INTERNATIONAL RESEARCH NETWORK ON COLD FORESTS

ANNUAL CONGRESS

06/10/2022 - 08/10/2022

UNITE
FOREST-HUMAN-MACHINE INTERPLAY

IRN
Cold Forests

UNIVERSITY OF EASTERN FINLAND

UNIVERSITY OF EASTERN FINLAND, JOENSUU

October 6th

Time Zone: UTC + 3 (EEST) Eastern European Summer Time; Helsinki
Venue: Auditorium F100 and online (Hybrid event)

12:00 – 12:30	**CONFERENCE OPENING**	
	Presenter	**Title**
12:30 – 14:00	**Session 1 – FOREST ECOLOGY, MANAGEMENT AND BIOINDICATORS**	
	Yves Bergeron – UQAT, Canada *(Keynote)*	Towards ecosystem management of the Canadian boreal forest.
	Clémence Boivin – UQAT, Canada *(Presentation)*	Multifunctional forestry: Is it possible to encourage simultaneously biodiversity and carbon sequestration?
	Ari Kainelainen – UQAT, Canada (*Presentation, online)*	Wood volume accumulation rates of Balsam fir (*Abies balsamifera*) after two different designs of low-intensity partial cutting in boreal mixedwoods.
	Valentina Buttò – UQAT, Canada (*Presentation, online)*	Endogenous factors of tree growth: the submerged part of the iceberg.
	Jérémie Tixier – Ulaval, Canada (*Poster, online)*	Nesting habitat characteristics of a northern population of chimney swifts (*Chaetura pelagica*) in a forested landscape.
	Mariina Günther – UEF, Finland *(Poster)*	Drivers of kelo wood formation in forest ecosystems.
	Aleksi Nirhamo – UEF, Finland *(Poster)*	Lichen communities on deadwood of *Pinus sylvestris* – project presentation.
	Pemelyn Santos – UEF, Finland *(Poster)*	Dynamics of kelo trees in boreal forest landscapes.
	Jonathan Kusa Kimbukusu – UQAT, Canada *(Poster)*	Controlling speckled alder (*Alnus rugosa* Du Roi) Clausen) to restore productivity in the boreal forest.
14:00 – 14:30	**COFFEE BREAK AND POSTERS**	
14:30 – 15:20	**Session 1 *(cont.)* – FOREST ECOLOGY, MANAGEMENT AND BIOINDICATORS**	
	Maxence Martin – UQAT, Canada (*Presentation, online)*	Tree-related microhabitats: A promising yet underused biodiversity indicator for northern forests.
	Junior Tremblay – ECCC, Canada (*Presentation, online)*	Introgression, phylogeography, and ecological niche: Implications for the Nearctic Woodpecker clade.
	Anoj Subedi – UQAT, Canada (*Presentation, online)*	Increasing temperature makes black spruce more vulnerable to spruce budworm.
	Jeanny Thivierge-Lampron – UQAT, Canada (*Presentation, online)*	Boreal tree species response to a short-term drought.
15:20 – 16:00	**Session 2 – BIOGEOCHEMISTRY AND CARBON CYCLE**	
	Charlotte Angove – LUKE, Finland *(Presentation)*	Leaf water heavy isotope concentrations related to ecosystem-level processes in boreal forests.
	Frank Berninger – UEF, Finland *(Presentation)*	Long term effects of fire on biogeochemistry in permafrost and non-permafrost forests.
	Carsten Meyer-Jacob – UQAT, Canada *(Presentation)*	Impacts of acid deposition on long-term organic carbon storage in northern forest lakes.

October 7th

Time Zone: UTC + 3 (EEST) Eastern European Summer Time; Helsinki
Venue: Auditorium N100 and online (Hybrid event)

	Presenter	Title
12:30 – 14:10	**Session 3 – PALAEOCOLOGY AND FOREST FIRES**	
	Matthew Hurteau – Univ. New Mexico, USA and Adam Ali – Univ. Of Montpellier, France *(Keynote)*	Increasing potential energy flux from wildfire with ongoing climate-driven mortality and increasing aridity.
	Jari Kouki – UEF, Finland *(Keynote)*	Re-introducing fires to fire-suppressed landscapes: Experiences from Fennoscandia.
	Igor Drobyshev – SLU, Sweden *(Presentation)*	Can dendrochronological records reveal fuel-related feedbacks in boreal fire histories?
	Marion Lacand – UQAT, Canada *(Presentation)*	Fire history along an elevational gradient in the northern Finnish Lapland.
	Gargi Tariyal – UEF, Finland *(Presentation)*	Local or regional factors influencing historical forest fires in Fennoscandia.
	Milva Druguet Dayras – UBFC, France *(Poster)*	Ancient sedimentary DNA as indicator of past disturbances in boreal forests.
	Marion Blache – UM and UQAT, France *(Poster)*	Multi-millennial reconstruction of fire-climate-vegetation interactions in white and red pine stands, eastern Canada.
	Jonathan Lesven – UFC and UQAT, France *(Poster)*	Fire, climate, and boreal forest dynamics in eastern Canada during the Holocene: Evidence for recent abrupt changes.
14:10 – 14:40	**COFFEE BREAK AND POSTERS**	
14:40 – 15:00	**Session 3 *(cont.)* – PALAEOCOLOGY AND FOREST FIRES**	
	Cécile Remy – UNA, Germany (*Presentation, online)*	Climate and vegetation controls of Holocene wildfire regimes in the boreal forest of northern Fennoscandia.
	Raphaël Chavardès – UQAT, Canada (*Poster, online)*	Converging and diverging burn rates in North American boreal forests from the Little Ice Age to the present.
	Ana Verhulst-Casanova – UQAT, Canada (*Poster, online)*	Wood anatomy to anticipate the silvicultural potential of future northern sugar maple forests.
15:00 – 15:50	**Session 4 – BIOGEOGRAPHY**	
	Mebarek Lamara – UQAT, Canada *(Presentation)*	Tree maladaptation under mid-latitude early spring warming and late cold spell: Implications for assisted migration.
	Guillaume de Lafontaine – UQAR, Canada *(Presentation)*	Expansion potential of a transcontinental boreal species at its altitudinal limit under climate change.
	Todor Minchev – UQAR, Canada *(Presentation)*	Holocene ecological dynamics of sugar maple (*Acer saccharum*) populations at their northern limits in eastern North America: A multi-proxy approach.
	Marianne Vogel – UM and UQAT, Canada *(Presentation)*	Early Holocene vegetation development on islands of proglacial Lake Ojibway in northwestern Québec.
15:50 – 16:00	**CLOSING REMARKS**	

October 8th

FIELD EXCURSION

Session 1

FOREST ECOLOGY, MANAGEMENT AND BIOINDICATORS

Towards ecosystem management of the Canadian boreal forest

Yves Bergeron

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Abstract

The Canadian boreal forest constitutes one of the last frontier forests in the world. But it is a forest under pressure. Traditional cutting practices have resulted in a greatly decreased percentage of old-growth forest. Fire – a source of soil disturbance that increases fertility – has been suppressed. The forest, once a patchwork of stands of different ages, is now characterized by large cutovers with small and highly fragmented islands of older forest. A change in modern forest management, from simply harvesting wood to managing all forest resources, requires new strategies. Forest managers need ways to reproduce the dominant attributes of natural forests, using practices that emulate natural disturbances and forest dynamics. Speaker Dr. Yves Bergeron will discuss research collaborations that are under way to develop these new approaches.

