A Critical Evaluation of Old-Growth Forest Definitions in Canada

Peter B. Issekutz

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Supervisor Dr. Peter Duinker

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Peter B. Issekutz

Department of Earth and Environmental Sciences, Dalhousie University, Halifax, NS

Supervisor: Peter N Duinker, School for Resource and Environmental Studies, Dalhousie University

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Abstract

Old-growth forests are a precious resource. As critical areas of biodiversity, they provide habitat for many species at risk. They also provide a multitude of ecosystem services and have enormous intrinsic biological value and aesthetic appeal. In order to properly conserve these forests for future generations, it is important that they can be appropriately identified. Canada has substantial old-growth forest areas in multiple provinces, the regulation of which falls under provincial jurisdiction. A series of different old-growth forest definitions have therefore been developed. The purpose of this study was to perform a critical analysis of the existing operational definitions of old-growth forest, focused on the commonality and utility of their key characteristics.

This study evaluated selected definition-characteristic frequency of use and utility across provincial jurisdictions with publicly available operational definitions of old-growth forest. This study aimed to address the knowledge gaps that exist surrounding the format and quality of different old-growth provincial and territorial old growth forest definitions to help inform the future development of old-growth forest definitions.

The results of our study showed that half of Canada's provinces had no official, publicly available definition of old-growth forest, or had only a conceptual definition. Only six provinces - Newfoundland and Labrador, Nova Scotia, New Brunswick, Ontario, Saskatchewan and British Columbia - were found to have an official operational definition of old-growth forest. Each of these provinces took a different approach, using different combinations of definition characteristics and format. Ontario's old-growth definition included the greatest proportion of high-utility definition characteristics.

We used the information obtained to develop a template definition for characteristics that might be included into new old-growth definitions. This incorporated high-utility definition characteristics from existing definitions and new old-growth assessment techniques such as the use of indicator lichens.

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INTRODUCTION

The importance of old-growth forests

Protection and preservation of Canada's old-growth forests is critical. Old-growth forests are some of the most biodiverse areas of our country (Mosseler et al. 2003a). Their removal has far-reaching effects on both forest and freshwater ecosystems nationwide (Penaluna et al. 2016). When old-growth stands of trees are felled, tree and root cover are diminished and biodiversity decreases, in terms of species richness (Humphrey 2005). Old-growth forests provide critical habitat and serve as wildlife refuges. Some species, such as American marten and woodland caribou, require old-growth forest habitat for their survival (Cox 2019; Thompson 1992). Old-growth forests also provide a wide range of other ecosystem services, many of which are shared by other mature forests, such as erosion prevention and carbon storage (Luyssaert et al. 2008). Old-growth forests were also once thought to be carbon neutral, but some can serve as carbon sinks and continue to sequester carbon (Luyssaert et al. 2008). Even the removal of decaying branches and trunks from an old-growth forest can cause a 20% decrease in species richness (Luyssaert et al. 2008; Nova Scotia Nature Trust 2002; Rankin, 2016).

Old-growth forests also contribute to our nation's economy through benefits to tourism, fisheries, hunting and the forestry industry. Old-growth forests create "mound topography" through their increased levels of dead and fallen trees with large root systems (Rankin 2016). This uneven ground and fallen wood can lead to formation of pools and varied habitats in rivers, streams and natural runoff, which are spawning grounds for salmon and other freshwater fish species (Franklin et al.1981; Luyssaert et al. 2008; Nova Scotia Nature Trust, 2002). Old-growth forests are areas of natural beauty, admired by visitors. Twenty five percent of the world's remaining old-growth forest is in Canada. Some of this is included in the one of the world's

largest continuous stretches of forested land, the Great Boreal Forest (Natural Resources Canada 2018a). However, Canada relies on a series of inconsistent definitions and guidelines, which vary regionally, to conserve and manage this precious resource.

Old-growth forests and their management

Forested lands in Canada are under provincial jurisdiction within the constitution. One exception to this rule are federal Crown lands, such as National Parks. These jurisdictional divisions mean that about (90%) of our forested land is under direct provincial and territorial stewardship with the remainder being divided between private owners (6%) and the federal government (4%) (Natural Resources Canada 2018b). The federal government has control over forests in National Parks, except where specific agreements have been made with indigenous groups or communities. Overall, around 95% of the 347 million hectares of forest land, in Canada, is publicly managed (Natural Resources Canada 2019). Canada is a highly forested nation, the second largest, in terms of area, in the world. Canadian forests are a massive expanse of land, in widely differing geographical and social contexts that require careful management and conservation. Notably, the proportion of old-growth forest differs widely from province to province with British Columbia (BC) having the highest density of these forest types, when considered as a proportion of overall forest area (Berry et al. 2018)**.**

The complexity of old-growth forest conservation and management

Multiple stakeholders are involved in the development of old-growth forest policy in Canada. For example, approximately 156,744,000 cubic metres of timber were harvested in Canada in 2016 alone, and over 317, 000 jobs directly were linked to the forestry industry and forestry activity in 2017 (Government of Canada 2015). This activity is critical to the economic

survival of many rural towns and settlements across Canada. The interests of resource extraction industries and developers may conflict with the views of conservation groups that monitor old-growth forest conservation and species at risk. The general public, forest user groups, and government agencies also have key roles and responsibilities related to forest conservation and management. Many indigenous groups have important claims and are major stakeholders in forest management, as well as harvesting trees and forest-resident animals, in some areas (Bombay 1993). The complex uses of forests for commercial, recreational and food supply needs, together with the need to conserve their ecological value, makes decisions regarding forest type definitions, management plans and regulations both important and challenging.

The challenges of balancing environmental and economic pressures and dealing with conflicting interest groups contributes to why old-growth forest management is considered a "wicked problem" that cannot be solved with a single approach (Pesklevits et al. 2011). A wicked problem is a problem that "... has innumerable causes, is tough to describe, and doesn't have a right answer" (Camillus 2008). The challenge of figuring out a good way to properly define the term "old-growth forest" contributes to the intractability of this problem (Pesklevitz et al. 2011). However, it is only one facet of many challenges faced by those concerned with effective conservation and management of old-growth forests and their resources.

The basis of current old-growth forest definitions

A set of defining characteristics involving thresholds is often developed to distinguish "younger forest" from old forest. Generally, old-growth forest definitions will "emphasize lack of disturbance by humans…use a minimum age…emphasize stand development… or use an economic threshold" (Henry 2017). In Canada, characteristics are applied to help define what "stands" of a forest are considered "old-growth". However, there is also no universal definition

for the term “stand”, despite its regular use as a forest unit (Snyder 2014). A stand is generally considered to be “a contiguous community of trees sufficiently uniform in composition, structure, age and size class distribution, spatial arrangement, site quality, condition, or location to distinguish it from adjacent communities” (Nyland et al. 2016). The idea to divide forests into “stands” originated from the Normalwald concept, a 19th century set of guiding principles used within the silviculture industry (Puettmann 2009). These were built upon the idea of maximizing harvest efficiency and income from timber production. The uniform requirements needed for trees to be considered “part of a stand” allowed for easier inventory and clearer planning for timber producers (Puettmann 2009). Groups of stands can also be categorized into what are known as “ecosites”, “ecoregions” or “forest units” which are generally a more modern way of referring to areas of a forest. Stands can be grouped under the terms ecosite or ecoregions as a method to create larger defined zones containing multiple stands where there is a higher degree of variability in tree species, size, density etc. (Nyland et al. 2016). Both these divisions of “stands” and “ecosites” are used throughout Canadian forestry documents to categorize forested land (Ontario Ministry of Natural Resources 2012; Uhlig et al. 2001).

Canadian old-growth forest definitions can be divided into two distinct categories i.e. “conceptual” and “operational” definitions. A conceptual definition tells you what the concept means in general terms, summarising the ideas behind it. Conceptual definitions tend to be more subjective and qualitative in nature. This contrasts with operational definitions which tell you how to measure the concept in precise, objective terms. These tend to have quantitative values associated with them. With regard to old-growth forest definitions, this means that conceptual definitions are often general statements about what an old-growth forest consists of. One example is Nova Scotia Nature Trust’s definition of old-growth forest which says “Old-growth

forests consist of primarily longer-lived species that survive well in shaded conditions" (Nova Scotia Nature Trust 2002). In contrast, operational definitions will define boundaries in specific terms e.g. the precise age or species characteristics of an old-growth forest (McMullin and Wiersma 2019).

It is important that environmental definitions and policies, involved with preserving ecosystems, such as provincial definitions of what constitutes an old-growth forest and consider multiple facets and stakeholders. Legal, scientific, practical, economic, and social implications of these definitions should be considered. The proposed analysis will therefore include both a formal analysis of all operational definitions of the term "old-growth forests" in provincial documents and an evaluation of their utility with reference to related literature.

Goals and research questions

The purpose of this study is to critically analyse the existing definitions of an old-growth forest, focused on the commonality and utility of the key characteristics contained within each province's operational definition. This critical analysis will document the similarities and differences between operational definitions used for old-growth forest. It will also be used to rank each definition-characteristic's frequency and utility across the different jurisdictions and will be used to develop a template of the most effective and practically useful old-growth forest definition characteristics. This study aims to address the knowledge gaps that exist surrounding the overall structure and quality of different old-growth forest definitions and old-growth forest definition characteristics across Canada and to inform the future development of old-growth forest definitions. This analysis was informed by the requirements for old-growth forest management according to the Forest Stewardship Council (FSC) (2019), the Sustainable Forestry

Initiative (2019), and the Canadian Standards Association (2019). A variety of different scientific perspectives and relevant literature were also considered.

LITERATURE REVIEW

The literature review for this project is based on a thorough search using both traditional library and online resources. It is focused on examining the historical and present forces that have driven the creation and enforcement of Canadian old-growth forest definitions. It also provides context for the research project by considering recent, related studies in this area. Currently, only limited studies of old-growth forest definitions and their functionality in specific provinces and territories have been carried out. These include historical policy perspectives (Paranteau 2014) that relate to Canada and examination of relevant definitions (National Council for Air and Stream Improvement 2005). This project will address an important current knowledge gap that exists in this area.

Canada's forest resources

Canada has rich forest resources, including a wide variety of forest types that differ across the country. These forest types are divided into eight distinctly different official "forest regions": Boreal Forest, the Acadian Forest, the Great Lakes-St Lawrence Forest; the Carolinian Forest, the Subalpine forest, the Columbia forest, the Montane forest and the (Pacific) Coastal forest (Natural Resources Canada 2019) (Figure 1). Canada also has one of the world's largest continuous stretch of forest, the Great Boreal Forest, and over 347,000,000 hectares of forest in total. According to Natural Resources Canada only 7% of this has formal protected status, and only 5% is considered old-growth, but it is unclear how these figures were derived (Natural Resources Canada, 2019). However, Canada's forests represent around 10% of our entire

planet's forested land (Howlett, 2001). Many forests have a modern composition, as a result of large-scale logging and development activities which can alter the biodiversity and level of canopy cover (Reich et al. 2001). These forests are very different from untouched old-growth ecosystems composed of climax species.

The critical role of old-growth forests and their ecosystem services

Globally, the amount of old-growth forest has declined dramatically over recent decades (Beadle et al. 2009; Wirth, 2009). Old-growth forests support greater species diversity than less mature forests and provide habitat for many rare and endangered species both internationally and in Canada. These include Spotted Owl, American Marten and other threatened old-growth residents in Canada (David Suzuki Foundation, 2019; Peeples et al. 2009; Thompson, 1992). Multiple plant and insect species are also highly dependent on this habitat. Globally, old-growth forests are well-documented areas of greater species diversity. However, we lack key data in some areas of Canada (Hendrickson 2003). For example, it has been suggested that some Canadian lichen species are found only in deep fissures in the bark of old trees (Rankin 2016). The critical importance of old-growth forests, in supporting species diversity and providing a habitat for multiple threatened species, is unquestioned. Old-growth forests provide a variety of ecological services beyond their role as a diverse habitat. First, old-growth forests are critical carbon sinks in the context of global warming (Luyssaert et al. 2008). Second, they provide increased groundwater and surface water supplies (Franklin and Spies, 1991). Third, they lead to reduced flood risk in the case of storms. Old-growth forests diminish the peak flows of streams following storms by 33 – 50 percent (Jones and Grant 2001). The ecological services provided by old-growth forests, together with the species diversity they support, are critical to our planet.

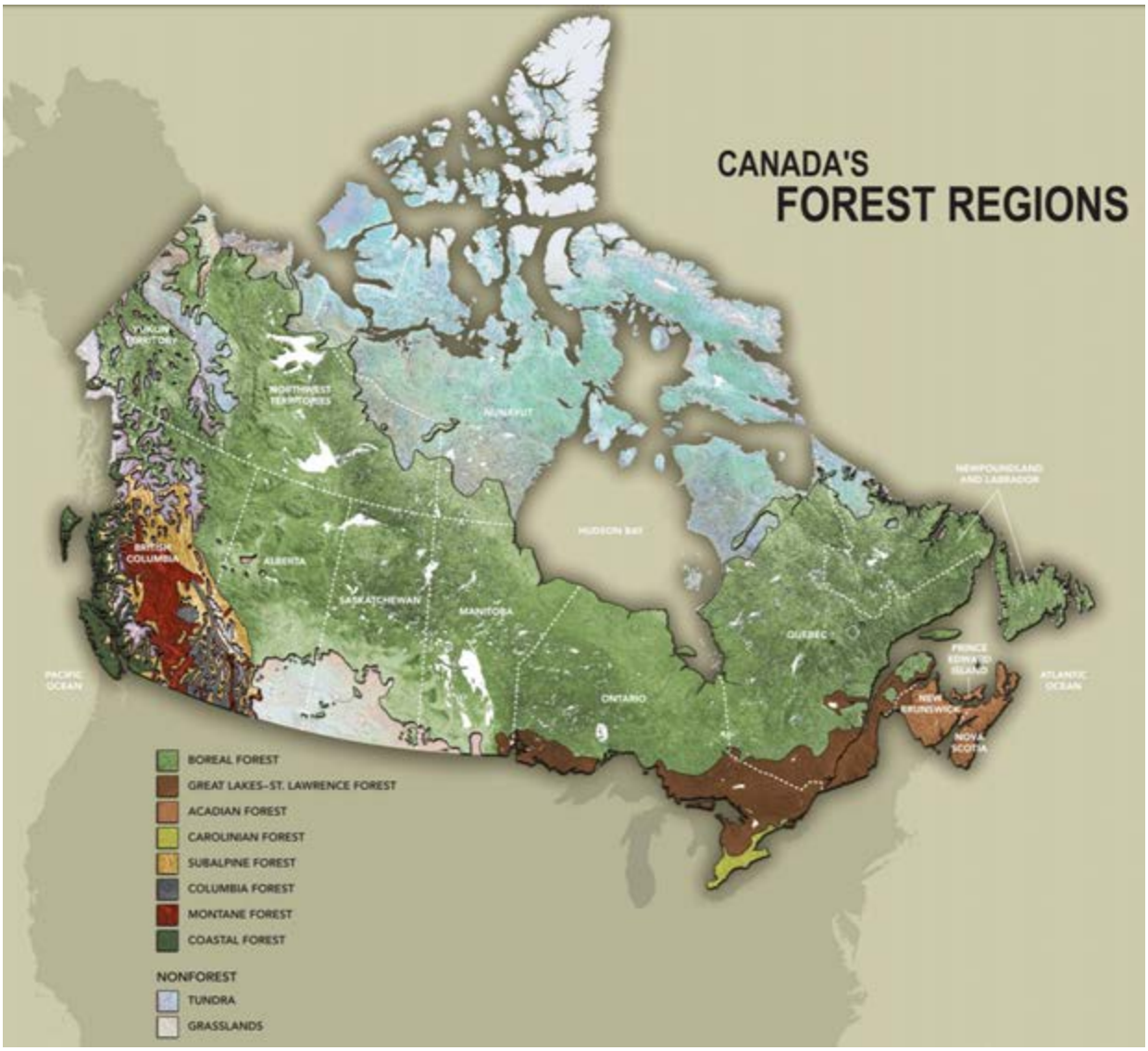

Figure 1. A map of Canada's Forest regions. According to Natural Resources Canada, "A forest region is a geographic zone, or belt, whose vegetation cover is characterized by a fairly uniform dominant species and stand type." (Natural Resources Canada 2017). Note the wide diversity of forest types across the country.

