ministry and industry clients involved in planning, tree breeding, orchard management and silvicultural activities Forest Genetics Council (advisory body): representatives of the provincial and federal governments, forest companies, woodlots, seed orchards, nurseries and universities	Provenance and progeny tests or observations Biogeoclimatic ecological classification system mapping tools Seed transfer based on seed planning zone–specific geographic features (e.g. latitude, longitude, elevation)	Increasing concerns about maladaptation risks and subsequent growth losses as a result of seed transfer

Table 2:4 Overview of seed transfer policy in British Columbia from 2005 to 2019.

Era	Time-frame	Governance attributes						
		Significant events	Policy instrument	Enforcement mechanism	Seed transfer objectives	Decision-making actors	Knowledge used	Risks considered
Interim standards for seed use amendments and emergence of climate objectives	2005-2012	2005 - The Seed & Vegetative Material Guidebook replaced with the Chief Forester's Standards for Seed Use 2008 - Amendments to the Standards: species movement was expanded +200 meters north of their current ranges. Assisted migration within native range is introduced 2010 - Amendments to the Standards: Assisted migration beyond native range of western larch allowed	Forest and Range Practices Act (replaced the Forest Practices Code) Chief Forester's Standards for Seed Use	Mandated and legislated regulation of seed movement More prescriptive and more specific regulations based on geographical variables	To maintain the identity, adaptability, diversity and productivity of the Province's tree gene resources Standards were amended to address forest health and productivity impacts associated with climate Assisted migration would help maintain healthy, productive forests, and ensure capture of gains obtained from decades of selective breeding. Assisted migration of western larch would also reduce the dominance of lodgepole pine increasing diversity	BC Chief Forester ultimately makes seed transfer decisions Forest Genetics Council makes recommendations	Provenance and progeny tests or observations Geographic Information Systems and modelling Field trials, provenance trials, and key in-depth modelling work done by Rehfeldt and Jaquish (2010) combining forest inventory plots, ecological plots and genetic variation alongside climate variables Scientists at the BC Ministry of Forests - Research and Knowledge Management Branch recommended AM of western larch	Concerns with forest health and tree maladaptation as a result of climate change
Climate-based seed transfer and assisted migration implementation	2012 – 2019	2012 - Forest Stewardship Action Plan for Climate Change Adaptation is rolled out 2012 - the Climate-based Seed Transfer (CBST) project is established, enabling a wider adoption of assisted migration actions 2018 - Amendments to the standards to legislate and enforce a CBST system	Forest and Range Practices Act Chief Forester's Standards for Seed Use	Mandated and legislated regulation of seed movement based on climate variables	Increased emphasis on climate change adaptation and forest health, often with a sense of urgency For trees to adapt to climate change and associated droughts and pests, but underlying objective is ensuring forest productivity and growth CBST promotes healthy, resilient and productive forests and ecosystems	BC Chief Forester ultimately makes seed transfer decisions Forest Genetics Council makes recommendations	Transition from a geographically-based science, policy and decision support framework to one that is climate based Internal expertise on genecological research, provenance trial data, fine-scale climate mapping, improved General Circulation Models, and to a lesser extent genomics	Escalated concerns about the impacts of climate change on forests as well as concerns with forest health

2.5 Discussion

By utilizing analytics from the policy change and STS literatures, this research examines seed transfer policy in BC over time. We track actors involved, rationales for changes in seed transfer practices, policy instruments and institutions, risks considered and knowledge used over an 80-year period. We start our analysis at the inception of seed transfer regulation in BC, which aligns with similar efforts in North America at the time. For example, constraints on seed deployment through seed zones were recommended as early as 1930 in the United States (Bates, 1930). However, it was not until the 1960s that governments started introducing a system of fixed seed zones in the Pacific Northwest (Johnson, Sorensen, St Clair, & Cronn, 2004). The 80-year history of seed transfer and tree improvement governance in BC examined here reveals that BC's geography-based seed transfer system has been relatively unchanged since its introduction in 1987, and for most of the time period we examined, changes in seed transfer and tree improvement policy are best described as incremental. Similar arguments have been made about forest governance in BC more broadly (Hagerman et al., 2010; Nelson, 2007). Paradoxically, changes in BC's seed transfer regulations have incrementally provided more flexibility to allow for longer seed transfer distances, but have over time become more prescriptive in how to go about seed transfer.

The evidence provided in this study also reveals a substantive shift in the last decade in the way seed transfer and seed deployment are based on, culminating in the implementation of a climate-based seed transfer system. Moreover, the knowledge used to inform seed transfer has changed: genetic insights have been dominant throughout, whereas ecological insights have been deemphasized, and local practitioner knowledge has been marginal to inform seed transfer in the last two decades. In contrast, governance processes related to seed transfer, including the disproportionately influential role of the forest industry, remained relatively unchanged for the four eras examined. The implications of these observations (further discussed below) underscore three notable insights for understanding the emergence of a climate-based seed transfer system, and the knowledge used to inform it: i) legacies of a strong government-industry forest policy coalition that have influenced seed transfer objectives; ii) the emergence a new seed transfer regime based on climate that emerged through the opening of a policy window, and iii) an

ongoing dominance of particular forms of knowledge used to inform seed transfer policy. We elaborate on each insight below.

2.5.1 Legacies of government-industry forest policy coalitions

We find a persistent government-industry forest policy coalition over time, in which BC's forest industry has had a disproportionally influential role in seed transfer and tree improvement policy-making. This influence was overt prior to the 1990s, and it was obscured in the last two decades by, for example, the creation of the FGC. Nevertheless, this coalition remained relatively intact in practice, and its legacies are far-reaching. The BC forest sector has a long history of government-controlled authority and formal institutions that have often made either unilateral, top-down decisions, or coordinated decision-making with the forest industry (Cashore et al., 2001). Kamieniecki (2000) argued that forest companies in BC benefited from a "policy monopoly" – a term coined by Baumgartner and Jones (1993) - for over 100 years before the establishment of the Forest Practices Code, which mandated forest policies to be made in consultation with First Nations, environmental and recreation organizations, and local communities (at least on paper). Thus, the relatively unchanged government-industry policy coalition in seed transfer contrasts, at least partially, with the broader trend towards an increasing consideration of non-industry actors in BC forest governance, especially environmental groups (Howlett, 2001) and First Nations (Wyatt, 2008).

Despite the increasing acknowledgement that First Nations and the general public should be involved, a command-and-control model of seed transfer and tree breeding regulations, a legacy of a strong industry-government policy coalition, has remain unchanged in practice. Our historical examination finds no written records of consultations with First Nations regarding seed transfer or tree improvement policy. Interviewees mentioned that there were efforts to bring a First Nations representative to the FGC, but the council could not find a representative willing to participate. We did find evidence of involvement of First Nations in climate change adaptation strategies more broadly within the MFLNRO in regional contexts (Caverley, 2011). Similarly, the BC Ministry of Environment and Climate Change recently created an Indigenous Climate Adaptation Technical Working Group, whose mandate includes advising how to integrate Indigenous knowledge into climate change adaptation efforts (BC Ministry of Environment and

Climate Change, 2019). Yet, equivalent efforts in seed transfer and tree improvement governance remain elusive. The absence of public input is also notable. Public consultations were held for three weeks when western larch seed transfer policy was changed (Klenk & Larson, 2015), but we found no records of government-run public consultations in the CBST era, and decreasing expenditures on communication and extension activities by the FGC over time. This is problematic considering the substantial change CBST represents.

Another legacy of a decades-long government-industry forest policy coalition percolates to the objectives of seed transfer and tree improvement. For decades, forest companies in BC relied primarily on narrowly trained forest industry professionals to formulate logging strategies (Kamieniecki, 2000). The main objective of these forest industry professionals before the 1990s was to log as many trees as possible at the lowest possible cost (Haley & Luckert, 1995). Timber also remained the dominant value assigned to forests when BC's Forest and Range Practices Act (FRPA) was enacted years later. Given the close government-industry partnership in BC's forest policy-making, it is unsurprising that sustained growth and productivity of forests have been persistent objectives driving seed transfer and tree improvement over time. Despite an increasing diversification of seed transfer objectives since the late 2000s (e.g. climate adaptation), the underlying rationale continues to be sustained growth and productivity (albeit deemphasized in the last decade). In line with a study on coupling climate change and forest conservation (De Koning et al., 2014), our historical analysis suggests that the emergence of a CBST regime coalesced along with economic drivers, allowing decision-makers to legitimize objectives already present before climate change drivers surfaced. Klenk and Larson (2015) make a similar argument in the context of western larch seed transfer policy changes.

2.5.2 Emergence of a climate-based seed transfer regime through a policy window

Climate change started to attain a higher profile in Canadian forestry in the early 2000s, as concern about climate change in forest management started calling for action and investment into research and outreach (Williamson, Johnston, Nelson, & Edwards, 2019). In BC, despite the fact that climate started gaining attention in seed transfer and tree improvement policy since the late 2000s, it did not become a significant catalyst of change until the inception of a CBST regime.

For example, climate change was not considered in the development of FRPA (Barber, 2007), and FPRA itself does not reference climate change. Similarly, although western larch constituted the first explicit Canadian policy allowing for the AM of a commercially valuable tree species as a climate change adaptation strategy, it was framed as an extension of what had been done in the past (Klenk, 2015; Klenk & Larson, 2015) and was meant to be an interim measure. CBST was different. We argue that a 'policy window' of opportunity (Kingdon, 1984) opened through the convergence of three governance streams (problem, policy and politics) to allow for a new climate-based seed transfer regime in BC's forest sector. The result was a shift towards a seed transfer and deployment system based on climate - a new seed transfer regime - and a subsequent strong initial uptake.

The problem stream - policy issues that require attention (Kingdon, 1984) – emerged through compelling focusing events pre-dating CBST, including the mountain pine beetle epidemic (Nelson, 2007; Klenk & Larson, 2015) and droughts that threatened forest productivity. These 'problems' were explicitly referenced in MFLNRO's climate change adaptation plans, and echoed in subsequent CBST documents. Decision-makers often find out about focusing events via 'indicators' (Kingdon, 1984), which include data and reports. In this regard, the role of key influential reports such as the work of Rehfeldt and Jaquish (2010) projecting western larch under future climate (explicitly cited in seed transfer policy documents) is a notable example.

The policy stream includes a "primeval soup" of ideas or policy proposals that compete with one another to win acceptance in policy networks (Kingdon, 1984). Only a number of policy proposals receive serious consideration, and selection criteria may include technical feasibility, value acceptability, and resource adequacy (Kingdon, 1984). One of these policy proposals, a CBST system, had already been proposed by government scientists who deemed the system technically feasible and cost-effective (O'Neill et al, 2008). "Buy-in" from industry was also not a significant barrier at this stage either. The process by which government scientists and the forest industry modified seed transfer policies, including CBST, over time (described in detail below) constitutes an example of how policy proposals in the policy stream are often generated in relatively narrow policy spaces, often composed of experts in a given policy area within and outside of government (Kingdon, 1984).

The politics stream consists of the national (or subnational) mood (including public opinion), interest group advocacy campaigns, and administrative or legislative turnover (Kingdon, 1984). Nationally, the Canadian Council of Forest Ministers had identified climate change adaptation (and mitigation) one of two priority issues of national importance for Canada's forest sector (Williamson et al., 2019). At the provincial level, BC's Chief Forester has personally been supportive of climate change adaptation (Klenk, 2015). For example, the Chief Forester launched BC's Future Forest Ecosystem Initiative (FFESC) in 2006, and as discussed in previous sections, has amended BC's Seed Standards for Seed Use over four times directly referencing climate change, among other things. There is also evidence that a large majority of BC's general public is in favour of AM within natural range (enabled by a CBST system) implemented in the forest sector (Peterson-St Laurent et al., 2018), and this public acceptance has been relatively stable over time compared to previous studies in BC (Hajjar & Kozak, 2015).