Multifunctional forestry: is it possible to encourage simultaneously biodiversity and carbon sequestration?

Clémence Boivin

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Abstract

In a context where carbon emissions are twice as high as those in the pre-industrial situation, the Intergovernmental Panel on Climate Change sounds the alarm in its 6th report. To sequester more carbon, it is essential to rely on biogeochemical cycles and natural carbon sinks, such as the boreal forest of Québec. Until recently, carbon sequestration has been neglected in the study of silvicultural practices, preferring the study of specific diversity. We propose to study the functional traits of understory vegetation and soil microbiome in relation to carbon sequestration, on a gradient from east to west of the Québec's boreal forest, following different silvicultural treatments. The effects of mammal herbivory (moose and hare) on understory carbon stocks and rapid carbon cycling will also be measured. The soil microbiome will be studied using the environmental DNA technique. Vascular plants and bryophytes will be sampled to quantify their role in biogeochemical cycles. Finally, grazing tracks and feces will be quantified to assess the effect of herbivory on carbon stocks. This study will link forest carbon dynamics to the functional diversity of several taxonomic groups, and thus determine under which conditions sustainable forest management practices can ensure the joint maintenance of these two important ecosystem services.

Keywords: Bryophytes; Carbon sequestration; Ecosystem-based management; Functional traits; Herbivory; Soil microbiome; Understory vegetation

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Wood volume accumulation rates of Balsam fir (*Abies balsamifera*) after two different designs of low-intensity partial cutting in boreal mixedwoods

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Abstract

This study aims to improve our understanding of the long-term response of residual balsam fir *(Abies balsamifera)* trees to partial cutting practices from two different designs. Growth rates have been reconstructed by estimating the annual wood volume increments from stem analyses. The sampling took place at the Lake Duparquet Research and Teaching Forest (FERLD) in the Abitibi region of Québec, on the sites of previous SAFE *(Sylviculture et Aménagement Forestier Écosystémique)* experiments. In autumn 2021, 20 years following the cutting, we sampled 47 mature balsam fir trees (>40 years old) originating from 6 different sites with 3 types of treatment: uncut control, dispersed cutting and gap cutting (both partial cuttings with removal of ≈ 40% of merchantable tree basal area). In addition to the effect of partial cutting, the effects of neighboring competition and biodiversity have been estimated and their impact on the growth rates of residual trees have been assessed. The neighboring competition was estimated through the calculation of different neighborhood competition indices (NCI). Biodiversity was estimated with the calculation of Shannon Diversity Index (SDI) within the 7-m radii circle, centered on the focal tree. The analysis of wood volume accumulation rates was done with the implementation of generalized additive mixed models (GAMM), with wood volume accumulated by sampled trees being the response variable and diameter at the time of the cutting, NCI, SDI, mean volume accumulation rates for the 20 years prior the treatment and the event of treatment being the predictors. The type of treatment was also added in the model interacting with the effect of time (years after treatment) to account for temporal variability in growth rates. This study provides valuable data on the effect of partial cuttings and on the role of competition and biodiversity on growth rates of residual balsam fir trees. The acquired results should be used to improve the understanding of the effects of partial cutting practices on the residual balsam fir trees, and the role of competition and biodiversity on the wood volume accumulation.

Keywords: Boreal mixedwoods, balsam fir, partial harvesting, neighborhood competition, Shannon Diversity Index, growth rates

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Endogenous factors of tree growth: The submerged part of the iceberg

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Abstract

The northern hemisphere has been experiencing extreme weather events with a frequency and intensity expected to increase due to climate change. Witnessing the effects of environmental fluctuations over many decades, tree-ring density and tree-ring widths are considered reliable metrics to assess the impact of environmental factors and tree performances. Shaped by seasonal dynamics, tree-ring features provide a screenshot of the tree-growth responses to environmental cues. However, environmental variability is only one of the components affecting wood growth, which is a process driven by endogenous factors featuring its own phenology. An integrative framework to study plant phenology, wood anatomy and micro-density has proven that tree-growth intra-annual patterns are modulated by seasonal developmental dynamics involving both primary and secondary tissues. This framework has been tested on black spruce (*Picea Mariana* Mill.), a widespread boreal tree species in North America, with weekly sampling of 5 sites along a latitudinal gradient in Québec performed over 15 years. During wood formation, the interplay between wood cell differentiation stages (*i.e.*, enlargement, secondary wall deposition and lignification) was the main driver of earlywood – latewood transition, indirectly engineering wood-density variation along the ring. During earlywood formation, the differentiation of large cells was supported by a long duration of enlargement, a high-water supply, and a long photoperiod. Conversely, latewood formation started once shoot elongation was achieved, which made available for secondary growth new photo-assimilates that were previously monopolized by primary growth. With favorable temperatures, this increase in resources availability enabled longer duration of secondary wall deposition, which rapidly stiffened the cell secondary wall, shaping smaller latewood cells. If studies on the environmental drivers of density and tree-ring width represent the tip of the iceberg of our understanding of wood formation, there results invite us to carry on with our dive to finally reach the bottom of the iceberg

Keywords: Wood phenology, Boreal Forest, Bud phenology, Wood anatomy, Micro-density, *Picea Mariana* Mill.

Nesting habitat characteristics of a northern population of chimney swifts (*Chaetura pelagica*) in a forested landscape

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Abstract

Chimney swift (*Chaetura pelagica*) populations have declined drastically in the past decades and the species threatened since 2018 in Canada. Loss of roosting and breeding habitats have been identified as the main threats to the species. While little information is known on the nesting habitats in forests, the potential of breeding in natural habitats remains a pending concern and could be an important component for the long-term viability of the species. In the province of Québec (Canada), within the last 55 years, only five nests in hollow trees have been reported, and have been found once the trees were cut. Our main objectives were to find and characterize active swift nesting trees using the Motus telemetry system. We also conducted field surveys to determine tree and natural cavities availability in the study area. The study took place at Lac-Édouard, which is a forested landscape located at the northern limit of the species' range in Québec. The captured swifts were equipped with nanotags and, hopefully, tracked to their nests using seven Motus receiving stations distributed throughout the study area as well as mobile telemetry done by car, boat, off-road vehicles and foot. Over three years of fieldwork, 55 swifts were captured and equipped with nanotags from which five led us to their nesting trees, located at up to 30 km of the roosting site. Out of five nests, four were found in yellow birches (*Betula alleghaniensis*; two live and two dead trees) and one was in a dead sugar maple (*Acer saccharum*). Nesting trees had a mean diameter at breast height (DBH) of 77.7 ± 9.79 and were taller than four meters. Our results suggested that Chimney swifts' nests are more likely to be found in large, living, or dead yellow birches located in old growth deciduous forests. Overall, these results hold promise for the identification and protection of suitable nesting trees, as well as for a better understanding of the swifts' natural nesting habitats, which are key factors for the species' recovery in Québec.