Barriers to effective forestry regulation by Canada's provinces.

Effective old-growth forest policy is dependent on appropriate definitions at both a national and regional level (Wirth *et al.* 2009). This is a challenge for Canada since forestry policy falls almost entirely under provincial jurisdiction. According to the National Council for Air and Stream Improvement (2005),

> " a decades-long discourse regarding a generally acceptable definition of old-growth, in both conceptual and practical terms, has gone largely unresolved. This is partially because old-growth is simultaneously an ecological state, a value-laden social concept, and a polarizing political phenomenon, each facet of its identity influencing the others in complex ways". Moreover, "The forest management arena has witnessed the collision of impassioned and contradictory opinions on the "right way" to manage old-growth forests, ranging from strict preservationism to utilitarian indifference" (National Council for Air and Stream Improvement 2005).

This latter statement summarizes the conflicts among governmental policy-makers and the variety of approaches taken towards defining old-growth forests in Canada.

Aspects of Canadian geography have likely contributed to conflict within the forest management community, specifically, the differences between the environmental conditions and tree compositions of the many different forest regions across the country (Figure 1). Different tree compositions have led to the creation of different definitions and different ways of incorporating stands into larger groupings. For example, Ontario uses Ecosites and Ecoregions to group stands in their forestry policies but BC uses Biogeoclimatic zones, likely due in part to the higher variation of microclimates in BC since this province contains a greater variety of forest

regions within its borders (Government of British Columbia 2019; Berry et al. 2018; Pesklevitz et al. 2011). Continuous forests that cross provincial boundaries and similar forests in different provinces do not necessarily have consistent classification, or supportive conservation management and regulation, as a result of the patchwork of different legislation and regulations at the provincial level (Berry et al. 2018; Hirt et al. 1996). Differences in regulations and legislation across provinces have also contributed to regional variations in the success in conserving old-growth forest. As mentioned earlier, provincial definitions of old-growth forests and associated protection from logging or development vary widely. For example, Ontario's operational definition of an old-growth forest includes any species of tree that has reached the sigmoidal trigger age for a specific ecosite over a certain time period, leading to 59 separate sub-definitions of old growth being used (Uhlig et al. 2001). In contrast, Nova Scotia's definition can be summed up in a single sentence indicating that a stand has to include trees of over 125 years old with a high proportion of climax species, and over 30% crown closure, to be considered old-growth (Berry et al. 2018; Pesklevits et al. 2011).

Differences in resource availability and forestry practices, across Canada's forest types, have also historically influenced provincial legislation and forest conservation behaviours. For example, the Pacific Coast forest was historically dominated by the Coast Redwood which was prohibitively difficult to harvest (Watts 2005). This led to an initial culture of forest management in British Columbia which did not place an emphasis on protecting these from logging. This historical context influenced their old-growth forest policies, although more modern logging methods can now harvest such Redwoods (Watts 2005).

The influence of forestry culture and old-growth values also needs to be taken into consideration when examining how old-growth forest definitions have evolved over time. There

are many functional old-growth forest definitions and policies, derived from historical approaches, which do not necessarily support current conservation and management objectives. For example, in reviewing old-growth definitions in BC, both historical and modern, our current focus is often on defining old-growth based on ecological definitions that have preservation and biodiversity conservation in mind. However, it is also important to realize that the concept of "old-growth forest" was an idea traditionally developed from a lumber industry perspective, and was a term used to identify trees at the end of their lifespan, so they could be harvested before they rot. Old-growth stands were often given harvesting priority because they "have the highest standing crops of commercial timber; are considered to be at a greater risk of deterioration through root rot or insect infestation; and occupy land that could be used for more productive young, second-growth stands" (Arsenault 2003). The Royal Commission on Forestry in BC in 1956, provided a particularly striking example of this historical view, by noting that "old forests should be harvested before they rot and have no value" (Arsenault 2003). The difference between this historical approach and the justification for today's old-growth definitions "because they are the most biodiverse areas of the country" (Hilbert and Wiencsyk 2007; Mosseler et al. 2003), demonstrate the major gap between the anthropocentric values, that were involved in our historical attempts to define old-growth forests, as compared to more ecocentric current old-forest values.

An example of a modern forestry policy shift, that is guided by more ecocentric, biodiversity preservation views, is Nova Scotia's current effort to update forestry policy**.** This may include a renewed definition of what constitutes old-growth forest. As part of this process, a panel of experts is being informed by a report completed by Dr. William Lahey (Lahey 2018) commissioned to help inform a potential renewal of legislation and associated regulations. This

report reviews the current forestry policies in Nova Scotia, including the definitions they include. It concludes that the most recent forestry legislation should be updated to include a new ecosystem based "forest triad" management system, which recognizes that the goal of Nova Scotia's forestry policy is to achieve "ecological well being that supports a thriving forestry economy" (Lahey 2018). These recommendations include greater accountability for the forestry industry and greater incentives for landowners to ensure their forested land is conserved. In Nova Scotia, the role of private landowners is particularly important, since only 30-35% of the province's forests are on public land (Lahey 2018). The recommendations contained in this report, also show the complexity of the policy development process.

The nationwide old-growth forest policy environment

It is important to recognize that, despite widespread awareness of the importance of the issue, Canada's old-growth forest policies and definitions may not be optimally effective at preventing destruction of old-growth forests (Mosseler et al. 2003). A recent government report confirmed that there are many areas of forest, including old-growth forest, currently under threat (Natural Resources Canada 2018). Historically, forest policy has also failed to protect key ecosystems. For example, in the prairie provinces there was mass deforestation between the 1970s and 2000s. 94% of this was to make way for agricultural development (Saskatchewan 2018). Deforestation of the boreal forest in Saskatchewan occurred at three times the national rate for a sustained period, from 1970 onward (Hobson et al. 2002) without substantial legislative intervention. In provinces with limited employment opportunities, the economic impact of employment and tax income from forestry and pulp and paper mills is balanced against other priorities, such as conservation (Paranteau, 2014; Mosseler et al, 2003). Provincial legislation and regulations, developed over decades, does not provide consistent protection for Canada's old-growth forests

and the many species that live within them (Wang et al. 2002; Pierce, 2019). While current regulatory and legislative frameworks have provided protection for some old-growth forests, there have been notable failures and their future is not secure.

Major knowledge gaps in our understanding of how best to regulate Canadian old-growth forests

There is still a high level of uncertainty inherent in old-growth forest management and what the consequences of specific old-growth policy changes will be. This is, in part, due to the high levels of environmental and socio-economic variability involved. Few longitudinal studies have effectively addressed the strengths and weaknesses of long-term forest management plans (Thompson, 2003). Case studies most often examine the recognized failures of forest management but do not report as extensively on successes. Additional uncertainty is introduced by the ongoing impacts of climate change. Higher average temperatures, more severe weather events, increased incidence of wildfires and conditions that can promote disease development and spread will inevitably impact forests (Global Change 2014; Gray 2019). While Canadian forest stakeholders are aware of climate change issues, there is considerable variability between provinces and sectors to the extent this is taken into account when considering forest practices (Ameztegui 2018). Canada's vast expanses of inaccessible forest and unmanaged land in the Northern hinterland, and barriers to assessments of forests on privately owned land, can also make evaluating the condition of old-growth forests challenging. This has led to a significant knowledge gap in our understanding of the effectiveness of forestry policy in Canada. Clear definitions of what constitutes old-growth forest, with shared terminology use across multiple provinces, could help facilitate the identification and tracking of such areas, longitudinally, in different jurisdictions across the country.

Review conclusion

More robust and consistent old-growth forest definitions and regulations across Canada and the effective engagement of multiple stakeholders and forest policy would help enable more effective old-growth forest conservation. A consultative approach involving multiple levels of government together with key stakeholders could most effectively address this problem. More research is needed to better understand the nature and impact of current old growth forest definitions and how they could be modified to be more effective at a practical level. Reviewing relevant societal and stakeholder values, as well as relevant scientific findings, is critically important to understand and incorporate into plans to better define and effectively manage old-growth forests (Moyer et al. 2008). Although there are a diversity of views and approaches to the issue of defining old-growth forest, this remains an important task in ensuring their effective long-term protection.

METHODS

Scope of study

The geographic scope of this study was limited to the forested regions of Canada, excluding the forested land within provinces and territories with no publicly available definition of old-growth forest. The disciplinary scope covered the legal and socio-political environment surrounding definitions of old-growth forests in Canada. This study was limited to analyzing the definitions of old-growth forests currently in effect and publicly available, with a focus on their operational characteristics. Official documents and government-created scoresheets or field manuals containing a definition, or partial definition, for each jurisdiction, were analyzed to determine the characteristics of the definitions along with their format, frequency, and utility.

Old-growth forest definition characteristics were ranked in terms of their utility based on a qualitative analysis process, in which research findings, from the literature, concerning the utility of using carious characteristics, such as the benefits and drawbacks of different species specific restrictions or different ways of seral stage in the definitions, were considered. The results of these combined analyses were reported in three sections. The first section examined the percentage of use of selected definition characteristics within each of the provincial definition documents. In the second, the formats of the provincial definitions themselves were analysed. Specifically, this evaluation examined how the characteristics worked together to create the boundaries of what was considered “old-growth forest” in each jurisdiction. recording how the different characteristics were measured and incorporated with one another, in each province. Finally, the third section examined the quality and utility of each of the definition characteristics that were recorded in the first section of our study. This analysis was achieved, using qualitative analysis of scientific literature consensus, with respect to the benefits and drawbacks of the

characteristics, such as age or stand height for example, that were being used to define old-growth forests in Canada. In addition to incorporating analysis of the definition characteristics, we also included potential new methods to measure old growth that were recommended by the literature in our utility analysis. We also examined some data from non-binding advisory guidelines from groups such as the Canadian Forest Service, Forest Stewardship Council, Canadian Standards Association, and Sustainable Forestry Initiative in order to ensure their viewpoints were incorporated. These helped inform the analysis and decisions regarding which definition characteristics were of importance, within each of the provincial definitions. The analyses from all three sections, listed above, were then used to help develop a proposed, optimal, old-growth forest operational definition template.

Document search

The initial phase of the study, consisted of a search for relevant old-growth forest definition documents, to analyze, from each of the ten provincial and two territorial jurisdictions and obtaining relevant contextual documents**.** This included internet-based searching for provincial documents which provide definitions of old-growth forest within all twelve jurisdictions. These included official old-growth forest operational definitions from both regulatory bodies (initial search) and relevant non-governmental national bodies such as the Forest Stewardship Council (secondary search). Documents containing industrial perspectives on forestry, relevant to old-growth forest conservation, were also obtained, through both library database and internet searches, as resources for the definition utility analysis that informed the proposed template old growth definition. Contextual sources, gathered during this stage, also included external analyses such as “An Independent Review of Forest Practices in Nova Scotia” (Lahey, 2018). Supplementary documents also included relevant scientific literature, and publications from The

Sustainable Forestry Initiative (SFI) and other non-governmental organizations. Copies of key federal legislation and regulations were used for further investigation and analysis, where relevant.

Establishment of an analysis framework

A set of key questions about the characteristics that make up old-growth forest definitions were developed to analyze the different definitions of old-growth forest in each jurisdiction. Sources of definitions were organized by jurisdiction, as a document list, and the old-growth forest definitions within these documents were identified. A series of characteristics mentioned in official documents and past policy analyses, as well as scientific and federal sources, were considered in this process to generate a question set for analysis. Secondarily, question sets which accessed both quantitative data and qualitative information about the utility of each definition characteristic using the frequency and format data collected in the first part of the study were also created. Additionally, for each jurisdiction, the major forest types present were also identified, since these could influence the definitions put in place and their usage, as well as the forest classification system each jurisdiction used, such as BC's biogeoclimatic zones or ON's ecoregions (Government of British Columbia 2017; Uhlig et al 2001; Ontario Ministry of Natural Resources 2012). To give enhanced level of depth to the analysis of the definition characteristics, official sources and quotes from the documents where each definition characteristic was identified were recorded, as well as the proposed method for measuring the definition characteristic.

Pilot Analysis of Nova Scotia's old-growth forest definitions

A pilot analysis was carried out using documents available from the province of Nova Scotia. This served as a "test run" of our list of definition characteristics and associated

analytical questions to verify the utility of the analysis tools and approach. After this process was complete, the results of this test run of the analysis framework were examined for any areas that lacked clarity and reviewed for accuracy. Based on this evaluation, the question set was revised before full analysis began. This process helped adjust the wording and format to optimize the analysis tool's utility in examining old-growth forest definitions and the frequency and utility of old-growth forest definition characteristics across Canada. This process also caused the method to be edited to add in the requirement to separate definition characteristics mentioned in official scoresheets and field manuals from definitions characteristics mentioned in the official old-growth forest definition documents themselves. This led to two separate data sets about the frequency of different definition characteristics in each province, one including those characteristics that were mentioned only in scoresheets in field manuals, and one only including characteristics that were mentioned in the central official old-growth definition documents.

Analysis procedure

A full analysis was carried out using our optimized definition characteristic list(s) and associated analysis questions for all jurisdictions. This involved a systematic analysis of the old-growth forest definition documents taken from included provinces. As time permitted, additional documents from selected provinces were also included, to help analyse the format and measurement methods used in each jurisdiction including the associated official scoresheets and field manuals as well as forestry management planning standards. Decisions on how to rate the frequency and utility of all the definition characteristics, in order to help inform the final old growth definition template, were also finalized at this stage. In addition to assessment of the characteristics used for defining old-growth forest, this project also included a comparative

analysis of definition format and a consideration of the utility of different elements based on literature review.

The final analysis step, of this study, involved examining patterns, similarities, and differences across the frequency of different definition characteristics in various Canadian jurisdictions. It also included making lists of unique and common elements across each of the old-growth forest definitions to be used in developing a ranking of definition characteristic frequency and utility. This step included creating a final template old-growth forest definition using the rankings of the frequency and utility of the definition characteristics obtained. This template forms a proposal for what an old-growth forest definition optimally requires in Canada.

A final phase of all effective research is dissemination of its findings. By bringing together all the analysis information together in an effective package for dissemination, we developed the opportunity to share this work with the local scientific and policy community. We also aimed to bring this work to the attention of the committee working on developing NS's new old-growth forest policy.