Policy entrepreneurs are individuals or corporate actors who gain the attention of decision-makers, and take advantage of policy windows that can lead to policy change (Kingdon, 1984). CBST's policy entrepreneurs were government scientists within MFLNRO's Forest Improvement and Research Management branch. Their collective action pushing for a pro-active climate change adaptation policy in the forest sector started with the successful amendments to the Chief Forester's Standards of Seed Use in 2008 as an interim measure (Klenk, 2015), which was a precursor to CBST. Moreover, policy entrepreneurs often present solutions for new problems or political changes, and provide meaning and paths for decision-makers under conditions of ambiguity (Zahariadis, 2003). Government scientists in this case presented a convincing scientific basis for a CBST system that would address increasing concerns and uncertainties about climate change in BC's forestry.

The emergence of a CBST regime is not only significant because of the greater attention to climate, but also because a CBST system enables AM, a controversial strategy even in forestry contexts (Aubin et al., 2011). Arguments in favour of AM include the need to maintain forest productivity (Gray et al., 2011) and forest health (Kreyling et al., 2011) – which are echoed throughout our document sample. In contrast, one of the most commonly cited AM risks is the

potential creation of new invasive alien species, or the disruption of recipient ecological communities (Hewitt et al., 2011). Yet, we find no evidence of CBST-enabled AM being framed as controversial in our document analysis. One partial explanation for the absence of potential controversy is because as of 2019, CBST does not move tree seed outside of its current species native range (BC Chief Forester, 2018) unless policy is also developed to apply AM to tree species selection, as it is the case with western larch. Research ecologists within the BC government are currently leading the development of an approach to climate change-informed species selection, which includes the potential to implement AM beyond outside of natural range (BC MFLNRORD, 2019b). Both systems are expected to be integrated in the future. A second explanation for the lack of public records of potential AM controversy is explored in detail by Klenk (2015), who found that decision-makers in BC had anticipated resistance to AM of western larch, especially if it was perceived to be driven by economic objectives. Yet, in order to mitigate controversy, western larch AM was framed as a natural extension of seed transfer practices (Klenk, 2015), effectively bypassing the key political question of how BC's future forests ought to be composed (Klenk & Larson, 2015).

2.5.3 Dominance of particular forms of knowledge over time

Since the inception of the first seed transfer guidelines and regulations, we find evidence of an influential community of government scientists within MFLNRO (most of whom have a genetics background). As discussed above, government scientists have not only maintained a dominant position in informing seed transfer and tree improvement policy, but were also instrumental in the inception of the process itself by acting as policy entrepreneurs. This influential role of experts also illustrates how Western scientific knowledge holds a dominant position in environmental decision-making more broadly (Turnhout & Gieryn, 2019).

Our results point to a persistent reliance on genetic insights (specifically provenance data) to inform seed transfer tree improvement policy over time. Ecological data was used to guide some early seed transfer policies, and CBST itself incorporates some elements of ecological mapping (e.g. by using BC's Biogeoclimatic Ecosystem Classification (BEC) variants as the base unit for seed transfer). Nevertheless, genetic insights dominated the science behind seed transfer by the time CBST was in place. Even though ecosystem-based forest management has been the

prevailing approach in Canada and the Pacific Northwest since the mid-1990s (Winkel, 2014), there is evidence that a genetic framing is increasing in Canada's forest policy (Klenk, 2008). For example, Klenk and Larson (2015) found a change from an ecological scientific discourse to a genetic one which was key to developing western larch AM policy. However, geneticists' characterization of forests does not necessarily fit well within an ecological paradigm. A genetic framing of AM gives genes, individual trees, and evolutionary time a more prominent place than in an ecological perspective, which tends to emphasize community composition and interactions among species (Klenk & Larson, 2015). Yet, scholars are increasingly calling for forest management responses to climate change at multiple scales, including broader landscape scales and beyond a focus on trees (Messier et al., 2019). Indeed, with different conceptions of forests (e.g. genetic conceptions), we would expect different proposed solutions (e.g. tree-centric solutions) and different ways of acting upon forests (Turnhout et al., 2016).

The dominance of genetic insights in informing BC seed transfer policy over time and the virtual absence of socio-economic evidence to inform seed transfer are unsurprising. Based on a systematic review of the scholarly literature, Hagerman and Pelai (2018) found that the majority of recommendations for responding to climate change in forest management (including changes to seed transfer guidelines) over the past two decades have been informed by biophysical sciences insights, while only a quarter of these recommendations were based on insights from the social sciences and humanities. Furthermore, our results reveal a prominent role of the forest industry in seed transfer policy development in BC. However, the nature of this involvement has primarily been providing input to the operational feasibility as well as the administrative capability and efficiency, a point reiterated by Ying and Yanchuk (2006). Yet, we find limited evidence of *knowledge* input from local foresters, especially leading up to and including CBST. Although we find records of "local knowledge" (in addition to provenance data) being used once to inform seed transfer policies in the 1990s, the absence of local knowledge in seed transfer policy is a missed opportunity. Ying and Yanchuk (2006) – who are themselves affiliated with the then-named BC Ministry of Forests and Range – argue for the importance of incorporating local knowledge and experience into seed transfer changes. We join other scholars in highlighting the potential for social sciences, local practitioner knowledge and Traditional

Ecological Knowledge to inform climate change adaptation actions (including CBST) in the forest sector (Hagerman & Pelai, 2018; Williamson et al., 2019).

2.6 Conclusions

By taking a historically-informed approach to examine policy change, this study highlights how the legacies of historical events continue to influence seed transfer practices in BC today. From little to no regulation of seed transfer, to an increasingly prescriptive geography-based system, there have been no major changes in seed transfer policy until the inception of a seed transfer system based on climate. We argue that the pattern of change in this new climate-based system emerged as a result of the opening of a policy window, and constitutes a paradigmatic shift in policy. However, we also argue that the governance processes by which changes to seed transfer occurred remained relatively static in practice, with a disproportionally high influence of the forest industry in seed transfer policy-making prevalent throughout the time periods examined. The knowledge used to justify seed transfer policy changes has become increasingly dominated by genetic insights generated within government ministries, and with limited to no input from social sciences, local practitioner knowledge, and Indigenous knowledge.

Looking ahead in anticipation of a mandatory CBST system in place by 2020, we can expect from the insights from history an even more prominent reliance on genetic insights, especially as the use of genomic techniques to inform tree improvement and seed transfer starts to gain more traction. The dominance of genetics insights will likely clash with ecological insights as climate change informed species selection tools for reforestation are created. Finally, we can expect an ongoing influential role of the forest industry, but an increasing presence of other actors and their objectives, including First Nations whose participation in the BC forest sector has increased in the past two decades (Nikolakis & Nelson, 2015). Our analysis highlights the need for increased contributions from a wider range of expertise, stakeholders, and rights holders in developing seed transfer guidelines, and in determining tree improvement objectives for the future of BC's forests.

Chapter 3: Whose expertise counts? Knowledge politics and risk perceptions of assisted migration in British Columbia's forests

3.1 Summary

The assisted migration (AM) of trees is increasingly being proposed and trialed as a means of adapting forest management to climate change impacts. Social science research in this domain has increased in the past few years, but key questions relating to knowledge and risk governance remain underexplored. We use the case of British Columbia (BC), Canada (where AM policy is currently in development) to examine the different types of knowledge that inform AM, and how that knowledge shapes perceived AM risks and ways of addressing them. Based on 27 in-depth, semi-structured interviews with key government officials and forest industry professionals involved with AM, we find an overall optimistic view of AM. However, we identify three issues relating to knowledge, risk and governance that are collectively shaping how AM policy is being developed and trialed in BC. First, the type of evidence deemed credible to inform AM decision-making is restricted to biophysical, model-based, scientific knowledge. Second, the primarily biophysical framing of AM arises from the objectives and worldviews of actors working in the AM space and gives rise to relatively narrow ways of understanding potential AM risks and solutions to them. Third, while policymakers and government scientists recognize the need to engage industry, First Nations, and the general public, these groups are characterized as knowledge receivers. Interviewees also hold the problematic view that the provision of scientific information to different publics will prevent AM controversy. We argue that patrolling the types of AM expertise serves to exclude other forms of knowledge and possibilities for generating transformative change. These findings demonstrate the contributions that different forms of knowledge (produced at multiple scales and from different worldviews) can make to decision-making for the implementation of AM.

3.2 Introduction

As climate changes and threatens the productivity and overall health of forests, assisted migration (AM) of trees is being increasingly proposed as an option for climate change adaptation (Hagerman & Pelai, 2018). AM actions have moved forward in various jurisdictions, including the Canadian provinces of British Columbia (BC), Alberta, and Quebec (Williams & Dumroese, 2013). While these regions have altered their seed transfer regulations to enable AM of trees to proceed (Pedlar et al., 2012), this type of intervention remains controversial (Aubin et al., 2011), in part because it is at odds with the conventional forest management paradigm that assumes ecological stability (Messier et al., 2015). There is a plethora of terms in the literature (Ste-Marie, Nelson, Dabros, & Bonneau, 2011), but we refer to AM here as the intentional translocation of tree species and/or populations within or outside their natural range in direct management response to climate change (Aitken & Whitlock, 2013; Vitt, Havens, Kramer, Sollenberger, & Yates, 2010). We further distinguish between AM within natural range (also referred to as assisted gene flow) and AM outside of natural range (also referred to as assisted colonization). To date, most AM actions and proposals in forestry have focused on intra-continental, single-species movements (Pedlar et al., 2012).

In the context of commercial forestry specifically, AM has the potential to ensure that plantations of commercially valuable tree species are established using species and seed sources that will be climatically adapted (Aitken & Bemmels, 2016; Gray, Gylander, Mbogga, Chen, & Hamann, 2011), support ecosystem services, and maintain forest health (Kreyling et al., 2011). In contrast, one of the most commonly cited risks of AM is the potential creation of new invasive alien species, and the potential disruption of recipient ecological communities (Hewitt et al., 2011). Other concerns include regulatory challenges, such as the lack of AM legislation (Camacho, 2010), and public opposition, especially to AM outside natural range (Peterson St-Laurent, Hagerman, & Kozak, 2018). The implementation of AM will therefore be influenced not only by technical and biophysical aspects, but also by societal dimensions.

Previous research on AM of trees has historically focused primarily on biophysical aspects (e.g. climatology, genetics, ecology), with research on social sciences aspects (e.g. ethics, policy) gaining momentum in the past 10 years (Hagerman & Pelai, 2018). For the former, previous studies have examined the impacts of range shifts, tree species suitability to AM, and species-specific capacity for adaptation (Aitken & Bemmels, 2016; Wang, Campbell, O'Neill, & Aitken, 2012; Winder, Nelson, & Beardmore, 2011). Examinations of AM from the social sciences and humanities perspective have thus far focused on three main strands: perceptions of risk, institutional and policy analysis, and ethics. Each is discussed in turn.

Previous research on public perceptions of risk suggests that support for AM in forestry by different publics is both highly contested and prone to change in response to new information (Hajjar, Mcguigan, Moshofsky, & Kozak, 2014; Peterson St-Laurent et al., 2018). More specifically, studies have found that the BC's general public has very high levels of support for AM within natural range, and more than half of BC's general public supports AM outside of natural range (Peterson St-Laurent et al., 2018). Public acceptance of AM has been fairly stable over time compared to previous studies in BC (Hajjar & Kozak, 2015). Peterson St-Laurent, Hagerman, Findlater, & Kozak (2019) found that individuals who are more trusting of decision-makers are more likely to support AM, and higher levels of forestry knowledge are associated with support for AM within natural range. Moshofsky, Gilani, & Kozak (2019) also found that foresters in BC perceive locally-based reforestation strategies as significantly more acceptable than AM than local citizens. Finally, studies have found that knowledge itself is not a strong predictor of support for controversial interventions perceived as risky (Hajjar & Kozak, 2015) as there are multiple other factors, including cognitive, affective, values, and trust that are implicated in shaping preferences for novel and uncertain policies (Burgman & Yemshanov, 2013; Kujala, Burgman, & Moilanen, 2013).