Keywords: Radiotelemetry, tree cavity, avian reproduction, Motus, hardwood forest.

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Ecology meets wood material science: Drivers of kelo wood formation in forest ecosystems

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Abstract

Kelo trees are dead, silver-coloured and debarked Scots pine (*Pinus sylvestris*) trees. They are one-of-a-kind characteristic in old-growth boreal forests, as they may stay stand for hundreds of years after their death. Because kelo trees are products of slow growth and death, their regeneration is not supported by modern forest management with relatively short rotation cycles. Kelos have thus started to disappear from the boreal landscape, also threatening species dependent on kelo trees. The factors causing the formation of kelo trees have not been comprehensively studied. Slow death and influence of fire scars or injuries are some discussed factors. These factors could change the chemical composition of a Scots pine tree, enabling the resistance to decay and longevity of a kelo. In this project we will study how the chemical composition of kelo trees differs from other dead Scots pine trees and trees subjected to forest fires and different injuries. The aim is to unravel the drivers of kelo formation. The study will be done in protected old-growth forests of Finland. Samples for the chemical analysis were collected from study sites established for this project, and from an injuring experiment site as well as from burned forest areas. The extractive content of the samples was analyzed aiming to find the chemicals ~~are~~ responsible for the resistance to decay of kelos and how factors like fire scarring and injuries change the extractive content of a Scots pine tree. Using the results of this project we may find ways to create kelo trees within the modern forest landscape.

Keywords: extractives, boreal forests, resistance to decay, chemical composition, deadwood, fire scarring

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Lichen communities on deadwood of *Pinus sylvestris* – project presentation

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Abstract

I will present my research plans for my PhD project. My PhD project consists of two parts, each of which are connected to larger research projects. The first part is completed in an experimental setup that focuses on the ecological effects of tree retention and prescribed burning. We will be able to look at relatively long-term effects, since 21 years have passed since the experimental treatments at the time of the lichen survey. Lichens have previously been surveyed on the study sites ten years ago, and thus we will be able to investigate the development of the lichen composition since then. We expect tree retention to be able to successfully maintain most of the lichen flora of *Pinus sylvestris*, although species richness may be limited by low habitat heterogeneity. Previous studies have shown the effect of fire to be clearly adverse for epiphytic lichens, however, the formation of deadwood by fire may benefit some lichen species in the long term. The second part of the PhD project is embedded in a research project on kelo trees. I will be looking into, for example, the development of lichen communities on kelo trees over time after tree death, and the effects of wood chemistry on lichen communities. Bark chemistry has a crucial effect on the species composition of living trees, and thus wood chemistry could have a similar effect on dead trees. We expect the species richness and cover of lichens and the presence of rare and specialized species on kelo trees to increase with time since tree death.

Keywords: Epiphytic lichens, tree retention, prescribed burning, kelo tree

Dynamics of kelo trees in boreal forest landscapes

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Abstract

Large-diameter *Pinus sylvestris* trees that have shed their bark and have a distinctive silvery-grey wood surface are known as kelos. The European woodlands have frequently included kelo trees. When a pine tree naturally dies, starts to dry up, and sheds its bark, kelo trees are created. These trees are structural elements of natural forests that have evolved over many generations and last for hundreds of years. A variety of highly specialised fungi and other species can also find a home in kelo trees when they inevitably die or fall. They are common in unmanaged pine-dominated forests and considerably increase substrate and structural diversity at the stand and landscape levels. Kelo trees can also serve as long-lasting carbon storage in forest ecosystems because of their exceptional longevity. Due to their long existence, extraordinarily slow turnover dynamics, and importance for biodiversity, kelo tree populations need to be protected and maintained for forest restoration and sustainable management. In this project, we will study the kelo trees at an individual and landscape levels in three unmanaged boreal forest landscapes, including the influence of forest disturbances such as fire. Tree rings will be used to examine the process of kelo formation through the growth history and time series of tree death. Additionally, patterns and what affects kelo formation, for example, the role of climate and stand fertility, will also be investigated. Kelo standing duration data will be collected from a network of permanent plots and will be analyzed to understand which factors affect the length of time that trees remain standing at the site and tree levels. The knowledge acquired will be applied to creating recommendations for restoring kelo trees to the Finnish commercial forest.

Keywords: dendrochronology, tree-rings, growth history, fire, *Pinus sylvestris*, forest dynamics, boreal forest, cross-dating

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Controlling speckled alder (*Alnus rugosa* (Du Roi) Clausen) to restore productivity in the boreal forest

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Abstract

Since the beginning of the 20th Century, Canadian forestry has been subjected to multiple ecological, social and economic challenges to meet societal demands. In managed stands, dense alder populations result from increased light availability and water table elevation after harvest. Previous studies demonstrated the ability of alder to naturally fix soil-nitrogen, which can therefore contribute to the growth of other plants. Alder may also play an important role in the evapotranspiration balance of forested bogs by lowering the water table. In this context, the presence of alders could, through mechanical site preparation, promote the growth of conifers in forest ecosystems where soil nitrogen availability is low and the water table is close to the surface. On the other hand, alder's dense and abundant foliage can hinder the growth of forest seedlings used to restore production in cut stands. To investigate the potential for restoring wet forest sites dominated by speckled alder to production, in the fall of 2019 we set up a setup in which we tested four site preparation methods (stripping, inversion, chipping, and an untreated control), repeated four times at the Lake Duparquet Teaching and Research Forest. In the summer of 2020, we replanted with black spruce seedlings. During the summer of 2021, we measured the growth of the reforested plants and took environmental measurements (light, soil moisture, soil temperature, competing vegetation) with the recommended equipment and tools in each treatment tested. Once the data were available, we used R software for our preliminary statistical analyses of spruce growth. The results showed that all treatments improved the size and growth of black spruce plants. The environmental and nutritional data being analyzed will further highlight their effects on black spruce growth. These results will be an asset in the context of the management of the boreal forest of Abitibi-Témiscamingue.

Keywords: Mechanical site preparation, silviculture, forest restoration, speckled alder, black spruce, forest management

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Session 2

BIOCHEOCHEMISTRY AND CARBON CYCLE

Tree-related microhabitats: A promising yet underused biodiversity indicator for northern forests

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Abstract

Detailed biodiversity surveys are time-consuming and costly. Some taxa are also often over-represented in these surveys, while others are under-represented due to a lack of interest or difficulty in their sampling. The use of indirect indicators of biodiversity is therefore a compromise to address these different issues. Tree-related microhabitats, *i.e.*, any well delineated structure occurring on tree that can serve as habitat, such as cavities, trunk cracks or microsoils in the bark, are increasingly popular indicators that can indicate the presence of a wide range of taxa. In a recent literature review we produced we however noted that the ecological importance of tree-related microhabitats is still poorly studied in northern forests. Early research has shown that in boreal and hemiboreal regions, tree-related microhabitats are an important attribute of natural forests, especially old-growth forests, and that silvicultural practices can lead to their loss in managed forests. Further, questions related to the impact of climate change on tree-related microhabitats, their restoration or identification by remote sensing remain poorly addressed, although these are important issues in northern forests. The social perception of tree-related microhabitats is also generally ignored in current research. Promoting the study of tree-related microhabitats in boreal and hemiboreal forests would therefore allow to refine our knowledge of biodiversity, as well as the impacts of global changes.