Limitations and delimitations of approach

One delimitation of this study is that it did not examine historical old-growth forest definitions. However, although historical definitions were not considered part of the temporal scope of this project, historical documents and research studies were used to help inform various aspects of the analysis. They were also referenced in the critical analysis and discussion of the utility analysis of each of the definition characteristics as supporting evidence regarding the utility of certain characteristics.

Another delimitation of this study is that it was not focused on the practical effectiveness of each old-growth definition, in terms of motivating the protection of forested lands. Instead, it focused solely on examining the key operational features and apparent utility of old-growth forest definitions. Additionally, while several jurisdictions have both conceptual and operational definitions for old-growth forest, our focus was on the operational definitions, and the specific operational features of each operational definition, which could be more readily compared and have greater practical implications for determining which areas of Canada's forested land are protected.

Another important limitation of this analysis, resulting from Canada's geography, is that there are enormous variations in forest regions across Canada, some of which cross provincial boundaries (see Figure 1). This means that an inconsistent definitional framework may be applied to what are continuous tracts of forest land. Forest types and stands that cross provincial or international boundaries (such as those bordering the United States) are under different jurisdictions and therefore are defined differently. This limits how the utility of different definitions can be analysed. The utility for definition characteristics can differ with region but they are only analyzed according to the forest type that is within the province that they are related to. For example, a definition that includes special considerations for forest fires, with proximity to a forest fire related disturbance being a disqualifying metric for defining a stand as old-growth forest, might have high utility in Saskatchewan (SK) or BC where large forest fires are fairly common, but not in Newfoundland (NL) where forest fires are much less frequent (Natural Resources Canada 2019b)

A final limitation is that all definitions analyzed in this study along with all secondary sources were sourced from publicly available databases and governmental websites. This meant

that some information, which was only available on request from specific jurisdictions, was omitted. Official requests for more-detailed government documents were made, where they would assist our study, but we were limited to those definition documents obtained within our study time frame. A full list of the documents we examined for our analysis can be found in Appendix 1.

RESULTS

Document Selection

The readily accessible, official documents, related to forestry policy, in each of Canada's provinces and territories, were reviewed for the presence of operational old-growth forest definitions. A total of 60 government-sourced forestry policy documents and 33 scientific studies referencing old-growth forest definitions were reviewed (see Appendix 1). Out of Canada's ten provinces only six had an official definition of old-growth forest that was publicly available. This included those provinces with old-growth forest definitions that used an equivalent other descriptive term such as "late successional forest" or "late seral stage forest", such as Newfoundland (Government of Newfoundland and Labrador 2014). Quebec's official definition of old-growth forest was excluded because it was a conceptual definition and not an operational one. The Quebec example is open to broad functional interpretation, i.e. "The term old-growth forests refers to stands that have not been affected by man and that have experienced no major natural disturbances in recent times. These forests display a number of special features—they include living, senescent (aging), and dead trees, and the forest floor is littered with large trunks in varying stages of decomposition" (Bouchard 2001). Quebec's scientific community has developed its own detailed operational definition of old-growth forest, for use in government

funded research (Villeneuve et al. 2003). However, despite its apparent utility, this definition was not adopted as Quebec's official operational definition.

Certain jurisdictions also had no official definition of old-growth forest but had forest management or forest stewardship plans that reference old-forest such as Alberta's "Forest Management Plan Stewardship Report Requirements" stating a certain ratio of "Area of old, mature, and young forest by DFA subunit by cover class must be preserved" (Province of Alberta, 2016). This suggests that there must be some definition of "old-forest" in use despite a lack of documentation in official provincial documents.

Criteria selection and pilot testing of definition characteristic queries

Official, publicly available, operational definitions of old-growth forest were identified in six jurisdictions: BC, SK, ON, NS, NB, and NL. A list of 19 definition characteristics was developed for assessment (Table 1). These were validated through a surface level, pilot-test-style, analysis of definition documents conducted with the assistance of a forestry expert (Dr. P. Duinker). The frequency of use of each of these definition characteristics within each of the six eligible province's operational definitions of old-growth forest was then assessed. It was also determined whether each characteristic was assessed in a qualitative or quantitative manner, for each province (see Table 2).

Table 1. Definition characteristics used for analysis

Item	Characteristic included within definition
1	Age of trees
2	Stand height
3	Species based restrictions (tree species eligible for inclusion, and how much of the stand must be an eligible species
4	Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)
5	Diameter at breast height
6	Crown closure
7	Time since last stand-replacing - natural disturbance
8	Time since last forest management intervention
9	Evidence of human disturbance
10	Minimum stand area
11	Age of dominant trees compared to expected life expectancy
12	Spatial and temporal distribution of “cut and leave” areas
13	Mean Annual Increment compared to net annual increment
14	Stability of species composition;
15	Ecosite / Ecodistrict / Ecoregion type / Biogeoclimatic zones
16	Inclusion of existing protected areas within definition
17	Landscape connectivity
18	Seral stage distribution
19	Reference to specific old-growth forest protected areas

In order to better document this analysis, a relevant quote from the specific source mentioning each noted characteristic, was recorded. Several provinces had aspects of their definitions, such as age cut-offs and specific old-growth forest protected areas, that were derived from other, source-linked data. For example, the publicly available old-growth scoresheet for NS (Province of Nova Scotia 2011) provides operational details not available in the primary provincial document which defines old-growth forest. In other cases, for example SK, definitions were linked to forest inventory data that were collected using a type of field manual or point sampling guide, methods of data collection which have influenced the source data used to define old-growth forest in the province (Province of Saskatchewan 2017a;Province of Saskatchewan 2017b). Whether a given characteristic was included in an official government scoresheet or field manual was also recorded separately, and the frequency of each definition characteristics used in each jurisdiction was calculated (See Table 2 and Figure 1). The provinces with field manuals and score sheets, that were relevant to this assessment, were NS, SK, NL, and NB. Both the number of definition characteristics observed in each province's official definitions, as well as that number including characteristics observed in scoresheets and field manuals as well, were evaluated and their percentage of use was calculated. (see column 2 and column 4 of table 2) The frequency of use of each definition characteristic within Canadian old-growth forest definitions was also seen to vary considerably across jurisdictions (Figure 2).

Table 2. Percentage of use and style of measurement of each definition characteristic

Definition characteristics	Percentage of use (Official definition)	Source provinces	Percentage of use (Scoresheet + Source data included)	Source provinces (Scoresheet included)	Style of measurement (According to definition and policy)
Age	100%	SK BC ON NB NS NL	100%	SK BC ON NB NS NL	Quantitative
Ecosite / Ecodistrict / Ecoregion type / Biogeoclimatic zones	83.3%	SK BC ON NB NS	100%	SK BC ON NB NS NL	Quantitative
Inclusion of existing protected areas within definition	83.3%	SK BC ON NB NS	83.3%	SK BC ON NB NS	Quantitative
Reference to specific OGF protected areas	83.3%	SK BC NB NS NL	83.3%	SK BC NB NS NL	Quantitative
Species-based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	66.7%	SK ON NB NS	83.3%	SK ON NB NS NL	Quantitative
Time since last stand-replacing - natural disturbance	66.7%	SK BC ON NL	66.7%	SK BC ON NL	Quantitative
Spatial and temporal distribution of cut and leave areas	66.7%	SK BC ON NB	66.7%	SK BC ON NB	Quantitative
Evidence of human disturbance	50%	SK BC NL	66.7%	SK BC NS NL	Qualitative
Seral stage distribution	50%	SK BC NL	50%	SK BC NL	Quantitative
Minimum stand area	50%	ON NB NS	50%	ON NB NS	Quantitative
Crown closure	50%	NB NS NL	50%	NB NS NL	Quantitative
A deadwood indicator (including mentions of a presence of snags and logs in all stages of decay)	33.3%	ON, NB	50%	ON NB NS	Qualitative
Diameter at breast height	33.3%	ON NB	50%	ON NB NS	Quantitative
Landscape connectivity	33%	BC NB	50%	BC, NB, NS	Qualitative
Stability of species composition	33.3%	SK ON	33.3%	SK ON	Quantitative
Time since last forest management intervention	33.3%	SK NL	33.3%	SK NL	Quantitative
Stand height	16.7%	ON	33.3%	ON NL	Quantitative
Age of dominant trees compared to expected life expectancy	16.7%	ON	16.7%	ON	Quantitative
Mean annual increment compared to net annual increment	16.7%	ON	16.7%	ON	Quantitative

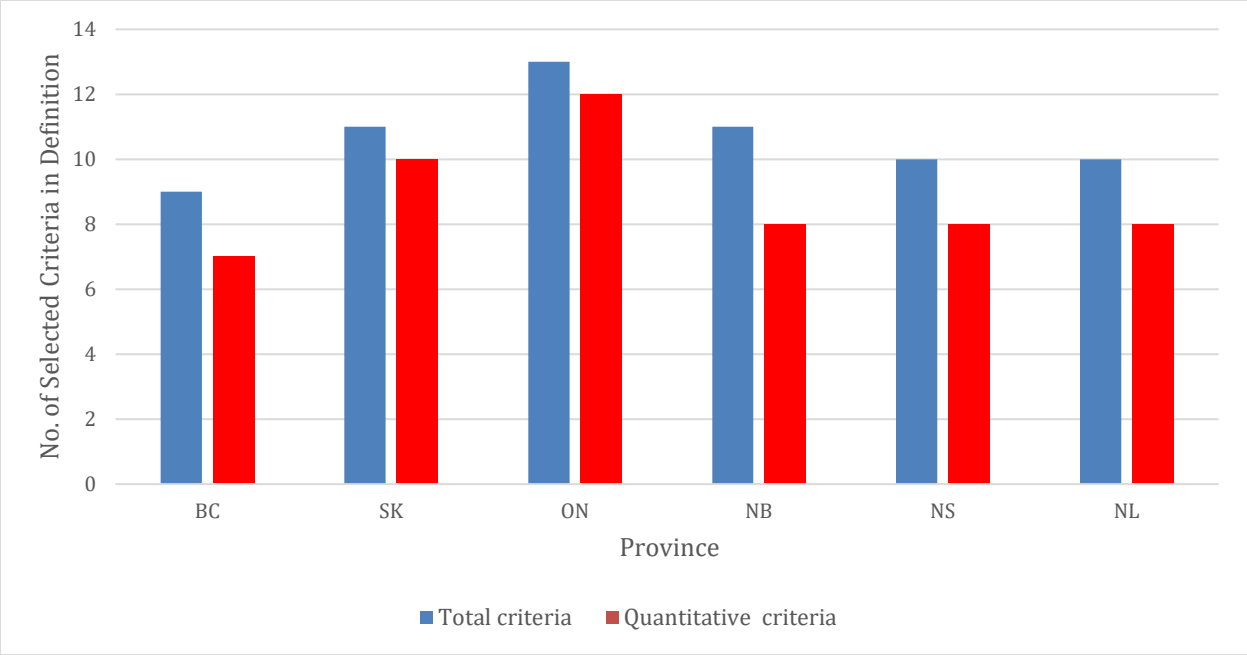

Figure 2. The total number of selected definition characteristics used in each province's old-growth forest official definition and official old-growth forest scoresheets/forestry inventory data collection field manual is represented by the blue bars. The red bars represent the number of these definition characteristics that are quantitative in the way they are measured.

Summary of frequency results

All the definition characteristics, selected for examination, were mentioned by at least one of the provinces examined (Table 1). Overall, the age of trees in a stand was the most commonly used characteristic to define old-growth and was used by all provinces examined. Six provinces also considered the use of subdivisions of "ecosite/ecoregion/ecodistrict type or biogeoclimatic zones" as a necessary factor in determining old-growth conditions, either in their official definitions or in a scoresheet. Time since last stand-replacing natural disturbance and evidence of human disturbance were also used by the majority of provinces as key components of their definition. However, only five out of six provinces included the next four most common criteria, i.e. distribution of cut and leave areas, inclusion of existing protected areas, reference to specific protected old-growth forest areas, and species-based restrictions (Table 2). The other criteria, selected for this study, were only used by three or fewer provinces out of the six examined (Table 2).

Variations in old-growth definition format among provinces

In addition to the frequency of old-growth forest characteristics used in each province, the ways that different provinces have chosen to format their definition of what constitutes an old-growth forest was also examined. Ontario, for example, has 59 separate definitions of what officially makes a stand to be considered old-growth (Pesklevits et al. 2011). These definitions also depend on what Ecoregion/Ecosite/Ecodistrict a stand is considered to be in (Uhlig et al. 2001). In contrast, BC separates its definitions for what constitutes old-growth conditions based on seral stage age categories and old-growth management areas, whose boundaries are defined and adjusted based on a stand's presence within one of 17 distinct Biogeoclimatic zones, as well as the presence of natural disturbances (Province of British Columbia 2019a; BC Environment

1995). More details are provided below on the format of the operational definitions, including a description of how each province structured their set of definition characteristics to define what they consider to be old-growth forest.

British Columbia

BC's operational definition of old-growth forest is based around three key characteristics: age, biogeoclimatic zones and natural disturbances, according to provincial documents.

> "Generally speaking, most of B.C.'s coastal forests are considered to be old-growth if they contain trees that are more than 250 years old. Some types of interior forests are considered to be old-growth if they contain trees that are more than 140 years old." (Government of British Columbia, 2017).

Stand ages are defined using the age data from the provincial forest inventory (Hilbert and Wiensczyk, 2007). There are also seral stage-based age categories for "mature" and "old" that BC uses to categorize its old-growth stands. According to BC's biodiversity guidebook, these categories

> "… are based on the estimated minimum age for developing structural attributes in even-aged management. These attributes may be achieved at earlier ages through structural retention or partial cutting strategies where appropriate" (BC Environment, 1995).

However, these 1995 guidelines have been further updated and built upon in the more recent Forest and Range Practices Act (Province of British Columbia, 2019a).

BC also has several special strategies and exceptions which modify the use of a simple definition of old-growth forest. The province uses specialized old-growth management areas

(OGMAs) which work in tandem with BC's old-growth definition and legislation to try to ensure old-growth forests in the province are properly protected. According to the BC government's website, "Currently, 55% of old-growth forests on Crown land in B.C.'s coastal region are already protected from logging" (Province of British Columbia, 2019b). Fifty-three individual iconic trees are also protected (Province of British Columbia, 2019b). However, National parks and First Nation reserves are not assessed for their potential to include old-growth and therefore are functionally excluded from BC's definition of old-growth forest (BC Environment,1995).

Another of the characteristics of BC's definition that decides what is designated as old-growth is "(amount of) area of incursion into OGMAs from human activities (forestry and non-forestry related) relative to limits of incursion set out in legal orders or in policy" (Province of British Columbia, 2018). This means that OGMAs can be decided based on evidence of human disturbance, and the spatial and temporal distribution of cut and leave areas. Since these OGMAs are part of the operational definition of old-growth forest, BC's definition of old-growth was assumed for the purposes of this study to be taking "evidence of human disturbance" into account. BC mentions relative lack of human disturbance as a potential conceptual factor in defining old growth, (BC Environment 1995). The spatial distribution of cut and leave areas, that BC measures, can also be seen as a method of measuring evidence of human disturbance (Province of British Columbia, 2018).