The legal context and challenges to the implementation of AM in forestry have also been analyzed, including the narrow circumstances under which AM would be legally permissible in current American laws, and how AM is antithetical to conventional natural resource law in the United States (Camacho, 2010). In the context of BC specifically, institutional aspects of the AM of western larch have been studied in detail. Klenk (2015) found that western larch AM policy

was framed as a natural extension of current reforestation standards and best practices, and Klenk & Larson (2015) explored the emergence of western larch AM policy through a shift in the scientific discourse associated with best forest management practices (i.e. from an ecological perspective to a genetic one).

Finally, ethical implications of implementing AM of trees have been explored in the literature, including the question of whether to deliberately manage natural systems or allow them to adapt on their own (Aubin et al., 2011) and the degree to which AM decision-making and actions should be a public or a professional/scientific endeavour (Minteer & Collins, 2010). Although previous social sciences research in AM hints at the importance of understanding how knowledge and policy interact, key questions related to the types of knowledge deemed credible (Cash et al., 2003) to AM policy, and the role of knowledge in shaping perceptions of risk and solutions to address them remain underexplored. The literature on governing environmental risks (such as AM) offers analytical tools for understanding the questions implicated above, but have not yet been applied in the context of AM. Specifically, insights from Science and Technology Studies (STS) and socio-cultural risk perception studies are relevant to understanding how knowledge and policy interact, what factors shape environmental risks, and how knowledge and risk are governed.

From an STS perspective, the relationship between knowledge and policy is mutually reinforcing (Jasanoff, 2003a), and recognizes the political nature of knowledge itself. In other words, knowledge is produced by and reinforcing of social and political contexts, meaning that knowledge is both an input to policy as well as a policy outcome (Jasanoff, 2004a; Turnhout, Dewulf, & Hulme, 2016). This perspective is often contrasted with a linear view of the relationship between knowledge and policy that assumes knowledge apolitically translates into policy (Turnhout & Gieryn, 2019). STS scholars also investigate the political mechanisms by which different forms of expertise (e.g. scientific, local and Indigenous expertise) are included or excluded in the production of knowledge for environmental governance (Brand & Vadrot, 2013; Turnhout, 2018). The risk governance literature highlights the importance of paying careful attention to the risks and benefits associated with emerging and potentially controversial interventions (such as AM) as they are perceived and experienced by different publics and actor

groups (Finucane, Alhakami, Slovic, & Johnson, 2000) and how decision-making takes place in the face of uncertainty, including scientific uncertainties (Poortinga & Pidgeon, 2005; Satterfield & Roberts, 2008). Connecting insights from STS and risk governance, the framing of environmental problems and risks (and thus the solutions to solving them) is shaped by the types of knowledge considered (Turnhout & Gieryn, 2019).

We focus on BC, where the health and productivity of its 55 million hectares of forests are increasingly threatened by climate change (Fettig et al., 2013; Winder et al., 2011). Approximately 95% of BC's forests are owned by the provincial government (BC MFLNRO, 2013). The development of forest resources on public lands occurs through a complex system of tenures allocated to private forest companies (and to a lesser extent local communities and First Nations) who are responsible for reforestation after logging until trees reach free growing. Forest governance in BC has also faced continuous court challenges from First Nations as most of their land was never ceded (Low & Shaw, 2012). BC's approach to forest governance has a long history of limited public participation and oversight (Day, Gunton, & Frame, 2003) that has contributed to one of the largest acts of civil disobedience in Canada in the 1990s (Tindall, 2004). All of these factors make BC's forests the epicentre of multiple, diverse, and often contested values, interests and management objectives.

BC also has a long history of AM actions, and is a pioneer in AM policy. Since the late 1950s, BC established numerous plantations of native and exotic species to test their growth and vigor in areas where they are not considered native (Klenk, 2015), including noble fir (*Abies procera*) (BC Ministry of Forests, 1998) and Siberian larch (*Larix sibirica*) (BC Ministry of Forests, 1993). BC has also gradually modified seed transfer guidelines in response to climate change. Most notably in 2010, where both the stocking guidance and seed transfer standards were modified to allow planting of western larch up to 1,000 km outside of its native range from southern BC to northern parts of the province (BC Chief Forester, 2010; Klenk, 2015). This was the first time such an explicit AM policy was implemented in Canada (Klenk & Larson, 2015).

Since then, BC has moved forward with additional policies and actions to support the use of AM in reforestation as a climate change adaptation strategy (BC Chief Forester, 2018; BC MFLNRO,

2012). Notably, BC has put in place a Climate-Based Seed Transfer (CBST) system, which has been in development for the past 10 years. Advancing this policy has been a priority for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD), specifically the Tree Improvement Branch (BC Chief Forester, 2010) – now called the Forest Improvement and Research Management Branch. CBST matches seedlings/seedlots to future (projected) planting site climates and is meant to eventually replace BC's geographically-based seed movement (BC Chief Forester, 2018). To enable CBST, the Chief Forester's Standards for Seed Use were amended in 2018 making it optional for licensees to use CBST (BC Chief Forester, 2018). Seed users can currently use the geographically-based transfer standards, the CBST standards, or a mix of both. The option to use the geographically-based transfer standards will be discontinued at the end of a transition period. CBST has been developed under the leadership and collaboration of forest geneticists within the government, along with tree seed policy analysts, and decision-support staff. As of now, CBST does not move seed outside of its current species native range (except for western larch) (BC Chief Forester, 2018) unless policy is also developed to apply AM to tree species selection. Research ecologists within the BC government are also leading the development an approach to climate change informed species selection (CCISS), which includes the potential to implement AM beyond outside of natural range (BC MFLNRORD, 2018).

The objective of this study is to examine the current role of knowledge and risks in AM governance using the case of AM in BC, which constitutes an ideal case to study AM given its long history of trailing AM actions. We address the following questions: i) what types of evidence are deemed credible for supporting contemporary AM decision-making? And ii) how do government officials and forest industry professionals in BC perceive the benefits and risks associated with assisted migration, and what are their proposed solutions to address such risks? In so doing, we identify opportunities for including multiple forms of knowledge in developing AM policies, highlight ways in which AM risks are linked to knowledge, and reflect on their implications for research and governance in this domain.

3.3 Methodology

3.3.1 Approach and data collection

We used semi-structured interviews as the primary method of data collection for this study. Semi-structured interviews allow for an in-depth, nuanced understanding of the views of the respondents (Charmaz, 2006), provide both flexibility and directionality to (co-)produce focused qualitative data on the themes of interest (Schensul, Schensul, & LeCompte, 1999), and allow for the exploration of specific ideas while remaining open to emergent themes (Creswell, 2013). While the semi-structured interview protocol ensured that key constructs of interest to this study (e.g. risks, knowledge) were examined, this approach and the open-ended nature of this type of interview allowed for an openness of additional themes that interviewees see as important and that may not have been anticipated in the initial research design (Marshall & Rossman, 1999).

The first author conducted 27 in-depth, semi-structured interviews with individuals in BC's provincial government and forest industry between December 2018 and June 2019. Interviewees were identified using a purposeful sampling strategy (Creswell, 2013). We identified individuals in government and industry whose work intersected with AM of trees (e.g. individuals responsible for tree improvement and seed transfer, and/or reforestation policies and practices in BC.) We sought variation across groups (government, industry) and scale (provincial, regional). We chose these two groups because the provincial government is a key player in the adoption of AM as it delineates and enforces seed transfer guidelines, and reforestation standards. The forest industry is also a key player in the adoption of AM as it is responsible for reforestation after timber harvest. Participant selection was guided by the following specific inclusion criteria: i) over 10 years of work experience in the BC forest sector, ii) relevant unit's portfolio on tree improvement, seed transfer, and climate change adaptation policy (for government), or tree improvement or reforestation practices (for industry), and iii) familiarity with the concept of AM. Participants were identified online (e.g. BC government directory, company websites, etc.), in consultation with government and industry informants, and from interviewees themselves who recommended key individuals to speak with.

Fifteen interviews were conducted in-person in a public location (e.g. place of work/office meeting room, coffee shop), and 12 interviews were conducted by phone or Skype. Interviews ranged from 40 to 90 minutes. The interview schedule was designed to examine topics relating to knowledge and risk and overall acceptability of AM in BC. Accordingly, we asked participants about their background and role, their views on the benefits and risks associated with AM, their overall preferred governance approaches (including preferred knowledge input) to AM moving forward, and specifically about CBST and species selection projects. The interview schedule can be found in the Appendices. Initial drafts of the interview schedule were piloted with graduate students in forest genetics and ecology to ensure clarity in questions' meaning across a broad range of groups and types of expertise, and an appropriate use of specialized terms. Through the piloting process, questions were adjusted to make them more coherent, to improve the logical transition from one question to the next (Chenail, 2011), and to keep each interview to contained to approximately one hour.

3.3.2 Analysis

All interviews were audio-recorded, transcribed verbatim and analyzed using NVivo (NVivo qualitative data analysis software for Windows; Version 11, 2016). Text was coded line-by-line, and systematically analyzed using a combination of a deductive and inductive approach to identify recurrent concepts and ideas, and subsequent analytical themes (Charmaz, 2006). Initial coding followed a deductive approach, in which a set of *a priori* themes (Saldana, 2009) were identified from the literature, and synthesized in the conceptual framework section of this article. More specifically, initial coding focused on issues relating to perceptions of risk, and types of knowledge considered. These themes informed the core design of the interview guide. However, we remained open to emergent themes raised by respondents themselves. Subsequent rounds of coding followed a more inductive approach (Charmaz, 2006), in which we identified a set of additional themes relating to knowledge in the AM science-policy interface, and the role of First Nations in AM governance. All of the codes and themes in the analysis were developed through an iterative process.

3.3.3 Validity

This study used triangulation and member checking as validation strategies (Maxwell, 2013) to address validity threats and confirm the interpretations we make. Triangulation involves using multiple sources to corroborate evidence (Creswell, 2013). Although this study used semi-structured interviews as the primary data collection method, we cross-referenced interviewees' statements with published AM policy and research documents. We also sent the quotes used in this study to the respective individuals that made them in order to confirm their accuracy.

3.4 Results

While respondents indicated near unanimous support for AM both within and outside of natural range, interviews also revealed a number of knowledge and risk-related dilemmas with implications for AM governance and practice. First, the types of evidence that are considered credible to inform AM decision-making are generally restricted to scientific knowledge – specifically biophysical, model-based knowledge. Second, this primarily biophysical framing of AM arises from the objectives, ideals and worldviews of actors working in the AM policy space and gives rise to particular ways of understanding risks and solutions to addressing them (while simultaneously obscuring other potential risks and solutions). Third, while policy-makers and government scientists recognize and acknowledge the need to engage different publics in dialogue about AM (such as industry and First Nations, and to a lesser extent, the general public), the only knowledge that is considered credible in relation to AM is produced within western scientific norms. Further, policymakers and government scientists typically view industry, First Nations and the general public as knowledge receivers (as opposed to knowledge holders of their own right) and hold the view that the provision of scientific information to these groups will ward off any potential AM controversy. Finally, policing the types of expertise to inform AM serves to exclude consideration of other knowledge forms, and thus more diverse possibilities for generating transformative change.

3.4.1 Overall positive views of assisted migration

Both government and industry interviewees were both nearly unanimous in the view that AM (within and outside of natural range) is necessary to address the observed and anticipated impacts of climate change in BC. AM benefits were most commonly described in relation to climate change (i.e. how trees can be better adapted to climate change), often with a sense of urgency.

> "Assisted migration is absolutely necessary with climate change. There's no doubt in my mind of how absolutely necessary it is." [I20 Industry]

Respondents identified multiple benefits of AM, including economic benefits, optimizing the available yield, and contributing to the resilience of ecosystems.