Keywords: Habitat tree, natural reference, biodiversity indicator, biodiversity crisis, sustainable forest management, systematic review

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Introgression, phylogeography, and ecological niche: Implications for the Nearctic Woodpecker clade

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Abstract

The projects funded by a Discovery Grant of the Natural Sciences and Engineering Research Council of Canada (NSERC) address previously unexplored perspectives on the possible existence of introgression of *P. arcticus* (Black-backed Woodpecker) genes into the genome of *P. dorsalis* (American Three-toed Woodpecker) and to assess the evolutionary mechanisms underway between these two species. These are innovative projects presenting a new perspective on the boreal woodpecker group by addressing issues of ecological niche, biogeography, and gene flow to directly provide essential and necessary information for the evaluation of the status of *P. dorsalis* and its subspecies by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The short-term goals under this 5-y Discovery Grant (2022-2027) are to: 1) document the structure and intra and interspecific genetic variation of boreal woodpeckers in North America and assess the existence and possible extent of introgression of *P. arcticus* genes into *P. dorsalis*, 2) determine the validity of *P. dorsalis* subspecies, 3) define the magnitude of their respective ecological niches, and 4) assess their level of overlap, which will offer insights into the strength of divergent selection or the potential presence of niche conservatism, and 5) create habitat niche models of *P. arcticus* and *P. dorsalis* that will be useful in predicting biogeographic responses to expected climate change in the coming decades of these species. Outreach from these projects will provide new insights into the phenomena of introgression and secondary contact that are potentially applicable to other species. For example, in a context of global changes, species will be confronted with rapid modifications, from an evolutionary point of view, in their habitat, involving new interactions with various species and potentially creating areas of "vulnerability" to hybridization. The expected development of tools (niche models) will be useful to predict for potential impacts ecological and evolutionary consequences of expected changes in climate. To achieve these objectives, 3 projects are envisaged, to be carried out by 2 MSc and 1 PhD student. Recruitment of students will start this fall, and expected starting dates are spring/fall 2023 for the MSc and winter/spring 2024 for the PhD.

Keywords: Ecological niche, genetics, habitat selection, *picoides*, phylogeny, species at risk

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Increasing temperature makes black spruce more vulnerable to spruce budworm

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Abstract

Climate change is altering forest disturbance regimes in the boreal biome. Major defoliator in North America, the spruce budworm (*Choristoneura fumiferana*, SBW) outbreaks have a major impact on the dynamism of the Canadian boreal forest by reducing the growth of dominant tree species, increasing mortality, and overall, by declining forest productivity. The increasing extent and the severity of the SBW defoliation in the recent climate change context have posed a continuous challenge to the forest management. Our goal was to evaluate the effect of the interaction between climate and outbreak severity on black spruce (*Picea mariana*) growth during the last outbreak (1968-1988) of the 20th century in Québec. For this, we compiled dendrochronological (2271 trees), outbreak severity (estimated by observed defoliation aerially), and climate data for 164 sites spread across 900,000 km^2. After computing site-specific basal area growth, cumulative defoliation over 5 years, and normalized climatic parameters, we used linear mixed-effects models to determine the standardized interaction effects on the growth. Our analysis revealed that at 70-100% defoliation level, the growth of black spruce was reduced by 2.7% per year. This was amplified by high values of the preceding summer minimum temperatures and the preceding summer climate moisture index that caused a further reduction in the growth of 2.1% and 0.7% respectively. Rather, high values of the preceding spring minimum temperature (1.7%) with the previous summer's high temperature (1.3%) attenuated the negative effect of defoliation. The increase in summer minimum temperature might have shortened the hibernation of SBW, which triggered the earlier emergence of budworm larva with enhanced opportunity to feed fresh tree buds, whereas increased summer maximum temperature was detrimental for larval survival which limited defoliation. This implies that the positive response of black spruce growth to an increase in temperature might be attenuated or even reversed with an increase synchrony between the larval emergence period of SBW and the timing of budburst. Our study improves the understanding of defoliation-climate interactions on tree growth, essential to establish sustainable forest management strategies under climate change.

Keywords: Defoliation, disturbances, dendrochronology, ecological modelling, forest management

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Boreal tree species response to a short-term drought

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Abstract

The current increase in frequency and severity of meteorological extremes such as droughts and heat waves have negative impact on boreal forest water and carbon fluxes. In this study, we analyzed the response of three common and widespread boreal tree species jack pine *(Pinus banksiana)*, black spruce *(Picea mariana)* and trembling aspen *(Populus tremuloides)* to a short-term 20 days drought that occurred during August 2021. We established four monitoring sites with contrasting soil surficial deposits (two on sandy and two on clay soils) in north-western Québec, as part of the pan-Canadian Smartforest monitoring network. At each site, together with detailed environmental monitoring of soil and meteorological conditions, high frequency, and precision stem dendrometers were deployed in April 2021 to continuously monitor stem radial variations. A total of 50 mature trees were monitored including 20 jack pine, 20 black spruce and 10 trembling aspen trees. Data were used to extract tree growth (*i.e.*, irreversible stem radial variations) and tree water deficit (*i.e.*, reversible stem radial variations that can be used to characterize the magnitude of tree water stress). August 2021 was characterized by exceptionally high temperatures (14% above normal values) and low precipitations (44% below normal values). These environmental conditions negatively affected tree water deficit and growth, with the magnitude of these responses varying between sites and species. Our results are an important contribution to the understanding of boreal forest responses to meteorological extremes and will help assess the impacts of short-term meteorological extremes on forest health and productivity.

Keywords: Climate change, dendrometers, drought, ecophysiology, forest ecosystems

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Leaf water heavy isotope concentrations related to ecosystem-level processes in boreal forests

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Abstract

Stable isotopes are non-radioactive variants of elemental atoms, where their differences in neutron frequencies lead to variability in atomic mass. Stable isotope variability in trees is a powerful tool to better understand forest response to climate change, and past climate. Climatic information, and tree-response information, can be stored in long-term stable isotope bioindicators such as the stable isotope variability of tree-rings and leaf n-alkanes. The source of such long-term information for two stable isotopes originates from leaf water heavy isotope concentrations. Leaf water heavy isotope concentrations represent the source water absorbed, and leaf evaporative conditions. Until now, leaf heavy isotope concentrations have been related to single environmental factors, such as relative humidity and temperature. However, amongst ecosystem engineers such as boreal forests, environmental factors are interlinked and related to larger-scale ecosystem processes such as gross primary productivity. Ecosystem-level processes measured by eddy covariance might allow us to better understand the climatic information stored in leaf water heavy isotope enrichment. In this study, we explored the relationship between leaf water heavy isotope enrichment and ecosystem-scale processes in boreal forests. We used a temporal survey of water vapor and *P. sylvestris* leaf water isotopic variability, and eddy covariance data, during 2019 at two boreal forests in Finland. Both forests represented different boreal forests, because one site (Hyytiälä, Finland) represented the southern boreal zone while the other site (Värriö, Finland), represented the northern tree line. The focus ecosystem processes were evapotranspiration and gross primary productivity. Results showed that ecosystem-level processes can be related to leaf water heavy isotope enrichment, but that relationships depend on localized factors. More investigation is needed to better understand the ecological relevance of the lesser-understood stable isotope, deuterium.