There is also a statement listed in BC's "Interim Assessment Protocol for Old- Growth Forests in British Columbia" that seems to contradict many of the previously stated facts about BC's definition of old-growth by making exceptions, where defining a stand as old-growth will cause significant potential economic impacts (Government of British Columbia 2017b). The provincial document states: "To minimize economic impacts to forest tenure holders, the

PNOGO contains provisions that allow the use of younger forests to meet old growth forest objectives where equal or better conservation benefits would result" (Province of British Columbia 2018). This seems to contradict the official old-growth definition documents on the province's website about how old-growth forests should be defined, and is highly unclear on how the "conservation benefits" of the old growth forests will be quantitatively measured to account for this exception. (Province of British Columbia 2019a; BC Environment, 1995).

Saskatchewan

SK defines old-growth forest as "A forest ecosystem or stand dominated by old (or very old) trees that have originated naturally and in which the genetics, species and structural diversities have not been significantly changed by human activity" (Government of Saskatchewan 2017). The measurements of unaltered structural diversity of the forest are based on qualitative observations; no quantitative metrics are mentioned. The policy documents reviewed did not mention the use of quantitative criteria such as stand height or diameter at breast height (see Table 2 and Appendix 1) (Government of Saskatchewan 2017; Province of Saskatchewan 2017; Saskatchewan Ministry of the Environment 2009).

Ages of stands in SK are subdivided by "Seral Stage-age categories" which also involves species-specific restrictions (Government of Saskatchewan 2017a; Government of Saskatchewan 2017b). Five age categories are used "Young, Immature, Mature, Old and Very old" and they differ depending on what species is considered to "lead the stand" (Province of Saskatchewan 2017b). For example, all "hardwood" and "hard-softwood" trees in a stand were considered "old" if they are between 91 to 110 years old; or "very old" if they are over 110 years old. In contrast, "softwood" and "mixed wood" spruce trees used alternate age categories, they were considered "old" if they were between 101 and 120 years in age, or "very old" over 120 years in

age (Province of Saskatchewan 2017b). This incorporation of species-specific restrictions, hardness of wood, and tree age, into a single category-based measure referred to as “Seral stage – age categories” seemed to be unique to SK (Government of Saskatchewan 2017). The provincial SK definition of old-growth also states that for a stand to be considered old-growth, the stand must have “species that originated naturally, included in approved species groupings" (Province of Saskatchewan 2017b). These age and species groupings are used to inform the use of SK forest management planning standard’s “Seral stage-age categories” which “form the basis for the targets respecting old and very old forest" (Province of Saskatchewan 2017b).

SK also places an emphasis on the role that natural disturbance plays in the aging of the forest ecosystem. SK identifies the role of forest fire boundaries as crucially important to accurately define old-growth forests (Province of Saskatchewan, 2019). SK’s policy states that “ages were reset to zero at the year of the fire for stands greater than 20 years old” (Province of Saskatchewan, 2019). Fire cycles in SK are measured using frequency, size and intensity data for each wildfire event, in addition to defined fire boundary lines within provincial government planning files, stored as GIS data (Province of Saskatchewan, 2019). SK also has a separate plan for conservation and identification of old-growth within the “island forests” that exist on the islands within SK’s lakes, and their associated riparian areas, areas which are also potentially likely to be at higher risk of flooding and have distinct non-avian land animal species populations from the mainland. (Province of Saskatchewan 2017a).

SK’s operational definition of old-growth forest also indicates that if any significant forest management intervention has occurred, then a forest area could be considered “significantly changed by human activity” and not considered to be old-growth forest (Department of Environment Saskatchewan 2011). However, the conclusions of the “Forest

Management Planning Guide" that sets up the rules surrounding the creation of new OGMAs (Province of Saskatchewan 2017b) and associated commentary on that guide from 2019, refers to "managed productive forest area" being able to count towards "old seral requirements" (Province of Saskatchewan 2019). This newer documentation seemingly contradicts the older official definition of old-growth forests and indicates that some management activities that alter forest composition would still allow for stand or forest area to remain classified as old-growth (Province of Saskatchewan 2019).

Specific old-growth forest-related protected land areas are also outlined in the SK operational definition documents. These old-forest protected areas aim for "a combined total of old and very old forest areas that meet or exceed 15% of the forested landscape, with a minimum of 5% comprising very old forests" (Province of Saskatchewan 2019). A set of spatially defined "old" and "very old" forest reserves have been designed to meet these percent requirements. Harvesting and road building are excluded from these areas, as of June 19th, 2019 (Province of Saskatchewan 2019). SK's old-growth forest definition is also considered "flexible" in that forests of other seral stages and age classes can be reclassified as "old-growth" to meet forest management planning targets (Province of Saskatchewan 2019). Old-growth forest in existing protected areas can also be assessed to meet these targets. This is done as part of a "representative areas network" (RAN) and "licence area" based system used, to help define stands of old-growth, within existing protected land such as provincial parks and ecological reserves (Government of Saskatchewan 2017b). These rules provide an opportunity for stands in existing protected areas that contain trees in the "mature", seral stage-age category, to be considered as old-growth "If the proportion of old and very old forest falls below 15% of the gross area (licence area plus RAN areas) as a result of natural disturbance" (Government of

Saskatchewan 2017b). In total, this means SK's definition of old-growth contained 12 out of the 19 definition characteristics we assessed in this study, which is the second most definition characteristics per province overall, second only to ON (see Figure 2).

Ontario

Old-growth forest in ON is defined based on specific ages of onset "where 59 different definitions are provided, based on specific ecotypes" (Pesklevits et al. 2011). According to the official old-growth forest definition document for Ontario, "The age-of-onset for old-growth conditions is defined as the age at which a species has attained at least 75 % of its maximum potential diameter (in each ecosite or forest unit) and makes up more than 50 % of the stand basal area" (Uhlig et al. 2001). The age at which the average stand height increment started to decline was used as an indicator of old-growth age-of-onset. This process led to age categories being established (Uhlig et al. 2001). Other ON government sources indicated that the amount of dead wood was key for identifying the old-growth ages of onset. This characteristic included

> "large dead standing trees (snags), accumulations of downed woody material, up-turned stumps, root and soil mounds, and accelerating tree mortality; and ecosystem functions (e.g. stand productivity, nutrient cycling, and wildlife habitat) that are different from earlier stages of forest development" (Ontario Ministry of Natural Resources 2012).

The trigger ages for old-growth conditions in ON vary per eco-site and per species and are also listed in the report (Uhlig et al. 2001). According to a review of old-growth definitions in Canada by Pesklevitz et al. (2011), the ecosite system used to categorize the 59 different age based definition was developed where firstly "The province is divided into three distinct forested regions: the Boreal, the Great Lakes-St. Lawrence and the Deciduous forest regions" (Uhlig et al.

2001). These forest regions were then subdivided into ecosites "based on specific soil and drainage characteristics, and the expected forest type that would normally grow on those sites" (Uhlig et al. 2001). These age classifications, paired with ecosite definitions, form the basis of the definition of old-growth forest in ON.

The ages of onset assigned to each ecosite, that form the threshold for when a stand is considered old-growth within ON's definition, involves multifaceted calculations, designed to take into account the ecological complexity of the area. These calculations use factors such as diameter at breast height for each species, stand height, spatial distribution of cut and leave areas, time since last stand replacing natural disturbance, volume increment, and other forestry inventory data. These factors are used to calculate the appropriate "true age" for a stand within an ecoregion. This information can be compared to the age of onset, outlined in the old-growth definition for the eco-site, to determine whether that stand had reached old-growth conditions. For example, "Age at breast height was translated to true age by adding a species-specific correction factor" (Uhlig et al. 2001). Even just calculating the true age of a stand based on the diameter at breast height involved the potential use of a specially designed polynomial formula and process described.

> "For each species in each plot, a quadratic mean diameter (QDBH) and a quadratic mean age (Qage) (i.e., age or DBH weighted by basal area) was calculated. It was hoped that this would reduce the effect of suppressed and intermediate trees on estimates of plot age and DBH, and thus more closely match information from the Forest Resources Inventory." (Uhlig et al. 2001).

This is just one example of the highly complex and multifaceted system that ON uses to calculate the ages of onset for old-growth conditions specific to each ecoregion. Qualitative factors

involved in measuring the ecological complexity of an area were also incorporated in this evaluation. This included the presence of "large dead standing trees (snags), accumulations of downed woody material, up-turned stumps, root and soil mounds, and accelerating tree mortality" (Uhlig et al. 2001).

ON is also unique in Canada in its use of "volume increment data", building off its former proposed 1992 definition that included "mean annual increment vs. net annual increment" (1994). These data are included within the aforementioned age of onset calculation process for each ecosite where "Age-of-onset for each ecosite was defined as the point where the current annual volume increment reached zero (i.e., volume peaked)." (Uhlig et al. 2001). A lack of human disturbance was also considered to be a key measure of old-growth conditions by the Ontario Ministry of Natural Resources (Duschene 1994); although it is not mentioned in the more recent definition documents (Uhlig et al. 2001) and therefore was not considered to be part of ON's current definition. Overall, it is this focus on volume increments as a characteristic for defining old-growth forest, the rejection of the use of "evidence of human disturbance" as a measure of old-growthness, and the creation of 59 separate definitions per ecotype (Pesklevits et al. 2011), that sets ON's definition of old-growth forest apart from the rest of Canada's jurisdictions. ON had the highest level of both our selected qualitative and quantitative characteristics included in its definition (13/19) due to the multiple metrics involved in ON's age-of onset calculations, for each ecosite.

New Brunswick

New Brunswick's old-growth forest definition is based on whether a stand falls into what NB calls "Old forest communities" (New Brunswick Department of Natural Resources 2012). According to the NB's old-growth definitions document, "Old Growth forests are divided into 18

old growth forest communities within New Brunswick's existing ecodistricts." There are 18 such "Old forest communities" which are defined at the stand level "by tree species composition and by stand structure, as described by basal area and density of various diameter classes of live and dead stems. They are named for the most abundant tree species (or group of species) and are composed of at least 35% of that species (or group)" This is specified as "Primary Species" and "Primary species %" for each stand. (New Brunswick Department of Natural Resources 2012). The densities of stem diameters are measured using "Centimeters of stem diameter" and used to classify stands, using a scoresheet-like document, through a system measuring "Stems per hectare" along with "stem diameter" of the different primary species in each stand. There are 26 separate primary species groupings including Black Spruce, Hemlock, White Pine, Larch and others (New Brunswick Department of Natural Resources 2012).

Percent crown closure is another factor used to determine whether a stand is considered to be part of an "Old Forest Community" and therefore defined as old-growth forest (New Brunswick Department of Natural Resources 2012). Landscape connectivity is also further incorporated in the assessments, to define what stands are included in these "Old Forest Communities" (New Brunswick Department of Natural Resources 2012). In NB, tree age is given less emphasis in their old-growth definition but is still included in the form of "Age Classes" measured within the "Old Forest Communities" (New Brunswick Department of Natural Resources 2014). These ages are measured using "Development stages" assigned during the forest inventory stage of the process.

Overall, what makes NB's definition unique, is its emphasis on old forest community groupings, the wide range of species included in its species restrictions and its emphasis on the physical structural characteristics of stands as a primary assessment of old-growth conditions.

This stands in contrast to the other five analysed provinces' operational definitions of old-growth forest, which all have age classification as a primary focus.

Nova Scotia

NS's definition of old-growth forest is arguably the most clear and simple to understand definition out of all the provinces. NS defines an old-growth forest as "A stand where 30% or more of the basal area is in trees 125 years or older where at least half of the basal area is composed of climax species and total crown closure is a minimum of 30%" (Province of Nova Scotia, 2012). NS defines a stand as containing "climax species" if it contains one of nine specific species, these being Hemlock, Red Spruce, White Pine, Sugar Maple, Yellow Birch, American Beech, Balsam Fir, Red Maple, and Black Spruce (Province of Nova Scotia, 2012). The first six of these are typically found in the Acadian Forest region, the last three represent those that are considered representative of old-growth within a Maritime boreal forest (Province of Nova Scotia, 2012).

Thirty percent crown closure is measured, in NS, in two separate ways. First, through examination of forest inventory and GIS data using what are known as "forest polygons" and second, through an ocular estimate within the stand (Province of Nova Scotia, 2012; 2017). This use of forest polygons could be potentially problematic in decision-making processes regarding the boundaries of old-growth forest areas (Wulder and Franklin 2003; Wulder et al 2008).

NS also has a scoresheet used to measure "old-growthness" of a stand which includes additional measures used to assess a stand that were not included in the "official definition" document (Province of Nova Scotia 2011). These scoresheet-specific definition characteristics include quantitative measures, such as diameter at breast height, and qualitative metrics such as

the level of dead wood observed on the forest floor, and whether there is "evidence of human disturbance" (Province of Nova Scotia 2011). The official old-growth forest policy documents for NS also mention targets for old-growth to be met for each ecodistrict. The province aims to "identify old-growth and the best old forest restoration opportunities on at least eight percent of publicly owned forest land in each of the province's 38 forested ecodistricts, (Stewart et al. 2003; Province of Nova Scotia, 2012) potentially indicating existing plans for protected areas associated with preserving old-growth forests.

As is the case with BC and SK, the NS old-growth definition is somewhat flexible and can be expanded in certain situations. The "Implementation of Interim NS OGF policy" document states that "All old-growth (> 125 years old) within existing protected areas (including federal parks) is given the first priority to meet the policy targets" (Nova Scotia Department of Natural Resources 2008). This policy to include old-growth forests within existing protected areas includes "land outside protected areas which are considered the best old forest restoration opportunities from public lands outside protected areas, considering their rank calculated from the second and third parts of the Old Forest Scoresheet, and contribution to ecological representivity" (Nova Scotia Department of Natural Resources 2008) and forest areas with "regionally important features" can also be considered legally to be "old-growth" in terms of protections (Nova Scotia Department of Natural Resources 2008). It seems to be implied within this document that this re-classification of forest can also occur regardless of whether they fit NS's original official definition for old-growth (Nova Scotia Department of Natural Resources 2008). However, these exceptions are also open to interpretation by decision-makers which may vary depending on the priorities of the government of the day. Nevertheless, NS is still the only province that has a single sentence summary of their operational old-growth forest definition that

we found in this study, and even when the aforementioned protected areas exception and the unique characteristics of NS's scoresheet are taken into consideration, NS still has arguably the most clear and unambiguous definition in Canada for what makes a stand considered old-growth forest.

Newfoundland and Labrador

NL's definition of old-growth forest actually rejects the term "old-growth forest" entirely and instead refers to such forests as "Late successional forests" and "Late seral forests. (Government of Newfoundland and Labrador 2014). NL's sustainable forest policy states that

> "Old-growth in the boreal forest is defined by the structure of a forest in the late stages of succession. None of the trees on an old-growth site may be particularly long lived, but through a succession of partial disturbances an uneven age structure has developed over time…..Thus this ecological niche is referred to as late-succession forest in this strategy and refers generally to forested portions of the landscape that have not been disturbed naturally or by humans for unusually long periods." (Government of Newfoundland and Labrador 2014).

These "Late successional" forests are further subdivided into two distinct categories, one of which is "Late seral forest" (Government of Newfoundland and Labrador 2014). This recharacterization of the term "old-growth forests" means that in the case of NL's policy, for the purposes of our study, the terms "old-growth forest" "Late succession forest" and "Late seral forest" were considered synonymous.