> "[Assisted migration] ensures that we are going to have a healthy timber supply going forward, both in an economic sense so that trees are healthy and they're going to survive in the next rotation, but they will also be able to support the habitat that's needed for non-tree species that are likely going to be moving north and up." [I3 – Government]

Even when the risks of AM were identified (discussed in further detail below), the risk of inaction – "the biggest risk is the do-nothing approach" [I19 Forest industry] – was the most common view. Interviewees expressed that the risk of not implementing AM in BC is greater than other potential risks that AM might bring. This perspective was shared by both government and industry.

> "By not doing assisted migration, one is making a very significant decision to not have tree species that are more likely to be resilient to climate change." [I4 Government]

3.4.2 Knowledge deemed credible to inform assisted migration

Interviewees emphasized the importance of scientific knowledge – specifically, biophysical, model-based knowledge – in developing AM policy.

> "We have a decision-making system historically, in which experts have been hired to make decisions for the benefit of society […] This is sort of a science-led decision-making process and I think it needs to remain that way […] Researchers who, for example in the case of CBST, are looking into the evidence at hand both in terms of climate change as well as how the genetics of tree species relate to

> changes in climate. That is the information base from which decisions can then be made from." [I27 – Government]

> "One can do assisted migration two ways: one can use a model approach, which is take your provenance data, plot it out to try to quantify what climate you should go to get seed lots that will be best adapted for the future. Or one can look at climate records, say, in this case since 1945 and then model climate for 15 years from now, quarter rotation and add those two together to calculate how far we ought to move seed. [CBST] elected to use the latter approach because there is very little uncertainty about the climate in 1945 or the thirty-year period centered on 1945, and there's very little uncertainty regarding what the climate will be 15 years from now." [I12 - Government]

The prospect of utilizing genomic tools to inform AM actions was met with enthusiasm among a few interviewees. This was not, however, the most common response as many interviewees did not know enough about genomics to be able to comment.

> "We are expecting that in the future, we'll be able to speed up our selection cycles significantly with the use of genomics in our tree improvement program." [I19 - Forest industry]

Expert knowledge, described by interviewees as knowledge generated predominantly by biophysical scientists, was characterized as superior to other potential forms of knowledge.

> "If they [industry] want to propose variants to the current standards, they can do that and then that would be evaluated by the experts in terms of whether it's reasonable or not." [I10 – Government]

Furthermore, many interviewees made the distinction between who should be consulted in producing AM knowledge, and who should be consulted regarding implementation and potential impacts of AM.

> "First of all, we need to consult with the scientific community, and I think that's been done because a lot of the research is out there, so the scientific community in universities and people that have the expertise. We also need to consult with the forest industry - the people that are going to be managing their reforestation obligations and planting the trees. We also need to consult with people that might

> be impacted; for example, First Nations groups that have specific interests in some species." [I15 – Government]

Some interviewees went a step further and made the distinction between who should provide information (e.g. biophysical scientists and in some cases, practitioners), and who should be informed (e.g. the general public, First Nations).

> "There are actually two aspects to that. There's who can provide information on developing policy, and who should be informed. Those who provide information should be the practitioners and the science community […] But who should be informed, that would be the general public, and various stakeholders that we've heard from like First Nations." [I1 – Industry]

Our findings reveal that non-scientists are often regarded as knowledge recipients as opposed to knowledge holders. In regards to the general public being informed, some interviewees noted potential public opposition to AM outside of natural range specifically. When asked how the general public would react to AM in BC, an interviewee noted the following:

> "Honestly, the [general] public doesn't really know much. They're not going to know any better - they don't even know the system we have. So, in general, it will be business as usual. Where it will change is where we plant species that never grew in an area there." [I21 – Industry]

Moreover, when asked how potential opposition to AM should be dealt with, many interviewees expressed that science (or education more broadly) is the best solution.

> "I think science is the best form. When you've got scientific evidence and sound results that you can show and have a discussion with the different stakeholders, and be able to understand what their concerns are and be able to show how science actually addresses their concerns." [I15 – Government]

We find some salient differences in genetic and ecological insights used to inform AM. For example, many interviewees expressed how historically, ecologists have been more "conservative" in considering AM of trees, especially in relation to geneticists.

> "We had the regional ecologist help guide where different species would go […], but the ecologists did not want to move species like larch into areas where it wasn't

> before. We were able to add ponderosa pine as acceptable where they would grow well, so we did move things out, but I would say it was a very conservative move on the government's part." [I22 – Industry]

An interviewee with an ecology background noted that despite these differences, ecologists and geneticists in BC are compatible and work towards a common AM goal, referencing CBST in particular.

> "CBST is also quite conservative in terms of applying measured change, and not some sort of radical departure from the current. I think it's certainly a compatible viewpoint. There are always differences of opinion around the specifics, but as a general rule, we're a compatible." [I27 – Government]

These different views towards AM materialize in the different approaches toward developing AM tools. CBST (which uses AM within natural range and is primarily the responsibility of forest geneticists) is more advanced than CCISS (which will include AM outside of natural range and is primarily the responsibility of ecologists).

> "That's something the ministry needs to resolve, and the timelines are also different so that if people see options for using a species outside of its native range, but that's not been backed up by the ecologists yet, that creates some tension." [I10 – Government]

As explained by interviewees, a coordinated approach between CBST and CCISS would have indeed been ideal, where one has a species selection tool first, and then one can select the best available seed based on the selected species. Interviewees further pointed out that part of this limited coordination to date can be attributed to institutional divisions (i.e. these two teams operate in different branches of government), and funding limitations by the CCISS tool compared to CBST. Still, as one interviewee involved with CBST described, there is a desire for the two initiatives to be better integrated.

> "We've had conversations with our friends working on tree species selection, and they're using a different climate model. There are possibilities for us to marry those two approaches or agree on one or the other as we move forward. I think of that as something that would be five years out at least, and that would be a much bigger policy piece. In fact, I think that is where the real assisted migration debate comes

> in, when you start to move species outside their natural, historic range." [I5 – Government]

This perspective further identifies greater anticipated opposition to AM outside natural range, which was a shared concern among most interviewees.

> "I think the public, including the Haida First Nation on Haida Gwaii, would be very opposed to government or industry trying to move Douglas-fir through assisted migration to Haida Gwaii despite the fact that some of the climate models suggest that on the east coast of Haida Gwaii, Douglas-fir would do quite well. They're quite concerned that it would further displace the native Sitka spruce, for example." [I16 – Government]

Conversations about this anticipated opposition revealed further tensions around who should be responsible for consulting with stakeholders who may be opposed to AM. A forest geneticist involved with CBST noted this trend.

> "The geneticists do not make the call on species selection, the ecologists do […] and as a result, it seems to me that it's not the responsibility of the geneticists to consult with folks who might take exception to Douglas fir being planted 200 kilometers outside of its natural range. It's the responsibility of the ecologists to consult with folks in that matter." [I12 - Government]

When asked about consulting stakeholders about AM, an interviewee with an ecology background involved with CCISS mentioned that there have been no consultations with the forest industry at this stage, citing weaker ties to the forest industry compared to CBST.

> "CBST has an additional challenge in that they're really integrated into nursery business models. They have people who have invested a large amount of money to grow trees and they really were changing the system up quite a bit. We sort of tie into that, but we're much less directly related to private industry in that way. The genetics group also has a whole organization based on that work. We do not have that. We are very thin on the ground. And so at this point, we don't have anything that's at that level of interaction with the business community like CBST was required to. The decisions around a lot of this stuff will come down to the Chief Forester." [I27 – Government]

Interviewees disagreed about the role of local knowledge (characterized here as professional reliance) in the implementation of AM. On the one hand, many forest industry professionals felt that having some latitude on the decisions that they make at the local level is important, and that the concept of professional reliance in BC should play a role in the implementation of AM.

> "I see professional reliance as critical to the implementation of assisted migration. To me, if a professional is doing his or her job and they're active, and they're practicing within their scope of expertise, they have an obligation to become fully informed of all of the different policies and all of the different science, and then they're the best people out there to make decisions at a local scale as to whether to implement assisted migration." [I19 - Forest industry]

A few forest industry professionals acknowledged the limits of professional reliance expressing that foresters may not have all the necessary knowledge to implement AM.

> "I love the concept [of professional reliance]. I think that if all parties were working with professional reliance principles, professional latitude could work. But when it comes to species choice, shifts and all that kind of stuff, I don't know how an individual forester would ever be able to acquire that breadth of knowledge in a lifetime." [I14 – Industry]

On the other hand, government interviewees expressed more skepticism towards the role of professional reliance in the context of AM. Talking about CBST, one interviewee expressed the following:

> "I guess it depends on what one means by the extent to and what sort of latitude is involved with professional reliance. Most foresters, and indeed most geneticists, don't have a good handle on the exact migration distance or an understanding of the climate of a seed source or the climate of a planting site past or future, so everyone needs a system to guide them." [I20 – Government]

Other interviewees were more adamantly opposed to professional reliance, and expressed a strong desire towards a prescriptive rules-based decision making process as it is indeed the case for the current CBST framework, which is part of a set of the Chief Forester's Standards of Seed Use (described as "the rule of law" in CBST training webinars).

> "I think the rules need to be firmly in place and they should not be subject to individual interpretation hidden behind professional reliance." [I22 – Government]

Our results reveal even more limited knowledge input from local forest industry practitioners to CBST specifically. Interviewees explained that CBST consisted of three committees: i) a science working group (led by geneticists, breeders, climate modellers, and seed planning representatives), ii) a policy working group (with representatives from different government branches), and iii) a stakeholder advisory group with representatives from government, forest industry, community forests, and the Tree Seed Centre (groups that would be immediately impacted by changes to the seed lot election system CBST causes). An interviewee familiar with CBST's science working group described the process by which AM knowledge was produced and reviewed, and noted that it was not an imposed top-down process.

> "We wrote a technical document that was reviewed by seventeen scientists from inside and outside of government. It was then reviewed by scientists around the world, and comments were incorporated. We published that document. […] We had extensive consultation with stakeholders, and we involved them at every stage of the process […] The whole thing was supported by tons of field trials even though those field trials did not identify migration distances, they were used as a guide to help corroborate the recommendations that our Technical Committee proposed. It was a long process and reviewed at multiple levels, and frankly I think that's part of the success of the project. Number one: we had the field data to support the changes that our Technical Committee put forward. Number two: we involved multiple scientists from multiple countries as well as stakeholders and policy people. This was not something that the ministry just imposed upon people." [I14 – Government]

Other interviewees who were part of CBST's stakeholder advisory group felt that knowledge from the CBST's science working group was simply presented to them (although later agreeing with such a process).

> "There was a policy and practices committee, and a science committee, so [government researchers] and a few of those other PhD people went away and figured out that side of it and the policy group was just presented the findings to, they were never reviewed by that group […] The science was another committee that went away, looked at all the science, they kind of approved it and brought it back to the committee saying that 'this is what we believe are the right climate variables.'" [I18 – Forest industry]

More broadly, many interviewees talked about the loss of local knowledge in the CBST knowledge generation process.

> "[…] a lot of that local knowledge is going to be sacrificed because now you have multiple seed lots that can be put across huge areas, so you're just going to pick the ones that are convenient for you; then it might be a really fast growing seed lot and you're supposed to get 18 or 20 percent genetic worth, but lo and behold, the snow comes along and it just pushes it right over and breaks it in half. All that stuff is really not captured in the process." [I24 – Forest industry]

The MFLRORD's Forest Improvement and Research Management Branch presented the CBST project to the BC First Nations Forestry Council. However, following this and other initial efforts, it was decided not to proceed with further engagement given that it would be more beneficial to have these conversations when the CCISS tool is in place.