Keywords: Boreal forests, ecosystem processes, stable isotopes, leaf water, bioindicators

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Long term effects of fire on biogeochemistry in permafrost and non-permafrost forests

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Abstract

While the immediate greenhouse gas emissions from forest fires have received much attention, long term effect via ecosystem structure and functioning are still relatively unknown. In this talk we summarize our work on the effects of fires on soil greenhouse gas emission in four fire chronosequences from Finland, Russian Siberia, and North-Western Canada. In young forests soils were warmer after fire, due to a reduction of the insulating humus layer. In the two chronosequences on permafrost active layer depth increased from about 30 cm to over 1 m. However, soil respiration after fire was decreased for several decades due to more recalcitrant organic matter and a reduction in microbial biomass and microbial diversity. Changes after fire focused on the top layer and, apart from soil temperature, little change was observed in the lower soil profile. Ecosystem carbon stocks increased during the whole length of the chronosequences. We, also, observed important change in microbial composition after fire: fungal biomass decreased while bacterial biomass was unchanged. Limitations of microbial growth seemed to change with succession after fire with increasing nitrogen limitations. Our research does, therefore, not support our initial hypothesis that fires in the forest zone trigger large carbon greenhouse gas emissions due to disintegration of the permafrost. However, biogeochemical models need to be adjusted to better reflect the decrease in decomposition after fire.
Keywords: Fire, microbial diversity, greenhouse gas, chronosequence, climate change

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Impacts of acid deposition on long-term organic carbon storage in northern forest lakes

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Abstract

Lake sediments are important carbon (C) sinks, removing C from the short-term C cycle; yet little is known about the sensitivity of this sink to anthropogenic disturbances. During the 20th century, atmospheric acid deposition disrupted terrestrial-aquatic C cycling by lowering organic C loads in many lakes across northeastern North America and northern Europe. Recovery from acid deposition has, in turn, increased organic C loads (*i.e.*, freshwater browning). To date, it remains unclear how acid deposition has affected long-term C accumulation rates (CAR). We present CAR, and other supporting infrared spectroscopic, isotopic, and elemental geochemical proxies, for eight lakes near Sudbury, Ontario, Canada – an area that has been heavily affected by acid deposition in the past. Lakes with direct watershed disturbances (*i.e.*, vegetation loss and soil erosion following acidification and metal contamination) showed short-lived CAR increases, but CAR changed little in remote lakes with minimal direct human disturbances. On a landscape scale, CAR did not change during the 20th century (median 1880–2018 CAR: 13.5±0.8 g/m^2/yr). This contrasts with other northern forest lakes with minimal direct catchment disturbances that experienced significant CAR increases during the 20th century. In contrast to these lakes, Sudbury watersheds received higher acid inputs in the past (~25 vs. ~13 kg/ha/yr in 1981–1983). We propose that acid deposition suppressed CAR increases during the 20th century and that, consequently, there is a large potential for increased future C storage in lakes from formerly high acid deposition areas following complete acid-deposition recovery.

Keywords: Paleolimnology, carbon cycling, long-term carbon storage, lake sediments, atmospheric deposition, climate change

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Session 3

PALAEOCOLOGY AND FOREST FIRES

Increasing potential energy flux from wildfire with ongoing climate-driven mortality and increasing aridity

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Abstract

The forest fire area burned is increasing exponentially with increasing aridity in the western United States. Moisture stored in live and dead vegetation acts as a regulator on fire behaviour and area burned. Climate change is altering the distribution of live and dead fuels in forests through drought and insect-induced mortality and simultaneously making dead fuels more flammable because of decreasing fuel moisture. These system changes, both of which are driven by increasing temperature, have the potential to increase the heat flux from combustion, contributing to an increased risk of fires in affected areas becoming plume-dominated. In the southern Sierra Nevada of California and the Rocky Mountains in Colorado, drought and insect outbreaks have increased tree mortality rates, increasing the proportion of biomass that is in dead versus live fuel pools. We sought to determine the contribution that high rates of mortality could have on potential changes in energy release (energy release component and fire radiant energy) for mixed-conifer forests in the southern Sierra Nevada and lodgepole pine forests in the Colorado Rocky Mountains, the site of two large wildfires during the 2020 fire season. We found in both the Creek Fire and Cameron Peak Fire footprints, the proportion of 1000-hour fuels available to burn because they fell below the 30% moisture threshold increased during the 2020 fire season, with approximately greater than 80% of the fuel available by the start of the Creek Fire in July in the Sierra Nevada. Similarly, data from the Cameron Peak Fire in the Colorado Rocky Mountains indicate that a 5% reduction in fuel moisture increases dead fuel availability by 7%. Our results demonstrate that climate-driven tree mortality and increasing temperatures that lead to lower fuel moisture are increasing the amount of energy stored in biomass that is available for combustion.

Keywords: Wildfires, natural disturbance, climate change, Sierra Nevada, Rocky Mountains

Re-introducing fires to fire-suppressed landscapes: Experiences from Fennoscandia

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Abstract

Starting from late 1800s and continuing until recently, Fennoscandia has experienced a dramatic transition from frequently burned landscapes to practically non-existing wildfires. The transition has modified the structure of forests and their biota. As a result of fire absence, several fire-associated species and post-disturbance forest types maintained by fires have become rare. Since the role of fires in maintaining forest structures and forest biodiversity has been widely recognized lately, re-introducing fires to forest ecosystems using controlled or prescribed or restorative burnings is commonly practiced nowadays. Yet, the ecological consequences of fire re-introductions have remained largely unexplored. Since fires vary widely in their characteristics (*e.g.*, severity), their historical occurrence (time since last fires), their effects on different taxa, and their long-term effects, drawing widely applicable yet precise conclusions on the effects of fires on biodiversity and forest characteristics is difficult. Empirical experiences of the effects of fire re-introductions show, *e.g.*, that severity of wildfire have a major influence on how fire modifies species responses; that the response of biota to fires depends on landscape, likely reflecting the historical fire regime in a region; that while many rare taxa benefit from the occurrence of fires, some groups face major risks; and that short- term and long-term effects of fires can be highly variable. Furthermore, these factors are often confounded in real world situations, hampering general conclusions on the effects of fires on biota. Despite the challenges in verifying clear cause-and-effect relations in how fires maintain biodiversity, the overall role of fires in maintaining habitat and species diversity in Fennoscandia appears evident. Re-introducing fires to fire-suppressed landscapes is probably one the most efficient management tools to facilitate and promote disturbance-based dynamics in intensively managed landscapes. However, the most efficient methods for fire re-introductions still waits for further explorations.