A major part of NL's definition of old-growth forests, is based on considering the amount of disturbance, including both evidence of human disturbance and evidence of natural

disturbance (Government of Newfoundland and Labrador 2014). This disturbance criterion was assumed to be qualitative as there were no examples of quantitative metrics, in any of the publicly available forestry documents we reviewed (see Appendix). The most important quantitative component of the NL definition, is the age threshold for when a stand is considered to be old-growth which states that “trees need to be 81 or more years old, including non-harvestable areas.” (Government of Newfoundland and Labrador 2014). This policy has significant implications for which stands are defined as old-growth in NL The province’s sustainable forest strategy states that “approximately 48% of the island of Newfoundland forests are 81+ years in age" (Government of Newfoundland and Labrador 2014). Taken together with the requirement for a forest remaining undisturbed, this means that 48% of Newfoundland’s forests could be considered “late seral forest” and therefore “old-growth forest”, if they had remained undisturbed (Government of Newfoundland and Labrador 2014).

Another type of “late successional forest”, and therefore another type of old-growth forest, mentioned in the document, occurs when “microclimate, geology, and circumstance create a region that has a low probability of natural disturbance, the eastern boreal forest can develop long-term gap dynamics” (Government of Newfoundland and Labrador 2014). This indicates that gap dynamics within stands can be used to define what is considered “old-growth” in NL, in addition to the established age classification system. Showing that age and disturbance regimes are not the only way for forest to be defined as old-growth in NL since even the “late successional forests” that are not “Late seral stage forests” are considered to be old-growth forest (Government of Newfoundland and Labrador 2014).

NL also has a publicly available field manual, known as the “Temporary Point Sampling Field Manual” which was used as an additional source of definition characteristics to define old-

growth forests in the province not included in the original official definition document (Government of Newfoundland and Labrador 2016). This field manual was used to develop the official provincial forestry inventory age data that is used to determine what stands are over 81 years of age and therefore considered “Late seral forest” (Newfoundland and Labrador, 2003; Government of Newfoundland and Labrador, 2014). This document also includes other characteristics such as the “species used for stand typing” and “Height range” of stands in addition to characteristics such as seral stage (Government of Newfoundland and Labrador 2016).

NL’s definition of old-growth forest supports the development of specific protected areas. The Forest Sustainability Board “has committed to maintaining at least 15 percent of the forest….. in the 81+ age class” (Government of Newfoundland and Labrador 2014), with the goal of ensuring appropriate habitat for species within a certain ecological niche. This idea of protecting a certain percentage of all forests over 81 years, regardless of their level of disturbance, stands in contrast to the official definition of “late seral” forest for the province which requires forests to be undisturbed. (Government of Newfoundland and Labrador, 2014) This approach would solidify protections for key areas, regardless of disturbances, and help prioritize the preservation of biodiversity. This could be especially important for NL bird species that require Balsam Fir old-growth stands to survive (Thompson et al. 1999). This strategy for defining which old-growth stands to protect was developed as part of the NL Department of Fisheries and Land Resources Environmental Management System which was “registered to the ISO 14001:2015 standard” (Newfoundland and Labrador, 2019). The International Organization for Standardization (ISO) is an independent, international organization of standard setting bodies which encourages the development and adoption of worldwide standards in multiple areas of

activity, including forestry (**ISO, 2019).** Newfoundland's adoption and incorporation of their international input into their old-growth forest protections and overall environmental policy appears to set NL apart from the rest of Canada (ISO, 2018). However, little or no new action was needed for NL to claim ISO 14001 compliance, since being compliant does not include specific requirements related to recommended protected areas. Overall, NL's simple definition of old-growth forest that includes any undisturbed tree over 81 years of age, according to the forestry inventory data informed by the field manual, is one of the simplest and clearest definitions in Canada, even including the impact of NL's decision to reject the use of the term "old-growth forest" in favour of "late successional forest" and "late seral forest" (Government of Newfoundland and Labrador, 2014).

Utility analysis

This section consists of a summary and qualitative analysis of the most important findings included in the quality and utility assessment components of this study. This utility analysis section is divided into sections that analyse the literature consensus on the utility and quality of the 19 different definition characteristics we used to examine each of the old-growth forest definitions (see table 1 for the list of characteristics). This section is informed by the literature we reviewed, regarding currently used characteristics, as well as suggestions for alternative novel ways of measuring some of the characteristics, in certain cases. The details are provided below.

Age thresholds

Age was determined to be useful as a definition characteristic because data are easily accessible in forest inventories for most provinces and jurisdictions. Age is directly linked to many provinces' conceptual definitions and the layperson's definition of old-growth forests as

simply being forests that are “very old” and have “very old trees” (Duschene 1994; Parker et al. 2000; Villeneuve et al. 2003). However, some of the literature considered age to be an “outdated” way of classifying stands as old-growth. The use of specific age thresholds, especially non-tree species specific thresholds, are overly simplistic. In addition, evaluation of the age of trees can be subjective and influenced by the biases involved with the creation of forest inventory data, especially in areas that have trees of multiple age cohorts in close proximity within each stand. These issues were addressed by Pesklevitz et al. (2011).

> "Age-specific definitions are limited by the fact that forests are very different and exist on a variety of soils with complex moisture and nutrient conditions. Age-specific definitions assume that forests age in consistent processes along relatively well-defined successional pathways. Under this assumption, an old-growth forest will have characteristics that are consistent over a range of time and environmental conditions. However, there is much variety in forests in Canada, and they evolve along different pathways, even though it may appear that the soil and moisture conditions are similar.”

This concept is further emphasized by Hilbert and Wiensczyk (2007): "There are also limitations to using age as the defining attribute for old growth…, the primary problem with working definitions is the lack of clear thresholds for when a forest becomes old”(Hilbert and Wiensczyk 2007).

Ontario has tackled the problem of age assessments through their use of complex methodology for determining 59 separate definitions and age classification schemes based on ecosite type and structural characteristics. They also incorporate ecosite assessment data that use factors, beyond stand structure, that could indicate ecological complexity (Ontario Ministry of Natural Resources 2012; Uhlig et al 2001). This age classification seems to have the least

sources of error, according to the research, as it manages to incorporate age into the definition as a characteristic but also incorporate an understanding of the difficulty of getting a true threshold age for when a tree becomes "old" by using many other factors including ecological and structural complexity indicators that reflect the diverse and complex nature of forest ecosystems. However, this approach was also criticized, since it does not fully take into account the differences in growth patterns due to local conditions (Hilbert and Weinsczyk 2007).

Modern alternatives to age thresholds

A simpler potential method to move beyond age thresholds is to categorize old-growth forests using the presence of members of climax forest ecosystems that are proven to only be able to survive in forests that are "old growth". This was suggested by Thompson et al. (1999) when analysing the presence of avian species in Newfoundland's mature balsam fir forests. This paper suggested that the presence of certain "old-growth requiring" avian species could be used to indicate the presence of old-growth forest. They observed in NL's balsam fir stands "a distinct old-growth bird community that could serve as indicator species for this forest type" (Thompson et al. 1999). However, the paper also says that the forests used for the study were "actively managed" (Thompson et al. 1999) which would mean that these species could still be present even in stands with "evidence of human disturbance".

Another interesting way to define old-growth forests was proposed by McMullin and Wiersma (2019) who suggested that using the presence of certain lichen communities to characterize old-growth forests was a better approach. This approach builds on the knowledge that certain lichen species that require old-growth forest conditions and resources in order to grow, such as the Old-growth Specklebelly Lichen, that grows in BC and can be a bioindicator of ecosystem health, (COSEWIC 2010). Lichen community assessment of stand age simply builds on

the characteristics of lichens, such as these, creating a database of the lichen communities in each forest region. This unique approach requires “the presence of a comprehensive suite of (lichen) species rather than any single indicator species that is required to deduce forest continuity” (McMullin and Wiersma 2019) This is done so that a certain change in range and properties of a certain lichen species due to natural adaptations cannot significantly effect whether the area is defined as old growth or not because it will be considered an outlier within the broader lichen community being examined. (McMullin and Wiersma 2019). According to our utility analysis, this method demonstrated greater respect for ecological variations, and was a more comprehensive measure of old-growthness than the alternative arbitrary age cutoffs. Thus it could have significant potential for old-growth forest definitions of the future. An earlier version of this tool was also used by Selva (2003) who analyzed an area known as the Townshend woodlot in PEI, which is considered to be one of the few potentially old-growth stands on that island (Selva 2003). This study by Selva also used NS’s old-growth scoresheet in tandem with the lichen classification scheme (Selva 2003). The diversity of microhabitats is known to increase over time in an ageing forest and calicioid lichens and fungi can be found growing in more of these microhabitats than any other group of species. Therefore, the presence or absence of these species can provide very effective evidence of forest age (McMullin and Wiersma 2019; Selva 2003).

Stand height

Despite its use by several provinces, literature sources generally did not include stand height as a useful characteristic for defining old-growth forests. Stand height restrictions were only observed as a requirement for old-growth forest definition in two jurisdictions. This

characteristic was mentioned in ON's guidelines and NL's "Temporary point sampling field manual" used to create the forest inventory data in NL (Newfoundland and Labrador 2016).

Species-specific restrictions

Tree species-specific restrictions were an important part of defining old-growth forests in definitions from many jurisdictions. Eighty three percent of the observed provinces had tree species-specific restrictions included in their definitions and/or field manual/scoresheet data. In Berry et al's (2018) recent review of Canadian old-growth forest policies, they suggest old-growth forests

> "are typically multilayered, comprising numerous late successional tree species of varying ages and sizes, but are dominated by old overstory trees. They are rich in biodiversity and ecologically continuous; they contain dead trees (both standing and fallen) and other forest debris that are left to decompose naturally; they have little evidence of human disturbance; there is natural regeneration occurring between canopy gaps; and, they function as important wildlife habitats, and nurture healthy soil composition" .

All these factors are dictated, in part, by the diversity of species present in the forest. The high frequency and high utility of tree species restrictions as an old-growth definition characteristic means that tree species restrictions should be included as part of a template old growth forest definition.

Dead wood indicators

Dead wood indicators were considered by several sources to be a major potential indicator of ecosystem complexity. Dead wood is a key old-growth attribute because it helps

determine age of stand and level of disturbance. Dead wood is one of a number of factors used to evaluate long-term forest changes in old-growth settings (Ducey et al. 2013). Dead wood indicators can work, together with defined tree species, to help identify old-growth forest ecosystems and can be used for multiple forest types (Ducey et al. 2013). Surprisingly, only ON included this characteristic as a factor in their old-growth definition, (Uhlig et al. 2001) while NS included it in its scoresheet's calculation of an "old-growthness" score (Province of Nova Scotia 2011). Both measured dead-wood using different blends of qualitative and quantitative approaches such as the visual presence of "large dead standing trees (snags) accumulations of woody material, up turned stumps, root and soil mounds and accelerating tree mortality" (Uhlig et al 2001). The lack of a reliable measurement system could potentially be improved through the incorporation of other measures. For example, soil samples could be collected in an area being assessed for old-growth status and then analysed looking for chemical signatures that would indicate high levels of decomposition of tree-sourced organic matter. Additionally, the visible presence of large amounts of detrivorous fungi and insects that feed off decaying large trees could also indicate high levels of dead wood in an area. Presence of visible "mound topography" that can be measured through aerial or satellite data, can also sometimes be considered, when used together with other data, as a useful tactic for assessing the amounts of fallen trees in an area (Kunttu et al. 2015). These approaches could make a potential new definition of old-growth forest, involving dead wood indicators, more scientifically rigorous.

Level of natural disturbance

The "Time since last stand-replacing natural disturbance" characteristic was generally considered to be useful in defining old-growth forests, according to our review of the literature, It was especially favoured in BC and SK BC Environment 1995; Province of Saskatchewan 2017

b). This characteristic was reportedly more useful when paired with species composition restrictions, as tree species differ in their response to fire and other natural disturbances. Combined consideration of these factors allows for better prediction of the effects of natural disturbances on forest succession patterns and therefore old-growthness. Natural succession patterns that are influenced by the last stand replacing natural disturbance, when paired with species composition, are the most important factors for identifying old growth forests (ref). As they note, "In temperate forests, processes such as natural succession in the absence of catastrophic disturbances (e.g. fire) and tree species composition will have special significance in determining old-growth conditions" (Mosseler et al. 2003). It has also been argued that fire disturbance impacts can be very useful for forest classification, especially when paired with data about the difference in natural disturbance responses that exist between Canada's forest regions (Figure 1) (Government of Canada 2015). The importance of natural disturbance data in defining old growth conditions is also reflected in mentions by SK's and BC's old-growth forest definition documents. Both of these provincial definitions reference fire-related natural disturbance as a factor that can affect old-growth age of onset considerations (Province of British Columbia 2018; Province of Saskatchewan 2019).

Evidence of human disturbance

In contrast to natural disturbance, "evidence of human disturbance" as a way of characterizing whether stands should be considered old-growth was found to be highly questionable in its utility. This was largely due to the highly qualitative nature of such assessments (Newfoundland and Labrador 2014; Province of Nova Scotia 2012). Old-growth experts were surveyed on this topic. Participants agreed that old-growth forests need not necessarily be primary forests - i.e. forests where no commercial or major anthropogenic

disturbances have ever occurred. In contrast, they suggested that “Secondary forest following harvesting could, in time become old-growth forest." (Mosseler et al. 2003). This conclusion supports the lack of utility for “evidence of human disturbance” as a defining characteristic. There remains some debate over whether a forest disturbed by humans (e.g. harvested or heavily used for recreation) can still be considered old-growth (Hendrickson 2003). Some ecologists still argue that an old-growth forest ecosystem would take thousands of years to be restored after harvesting (Hendrickson 2003). Others argue that terms such as “primeval” can be used to describe uncut forests, and that human disturbance need not be included in a broader definition of old-growth (Hilbert and Weinsczyk 2007).

Minimum stand area/spatial and temporal distribution of cut and leave areas

Other characteristics that were used to define old growth forests were the inclusion of “minimum stand areas”, “spatial and temporal distribution of cut and leave areas” and “crown cover”. What these metrics have in common is that, in the definitions we examined, they are mostly measured using GIS-based systems that involve satellite data and forest polygon-based analyses combined with forest inventory data. These assessments were not considered very accurate, in large part because while such analyses are widely used, especially for assessment for remote areas, there were a number of problems identified. In particular, there were concerns over the use and delineation of “forest polygons” (Wulder and Franklin 2003). When manual delineation of polygons is used to record areas of irregular natural formations (such as areas of a forest that are considered to be old-growth) experts suggest that the polygon-based analysis approach is “Highly subjective and hence not well suited for monitoring” (Wulder et al. 2008). The alternate, computer-polygon delineation approach can also give “Undesired results in areas with low contrast or where different appearance does not imply different meaning” (Wulder et al.

2008). Polygon based analyses can run into further problems when complicated by fire boundary line data and ecosite boundaries. Overall, these analytical factors are why I considered the aerial assessed characteristics, using polygon analyses, of relatively low utility and a low priority for inclusion in a template definition of old-growth forest.