> "We realized that climate-based seed transfer is […] a very small component of a much larger conversation, and that would be shifting species tree species across the landscape and building climatically-adapted resilient and healthy forests. So, we've identified the need for engagement with First Nations. Our project team has participated in training, but what we've reported is that it needs to come out at the tree species policy level, that larger conversation, and there are a lot of unknowns there." [I5 – Government]

Interviewees involved with CBST acknowledged that First Nations Forestry Council does not represent all of BC's First Nations. Interviewees further noted that the First Nations Forestry Council had more pressing issues to deal with and AM is not necessarily a priority.

> "We have presented what we're doing at the First Nations Forestry Council [FNFC] meeting, for their information. At the time, they [FNFC] were dealing with a lot of other issues that are more important to them and they see that the level of technical detail involved with CBST is beyond the majority of their membership in terms of their elders. They're mostly focused on economic development and social services requirements, they are dealing with life and death in many cases and this falls to the bottom level so they [FNFC] have asked us if once we've gotten a little further on our species selection, we would come back and talk to them on a more coordinated approach in the future." [I5 – Government]

Lastly, as with the public, some interviewees were similarly skeptical of First Nations engaging meaningfully in policy debates about CBST, citing the highly "technical nature" of the topic.

> "We are committed to working in strong partnership with First Nations and that commitment is front and center in terms of our work. Now, the work on forest management, the underpinnings like the [AM] decision support tools that we use can be rather technical in nature, and it would be similar to, in a sense, asking the public to weigh in on what components of a rocket ship are going to be used." [I4 - Government]

Despite this dismissive view of Indigenous input, a few interviewees expressed the need for integrating First Nations' knowledge into the development of AM in BC.

> "I'm not too sure if First Nations and Indigenous communities are being integrated into some of the forecasting and benefit assessments, particularly on the non-timber resources. I really want to know if they have put their personal and traditional ecological knowledge into this." [I19 – Industry]

A few interviewees also mentioned that MFLRORD's Forest Improvement and Research Management Branch hired an intern in 2016 as part of BC's Aboriginal Youth Internship Program who explored approaches for the development of a strategy to engage First Nations on climate change adaptation (using CBST as an example). This resulted in one day-long workshop with First Nations youth to hear about their perspectives on climate change.

3.4.3 Perceived risks associated with assisted migration

Despite overall support for AM, respondents identified some reservations, particularly with AM outside of natural range. These concerns were overwhelmingly ecological in nature as interviewees often cited ecological risks, including unintended interactions between migrated trees and other ecosystem components, and the potential introduction of pests and disease.

> "My biggest concern is about ecosystem interactions and the changes that we might be unknowingly or unwittingly causing. You know, the ecosystem perspective on things. […] The other thing that we don't talk about is the relationship between assisted migration and insects and disease. What do we know about how insects and diseases might change in terms of their life histories and their migration across the

> landscape? What can we do even to decouple some of those relationships? Is there anything that we can do with assisted migration to actually move the trees and leave the disease behind? [I7 Government]

Furthermore, a common concern among interviewees was that AM might trigger the introduction of exotic species, and the potential risk of migrated trees becoming invasive.

> "The only concern is that if we start moving too dramatically, we might be moving into exotic species and I know that's not on the table under the current format of the legislation around assisted migration and species seed use in BC, but that is my only concern." [I1 Industry]

Many interviewees stated that although they are in favour of AM (both within and outside of natural range), they are not supportive of introducing exotic species. When asked what their overall impressions of AM were, an interviewee stated the following:

> "I've been supportive professionally and personally of moving species just a little further north of their native range recognizing that in British Columbia, we see this evolutionary or adaptive lag post glaciation […] but I've never been supportive of exotic tree species, and species that are well outside this north-south continuum in the Pacific Northwest. There have been others that have been very vocal and adamant in trying things like Siberian larch here, or silver birch from Europe. I've never been supportive of those large migrating distance because of concerns with hybridization with native species and potential invasiveness or displacement of native tree species." [I8 Industry]

Finally, many interviewees expressed concern around the fact that AM in BC is focused on moving trees. However, other ecosystem components such as the understory vegetation, the mycorrhizal fungi, the soil, and other ecosystem components are not necessarily migrating along with trees.

> "I know that some of our initial concerns that we were addressing have not been resolved, and that is if you move the tree species, how does the rest of the ecosystem move? And for me that's probably the biggest outstanding question I have." [I5 – Government]

> "You simply risk migrating too fast and the other non-timber resources are confused by what's happening, which reduces the overall objective of a healthier forest

> because non-timber resources are not simultaneously assisted in their migration." [I8 - Forest industry]

It is important to mention that in addition to ecological concerns, which were by far the most prevalent, other concerns were identified by a fewer interviewees. One of these concerns was the potential risk of plantation failure and the associated costs that come with it.

> "If licensees have planted trees and are consistent with government policy around assisted migration, and we reached 20 years and the trees have died, then the licensees would be on the hook for it." [I21 – Industry]

> "All I'm saying is that nobody is going to give me the cost of reforestation back on that failed area." [I 19 – Industry]

Some concerns were raised specifically about the prospect of using genomics to inform AM. The potential for conflating genomics with genetic engineering was highlighted by many interviewees.

> "Given some of the genomics discussions I've seen and read, you know, they're just using this technology for information. They don't want it for the purposes of manipulating genes, and that's where I kind of draw my line." [I5 - Government]

Finally, although far less commonly mentioned, concerns were also raised about the availability of seed and the restructuring of seed orchards in the case of CBST, and the potential public opposition to AM outside of natural range (as mentioned above).

When asked about the best ways to address potential risks and uncertainties associated with AM, interviewees overwhelmingly invoked solutions characterized as technical. For example, interviewees often offered solutions involving the improvement of the current climate models used to inform AM.

> "There's still some uncertainty in the projections of precipitation, so if we could pin those down a little bit better, that would be good […] We'll tweak it here and there

> as we get new provenance data, and as our analytical methods improve." [I13 – Government]

Other common proposed solutions were ecological in nature.

> "One of my ideas is that we could be migrating whole ecosystems, so we could not just move the trees, but also move some of the understory." [I5 – Government]

A few interviewees spoke to the importance of BC's Timber Supply Review process (where seed use and forest genetic assumptions are verified) in assessing risks.

> "Through timber supply analysis and integrated silvicultural strategies, we can identify and assess risks and impacts, and implications of these in practice; and we do need to model, adjust our models, and incorporate these, so that's where I see we address risk and uncertainty in this process." [I4 - Government]

To put the quote above in perspective, it is important to mention that BC's Timber Supply Review also considers social, economic, and environmental factors as inputs to determine the province's AAC. Both the general public and First Nations are invited to participate in consultations as part of this process.

3.5 Discussion

Considering the relatively lengthy history of AM actions and gradual amendments to BC's standards of seed use as described above, the near unanimous acceptance of AM in light of climate change amongst this sample is expected. Our sample consists of many individuals who have directly worked on AM policy and knowledge production to inform it. Our findings are also consistent with recent surveys of forest industry professionals. For example, there is evidence that the majority of forest industry professionals in BC are open to taking climate change adaptation actions as they see climate change as a real threat to successful forest regeneration and future forest productivity, but wish to see an increased flexibility to select climactically suitable tree species (Nelson, Williamson, Macaulay, & Mahony, 2016).

In the section below, we discuss five insights for exploring knowledge and risk-related issues associated with AM that arise from our analysis: i) the prevalence of a linear model of science-policy and its implications for AM, ii) the overemphasis on some forms of knowledge and the

benefits of diversifying knowledge inputs, iii) emerging epistemic tensions in AM policy-making, iv) a proposed upstream approach to AM policy-making, and v) the role of First Nations in AM governance. We expand on each below and conclude with considerations for AM policy and practice.

3.5.1 Linear model of knowledge moving through the science-policy

Interviews reveal the widely held belief that knowledge ought to (and does) flow in a linear fashion at the AM science-policy interface. Broadly speaking, the linear model describes the view (unsupported in the literature) that scientific knowledge is paramount to decision-making, but that it can be apolitically translated into policy (Turnhout & Gieryn, 2019). This is a problematic perspective because it fails to take into account both how science and policy interact given that scientific knowledge is in most cases only one aspect that goes into decision-making (other aspects being societal concerns, for example), and the ways in which scientific knowledge itself cannot be understood as isolated from societal factors, including values, interests and power (Jasanoff, 2004a). More concretely, adherence to the belief in the linear model has the potential to fuel rather than resolve knowledge-related controversies (Turnhout & Gieryn, 2019). For example, in this study, the risks of AM are overwhelmingly framed as biophysical, and the solutions offered are technical in nature. This is expected given that a linear model of science-policy inherently promotes a technical framing of environmental issues, where both the definition of the problem (including risks) and the scope of potential solutions are placed in the domain of "experts" (Turnhout & Gieryn, 2019).

The desire expressed by interviewees in our study for AM actions to continue being an expert-driven decision-making process constitutes an example of "boundary work," a process whereby scientists attempt to assert claims of objectivity and demarcate their expertise from activities viewed as "non-scientific" (Gieryn, 1983). In the case of AM in BC, government scientists have not only maintained a dominant position in AM policy often patrolling the boundaries of what counts (and does not count) as relevant expertise, but were also instrumental in the inception of the process itself. Klenk (2015) found that in the case of western larch, neither its seed transfer nor its stocking standards changes would have been possible without the collective action of

government scientists who pushed for a pro-active adaptation policy in the forest sector, facilitated by the BC Chief Forester's support for climate change adaptation at the time.

3.5.2 Dominance of particular forms of knowledge to inform assisted migration

The emphasis on some forms of knowledge over others in the development of AM policy requires further scrutiny. The overwhelming emphasis on biophysical and model-based forms of knowledge as input into AM decisions as well as to address AM risks is unsurprising. Historically, governments have adopted predictive methods, such as risk assessments and climate modelling, to facilitate management and control, even in instances of high uncertainty (Porter, 1995). These methods gain power through claims of (scientific) objectivity and a disciplined approach to analysis, but one of their main limitations is that they tend to "pre-empt political discussion and create high entry barriers against legitimate positions that cannot express themselves in terms of the dominant discourse" (Jasanoff, 2012). A concrete result from the prevalent technocratic AM framing (shaped by specific forms of dominant knowledge) is the obscuring of political and ethical concerns. While there is evidence that the scientific debate on AM of trees is engaged with competing values and ethics (Aubin et al., 2011), these ethical and philosophical dilemmas (such as the extent to which humans should intervene in non-human nature) are nearly absent in our interviews. This is consistent with previous work on AM in BC. For example, when the western larch AM trial took place, the underlying philosophy of AM had been debated internally, but this philosophical debate remained within the research community (including government researchers) and was not communicated to the public (Aubin et al., 2011; Klenk & Larson, 2015).

The dominance of particular forms of knowledge in the case of AM can also be understood in relation to the concept of "epistemic selectivities." These are "mechanisms within political institutions that favour specific forms of knowledge, problem perceptions, and narratives over others" (Brand & Vadrot, 2013). Epistemic selectivities lead to defining a specific problem in terms of content and importance by strategies based on the use of science and expert knowledge. Knowledge can then be used to justify particular problem solutions, and to potentially delegitimize alternative pathways to dealing with environmental problems (Vadrot, 2017). In

other words, privileging some forms of knowledge does political work because knowledge at least partly shapes the understanding of a problem (in this case, AM), and helps shape the perception of which actors are deemed "appropriate stewards" of the environment (Adams, Brockington, Dyson, & Vira, 2003; Scoones, 2009). This in turn translates into decisions about whose knowledge is deemed credible (Cash et al., 2003) as input into decision-making, who should be involved and to what extent, and what are the appropriate solutions.