Keywords: Restoration, wildfires, prescribed burning, biodiversity, Fennoscandia, boreal

Can dendrochronological records reveal fuel-related feedbacks in boreal fire histories?

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Abstract

A fundamental feature of the boreal fire activity is the uneven distribution of burned areas among years, with single large fire years contributing to more than 90% of the area burned in a geographical region over a period of several decades. Although such events have had a major impact on the fuel availability in the affected landscapes over the following years, such changes have rarely been considered as an factor of self-regulating behaviour of fire activity. In this study, we use a novel approach to access presence of fuel-related feedback on fire activity. We use data from four European boreal landscapes covered by networks of sites with dendrochronologically dated fire histories. The annual fire history of each landscape (around 100^2 km) extended over the last 400-500 years. Our results suggest a presence of a moderate negative feedback limiting fire activity in the years following the ones with large fires. We discuss the limitations of the proposed approach and the role of fuel feedbacks in affecting future fire activity.

Keywords: Boreal forests, ecosystem processes, fire-vegetation feedbacks

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Fire history along an elevational gradient in the northern Finnish Lapland

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Abstract

In mountain boreal environments, wildfires are expected to decrease in frequency or size along an elevational gradient, mainly in response to climate, as well as fuel availability and quality. Here, we evaluated if sites located at different elevations might have different responses to climate change. To this end, we reconstructed Holocene fire histories (~11,000 years) from eight lake sediment sequences sampled in northern Finland. A pair of lakes was sampled in each of four different environments in terms of elevation, latitude, and vegetation type: (1) low elevation pine forests (*Pinus sylvestris*); (2) mid elevation mixed coniferous forests (*Pinus sylvestris* and *Picea abies*); (3) high elevation transitional mixed woodlands (*Pinus sylvestris* and *Betula pubescens* subsp. *tortuosa*); and (4) upper elevation birch woodlands (*Betula pubescens* subsp. *tortuosa*). Regional fire frequency, biomass burned, and fire size were reconstructed from charcoal analysis and compared between the four environments. Our results showed a strong negative correlation between regional fire frequency and elevation. During the cold and humid early Holocene period, trends in regional fire frequency were low but slightly increased following postglacial vegetation establishment. During the warm and dry mid-Holocene period, the regional fire frequency recorded in upper environments increased, due to higher fuel availability and proportion of conifers. During the cool and humid late Holocene, regional biomass burned, and fire size increased at higher elevations, possibly linked to increased anthropogenic activities. In lower coniferous forests, regional fire frequency remained stable, but fire size increased in response to higher spruce proportion.

Keywords: Boreal forests, charcoal particles, northern Finland, fire frequency, elevation gradient

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Local or regional factors influencing historical forest fires in Fennoscandia

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Abstract

Historically fire has been the most important natural disturbance in the European boreal forest. In these forests wildfires have virtually disappeared in the early 20th century. Climatic variations and human influence are the most addressed factors influencing fires, but the role of vegetation as a local scale modifier of fire histories remains poorly understood in the European boreal forest. The aim of this study was to analyze the role of vegetation characteristics for fire occurrence in the Fennoscandian boreal forests. For this, we studied fire history in the strict nature reserves of Salamanperä and Ulvinsalo, in middle boreal landscapes. We reconstructed past fires and studied the fire regime for the past 321 years. We used an existing tree-ring dendrochronological dataset on the occurrence of fires and added new increment core samples from fire-scarred *Pinus sylvestris*. In stands without fire scars, the oldest fire-intolerant trees *Populus tremula, Betula spp. or Picea abies* were sampled to calculate their ages, representing minimum time since the last fire. We then computed fire return intervals for both reserves, and for different site types, and classes of topographic wetness index. Survival analysis was then used to quantify the role of these landscape components on fire occurrence. Xeric sites (dry) had higher probability for occurrence of fire as compared to the mesic sites (moisture-rich) and stands in the Salamanperä reserve were more likely to burn than in the Ulvinsalo reserve. The average fire cycles (1800–2021) was 136 years in *Pinus sylvestris* dominant sites, and 232 years in *Picea abies* dominant sites.

Keywords: Forest fires, boreal forests, fire cycle, site type, biodiversity, vegetation, climate change

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Ancient sedimentary DNA as indicator of past disturbances in boreal forests

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Abstract

Boreal forests occupy 30% of the global forest area and provide many ecosystem services essential to the development of societies (water resources, timber production, maintenance of the global climate balance). Their functioning, structure and dynamics are intrinsically linked to that of natural disturbance regimes, particularly insect outbreaks and fires. While the dynamic of fire regimes in the context of climate change is well understood, insect outbreaks are poorly known, especially those of the spruce budworm (*Choristoneura fumiferana*, SBW), as well as the interaction of these two disturbance regimes. This project therefore aims to answer the following question: how have the cross-dynamics of these two disturbance regimes responded to past and present climate changes? Paleoecology, through its long-term approach, will allows a better understanding of these dynamics. The project will be conducted at a large spatial scale in different bioclimatic domains of Québec, selected as key ecosystems for the understanding of fire/epidemic dynamics. The objectives of our project are: (i) to develop a methodology for reconstructing SBW epidemics, over a 1500 year period through qPCR quantification of sedimentary DNA to obtain a complete warming - cooling - warming cycle; (ii) to investigate the interactions between these two natural disturbances, over the last 1500 years, using sedimentary DNA and macro-charcoals; and (iii) to evaluate the changes in macroinvertebrates communities (diversity and assembly rules) during SBW outbreaks, and the role of these communities in regulating SBW epidemic cycles, using *Next Generation Sequencing*. This project opens the perspectives for a better understanding of the cross dynamics of epidemics/fires in the context of various past climatic changes and would thus allow to better understand and predict the impacts of climate warming on the forest dynamics of Québec.

Keywords: disturbance ecology, fires, insect outbreaks, paleoecology, sedimentary DNA, spruce budworm

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Multi-millennial reconstruction of fire-climate-vegetation interactions in white and red pine stands, eastern Canada

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Abstract

The temperate forest of Québec is composed of two native conifer species: white (*Pinus strobus* L.) and red pine (*Pinus resinosa* Ait.). Of high economic, ecological and cultural interests these species have markedly declined over the last 150 years, mostly as a result of overexploitation, and suppression of surface fires that are essential to ensure stand regeneration. To conserve and restore pine stands in Québec, the government has employed prescribed burning. However, direct human actions are not the only threats to white and red pine forests. Insects and pathogens increase their vulnerability, and climate change might also be an issue. The challenge of this Ph.D. thesis will consist in documenting the effects of climate and surface fires on the regeneration dynamics of white and red pine in Québec, at a decadal to millennial scale. Understanding the historical relation~~ship~~ between fire and vegetation will help identifying key ecological processes and fire regimes (frequency and severity) that maintained populations through time. It will then allow to identify the best practices for restoring, managing, and maintaining pine forests. Specifically, this study aims to develop a method to differentiate surface and crown fires in charcoal records recovered from lake sediments (Chapter 1). A reconstruction of Holocene fire regimes will then be performed (Chapter 2), with a particular focus on surface fires. This part of the study will be conducted using charcoal analysis for fires. Analysis of X-ray fluorescence will also be performed to assess whether changes in chemical element concentrations in sediments over time could be related to fires that may have caused erosion in the watersheds. Finally, vegetation dynamics will be reconstructed for white pine, red pine and other tree species. Particular attention will be paid to the links between fire regime and pine dynamics during the Holocene (chapter 3).