Seral stage

When it comes to assessing the utility of using seral stage to define old-growth forest, the results were somewhat contradictory. Firstly, several old-growth definitions, such as those of BC and SK, seemed to simply consider seral stage as another type of age classification that also incorporated species specificity. Both provinces had seral stage tables that simply rated seral stage using age categories such as “young” or “mature” (BC Environment 1995; Province of Saskatchewan 2017b). BC’s guide, for example, indicates specific age categories “Early/young forests are defined as generally being less than 40 years old (except 20 years for deciduous stands). Mature forests are defined as 80 years or older for productive coastal forests, and 100-120 years or older for the less productive high elevation forests.” (BC Environment 1995). These definitions do not take into account that measuring seral stage is not the same as measuring age in a categorical manner. Measuring seral stage includes taking into consideration dynamics of tree species and how they interact with each other to form a certain successional condition. This more widely accepted scientific definition of seral staging can be seen in Manitoba’s forestry planning standard which, while not containing a formal definition of old-growth forest conditions, defines seral stage, citing a study by Dunster (1996). It indicates that a "Seral Stage is “The series of plant community conditions that develop during ecological succession from bare ground (or major disturbances) to the climax stage (Dunster 1996; Government of Manitoba 2007). This lack of proper consideration of seral stages are was also found in Saskatchewan’s

policy which stated that for softwood Jack pine the "old seral stage was considered to be "91 – 110" years old and the "very old" seral stage was any softwood Jack pine over 110 years old (Province of Saskatchewan 2017b), again demonstrating a misuse of the term seral stage in general, as a way to simply refer to age thresholds. Overall, our analysis of the utility of using seral stage classification as a definition characteristic found ambiguity about what different provinces use eral stage to measure, and how they determine seral stage. This uncertainty, combined with a lack of indication of the usefulness of seral stage as a defining characteristic for old-growth forests the literature we reviewed, led us to conclude that seral stage may not be a significantly useful metric when defining old-growth forests across Canada.

Inclusion of new protected areas <u>for</u> old-growth forest and existing protected areas <u>as</u> old-growth forest

An important additional set of definition characteristics were assessed for their utility in old-growth forest definitions. First, should the definition include existing protected areas? Should these areas be re-assessed for old-growthness or not?" and second, "What should be the conditions where defining an area as old-growth forest leads to that area being protected?" The consensus, in much of the literature, was that it was important to protect as many areas of old-growth forest and potential old-growth forest as possible (Berry et al. 2018; Duschene 1994). Additionally, it was deemed essential by many researchers that a revised definition of old-growth forest did not serve as a vehicle to remove protections from other areas (Beadle et al. 2009). It was also suggested that old-growth specific protected areas be implemented where old-growth forests assessed on private land were under threat, due to ongoing efforts to develop or clear cut the area. (Beadle et al. 2009; Berry et al. 2018). Other methods of encouraging preservation of private old-growth land were also discussed, such as providing incentives to landowners (Lahey 2018). Nevertheless, both the definition characteristic of including the existing protected areas

into old-growth assessment surveys as well as the characteristic of including old-growth forest in specific protected areas were determined to have high levels of utility by our literature review.

Template old-growth forest definition

A key research objective of this study was to develop a template operational definition of an old-growth forest, using the results of our study. The utility analysis portion of our study took place after results regarding frequency of selected characteristic use and definition format were compiled. A wide variety of different scientific studies were examined to gather opinions regarding the utility and quality of each of the 19 different definition characteristics we researched. A template definition was created including what we found were the most useful definition characteristics. We also included potential modern techniques that could help with defining old-growth forests. Age of trees was included in definitions from all provinces we studied in detail. This characteristic was formerly considered the most useful but has been increasingly declining in use as a primary evaluation tool. New methods that employ species-specific restrictions, involving using lichens as bioindicators of climax communities have seen increased attention from researchers (McMullin and Wiersma 2019). Holistic ecological methods of measuring climax forest conditions, such as mound topography, dead wood assessments, and ecosystem health and diversity, which indicate a long-lasting undisturbed forest environment, are also being increasingly viewed as improved methods to assess forest conditions. According to our utility review of 19 different old growth definition characteristics, there was some consensus regarding the most important factors in defining old-growth. This consensus included that measures of ecological complexity indicating a long-lasting environment were a good way of determining and defining old-growth forest, with basic age thresholds taking a second level of

importance (Bergeron et al, 2012; Duschene 1994; McMullin and Wiersma 2019; Pesklevits et al. 2011; Selva 2003; Villeneuve and Brisson 2003).

Based on our literature review, some of the worst options for evaluating old-growth forest status involved tree structural data from forest inventories such as stand height, minimum basal areas, landscape connectivity issues, and vague seral stage-based definitions (Government of Canada 2015; McMullin and Wierma 2019). The problematic measurement and assessment of forest inventory data using GIS (Wulder and Franklin 2003) were also considered to be a barrier to using forest inventory based structural characteristics to define old-growth.

Human disturbance as a definition characteristic was also determined to be not very useful, due to its subjectivity. Reference to specific old-growth protected areas that can only have "undisturbed forest" echo past ideas of conservation biology from those such as Soule (1985). Perhaps there could be a more quantitative measure of this criterion included, such as road density of an area, or the extent of forestry activities in an area based on satellite data. However, there was no mention of quantitative measurements of the "evidence of human disturbance" required for a forest not to be considered old-growth in any jurisdiction that used this metric in their definition. As it stands, this definition characteristic was seen to be purely qualitative in nature with low utility.

In contrast to human disturbance, evidence of natural disturbances in an area was considered to be highly important in determining old-growth status of a forest especially in provinces with frequent wildfires such as SK and BC. This was partially due to the fact that wildfires can cause what is known as "cambium/phloem necrosis and xylem damage" in the tree's internal structure and cause high likelihood of starvation and death for the trees in a stand impacted by natural disturbances such as fire and associated droughts in the long term (Bar et al.

2019). This means considering wildfire impacts, on a stand, may be important in determining its old-growth status and conservation value, in some settings.

Novel approaches to analysing ecological continuity within stands, such as using lichen identification paired up with NS's scoresheet in PEI (McMullin and Wiersma 2015; Selva 2003), and using "mound topography" analysis were seen as potentially useful future tools that could be employed as contributors to analysis of whether a stand constitutes old-growth forest. The specificity of lichen presence and the fact that lichens react to natural disturbances such as fire and nutrient imbalances allows them to be used as a key measure of ecological complexity As such they were important factors for operationally defining old-growth forests according to the sources used for our literature review and utility analysis (McMullin and Wiersma 2019; Peskevits et al. 201; Villeneuve et al. 2003).

The results of our utility analysis culminated in the development of our template old-growth forest definition. I concluded that for a stand to be considered old-growth it should have:

1. Presence of certain key old-growth tree species with 30% or more crown closure

AND/OR

2. Presence of indicator lichens (using a lichen identification chart modelled potentially off established published studies (Selva 2003; McMullin and Wiersma 2019)
3. Presence of large amounts of dead wood, assessed through a combination of visible "Mound topography" on forest floor and complementary methods, such as soil sampling.

The first two of these traits, key old-growth species and crown closure, were chosen because they were considered the most accurate out of the definition characteristics examined in our

study, particularly if they were assessed using a ground based measures. The second was chosen due to the indications that lichens are significantly better indicators of forest succession patterns and "old growthness" than age thresholds more commonly used in forest definitions (McMullin and Wiersma 2019; Selva 2003). Such analyses have already been used, in tandem with NS's existing old growth scoresheet framework, to assess the old-growthness, particularly in the Acadian forest ecoregion. The third component of this template definition was the presence of mound topography, chosen as it was seen by our utility analysis that the presence of fallen trees over time could be a very useful indicator of ecological complexity (Burrascano et al.2 008; Kunttu et al. 2015; Pesklevitz et al 2011). Mound topography could quantitatively measure this characteristic through satellite data or high-resolution airborne imagery measuring changes in forest floor elevation over time. This approach was used recently in a study conducted in Gatineau park in ON (Pasher and King 2009). Soil samples of the stand, to determine the level of dead organic matter, could be used in places where accurate enough satellite imagery or high-resolution airborne imagery is not available. This was done recently to categorize the levels of deadwood in a study conducted at various sites across China (Zhu et al. 2017).

It should also be noted that many old-growth forest stands are within current protected areas and indigenous reserves in Canada. The protection of these areas varies province to province. It is essential to ensure that any protections for new old-growth forests do not remove any of these protections. This is important to state because many provinces have quotas of "amount of old growth forests that must be protected". This means that areas that are already protected can sometimes be counted as "old growth forest" to meet these protection requirements. It is important for our template definition to also recognize that areas within existing protected areas cannot be used to meet existing old-growth forest quotas. Notably, our many provinces such as

BC, SK and NB have clauses within their old-growth definition documents to help avoid this situation with their respective old-growth protection quotas. These provinces will avoid this kind of situation by indicating that areas that are “potential old growth forests” in ON (Uhlig et al. 2001) or “mature forests” in SK (Saskatchewan Ministry of the Environment 2009) can be counted and protected as if they are full old-growth if the quota of a certain percentage of old-growth forests is not being met. However these factors are very region-dependent and I simply include this as a suggestion, for careful consideration, when developing new old-growth definitions.

DISCUSSION

Several of our findings are of potential significance. First, only six jurisdictions out of Canada’s provinces and territories had publicly available, operational definitions of what constituted old-growth forest. This has significant implications for how Canadian jurisdictions view old-growth forest protection. Many jurisdictions did not consider the management of old-growth forests of sufficient priority to put in place more than a basic conceptual definition. Several jurisdictions, lacking clear definitions, appear to regulate old-growth forests the same way they do the rest of their forestry sector. No special considerations are given to the unique values of old-growth forest in terms of biodiversity conservation, aesthetic and cultural importance and providing ecosystem services compared to other forest types.

A second significant finding was that many province’s definitions of old-growth forest relied extensively on qualitative measures such as “evidence of human disturbance” and visual estimates of “amount of dead wood" to indicate whether forests were defined as old-growth. In general, quantitative measures are easier to report and compare across jurisdictions. For

example, humans have disturbed most ecosystems on earth in some way if you consider the totality of our impacts such as industrial pollution on the atmosphere and global bodies of water. This makes the definition of “human disturbance” in a forest context open to a range of interpretations.

The definitions of old-growth forest we examined, for six provinces, all included significant broad exceptions. These, for example, can allow a province to redefine what constitutes “old-forest” to include “young seral stage forests that have the potential to become old growth forests” in the case of BC (Province of British Columbia 2018) and to include “mature forests” in the case of SK (Department of Environment Saskatchewan 2011). These strategies help provinces meet protected area requirements but, such flexibility of definition, does not necessarily promote the inclusion of all the most valuable old-growth areas.

A key issue raised by our review of the definition documents was an apparent lack of reliance on evidence from the scientific literature to back up the arguments being used in official definition documents and reports. Only half of the provinces examined included a reference list that linked their old-growth forest definition directly to scientific evidence. The provinces without reference lists within their definition documents were SK, NS and NL (Government of Newfoundland and Labrador 2014; Province of Nova Scotia 2012; Province of Saskatchewan 2011). These three provinces also rely on simple, one size fits all, age-based definitions, in tandem with a scoresheet in the case of NS and a field manual in the case of SK and NL. The approach taken by these provinces was in striking contrast to the definitions of the remaining three provinces examined, ON, NB and BC, where age of onset calculations, old-growth forest community definitions and biogeoclimatic zone data respectively were developed in partnership with external scientific researchers and based on evidence. The definition documents from these

latter provinces included extensive scientific reference lists of studies completed both locally and across Canada (New Brunswick Department of Natural Resources 2012; Uhlig et al. 2001; Province of British Columbia 2018).

Which province has the best current old-growth definition?

Ontario appeared to most clearly demonstrate a comprehensive measure of ecological complexity with clear quantitative assessments and therefore have the policy with the highest utility. In ON's definition, the ages of onset were calculated using formulas that involved structural characteristics of a stand and also taking into account dead wood indicators and other ecological complexity factors; moreover, any stand with any species is included (Uhlig et al 2001; Ontario Ministry of Natural Resources 2012). According to my interpretation of the utility analysis, ON's definition seemed to have the highest utility of the six that were examined, because it included all the most useful definition characteristics according to my utility analysis and literature. It also provided the most comprehensive measure of the presence of an old-growth climax community within a stand.

In contrast, the least useful definition was found to be NB's due to its seemingly arbitrary focus on "stems per hectare" of certain primary species" as listed in NB's field manual, for use in its definition, and its potentially confusing "Old Growth Forest Community" based system (New Brunswick Department of Natural Resources 2012; 2014). However, this definition was certainly an important advance over those provinces which lacked published, effective, operational definitions of old-growth forest.

The significance of a robust old-growth forest definition for conservation

Finding an operational definition of what is considered "old growth forest" is a critically important task to further conservation of these highly biodiverse and threatened ecosystems. A concise definition that is easily understood by lawmakers and enforcement personnel is critical, Laws and regulations pertaining to "old growth forest" areas to be properly created and enforced. All those involved in those processes must understand where the boundaries for "old growth forest" land begin and end as accurately as possible. A robust definition of old-growth forest, on which there is general agreement will help conservationists better understand the overall ecosystem composition of Canada's old-growth forests consistently, even across some provincial boundaries. It will thereby help us better monitor the threats to these ecosystems posed by climate change, air and water pollution and increased levels of natural disturbances such as floods and forest fires. Better evaluation of the importance of old growth forests as a habitat and proper assessment of the other ecosystem services they provide also depends upon a robust definition. The data provided through these evaluations will help provide concrete evidence of the importance of these unique, ecologically rich areas for both governments and the broader community to consider.

Our study of Canadian old-growth forest definitions revealed the lack of prioritization placed by many provincial and territorial regulators on defining old growth forests. More than half of the jurisdictions didn't have any operational definition of old-growth. A more consistent basis for old-growth definitions would simplify the process whereby one could be adopted by these jurisdictions. Consistent, well accepted, national, definition criteria would allow comparative data to be obtained across provinces and aid in cross provincial protected status for forests that cross provincial boundaries. Data could also be collected regarding the effective

protection of old-growth forest areas, even if a specific jurisdiction did not provide an official guideline. Such data could help conservationists better understand the areas that require the most attention in terms of environmental advocacy and pro-environment lobbying, and show where the most unprotected old-growth forests in the country lie. It could also help identify areas where careful logging and forest management practices would have less overall ecological impact but still support economic activity.

Potential contributions of this study and future work needed

The results of this study and the template definition it informed can help with the process of developing improved old-forest definitions and provides some clear suggestions regarding criteria that should be included in an optimal template. This was based on both an evaluation of the characteristics currently used most frequently by provinces,with operational definitions and a qualitative analysis of the utility of these characteristics. More work is needed to identify what "climax species" and "indicator lichens" are applicable for each area. These necessary assessments of climax species and indicator lichens as part the proposed template definition will also help conservationists better understand and document the overall composition of Canada's old-growth forests and combat the threats to these ecosystems posed by climate change. Potential new methods for assessing dead wood indicators as well as for monitoring the changes in forest cover and forest condition, over time, are also important components to assess. The collection of that data in the process of defining old-growth will also be critically useful for further understanding the value of old-growth forests as moderators of the microclimate, through their ecosystem services that help buffer the most extreme effects of climate change on local environments. This regulation by old-growth forests of is done through a wide variety of ecosystem services and benefits provided by the old-growth forests such as through the old-

growth forests value as stores of carbon, (Nova Scotia Nature Trust 2002), through their role helping reduce flooding and erosion in times of storms (Jones and Grant, 1996) and through potentially also increasing ground and surface water supplies in coastal areas (Franklin and Spies 1991), all effects which are of critical significance for their effect on the conservation of species. Our results suggest that more attention surrounding the value of these ecosystem services, and the others provided by old growth forests, may be prudent to take into consideration when examining how broadly defined old-growth forest protections should be, and in helping advocate for the creation of operational definitions for old-growth forests in the areas that have none.