Overall, the prevalent view by most interviewees in our study that non-scientific groups (including local practitioners and First Nations) associated with/affected by AM are passive knowledge receivers as opposed to knowledge holders is unsurprising. When it comes to environmental issues, and especially controversial ones such as AM, science is often put in a dominant position, and frequently in control of the facts and problem definition (Turnhout, 2018). This in turn positions non-scientific groups as knowledge receivers (Maasen & Lieven, 2006). We do not seek to undermine the (scientific) knowledge that has gone towards the development of AM tools in BC. Rather, we argue that contributions from different forms of knowledge (produced at multiple scales and from different worldviews) can help us better understand and navigate anticipated dilemmas associated with AM in BC. The development and implementation of AM will inevitably be influenced not only by an understanding of biophysical impacts and responses, but also by human behaviour (e.g. perceptions of risks, normative values), and institutional dimensions (including how knowledge is governed). Insights from the social sciences and humanities, for example, offer an avenue to navigating and understanding what unique socio-cultural considerations exist when considering AM that can help guide inclusive governance processes in the long term (Hagerman & Pelai, 2018). There is also evidence showing that increased participation and interactive knowledge-making has the potential to improve accountability and lead to more credible assessments of scientific knowledge (Jasanoff, 2003b).

The role of local, place-based knowledge (often invoked in the professional reliance model of BC) is also important to highlight. Forest industry professionals are on the front lines of implementing forest management in BC, and they can provide valuable knowledge and

information on viable options for local adaptation (Nelson et al., 2016; Ogden & Innes, 2007). Indeed, our findings reinforce the fact that foresters feel like they have valuable knowledge to share, but as some interviewees expressed, such knowledge has been lost in the development of AM policy (and CBST in particular). We further note that the role of Indigenous knowledge associated with AM has compelling prospects, but these remain largely unexplored. More research needs to be done in this area. We offer the following tentative considerations for considering local knowledge to inform AM decision-making. First, in accordance with Turnout (2018) and others, we propose building on research and practice that treat scientific knowledge and local knowledge symmetrically, and not as supplementary to scientific knowledge (Agrawal, 2002). Second, we join other scholars in advocating for "technologies of humility" (Jasanoff, 2003b) in AM governance. In addition to formal processes of participation, "technologies of humility" would require an intellectual environment where the forest industry, First Nations, local foresters, and citizens are encouraged to bring their knowledge and skills to collectively tackle potential AM concerns. And third, we note that any attempts to systematically draw on local knowledge will inevitably entail major political adjustments, including dismantling traditional institutional forums to allow "experts" to be questioned by local knowledge holders as opposed to the other way around (Jasanoff & Martello, 2004).

3.5.3 Emerging epistemic tensions

In addition to the dominance of particular forms of knowledge in AM governance, we also find internal epistemic tensions between scientific disciplines. The tensions between ecological and genetic insights are consistent with other studies that found competing genetic and ecological scientific framings in BC, such as the case of western larch AM where a change from a genetic scientific discourse to an ecological one which was key to developing AM policy (Klenk & Larson, 2015). In the case of western larch, modifying its stocking standards proved to be more difficult than modifying its seed transfer policies, but even though the ecological "appropriateness" of AM remained an unresolved issue, it did not prevent western larch AM policy development due to compelling modeling research on future western larch distribution at the time (Klenk, 2015). Although we find additional evidence that a genetic framing continues to gain traction in the development of AM in BC (exemplified by CBST being more advanced and

better resourced than CCISS), we also find further unresolved tensions and persistent ecological concerns even among interviewees involved with CBST that will likely prevent a complete shift towards a genetic forest policy paradigm in BC (Klenk, 2008). These epistemic tensions have the potential to hinder a cohesive and coordinated AM approach in the long term.

The implications of these epistemic tensions are notable for policy and practice. First, with an increasingly genetic scientific framing of AM, different ways of thinking about forests and different conceptions of the role of humans in forests that tend to support AM emerge (Klenk & Larson, 2015). Second, as noted earlier, with different conceptions of the environment, different preferred solutions and different ways of acting upon the environment arise (Jasanoff, 2004b; Turnhout et al., 2016). Indeed, the normative shift to a genetic conception of AM has the potential to circumvent valid ecological concerns as it was in the case of western larch. Despite the prevailing invocations of ecological risks, we agree with Klenk & Larson (2015) that this shift has the potential to legitimize other forest management strategies that may be ecologically concerning (such as the introduction of more economically valuable non-native species) in the future. Third, the issue of who is deemed responsible (and accountable) for addressing concerns around AM unfolded in our interviews. As our results show, many of the forest geneticists that we interviewed believe that ecologists should be responsible for dealing with opposition to AM outside native range. Ecologists, on the other hand, express that geneticists' closer ties to the forest industry makes them responsible.

3.5.4 Moving towards an upstream approach to AM policy-making

Going back to the prevalence of the linear model of science-policy discussed earlier, we note that another assumption the model makes is that when public views on potentially controversial interventions (such as AM) do not match those of the experts, then the public must suffer from a knowledge deficit (Brown, 2009; Turnhout & Gieryn, 2019). Following this reasoning, the solution tends to be communicating/delivering knowledge to different publics (often materialized in the form of education) (Dickson, 2005). In line with this model, our results show recurrent calls from interviewees to "educate" different publics to address opposition to AM (especially AM outside native range). This is problematic for many reasons. There is abundant empirical

evidence suggesting that perceptions of risk are not easily shifted in response to new information (Satterfield, Kandlikar, Beaudrie, Conti, & Herr Harthorn, 2009). Kahan et al. (2012) also found that a higher degree of science literacy and technical reasoning capacity, for example, are not necessarily associated with greater concerns for climate change. Furthermore, knowledge is not a conclusive predictor of acceptance of new forest policies (including AM in the BC context) (Hajjar et al., 2014). Thus, we argue that seeking to simply 'educate' different publics to fill a real (or perceived) knowledge gap merely offers a unidimensional way of understanding societal concerns at best, and constitutes a tokenistic response to AM opposition that could backfire at worst.

Although we note that there is evidence showing low levels of knowledge on forest management in BC by the general public (Peterson St-Laurent et al., 2019), which was anticipated by many interviewees in our study, we caution that this should not further legitimize a knowledge deficit model in AM governance. Instead, we offer an alternative proposition from the risk governance literature which highlights an increasing acknowledgment among decision-makers, researchers, and industry that attempts should be made to involve stakeholders and the general public in constructive dialogue about emerging and potentially controversial interventions (such as AM) at the earliest possible stage of implementation, and before decisions are made. This is often referred to as an "upstream approach" (Hagendijk & Irwin, 2006; Partridge et al., 2017). We invite researchers and decision-makers to understand the concerns and ethical sensitivities deemed important to different publics (Corner, Pidgeon, & Parkhill, 2012), and incorporate these into AM policy, especially in light of anticipated public opposition to AM outside of natural range.

3.5.5 Role of First Nations in assisted migration governance

The very limited input from First Nations to the development of AM policies in BC to date is deeply concerning. First Nations having (joint) decision-making power over potential responses to forest management in BC is not only important from an ethical and legal perspective, but also from a practical one. For example, participation from First Nations in the BC forest industry has increased in the past two decades (Nikolakis & Nelson, 2015). Our findings reveal ambiguity

about who is responsible for consulting with First Nations, recurrent references to AM as "too technical," and overall limited input (both knowledge and policy input) by First Nations, all of which exemplify a prevailing relationship between First Nations and the forest sector in BC characterized by paternalism and inequity.

An important point raised by a few interviewees was the burden on consultation First Nations experience, which continues to be a challenge in the natural resources sector (Booth & Skelton, 2011). We did not interview First Nations for this study, and although some interviewees anticipated opposition to AM outside of natural range, there is very limited research exploring First Nations' views on AM. Yet, it is vital to understand their views and values (including cultural and sacred values of trees) as they relate to AM. It is also paramount to adequately address potential cultural critiques of AM that are so far absent from the dominant AM discourse in BC for reasons we have discussed above. A first step may be to incorporate cultural risks assessments in addition to biophysical risk assessments (Satterfield & Roberts, 2008).

We note that many of the interviewees in our study share the concerns we outline here, and we do not seek to dismiss genuine interest from some of our interviewees to include First Nations in AM actions as they move forward. As mentioned in previous sections, there is currently a desire to further engage with First Nations once BC's CCISS tool is better integrated with CBST. In an effort to move beyond treating First Nations as "just another stakeholder" in BC forest governance (Stevenson & Webb, 2003), we urge decision-makers to take First Nations' input seriously moving forward, to start consultations early in the process (as part of an upstream approach), and to recognize that meaningful consultations take time and good faith (United Nations, 2007). Further, we call for greater autonomy in decisions regarding forestry activities (including AM actions) affecting First Nations' traditional, ancestral, and largely unceded territories in BC.

3.6 Conclusions

By examining knowledge and risk governance of AM in the BC forest sector, this study highlights how some types of knowledge are dominant and deemed more credible in AM policy-making. This dominant knowledge invoked has at least partially shaped the understanding of AM

risks (and solutions to addressing them), characterized somewhat narrowly. This study also shows how forest industry professionals, First Nations and the general public are overwhelmingly viewed as knowledge receivers, which we argue is not only a missed opportunity, but also problematic. Narrowing the fields of expertise as well as the risks associated with AM can obscure alternative pathways to pursue adaptation and transformation in the forest sector for the decades to come.

This research does not seek to undermine the importance of biophysical scientific knowledge as input to policy-making. Rather, insights from this study point to a more critical reflection of the types of expertise that are deemed credible as input to policy, and call for a greater awareness of the political processes by which (scientific) knowledge is produced and at times, policed in policy development processes.

Insights from this study implicate additional research questions, which include respectfully exploring Indigenous views of AM, and examining how institutions can symmetrically include different forms of knowledge more systematically (such as by trialling shared learning processes or co-management approaches). Additional research gaps include examining changes to the AM science-policy as genomic tools increasingly inform AM actions, and further investigating the implications of epistemic tensions between genetic and ecological insights as they attempt to fuse to inform policy on AM outside of natural range.

Our analysis also provides applied insights for practitioners and decision-makers who are considering AM as a climate change adaptation option, including i) the need for a better for increased contributions from a wider range of expertise (such as the social sciences and humanities, local and Indigenous knowledge) in the design and implementation of AM policies, and ii) the need for meaningful ways of involving stakeholders, rights holders and different publics at the earliest possible stage of implementation (i.e. upstream approach) in light of anticipated opposition to AM.

Chapter 4: Summary and conclusions

Through a qualitative inquiry approach utilizing document analysis and semi-structured interviews, this thesis explored the historical and contemporary interactions among knowledge, policy, and risk associated with AM to better understand its emergence and current implementation in BC. This concluding chapter recapitulates the major findings of this thesis. Results from each chapter are briefly reviewed for their individual contributions, and subsequently concluding insights from both chapters are integrated to explore overarching implications. Salient empirical and policy-relevant contributions of this thesis are then discussed, followed by the strengths and limitation, as well as some methodological reflections. Finally, avenues for future research are explored, and a case for a non-technical framing of AM is made.

4.1 Key Insights and Findings

Using a historically-informed approach, this thesis examined the governance landscape of AM policy in BC's forest sector, paying particular attention to the types of knowledge used to inform policy, risks considered, and the role of different actors in decision-making. Collectively, this thesis underscores the dominant role of particular forms of knowledge to inform AM policy, both historically and at the inception and implementation of a new seed transfer regime in BC that enables AM. Further, this thesis reveals the legacies of government-forest industry coalitions that have served to shape seed transfer policy (including AM policy) in BC to date.

The first objective of this thesis was to construct a historical timeline of seed transfer governance in BC (Chapter 2). This was done by examining a key set of governance attributes across an 80-year period. Evidence considered included over 1,000 pages of policy documents as well as seven in-depth semi-structured interviews with key informants. This approach to examine change through time revealed how the legacies of historical events in BC continue to influence seed transfer policy today. From little to no regulation of seed transfer, to an increasingly prescriptive geographically-based seed transfer system, BC did not experience major changes in seed transfer policy until the establishment of a climate-based seed transfer system in 2018. Findings from this research demonstrate how the pattern of change in this new climate-based system emerged through the opening of a policy window, instituting a paradigmatic shift in seed transfer policy.