Keywords: pollen, Holocene, charcoal, white pine, red pine, surface fire

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Fire, climate, and boreal forest dynamics in eastern Canada during the Holocene: Evidence for recent abrupt changes

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Abstract

Representing 30% of the global forest, boreal biomes play a key role for human activities and climate regulation. Their dynamics are intrinsically linked to fire, developing mainly in mature stands of black spruce (*Picea mariana* (Mill.) B.S.P.). Recent studies project an increase in fire regimes of Canadian forests under future climate change; however, eastern Québec and Labrador remain poorly studied on a millennial timescale. The objective of our study is therefore to better characterize the mechanisms by which climate change affects disturbance regimes, and consequently forests' structure and functioning. Our study is based on a north-south transect of Holocene lacustrine sediment cores on which we study macrocharcoal, pollen grains and chironomid assemblages to reconstruct fire, vegetation and climate dynamics, respectively. Chronologies were based on ^{210}Pb/^{137}Cs and radiocarbon dating. The warmest and driest periods were characterized by frequent but small fires - depending on the amount of biomass available - favoring pioneer species such as jack pine (*Pinus banksiana* Lamb.). Conversely, wetter and colder periods showed a decrease of fire occurrence, but an increase in their size due to a greater biomass accumulation. Black spruce has been the dominant species on most of the transect for the last 6,000 years. However, since the beginning of the industrial revolution ─our study reveals an abrupt decrease in its abundance and an increase in pioneer taxa. In parallel, macrocharcoal analysis showed an increase in fire occurrence and size, leading to a decrease in black spruce populations resilience, and consequently to an increasing openness of forest ecosystems. In summary, our results suggest that recent and repeated large fires have already altered the vegetation composition and adaptation cycle of the eastern Canadian boreal forests and may radically alter its carbon sink function in the future.

Keywords: boreal forests, climate, fire, vegetation, black spruce, resilience

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Climate and vegetation controls of Holocene wildfire regimes in the boreal forest of northern Fennoscandia

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Abstract

Climate change is expected to increase wildfire activity in boreal ecosystems, thus threatening the carbon storage capacity of these forests, which are currently the largest terrestrial carbon sink in the world. Describing future fire regimes in terms of frequency, size, type (surface *vs.* crown) would allow better anticipation of the impact of climate change on these forests. In Fennoscandia, this objective is currently difficult to achieve due to the lack of knowledge of long-term (centuries to millennia) relationships between climate, fire, and vegetation. We investigated the causes and consequences of changes in fire regimes during the Holocene (~ 11,000 years) on vegetation trajectories in the boreal forest of northern Finland. We reconstructed fire histories from charcoal, vegetation dynamics from pollen, moisture changes from *Sphagnum* abundance, and complemented these with published regional chironomid-inferred July temperature reconstructions. Warm and dry periods of the Holocene favored low-frequency, large surface fires, whereas cool and wet periods were more associated with high-frequency, small crown fires. Higher abundance of *Picea abies* increases the humidity within forest stands and causes a build-up of ladder fuel (low-lying branches) favoring small crown fires. Our results show both a direct and an indirect effect of climate on fire regimes in northern Fennoscandia. Warm and dry periods are conducive to large surface fires, whereas cool and moist periods are associated with small crown fires. Climate-induced shifts in forest composition also affect fire regimes. Spruce forests are moist (smaller fires), and their low-lying branches allow flames to reach the canopy (crown fires), whereas pine forests are drier (larger fires) and have low connectivity between ground and canopy (surface fires). We found little evidence in the past hinting at an increased risk of crown fire occurrence under projected climate conditions in northern Fennoscandia, which will more likely experience large surface fires.

Keywords: Northern Fennoscandia boreal ecosystems, vegetation dynamics, Holocene fire regimes, charcoal, pollen, sphagnum, chironomid-inferred temperature reconstructions

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Converging and diverging burn rates in North American boreal forests from the Little Ice Age to the present

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Abstract

Understanding how burn rates vary over time and space is fundamental to support research on drivers of forest dynamics and elaborate adaptation strategies in the context of climate change. Using 16 fire-history study sites distributed across North American boreal forests, we investigated variation in historical burn rates from 1700–1990. These were benchmarked against recent burn rates estimated for the modern period 1980–2020 using various data sources. Burn rates during the historical period for most sites showed a strong decreasing trend, particularly during the early to mid 1900s. The synchronicity of this decreasing trend across most sites suggests that large spatial patterns of atmospheric conditions at least partly drove decreasing fire activity across North American boreal forests. Compared to the historical period, the modern period showed less variability in burn rates across sites and lower burn rates for all but one site. This suggests that boreal fire activity has predominantly decreased over the combined windows of analysis, and that burn rates during the modern period are broadly within the historical range of variability. We also found mean burn rates during the modern period presented divergent trends among eastern versus northwestern sites, with increasing area burned in western North American boreal forests over the last 50–70 years, consistent with other research findings. Our research highlights the ongoing need to better understand the drivers of changing fire regimes.

Keywords: North American boreal forests, burn rates, historical range of variability, tree cohort records, national fire databases, climatic variability, fire exclusion and suppression

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Wood anatomy to anticipate the silvicultural potential of future northern sugar maple forests

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Abstract

Trait plasticity supports tree growth and survival in multiple environments and is important at the edges of species ranges, with limited tree growth. Xylem anatomical traits determine sap, nutrient flow and mechanical strength. Trait analysis can provide information on species adaptation to extreme climatic conditions. My project studies xylem anatomical traits over the distribution range of the sugar maple *(Acer saccharum)* in Québec, where it finds its northern limit. We intend to understand the links between environmental conditions and wood anatomy in northern populations to determine the species adaptation to its environments. Seventeen sites were inventoried along north-south and east-west gradients from 2019 to 2021. A total of 180 wood disks were sampled, including 6 trees per site. Wood cores will also be sampled to complete the data. The size, number and distribution patterns of wood conductive cells will be identified from microscopy and image analysis. Measurements of wood density via X-ray densitometry and wood fiber quality will help characterize the evolution of wood quality along gradients. Data will be investigated to describe the variability of wood anatomical traits along latitudinal and longitudinal gradients, to link them to climate variations and understand the relation with the wood quality. We expect a higher variability of wood anatomical traits at the northern limit where the inter-annual environmental sensitivity should be higher. We also expect a decrease in fiber quality and wood density northward. Our results will better anticipate how sugar maple will respond to climate change at its northern edge and determine which environmental factor limits its wood quality and growth.