Much of the impact of old-growth definitions depends on factors such as whether a province's definition extends old growth protections to "near old growth" or "mature" forests, or whether the definition considers its effect on species at risk habitat areas, may indicate higher or lower conservation value of the different provincial definitions. This would be especially relevant data to be used for conservation research and initiatives that are focused on protecting species at risk that live within old-growth forest ecosystems. Revaluation of critical habitat areas for species at risk that rely on old growth forests based on novel definitions of old-growth forests (such as the novel definition for old growth forest presented in the template in our results) also have potentially serious implications for Canadian law as well if new definitions for critical habitat of certain endangered species are accepted, due to the fact that under the federal species at risk act it is "an offence to destroy critical habitat of a species classified as endangered, threatened or extirpated" (Government of Canada 2019). This demonstrates yet another way that novel definitions of old growth and better understanding of how to define old-growth forests in Canada can have a significant impact on the success of conservation initiatives.

Understanding the different provincial approaches to biodiversity protection within old-growth ecosystems differ is also very important for conservation. NB, for example, may end up being better prepared for climate change impacts, due to their system of categorizing not only old-growth forests, through their old growth forest community system but old growth forest habitat areas marked as priority areas (New Brunswick Department of Natural Resources 2012). In contrast, other provinces, such as NS, had separate plans for conservation of endangered species, such as Mainland moose, that were not linked to the old-growth forest plan. The conservation of old-growth areas in NS is guided around the importance of protecting the tree species in the forest rather than the resident fauna. Ontario and BC's policies also did not mention animal species within the forests and focused more on preservation of key tree species that were included within their definition's specific ages of onset (Uhlig et al 2001; BC Environment 1995, Province of British Columbia 2018). These results about the different conservation priorities of different provinces and their relevance to protections for species at risk is another result of our study that is important for conservationists to consider.

Hopefully this paper can lead to future conservation studies that examine the importance for species and ecosystem survival of each for the different 19 definition characteristic's we examined, now that their presence in each of Canada's different old growth definitions has been identified and their utility been analyzed. Overall, it is abundantly clear that there is much work to be done to better define old growth forest in Canada so it can be better conserved and protected in the future and this study indicates potential avenues on where the biggest weaknesses and gaps lie in Canadian old-growth forest definitions.

Sources of error

This study of Canadian definitions of old-growth forest contained a wide range of sources of error that could have potentially influenced our data. First, there is the issue that we only used the 63 documents that we could easily access from public sources to examine old-growth policies across Canada and did not have access to many documents that were considered private, or were behind barriers that required government authentication before viewing. This led to the old-growth policy documents of certain jurisdictions being skipped over, especially those jurisdictions with fewer policy documents online, such as Manitoba and Alberta. There are artifacts in the documents reviewed, associated with provinces that have no public old-growth definitions, that indicate that old-growth forest definition documents that exist, but are not posted online. For example, Alberta's mention of "Old forest requirements" in its "Forestry Directives and standards" document's and stating a certain ratio of "Area of old, mature, and young forest by DFA subunit by cover class must be preserved" (Province of Alberta 2017) .

A second potential source of error is that it is well known that there is a wide range of scientific literature and third party sources that are influenced by political and industry biases when it comes to defining what forest areas get protected. Therefore, some of the supplementary sources used for the review of policy quality and utility as part of this project may in fact be biased sources that are not giving an opinion of the old-forest definition based on what is most useful for protecting biodiversity, but instead are more focused on what is more useful for the forestry industry or other stakeholders. Additionally, there is a massive amount of literature that exists online and in reputable peer reviewed scientific journals on the topic of potentially useful old-growth definition characteristics. The literature review completed as part of the old growth

definition quality and utility assessment component of this study only barely scratched the surface of these resources and may have had a selection bias.

A final potentially significant source of error is also the fact that certain definition characteristics included in scoresheets and field manuals may not be still in use but were still included as part of this studies assessment of the official definition. Examples of this could be NL's temporary point sampling field manual, which seems to be focused exclusively on categorizing forest inventory. Its influence on the interpretation of provincial old-growth forest policy was likely not considered when it was written (Newfoundland and Labrador 2019).This could mean that the government actually does not consider this document to be part of their late successional forest's / old-growth forest definition currently, even though it influences the definition through its impact on the forest inventory. Thus the old-growth definition characteristics this field guide mentions, such as stand height, that were said for the purposes of this study to be part of NL's old forest definition requirements, (Government of Newfoundland and Labrador 2014) should not in fact be included if the field guide is possibly no longer in common use. Verification of the use of specific documents and regulation with direct provincial sources could help alleviate this type of problem.

CONCLUSION

In conclusion, our study showed a wide variety of different approaches are being taken in Canada by different provincial jurisdictions in order to address the challenge of how to define Canada's old-growth forests. Many provinces were found to have no official, operational, public definition of what an old growth forest was at all or had only a very basic conceptual definition. Six provinces were found to have an official definition we could evaluate, and of those everyone

took a different approach. These ranged from Ontario's 59 separate age-based definitions for each of its ecosites through NS''s single sentence definition including six species and a scoresheet to NB's "Old Forest Communities" system and BC's system based on "Biogeoclimatic zones" and time since last natural disturbance. Every province had a very different approach, and format of their operational old growth forest definitions. The utility analysis of definition characteristics contained in this report, and the development of our template definition in this report, aims to help serve as a model for future researchers attempting to define the term "old-growth forest" while also aiming to help fulfill the more immediate goal of better informing the committee working on Nova Scotia's new old-growth definition.

This is just a single step of research input in a long process. It is clear that much work remains yet to be done in order to make a more useful template definition that incorporates the best parts of the cutting edge research results and experience of multiple jurisdictions, to better define Canadian old-growth forests in the future. We must act to protect old-growth forests in NS, and throughout Canada, and the best first step is developing a clear operational definition to work from. Overall, the findings in this report emphasize that we have a long way to go throughout Canada to improve the quality and clarity of the existing definition, as a first step in protecting precious old-growth forest ecosystems. Hopefully, these findings, along with the novel old-growth forest definition template suggested in this report, can be useful in helping confront that challenge.

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Appendix

Reference code	Title	Data used for analysis	Link or Citation	Year
LIT 1	IEC def Exp1	Yes	https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2016	2019
LIT 2	OGF of Acadian Forests region	Yes	https://www.researchgate.net/publication/249543995_Old-growth_forests_of_the_Acadian_Forest_Region	2003
LIT 3	OGF Regulatory frameworks compared	Yes	https://pubs.cif-ifc.org/doi/pdfplus/10.5558/tfc2018-003	2018
LIT 4	Defining old growth in Canada	Yes	https://www.ncasi.org/wp-content/uploads/2019/02/tb909.pdf	2005
LIT 5	OGF Anatomy of a Wicked problem	Yes	https://pdfs.semanticscholar.org/45a8/5eb3decd4eb2a2d0763ebe985f20c2fd369c.pdf	2011
LIT 6	New management and conservation of OGF	Yes	Beadle, C., Duff, G., & Richardson, A. (2009). Old forests, new management: The conservation and use of old-growth forests in the 21st century. Forest Ecology and Management, 258(4), 339–340. doi: 10.1016/s0378-1127(09)00411-3	2009
LIT 7	Defining Canada's Old Growth Forests	Yes	https://pubs.cif-ifc.org/doi/pdfplus/10.5558/tfc70739-6	1994
LIt 8	Using Lichens to assess ecological continuity	Yes	https://pubs.cif-ifc.org/doi/pdf/10.5558/tfc79550-3	2003
LIT 9	Toward a conceptual definition	Yes	Hunter, M.L. 1989. What constitutes an old-growth stand? Toward a conceptual definition. J. Forestry 87: 33-36.	1989
LIT 10	OGF defined by key EC's (Maine source)	Yes	http://www.forestsformainesfuture.org/fresh-from-the-woods-journal/old-growth-forests-defined-by-key-ecological-characteristics.html	2016
LIT 11	OGF definitions	Yes	https://www.researchgate.net/publication/42090009_Old-Growth_Forest_Definitions_a_Pragmatic_View	2009
LIT 12	Boreal forests of eastern Canada revisited	Yes	https://www.researchgate.net/publication/237155367_Boreal_forests_of_eastern_Canada_revisited_Old_growth_nonfire_disturbances_forest_succession_and_biodiversity	
LIT 13	OGF definitions lit review BC journal	Yes	https://www.merseytobeatic.ca/userfiles/file/projects/Forest/Old%20Forest%20Project/Hilbert%20&%20Wlensczyk%202007%20-%20Old%20Growth%20Definitions%20and%20Management.pdf	2007
LIt 14	Avian Communities In OG Balsam Fir	Yes	https://academic.oup.com/condor/article/101/2/311/5126128	1999
LIT 15	Lichens are better then Age for measuring OGF	Yes	https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2016	2019
Lit 16	Forestry Canada	Yes	Kimmins, J.P. 1993.Old-growth forests in Canada. What are they, how extensive are they, and are they a sustainable resource? Old-growth forests in Canada, Part 1. Forestry Canada, Hull, QB.	1993
ISO 1	ISO 14001:2015 (Full rules document)	Yes	https://www.iso.org/standard/60857.html	2015
CFS 1	State of Canada's Forests Report PDF	Yes	https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/39336.pdf	2016
CFS 2	Old Growth Forests in Canada	Yes	http://www.fao.org/3/xii/0042-b1.htm	
CFS 3	Section2, Forests and the forest sector	Yes	https://www150.statcan.gc.ca/n1/pub/16-201-x/2018001/sec-2-eng.htm	2017
CFS 4	Trees dying in Northeastern QB OGF stands	Yes	https://cfs.nrcan.gc.ca/publications?id=26996	2007
AB 1	SFM Province of Alberta	No	https://www.sfmcanada.org/images/Publications/EN/AB_info_Provinces_and_territories_EN.pdf	2016
AB 2	Forests Act	No	http://www.qp.alberta.ca/1266.cfm?page=F22.cfm&leg_type=Acts&isbncln=9780779752509	2019
AB 3	Forestry Directives and Standards	Yes	https://www.alberta.ca/forestry-directives-and-standard-operating-procedures.aspx	2020
BC 1	Forest Range Practices Act	No	http://www.bclaws.ca/civix/document/id/complete/statreg/02069_01	2002
BC 2	Interm Assement Protocol for OGF in BC	Yes	https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/interim_old_growth_protocol_v11_jan2018_final.pdf	2017
BC 3	Biodiversity Guidebook (Operational Def)	Yes	https://www.for.gov.bc.ca/hfd/library/documents/bib19715.pdf	1995
BC 4	Old Growth Definition (webpage)	Yes	https://engage.gov.bc.ca/oldgrowth/definition/	2020
BC 5	Old Growth Management Tools	Yes	https://engage.gov.bc.ca/oldgrowth/old-growth-management-tools/	2020
BC 6	Managing the Dry Douglas Fir Forests	Yes	https://www.for.gov.bc.ca/hfd/pubs/docs/wp/wp34.pdf	1997
BC7	Iconic OGF tree official press release	Yes	https://news.gov.bc.ca/releases/2019FLNR0189-001452	2019
BC 8	Biogeoclimatic zones of BC	Yes	https://www.for.gov.bc.ca/hfd/library/documents/treebook/biogeo/biogeo.htm	2020
MB 1	SFM Province of Manitoba	No	https://www.sfmcanada.org/images/Publications/EN/Manitoba_info_Provinces_and_territories_EN.pdf	2017
MB 2	Forest Health Protection Act	No	http://web2.gov.mb.ca/laws/statutes/ccsm/f151e.php	2007
MB 3	The Forest Act	No	http://web2.gov.mb.ca/laws/statutes/ccsm/f150e.php	2015
MB 4	20 year Forest guidelines	Yes	https://www.gov.mb.ca/sd/forestry/pdf/practices/20_year_forest_plan_2007.pdf	2007
NB 1	OGFC Definitions	Yes	https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/OldForestCommunityWildlifeHabitatDefinitions.pdf	2012
NB 2	Forests Act	No	https://www.canlii.org/en/nb/laws/stat/snb-1980-c-c-38.1/latest/snb-1980-c-c-38.1.html	2019
NB 3	Forest Management Manual for NB	Yes	https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/ScheduleE_FMM_En.pdf	2014
NB 4	The act to amend the Forests Act	No	https://www.gnb.ca/legis/bill/FILE/58/3/Bill-29-e.htm	
NL 1	Forestry Act	No	https://www.assembly.nl.ca/Legislation/sr/statutes/f23.htm	2019
NL 2	Environmental Protection Act	No	https://www.assembly.nl.ca/legislation/sr/statutes/e14-2.htm	2019
NL 3	Sust. Forest Strategy	Yes	https://www.faa.gov.nl.ca/publications/pdf/psfms_14_24.pdf	2014
NL 4	Review of Forest Site Classification	Yes	https://pubs.cif-ifc.org/doi/pdfplus/10.5558/tfc68025-1	1992
NL 5	Environmental Management System	Yes	https://www.faa.gov.nl.ca/forestry/ems/index.html	2019
NL 6	TPS Field manual	Yes	https://www.faa.gov.nl.ca/forestry/managing/pdf/TPS_Field_Manual.pdf	2016
NL 7	Forest Inventory Program	Yes	https://www.faa.gov.nl.ca/forestry/managing/inv_plan.html	2019
NL 8	Structure of Gap-Dynamics in NL	Yes	https://www.researchgate.net/publication/254987604_Age_and_Size_Structure_of_Gap-Dynamic_Old-Growth_Boreal_Forest_Stands_in_Newfoundland	2006