Yet, the governance processes by which changes to seed transfer occurred remained relatively static in practice, with a disproportionally high influence of the forest industry in seed transfer policy-making prevalent over time. Most notably, Chapter 2 reveals a longstanding technocratic seed transfer governance regime in BC. The knowledge used to justify seed transfer policy changes has become increasingly dominated by genetic insights generated within government ministries, and with limited to no knowledge input from social scientists, local practitioners, and First Nations.

The second objective of this thesis was to examine the ways in which different types of knowledge inform current AM policy in BC, and how this knowledge shapes perceptions of risk (Chapter 3). Evidence considered included 27 in-depth, semi-structured interviews with key government officials and forest industry professionals whose work intersected with AM actions and policies. With an emphasis on processes, this chapter highlights how particular forms of knowledge (i.e. biophysical knowledge produced primarily internally) have been dominant in informing BC's current AM policy landscape. Results show how these dominant knowledge forms have (at least partially) shaped the understanding of AM risks, and the potential solutions to address them, both of which characterized somewhat narrowly. Finally, Chapter 3 reveals that forest industry professionals, First Nations and the general public are overwhelmingly viewed as knowledge receivers and have not been able to contribute to knowledge production used to inform AM policies and actions. Findings are summarized in Table 4:1.

Collectively, this thesis offers two core findings reinforcing of one another. First, the knowledge considered relevant to inform AM policies in BC has been restricted to genetic and climatic evidence produced mostly internally by the Forest Improvement and Research Management Branch of the MFLRORD. Other knowledge, such as insights from ecology, the social sciences, local practitioner knowledge, and Indigenous knowledge have been limited or absent in informing AM policies. Second, despite having a limited knowledge input, the forest industry has had an influential role in every other aspect of AM policy-making, with no policy input from First Nations and the general public, which was in part rationalized by the highly "technical" nature of AM. Connecting these two core findings, privileging some types of knowledge over others does political work because knowledge shapes how a problem (in this case, AM) is

understood, and helps shape the perception of which actors are deemed “appropriate stewards” of the environment (Scoones, 2009). This in turn translates into decisions about whose knowledge is considered credible as input to decision-making, who should be involved and to what extent, and what solutions are deemed approapriate.

Table 4:1 Summary of research findings.

Overall research aim: To explore governance dimensions related to interactions between knowledge, policy, risk and history to better understand the emergence and current implementation of AM in BC's forests	
Research questions	**Key findings**
How has seed transfer policy changed in BC over the past 80 years in terms of actors involved, stated objectives, policy instruments and institutions, and knowledge considered?	• From little to no regulation of seed transfer, to an increasingly prescriptive geography-based system, there have been no major changes in seed transfer policy until the inception of a climate-based seed transfer system in 2018 • The governance processes by which seed transfer changes occurred remained relatively static in practice, with a disproportionally high influence of the forest industry in seed transfer policy-making • The knowledge used to justify seed transfer policy changes has become increasingly dominated by genetic and climatic evidence produced internally, with limited to no input from social sciences, local practitioner knowledge, and Indigenous knowledge
What drivers contributed to change in seed transfer policy in BC over time?	• Climate-related focusing events, including the mountain pine beetle epidemic and droughts that threatened forest productivity • Government scientists acting as policy entrepreneurs collectively pushed for a pro-active climate change adaptation policy in the forest sector
What types of knowledge are deemed credible for supporting contemporary AM decision-making in BC?	• The type of knowledge deemed credible is restricted to biophysical, model-based, scientific knowledge produced primarily within government ministries • Government officials recognize the need to engage the forest industry, First Nations, and the general public, but these groups are characterized as knowledge receivers • Policing the types of assisted migration expertise serves to exclude other forms of knowledge and possibilities for addressing assisted migration concerns
How do government officials and forest industry professionals in BC perceive the benefits and risks associated with assisted migration?	• Nearly unanimous view that assisted migration is necessary to address climate change, in addition to economic benefits (e.g. ensuring a healthy timber supply) • Interviewees identified numerous ecological risks such as the potential introduction of pests and disease • Interviewees hold the view that the provision of scientific knowledge to different publics will prevent assisted migration controversy

4.2 Contributions

4.2.1 Empirical evidence

Previous social sciences insights on AM of trees have touched on the importance of understanding interactions between knowledge and policy (Peterson St-Laurent et al., 2019) but empirical evidence has been limited. Furthermore, there is a need within the STS scholarship to move beyond static assessments of knowledge politics (Schut, van Paassen, & Leeuwis, 2013) and to situate these debates in their broader historical contexts instead. This thesis addressed these gaps. Through a qualitative inquiry approach and by utilizing multiple methods, the research presented here attempts to shed light to the processes by which AM knowledge is produced within socio-political and historical contexts as an input to AM policy (Jasanoff, 2004a).

This thesis contributes to the field of environmental social sciences to better understand the governance dimensions of novel forest management interventions (such as AM) as they become increasingly more common (Hagerman & Pelai, 2018). More specifically, this thesis offers an in-depth examination of the ways in which knowledge, policy, and risks interact in the emergence and inception of AM actions. This thesis also constitutes the first empirical and systematic exploration of seed transfer governance over time in BC (Chapter 2). Finally, this thesis contributes to the socio-cultural risk perceptions and risk governance literatures by calling attention to the role of (scientific) knowledge in shaping perceptions of risk and solutions to address them (Chapter 3).

More concretely, this research offers empirical evidence to support an enhanced understanding of knowledge politics that prevail in policy decisions about controversial environmental interventions. The findings of this thesis speak to how different knowledge forms can be deemed more or less credible, and thus policed. This thesis also shows how even within the realm of biophysical scientific knowledge, there are many *sciences* (as opposed to just one *Science*) (Latour, 2004) that may have competing insights regarding controversial interventions such as assisted migration. Overall, this thesis offers rich empirical evidence to exemplify how environmental expertise is not found, but made (Jasanoff, 2003a).

4.2.2 Policy and practice

This thesis highlights the need to include a broader range of expertise in informing AM actions and other novel forest management interventions. More specifically, insights from ecology, the social sciences and humanities, as well as local (placed-based) knowledge from forest industry practitioners and Indigenous Peoples offer multiple benefits, including an enhanced understanding of future anticipated climate change adaptation dilemmas (Hagerman & Pelai, 2018), and more credibility in scientific assessments (Jasanoff, 2003b).

This research also reveals the urgent need to meaningfully include First Nations in AM policy-making. Doing so is paramount given the anticipated opposition to AM outside of natural range, the possible cultural and ethical critiques of AM, and the potential for infringing upon First Nations rights and interests by restricting access to ceremonial uses of trees if alternative tree species are migrated and planted (Barber, 2007). Consultations with First Nations, which take time and good faith, should occur early in the AM policy-making process, and should move beyond an information-sharing model to offering a genuine opportunity to participate in decision-making in their own terms (Wyatt, 2008).

Another important implication of these findings centers on a greater involvement of the general public in decisions about publicly-owned forests. Although public input to seed transfer policy has been historically limited (Chapter 2), understanding the concerns and ethical sensitivities deemed important to different publics (Corner, Pidgeon, & Parkhill, 2012) has the potential to increase the legitimacy of decisions and contribute to greater trust in decision-making processes (Rogers-Hayden & Pidgeon, 2007). The last point is especially important given the low levels of trust in governments in BC (Peterson St-Laurent, Hagerman, Findlater, & Kozak, 2019). Viewing the general public (and other groups) as passive knowledge receivers in the context of AM is also a missed opportunity. A greater public knowledge input can help frame problems (including AM) in different ways contributing to a broader range of potential solutions (Jasanoff, 2003a).

Finally, this thesis highlights the need to clarify who is responsible for consulting with various groups interested in and affected by AM actions, including the forest industry, First Nations, and the general public. Given the multi-faceted nature of AM, it is expected that multiple government agencies will work on AM policy-making and implementation. Thus, an enhanced communication between such agencies is crucial. In the case of BC, the MFLRORD's Forest Improvement and Research Management, and Resource Practices branches work on the CBST and CCISS projects related to AM respectively. Yet, it is only the Forest Improvement and Research Management that carried out consultations despite an expected higher opposition to AM outside of native range that CCISS project would enable.

4.3 Research strengths, limitations and methodological reflections

All methodological approaches (both quantitative and qualitative) have strengths and limitations. The most salient methodological strength of this thesis is its empirical richness, including the detailed and varied data from over 1,000 pages of documents, and over 300 pages of verbatim interview transcripts. Another notable strength of this thesis is the use of multiple data collection methods, not only to corroborate evidence, but also to understand different aspects of assisted migration policy. The analytical use of documents as the primary source of evidence (as opposed to using them just to corroborate information) is also rare in forest contexts despite its untapped potential (Siegner, Hagerman, & Kozak, 2018).

It is important to acknowledge the methodological limitations of this thesis as well. There are likely documents (e.g. internal documents) to which I did not have access to conduct the document analysis (Chapter 2). An interviewee recommended the use of Freedom of Information requests to gain access to a broader range of internal documents, including correspondence between key political and public service actors. This would have been a stimulating research endeavour, but such a level of scrutiny is beyond the bounds of the thesis aim, and would have been more appropriate for a Master's in environmental history.

Moreover, documents should not be uncritically treated as firm evidence of what they report, as they are social constructs produced, shared and used in particular socio-political contexts (Coffey, 2014). For example, focusing on publicly available documents likely limited the extent

to which diverse perspectives were given a space (e.g. debates on AM terminology or negotiation of text are rarely captured in published documents). Although the semi-structured interviews allowed for an enhanced understanding of the context in which documents were published and shed light to AM governance processes, this research could have been aided by participant observation methods (e.g. systematic observation of CBST meetings). This methodology would be most useful to understand contemporary (as opposed to historical) processes by which AM knowledge is communicated or delivered to different groups, and the ways in which evidence is negotiated to inform AM policy constitute research to consider in the future.

As for the semi-structured interviews (Chapters 2 and 3), I was able to interview most of the participants who met the inclusion criteria of this research. There were a few individuals I wish I had spoken with for the history chapter (Chapter 2), but did not have the opportunity to interview. In part, the small sample size of that chapter was due to a rather stringent inclusion criteria (e.g. more than 15 years of experience in the BC forest sector, familiarity with seed transfer practices), but many of the potential interviewees for this historical chapter had also retired, making it difficult to contact them.

Despite multiple invitations and my persistence over several months, securing interviews was a challenge. I tried to mitigate this by offering Skype and phone interviews, which made it more convenient for some interviewees, but I was concerned Skype and phone interviews may negatively impact the quality of my data. For example, the literature points to potential interpersonal communication challenges, specifically in forming trust, associated with interviews that are not conducted in person (Block & Erskine, 2012). Fortunately, similar to other studies (Sturges & Hanrahan, 2004), the data I obtained from Skype and phone interviews (one-third of my interviews) was equivalent to the in-person interviews. I base this observation on the comparable length, depth, and nature of responses I received from both types of interviews.

At the inception of this research project, I contemplated using a quantitative approach via surveys in my methodology. This approach would have enabled me to potentially externally generalize the results of this research, and it would have made it easier to communicate my findings to inter-disciplinary audiences. As the research avenues I was interested in exploring

solidified, I realized a qualitative approach was more appropriate to address my research questions. The detail and richness of my qualitative data, the opportunity to ask follow-up and clarification questions, and the ability to delve deeper into a topic and explore the nuances of a complex and controversial subject such as AM are some of the benefits of taking a qualitative approach.