Keywords: Xylem, wood anatomical traits, sugar maple, Québec, wood properties

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Session 4

BIOGEOGRAPHY

Tree maladaptation under mid-latitude early spring warming and late cold spell: Implications for assisted migration

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Abstract

Global warming is predicted to extend the growing season of trees and plants, and advance spring phenology. However, intensification of extreme climate events in mid-latitude forests, from weakening of the jet stream and atmospheric blockings, may expose trees to increased risk associated with more frequent late-spring frosts. Still, little is known regarding the intraspecific variation in frost tolerance and how it may be shaped by local adaptation to the climate of seed origin. As part of an assisted migration trial located in different bioclimatic zones in the province of Québec, Canada, and following an extensive late-spring frost that occurred at the end of May 2021, we evaluated the frost damages on various white spruce (*Picea glauca*) seed sources tested on three sites (south, central and north). The severity of frost damages was assessed on 5376 trees after the cold spell and an early spring warming which advanced bud flush by approximately 10 days on average. The frost damage rate was similar among sites and seed sources and averaged 99.8%. Frost damage severity was unrelated to the latitude of seed origin but was variable among sites. The proportion of severely damaged trees was higher in the northern site, followed by central and southern sites. The proportion of severely damaged trees was linearly and inversely related to tree height before the frost event. Apical growth cancellation was not significantly different among seed sources including local ones, and averaged 74%, 46%, and 22%, respectively, in central, northern, and southern plantation sites. This study provides recommendations to limit the loss of plantation productivity associated with such a succession of spring climate anomalies. Implications for seed transfer models in the context of climate change and productivity of spruce plantations are discussed in the light of lack of local adaptation to such pronounced climate instability and ensuing large-scale maladaptation.

Keywords: Climate change and instability, assisted population migration, late-spring frost, phenology, *Picea glauca*, seed transfer modelling, shoot growth cancellation, white spruce

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Expansion potential of a transcontinental boreal species at its altitudinal limit under climate change

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Abstract

In response to global change, we expect both altitudinal and latitudinal shifts in natural populations. However, the migration of sessile and long-lived species, such as trees, may lag the velocity of contemporary climate change. Colonization of newly favorable environments is predicted to rely primarily on populations currently located at the cold margin of species distribution (leading edge). The eco-evolutionary dynamics of these peripheral populations could deviate considerably from core populations. Specifically, they could exhibit increased dispersal potential, which would increase their ability to locally track the rate of climate change. In this study, we assess intraspecific variation in dispersal potential of marginal white spruce (*Picea glauca*) populations at multiple spatial scales. At the latitudinal scale, we estimated seed-dispersal ability in subalpine stands in the northern part of the closed-crown boreal spruce-moss forest (Monts Groulx, 51.5°N, >800 masl) as well within the southern boreal balsam fir-white birch forest (Monts McGerrigle, 49°N, >800 masl) in addition to low altitude stands in the temperate mixedwood balsam fir-yellow birch forest (Bic and Mitis, 48.3°N, <100 masl). At the altitudinal scale, dispersal capacity is assessed along the elevation gradient in the two mountain ranges. Within the Monts Groulx (northern closed-crown forest), we report significant difference in dispersal capacity according to elevation, which suggests dispersal potential is subject to spatial sorting that modulates the expansion dynamics according to fine-scale climatic velocity. Results differ in the Monts McGerrigle (southern boreal), where there was no difference in dispersal capacity along the altitudinal gradient. However, we report a latitudinal difference across the northern closed-crown, the southern boreal and the temperate mixedwood biomes which suggests that a spatial sorting of dispersal capacity occurred during postglacial migration in response to historical broadscale climatic changes induced by alternating glacial and interglacial conditions.

Keywords: Altitude, dispersal, eco-evolutionary dynamics, global change biology, latitude, leading edge, marginal populations, *Picea glauca*, range expansion, treeline

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Holocene ecological dynamics of sugar maple (*Acer saccharum*) populations at their northern limits in eastern North America: A multi-proxy approach

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Abstract

The use of historical climate-model tree species interactions helps in our understanding of present and future forest dynamics. Changes in climatic conditions during the Holocene and consequent shifts in the composition of the north-eastern North American temperate-boreal forest ecotone might provide key insights to the importance of marginal populations for forest resilience in the context of ongoing climate change. Sugar maple *(Acer saccharum)* is example of a temperate species whose northernmost stands are isolated within the boreal forest. Responses of these stands to past climate change could be indicative of greater changes in the ecotone. This study consists of the historical reconstruction of Holocene dynamics of northernmost sugar maple populations using forest soil charcoal and lake sediment ancient DNA (*seda*DNA). These complementary analyses will allow to decipher the ecological factors driving past occurrence and abundance of the species within the boreal biome. The difference in scales, from local based on charcoal fragments, to regional based on *seda*DNA data, as well as differences in proxy characteristics will allow a more comprehensive inference about past species dynamics. Initial findings support paleopollen data and challenge our understanding of sugar maple ecology and dynamics. The *seda*DNA analysis is in preparation, as it is an emerging field in Québec, and genetic information for maple and companion species are still scarce.

Keywords: Paleoecology, *Acer saccharum*, ancient eDNA, soil charcoal, marginal populations

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Early Holocene vegetation development on islands of proglacial Lake Ojibway in northwestern Québec

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Abstract

At the beginning of the Holocene, the Laurentide Ice Sheet was progressively melting and liberating eastern Canadian landscapes. Meltwater accumulated at the glacier front, forming proglacial Lake Ojibway, which covered western Québec and eastern Ontario for approximately 2,000 years before flushing into James Bay around 8,200 years ago. Paleoecological reconstruction of vegetation development in the area once covered by Lake Ojibway shows that spruce forests were present from the onset, whereas sites located south of the southern extent of Lake Ojibway first went through a steppe period before being afforested. One possible explanation for rapid postglacial forest establishment in western Québec and eastern Ontario is that islands present on Lake Ojibway (paleo-islands) could have been colonized by forests before the drainage of the lake, hence acting as migration outposts. However, this hypothesis had not yet been tested with empirical data. We studied sediments from two small lakes located on paleo-islands (current hilltops) of Lake Ojibway to reconstruct vegetation development and diversity at the local (macro-remains) and regional (pollen) spatial scales. Afforestation occurred between 9,500 and 8,800 years before present, as indicated by a transition from open woodlands to forests. *Pinus banksiana*, *Picea mariana* and *Betula papyrifera* were thus present on the islands almost 1,000 years before the drainage of Lake Ojibway. Diversity indicators show opposite trends for macro-remains and pollen, indicating local complexification and regional homogenization supporting the boreal-mixedwood establishment. Charcoal particles reveal that local fires occurred on the paleo-islands and that vegetation dynamics was affected by fire even during the first stages of vegetation establishment. Our results provide strong empirical evidence for early establishment of mixedwood forest outposts on paleo-islands, which likely fostered colonization of the lowlands following the drainage of Lake Ojibway.

Keywords: paleoecology, postglacial colonization, island biogeography, lake sediments, XRF analysis, charcoal analysis, macro-remains, pollen

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