Reference code	Title	Data used for analysis	Link or Citation	Year
NS 1	Forests Act	No	https://nslegislature.ca/sites/default/files/legc/statutes/forests.htm	2010
NS 2	OGF Reg.	Yes	https://novascotia.ca/natr/library/forestry/reports/Old-Forest-Policy-2012.pdf	2012
NS 3	Forest Sustainability Regulations	No	https://www.novascotia.ca/just/regulations/regs/fosust.htm	2007
NS 4	NS Forest Notes, the polygon problem	Yes	http://nsforestnotes.ca/what-is-old-growth/the-polygon-problem/	2018
NS 5	OGF Scoresheet	Yes	https://novascotia.ca/natr/forestry/programs/ecosystems/scoresht.asp	2018
NS 6	Lahey Report	Yes	https://novascotia.ca/natr/forestry/Forest_Review/Lahey_FP_Review_Report_ExecSummary.pdf	2018
NS 7	Code of Forest Practice	Yes	https://novascotia.ca/natr/forestry/reports/Code-of-Forest-Practice.pdf	2012
NS 8	Implementation of Interim NS OGF policy	Yes	https://novascotia.ca/natr/library/forestry/reports/state-of-forest-old-growth.pdf	2008
NWT 1	Forest Health Report	No	https://www.enr.gov.nt.ca/sites/enr/files/2016_forest_health_report.pdf	2016
NWT 2	Timber harvest planning rules	No	http://reviewboard.ca/upload/project_document/EA00-005_35_1184615013.PDF	2001
NWT 3	SFM Northwest Territories	No	https://www.sfmcanada.org/images/Publications/EN/NWT_info_Provinces_and_territories_EN.pdf	
NWT 4	Forest Management Act (1988)	No	https://www.justice.gov.nt.ca/en/files/legislation/forest-management/forest-management.a.pdf?t1507236106455	
NWT 5	Forest Management Regulations	No	https://www.justice.gov.nt.ca/en/files/legislation/forest-management/forest-management.r2.pdf?t1507236106456	
NWT 6	Forest Protection Act (1988)	No	https://www.justice.gov.nt.ca/en/files/legislation/forest-protection/forest-protection.a.pdf?t1507237086488	
ON 1	OGF Definitions	Yes	http://www.ontla.on.ca/library/repository/mon/6000/10310919.pdf	2003
ON 2	OGF policy for crown forests	Yes	https://docs.ontario.ca/documents/2830/policy-oldgrowth-eng-aoda.pdf	2003
ON 3	Understanding old growth pine forests	Yes	Carleton, TJ. and A.M. Gordon. 1992. Understanding old-growth red and white pine dominated forests in Ontario. Ontario Ministry of Natural Resources.	1992
ON 4	SFM Province of Ontario	No	https://www.sfmcanada.org/images/Publications/EN/Ontario_info_Provinces_and_territories_EN.pdf	
ON 5	Crown Forest Sustainability Act	No	https://www.ontario.ca/laws/statute/94c25	1994
ON 6	Policy Framework for Sustainable Forests	No	https://docs.ontario.ca/documents/2826/policy-framewrk-eng-aoda.pdf	1994
ON 7	Forest Management Planning Manual	Yes	https://files.ontario.ca/forest-management-planning-manual.pdf	
ON 8	Forest Biodiversity Management Guide	No	https://docs.ontario.ca/documents/4816/stand-amp-site-guide.pdf	2010
PEI 1	State of the Island's Forests report	No	https://www.princeedwardisland.ca/sites/default/files/publications/2000_state_of_the_forest_report.pdf	2002
PEI 2	Beetles in the OGF of Townshend	Yes	http://www.acadianes.ca/journal/papers/majka_townshend_jaes1009.pdf	2010
PEI 3	Townshend OGF defnition quotes	Yes	https://www.theguardian.pe.ca/news/local/seeing-old-forest-in-a-new-light-95290/	2012
PEI 4	Forest Management Act	No	https://www.princeedwardisland.ca/sites/default/files/legislation/f-14-forest_management_act.pdf	
PEI 5	SFM Province of PEI	No	https://www.sfmcanada.org/images/Publications/EN/PEI_info_Provinces_and_territories_EN.pdf	
PEI 6	PEI 6: Forest management Act regulations	No	https://www.princeedwardisland.ca/sites/default/files/legislation/F%2614-2-Forest%20Management%20Act%20Provincial%20Forests%20Regulations.pdf	
QB 1	Sustainable Forest Development Act	No	http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/A-18.1	2019
QB 2	SFM Province of Quebec	No	https://www.sfmcanada.org/images/Publications/EN/QC_info_Provinces_and_territories_EN.pdf	2020
QB 3	Exceptional Forest Ecosystems in Quebec	Yes	https://mffp.gouv.qc.ca/english/publications/forest/publications/20013073.pdf	2001
QB 4	OGF in QB's temperate deciduous zone	Yes	https://www.researchgate.net/publication/276217036_Old-growth_forests_in_the_temperate_deciduous_zone_of_Quebec_Identification_and_evaluation_for_conservation_and_research_purposes	
QB 5	Standards of forest management	No	http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/A-18.1,%20r.%207	
SK 1	Saskatchewan Environmental Code	No	https://www.saskatchewan.ca/business/environmental-protection-and-sustainability/environmental-code	2020
SK 2	SFM Province of Saskatchewan	No	https://www.sfmcanada.org/images/Publications/EN/SK_info_Provinces_and_territories_EN.pdf	
SK 3	2009 State of the Environment Report	Yes	http://www.environment.gov.sk.ca/soereport	2009
SK 4	2011 State of the Environment Report	Yes	http://www.environment.gov.sk.ca/soereport2011	2011
SK 5	SK Forest Management Planning Standard	Yes	https://pubsaskdev.blob.core.windows.net/pubsask-prod/86843/86843-Forest_Management_Planning_Standard.pdf	2017
SK6	Island forests Management Plan 2018	Yes	https://pubsaskdev.blob.core.windows.net/pubsask-prod/98889/98889-Island_Forests_2018-	2018
SK7	Forest management plan Update 2019	Yes	https://publications.saskatchewan.ca/api/v1/products/104053/formats/115744/download	2019
SK 8	Forest Resources Management Act	No	https://publications.saskatchewan.ca/#/products/525	
SK 9	Forest Resources - Environmental Code	No	https://publications.saskatchewan.ca/#/products/72374	
YK 1	Landscape Conservation planning	No	https://www.wcscanada.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=33346&PortalId=96&DownloadMethod=attachment	
YK 2	Sfm Yukon	No	https://www.sfmcanada.org/images/Publications/EN/YK_info_Provinces_and_territories_EN.pdf	

British Columbia

Definition characteristics	Does the official definition include the characteristic?	Is the characterisic included in an official scoresheet or guideline document?	Official Source for mention of characteristic
Age	Yes	No	BC4, BC3, BC5, LIT13
Stand Height	No	No	
Species based restrictions (tree species eligible for	No	No	
A Dead wood indicator (including mentions of a presence	Yes	No	BC3, BC4
Diameter at Breast Height	No	No	
Crown Closure	No	No	
Time since last stand-replacing - natural disturbance	Yes	No	BC3, BC4, BC2
Time since last forest management intervention	No	No	
Evidence of human disturbance	Yes	No	BC2
Minimum Stand Area	No	No	
Age of dominant trees compared to expected life expectan	No	No	
Spatial and Temporal distribution of Cut and leave areas	Yes	No	BC2
Mean Annual Increment compared to net annual incremen	No	No	
Stability of species composition	No	No	
Ecosite / Ecodistrict / Ecoregion type / Biogeocimatic zones	Yes	No	BC 4 BC3
Inclusion of existing protected Areas within defintion	Yes	No	BC3, BC2
Landscape Connectivity	Yes	No	BC3
Seral stage distribution	Yes	No	BC3, BC2
Reference to specific OGF protected areas	Yes	No	BC2, BC5, BC7, BC3

New Brunswick

Definition characteristics	Does the official definition include the characteristic?	Official Source for mention of characteristic:	Is the characterisic included in an official scoresheet or guideline document?	Scoresheet or field manual source for characteristic:
Age	Yes	NB3 , LIT 2	No	
Stand Height	No		No	
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	Yes	NB1	Yes	NB1
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	Yes		Yes	NB1
Diameter at Breast Height	Yes	NB1	Yes	
Crown Closure	Yes	NB1	Yes	NB1
Time since last stand-replacing - natural disturbance	No		No	
Time since last forest management intervention	No		No	
Evidence of human disturbance	No		No	
Minimum Stand Area	Yes	NB1		
Age of dominant trees compared to expected life expectancy	No			
Spatial and Temporal distribution of Cut and leave areas	Yes	NB1	Yes	NB1
Mean annual increment compared to the net annual increment	No		No	
Stability of species composition	No			
Ecosite / Ecodistrict type	Yes	NB1	No	
Inclusion of protected Areas	Yes			
Landscape Connectivity	Yes	NB1	No	
Seral stage distribution	No		No	
Inclusion of Specific OGF protected Areas	Yes	Lit 5	No	

Newfoundland and Labrador

Definition characteristics	Does the official definition include the characteristic?	Official Source for mention of characteristic	Is the characterisic included in an official Scoresheet or Field Manual document?	Scoresheet or field manual source for characteristic
Age	Yes	NL3	Yes	NL6
Stand Height	No		Yes	NL6
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	No		Yes	NL6
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	No		No	
Diameter at Breast Height	No		No	
Crown Closure	Yes	NL3, NL7	Yes	NL 6
Time since last stand-replacing - natural disturbance	Yes	NL3	No	
Time since last forest management intervention	Yes	NL3	No	
Evidence of human disturbance	Yes	NL3	Yes	
Minimum Stand Area	No		No	
Age of dominant trees compared to expected life expectancy	No		No	
Spatial and Temporal distribution of Cut and leave areas	No		No	
Mean annual increment compared to the net annual increment	No		No	
Stability of species composition	No		No	
Ecosite / Ecodistrict/ Ecoregion type / Biogeoclimatic Zones	No		Yes	NL6, NL4
Inclusion of existing protected Areas within defintion	No		No	
Landscape Connectivity	No		No	
Seral stage distribution	Yes	NL3	No	
Reference to specific OGF protected areas	Yes	NL3, NL5 + ISO 1	No	

Nova Scotia

Definition characteristics	Does the official definition include the characteristic?	Official Source for mention of characteristic	Is the characterisic included in an official Scoresheet or Field Manual document?	Scoresheet or field manual source for characteristic
Age	Yes	NS 2	Yes	NS 2, NS7
Stand Height	No		No	
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	Yes	NS 2	Yes	NS 2, NS7
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	No		Yes	
Diameter at Breast Height	No		Yes	
Crown Closure	Yes	NS 2	Yes	NS 2, NS7
Time since last stand-replacing - natural disturbance	No		No	
Time since last forest management intervention	No		No	
Evidence of human disturbance	No		Yes	NS 2, NS7
Minimum Stand Area	Yes		No	
Age of dominant trees compared to expected life expectancy	No		No	
Spatial and Temporal distribution of Cut and leave areas	No		No	
Mean Annual Increment compared to net annual increment	No		No	
Stability of species composition	No		No	
Ecosite / Ecodistrict / Ecoregion type / Biogeoclimatic Zones	Yes	NS 2, NS7	Yes	NS 2, NS7
Inclusion of existing protected Areas within defintion	Yes	NS 8	No	
Landscape Connectivity	No		No	
Seral stage distribution	No		No	
Reference to specific OGF protected areas	Yes	NS2	No	

Ontario

Definition characteristics	Does the official definition include the characteristic?	Official source for mention of characteristic	Is the characterisic included in an official Scoresheet or guideline document?
Age	Yes	ON1, LIT5	No
Stand Height	Yes	ON1	No
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	Yes	ON1	No
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	Yes	ON2, ON7	No
Diameter at Breast Height	Yes	ON1	No
Crown Closure	No		No
Time since last stand-replacing - natural disturbance	Yes	ON1, ON2	No
Time since last forest management intervention	No		No
Evidence of human disturbance	No		No
Minimum Stand Area	Yes	ON1	No
Age of dominant trees compared to expected life expectancy	Yes	ON1, LIT7	No
Spatial and Temporal distribution of Cut and leave areas	Yes	LIT7	No
Mean annual increment compared to the net annual increment	Yes	ON1	No
Stability of species composition	Yes	LIT7, ON1	No
Ecosite / Ecodistrict/ Eco region type / Biogeoclimatic zones	Yes	ON1, LIT7, LIT 4, LIT5	No
Inclusion of existing protected Areas within defintion	Yes	LIT 4	No
Landscape Connectivity	No		No
Seral stage distribution	No		No
Reference to specific OGF protected areas	No		No

Saskatchewan

Definition characteristics	Does the official definition include the characteristic?	Official Source for mention of characteristic	Is the characterisic included in an official Scoresheet or guideline document?	Scoresheet or field manual source for characteristic
Age	Yes	SK3, SK4, SK5, SK7	Yes	SK5, SK6
Stand Height	No		No	
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	Yes	SK3, SK5, SK6, SK7	Yes	SK5, SK6
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	No		No	
Diameter at Breast Height	No		No	
Crown Closure	No		No	
Time since last stand-replacing - natural disturbance	Yes	SK7	Yes	
Time since last forest management intervention	Yes (with exceptions)	SK3, SK6, SK7	No	
Evidence of human disturbance	Yes	Sk3	No	
Minimum Stand Area	No		No	
Age of dominant trees compared to expected life expectancy	No		No	
Spatial and Temporal distribution of Cut and leave areas	Yes	SK5, Sk7	Yes	
Mean annual increment compared to the net annual increment	No		No	
Stability of species composition	Yes	SK3	No	
Ecosite / Ecodistrict / Ecoregion type / Biogeoclimatic Zones	Yes	SK7	No	
Inclusion of existing protected Areas within defintion	Yes	SK5	No	
Landscape Connectivity	No	SK5		
Seral stage distribution	Yes	SK5	Yes	SK3, SK5
Reference to specific OGF protected areas	Yes	SK7	No	

Ratings

Definition characteristics	Percentage of use (Offical definition)	Source provinces	Percentage of use (Scoresheet + Source data sources included)	Source provinces (Scoresheet included)	Style of measurement (According to definition and policy)
Age	100%	SK BC ON NB NS NL	100%	SK BC ON NB NS NL	Quantitative
Stand Height	16.67%	ON	33.33%	ON NL	Quantitative
Species based restrictions (tree species eligible for inclusion, and how much of the stand must be in the eligible species)	66.67%	SK ON NB NS	83.30%	SK ON NB NS NL	Quantitative
A Dead wood indicator (including mentions of a presence of snags and logs in all stages of decay)	33.33%	ON, NB	50%	ON NB NS	Qualitative
Diameter at Breast Height	33.33%	ON NB	50%	ON NB NS	Quantitative
Crown Closure	50%	NB NS NL	50%	NB NS NL	Quantitative
Time since last stand-replacing - natural disturbance	66.67%	SK BC ON NL	66.67%	SK BC ON NL	Quantitative
Time since last forest management intervention	33.33%	SK NL	33.33%	SK NL	Quantiative
Evidence of human disturbance	50%	SK BC NL	66.67%	SK BC NS NL	Qualitative
Minimum Stand Area	50%	ON NB NS	50%	ON NB NS	Quantitative
Age of dominant trees compared to expected life expectancy	16.67%	ON	16.67%	ON	Quantitative
Spatial and Temporal distribution of Cut and leave areas	66.67%	SK BC ON NB	66.67%	SK BC ON NB	Quantitative
Mean Annual Increment compared to net annual increment	16.67%	ON	16.67%	ON	Quantitative
Stability of species composition	33.33%	SK ON	33.33%	SK ON	Quantitative
Ecosite / Ecodistrict / Ecoregion type / Biogeoclimatic zones	83.33%	SK BC ON NB NS	100%	SK BC ON NB NS NL	Quantitative
Inclusion of existing protected Areas within defintion	83.33%	SK BC ON NB NS	83.33%	SK BC ON NB NS	Quantitative
Landscape Connectivity	33%	BC NB	50%	BC, NB, NS	Qualitative
Seral stage distribution	50%	SK BC NL	50%	SK BC NL	Quantitiative
Reference to specific OGF protected areas	83.33%	SK BC NB NS NL	83.33%	SK BC NB NS NL	Quantitiative