The data presented in this thesis in the form of quotes is preceded by a number of research judgements I had to make in consultation with my research advisors, including decisions on who to invite and which documents to examine, what questions to ask, what themes to highlight in the results, and which quotes to use to illustrate my claims. Therefore, the results of this thesis constitute a particular interpretation of AM governance in BC at a particular point in time by specific methodological and research decisions. The case presented here is not intended to represent all AM policies in Canada, or globally. However, there are broader implications of this work that may be relevant to other novel forest management proposals, including the role of a narrow set of expertise to inform decisions, and the influence of forest industry.

AM actions and policies in BC and elsewhere are changing and updating rapidly, especially as new information becomes available. The CBST project, for example, posts monthly updates. I included the latest available information as of September, 2019 in this research, but I recognize that by the time this thesis is published, there will likely be other pressing topics to cover as AM policy moves in real time, often faster than the academy. Ultimately, the results presented here are very much contextual in space and time.

As intellectually stimulating inter-disciplinary research is, I found it challenging at first to work with multiple bodies of literature. Part of me also wishes I had the opportunity to engage more deeply with one of the fields my thesis touches. Yet, none of these fields was sufficiently nuanced in my mind to understand the complexities and multi-layered nature of AM governance. Moreover, it is rare to rely on just one theoretical lens in qualitative inquiry. Rather, qualitative conceptual frameworks are constructed, and do not exist ready-made, making them an intellectual contribution unto itself (Maxwell, 2013). I was also much more interested in the problem and the potential solutions to address it as opposed to theory generating. “What field are

you in?" people often ask. For the longest time, I struggled to answer this question. Political ecology? Political science? STS? Public policy? I now confidently say I conduct inter-disciplinary social science research to understand environmental problems. I learned to embrace a problem-oriented, pragmatic approach to my research (Creswell, 2013).

Finally, I did not expect one of my salient findings to be about issues affecting First Nations in BC. In retrospect, this should not have surprised me as any conversation about forestry in BC is inevitably entangled with colonial legacies of contested land claims (Wyatt, 2008), limits on access to natural resources (Tennant, 2011), and a long history of inequitable relationships between Canadian governments and First Nations (Nikolakis & Nelson, 2015). I struggled to write about First Nations and AM governance without having interviewed First Nations, and although I truly wish I had spoken with First Nation leaders about their views on AM policy in BC, doing so respectfully would have been an entirely different project on its own. I hope scholars, especially Indigenous scholars, take interest in researching AM of trees with and for First Nations in the future utilizing de-colonizing methodologies (Smith, 2012).

4.4 Avenues for future research

The research presented in this thesis invites consideration of a number of questions for future research. Four key avenues for future research are proposed here. First, the role of external scientists in informing AM policy can be further scrutinized. Although this thesis focuses primarily on internal expertise, the results presented here hint at the influential role of university researchers in informing and framing AM in BC. For example, climate models used to inform the latest iteration of BC's CBST project were developed by researchers at the University of British Columbia (Wang, Hamann, Spittlehouse, & Murdock, 2012) and cited in official MFLRORD technical documents informing AM (O'Neill et al., 2017).

Second, I would anticipate different conceptualizations of AM, its perceived risks, and solutions to address them by Indigenous Peoples. For example, there is evidence that Anishnaabe communities view invasive species as natural forms of migration and are more concerned about a colonial "invasive land ethic" than the threats of invasive species themselves (Reo & Ogden, 2018). Indigenous epistemologies and worldviews, often emphasizing inter-connectedness

among living entities in forests (Castleden et al., 2009), will likely differ from the tree-centric vision of AM in BC to date. As mentioned above, respectfully investigating Indigenous views on AM actions, as well as their views on the process by which AM decisions are made remains an unexplored research avenue.

Third, further research on AM governance for forest conservation objectives (as opposed to AM for commercial forestry – the focus of this thesis) is needed. The conservation literature has explored this topic in the context of AM of fauna (IUCN, 2013; Shirey & Lamberti, 2010), but remains elusive in forest conservation contexts, with one notable exception (Palmer & Larson, 2014). Some scholars suggest that AM for the purposes of rescuing endangered tree species from the threats of climate change is riskier and less scientifically feasible than forestry AM (Pedlar et al., 2012). Investigating these differences as well as its governance implications would be a much-needed contribution to the AM literature.

Fourth, a wide range of research questions can derive from the increasing potential use of genomic techniques to inform AM. This thesis has only scratched the surface of genomics-informed AM. Namely, despite a cautious optimism to use this technology, it could potentially spark public opposition as it is conflated with genetic engineering. Yet, outstanding questions remain, including how these genomic insights interact with the already present tensions between genetic and ecological insights to inform AM, and how genomic tools will be incorporated into future AM policy.

4.5 Towards a political framing of assisted migration

At the core of AM of trees, a fundamental question emerged in this thesis: given climate change, what should our future forests look like? On the one hand, this is indeed a scientific question (e.g. what trees will be better adapted to future conditions?), as well as an economic question (e.g. what trees will ensure the forest industry remains healthy?). Yet, it is also a key ethical (e.g. should humans intervene in designing future forests?), and political question – the focus of this thesis (e.g. who decides which trees are moved, who benefits, and who is impacted?) These questions have been bypassed (and arguably obscured) by the processes described in this research that have framed AM as an exclusively technical problem. Thinking about AM as a

political problem has the potential to bring different perspectives and voices to light, revealing risks not captured by a scientific framing of AM, and illuminating alternative pathways to address such risks. Different publics, stakeholders, and rights holders (alongside scientists and policy-makers) should be given the opportunity to collectively shape the future of our forests.

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Appendices

Appendix A: Interview schedule (Chapter 2)

Background

- Can you tell me about your role/affiliation and background?

  - How long have you been working on this portfolio?
  - Which policies does your unit work most closely with?

- What are your unit's current objectives in terms of tree breeding or seed transfer?

- How have these objectives changed over time?

    - What caused changes in objectives/priorities for tree breeding or seed transfer?
    - Which actors were influential in these changes?
    - What kind of information/evidence was helped inform these changes?
    - Which policies have changed?

- Looking into the future, what are the most pressing threats that will impact tree breeding or seed transfer?

    - How effective are current policies in place in dealing with these threats?

- As you know, some people are suggesting the widespread application of assisted migration of trees in response to climate change. What is your understanding of AM in the forestry context?

    - What (if anything) is novel about AM compared to other seed transfer policies?

- Some researchers are proposing the application of genomic tools to facilitate tree breeding, and inform AM. Have you heard about this? What is your understanding of genomics for AM?

    - What (if anything) is novel about AM compared to other tree breeding methods?

Closing remarks

- Is there anything else you would like to mention?
- Is there anyone else you think I should speak with?

Appendix B: Interview schedule (Chapter 3)

Background

- Can you tell me about your role/affiliation and background?

Set-up

- As you know, BC is in the process of using assisted migration of trees as a management tactic. How do you use the term AM in your work? How do you define it?

    - Within/outside native range
    - Climate change-specific

- What are your overall impressions about using AM in the BC forest sector?

- What (if anything) is novel about AM as a management tactic?

    - Within/outside native range
    - Scale
    - Policy

Risks & benefits

- What specific benefits? (if any) do you see in adopting AM in the BC forest sector?

    - Who would benefit the most? Why?

- What concerns (if any) do you have with AM in the BC forest sector?

    - How feasible do you think it is to implement AM?
    - What uncertainties are you most concerned about?
    - Who would bare the most risk? Why?
    - Which of these concerns are the most important and urgent to address?

Acceptable trade-offs

- In your view, are there are any trade-offs associated with AM?

    - What would the future of our forests look like if we don't implement AM?
    - If AM is useful for traits like climate change adaptation, are other traits compromised?

Governance

- What is your overall take on the BC climate-based seed transfer policy?
    - What about the species selection policy?
    - How should these two policies interact?
    - (For industry): How confident are you in the BC government's ability to regulate AM?
- What should the process for making decisions around AM policy look like?
    - Who should be consulted, and how?
    - What role do local practitioners play in the development of AM policy? What role should they play?
    - What role (if any) should professional reliance play in the AM conversation?
- How do you see the implementation/operationalization of AM unfolding on the ground?
    - When do you anticipate AM can be up-taken on a larger scale?
    - Which groups/stakeholders do you anticipate will be the first to adopt AM?
- How do you think stakeholders in the community would react to AM?
    - How should opposition (if there is any) should be dealt with?
- What types of information would be useful to make a decision on whether to adopt this intervention?
    - Who would you like to hear from? (Regarding evidence, information, knowledge)?

Genomics

- Some researchers are proposing the application of genomics to inform AM. Have you heard about this? What is your understanding of genomics for AM?
    - What additional concerns (if any) would the use of genomics specifically bring?

Closing remarks

- Is there anything else you would like to mention?
- Is there anyone else you think I should speak with?

Appendix C: Interview Consent Form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Forestry
Department of Forest Resources Management
2nd Floor, Forest Sciences Centre
2045 – 2424 Main Mall
Vancouver, B.C. Canada V6T 1Z4

Interview Consent form

Government/industry views on assisted migration in the BC forest sector

STUDY TEAM

Principal Investigators: Dr. Shannon Hagerman, Assistant Professor, Faculty of Forestry, UBC; Dr. Rob Kozak, Professor and Associate Dean – Academic, Faculty of Forestry, UBC.

Co-Investigator: Ricardo Pelai, Master's student, Faculty of Forestry, UBC. The data collected on this study will be part of a Master's thesis (public document).

Purpose: You are invited to participate in a research project that aims to further understand government and industry's views on assisted migration in the BC forest sector. As someone involved with seed policy, forest management, and/or reforestation, you will provide valuable perspectives that could help advance the understanding about this forest management strategy.

Study procedures: Your participation would include a one-time ~60- minute interview to discuss your views about assisted migration. The investigator will take notes and audio-record the interview to ensure accuracy in final reporting.

Participation in any of the above is voluntary. If you agree to participate in the study and then decide that you do not wish to continue, you may withdraw at any time. You may refuse to discuss any questions during the interview. Again, your engagement in this study will only take place after you consented to it (see below for ensuring confidentiality). If you wish to opt to withdraw from the study, and information that you provided will not be used.

Study results: The main study findings will be published in academic journal article(s) and a Master's thesis (public document). If you wish to receive a digital or hard copy of the final publication (s), you may include your email or mailing address at the bottom of this consent form.

Potential Risks: No psychological, cultural, privacy or confidentiality risks are anticipated or intended through this study. We do not think there is anything in this study that could harm you, or be bad for you. Should you feel uncomfortable at any time during the interview, you do not have to participate, you have the right to stop the interview and/or inform the researcher about information you do not wish to have included in the final documentation.

Potential Benefits: You may benefit from this study by having an opportunity to discuss and reflect on your experience in the BC forest sector. Additionally, provincial decision-makers, industry and other stakeholders may benefit in the future from what is learned about governance challenges associated with the implementation of assisted migration.

Confidentiality: Only the researchers listed on page one of this form will have access to the information collected. At no time will your name appear on any research report. Please note that your confidential responses may be identifiable if a reader is able to link them to your public record. A copy of your transcript and the results will be provided to you via e-mail at your request. Similarly, all documents and information collected will be identified only by code number, encrypted and kept in a locked cabinet at UBC, and password protected computer files password, for at least five years. After five years, all material that might identify anyone who wished to remain anonymous will be destroyed, including consent forms and any audio material.

Who can you contact for more information about the study? Please contact any of the researchers that are listed at the top of the first page of this form. We are available to answer any questions you may have about this study.

Who can you contact if you have complaints or concerns about the study? If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598.

Participant consent and signature: *Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative impact. Your signature below indicates that you have received a copy of this consent form for your own records.*

Your signature indicates that you consent to participate in this study.

…….. …….

Participant's signature Date

……. ……

Printed name of the Participant signing above (optional) Participant's e-mail or mailing address

Check off all that you agree to:
(1) I agree that only notes can be taken of what I have to say.
(2) I agree to have my opinions voice-recorded.
(3) I would like to receive a copy of the research findings