CIF Forest Ecology Working Group Workshop

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Abstracts

(with contact information for senior author only)

1. *What is resilience in forestry? - is the term another dead end or can it be applied across scales?*

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Although there is reasonable consensus that managing for resilience will improve forest management and ensure longterm ecological sustainability, the application of this concept tends to be much more contentious. In large part, this may be due to the multiple definitions/conceptions that are in use, as well as the lack of understanding of the specific components to be managed for to make a forest resilient. As with other paradigms in ecology and forestry, the interpretation and evaluation of resilience also tends to vary with spatial and temporal scales. This talk will investigate the different concepts of resilience that are currently dominant (ecological to social), attempt to debunk some of the myths about its application, and propose a method for evaluating its application to sustainability across scales.

2. Resilience of Western Forests to Mountain Pine Beetle Outbreaks

Phil Burton, René Alfaro, Brad Hawkes, Mat Brown, Andy Black, Alan Vyse, Chris Hawkins, Craig DeLong and others

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The current outbreak of mountain pine beetle now affects more than 16 million ha in British Columbia, and 6 million ha in Alberta remain susceptible to attack. This issue has been responsible for aggressive control and salvage efforts, revised timber supply projections, and the expenditure of hundreds of millions of public dollars. However, empirical assessments of affected areas reveal that impacts are not as severe as generally assumed. Even in outbreak centers and pure stands of pine, it is unusual for all pine trees to be killed. Most of the affected pine is not found in pure stands, so other tree species thrive under reduced competition. In the BC Interior, about one-half of the pure or near-pure stands of lodgepole pine have understories stocked with spruce or other tree species. Even where pine is the only tree species, an uneven-aged stand tends to develop. Eddy flux measurements of CO_2 balance indicate greater net carbon uptake in beetle-affected stands than expected. Where there is little advance regeneration, stands may continue serving as carbon sinks due to an increased growth of shrubs. Beetle-affected stands often burn eventually, leading to the regeneration of even-aged stands of lodgepole pine. Stand development models and inspections of past infestations indicate that beetle-attacked stands remain forested and recover naturally. These facts can be used to strategically protect the timber supply. A mountain pine beetle outbreak is not an ecological disaster for lodgepole pine forests, as the pine-beetle-fire system is a co-evolved and highly resilient one.

3. Implications of incorporating considerations of post-MPB secondary structure for mid-term timber supply in the Prince George Timber Supply Area.

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Post-MPB secondary structure measured in 1370 mature leading pine samples in the Prince George Timber Supply Area (PG TSA) indicate significant levels of advanced regeneration (AR) in most biogeoclimatic subzones. VDYP7 and SORTIE ND natural stand growth and yield models are employed to predict growth of AR using species composition and SI (site index), as well as basal area, DBHg and density based on medians. Estimates are made of the equivalent age of AR where VDYP7 growth estimates are used. In British Columbia, traditional timber supply modeling does not incorporate considerations for AR because it is not collected in standard forest inventories and timber supply models have not been built to model it. The SELES (spatially explicit landscape event simulator) timber supply model is modified to incorporate AR into harvest forecasting.

SELES modelling for the PG TSA predicts that incorporating AR results in a 5.7 percent increase in mean mid-term harvest level (years 15 to 60) compared to a base case forecast. For a scenario where stands containing no AR, or low equivalent ages of AR are prioritized for short term salvage harvest, the mid-term is increased by 8.9 percent. For a scenario where stands with high equivalent ages of advanced regeneration are reserved from harvest during salvage the initial salvage period must be shortened by two years and the mid-term harvest level is increased by 15.4 percent. Refinements to existing policy protecting stands with advanced regeneration may be needed to fill the mid-term timber supply gap.

4. Grassland or forest? The impact of the mountain pine beetle on ponderosa pine forests in the southern interior.

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The mountain pine beetle (*Dendroctonus ponderosae* Hopk.) epidemic in British Columbia has severely impacted ponderosa pine (*Pinus ponderosa* Dougl. ex Lawson) stands in parts of the southern interior. We studied the impact of the epidemic by installing permanent transects in forest stands dominated by ponderosa pine. 12 one kilometre transects were established in the Thompson valley west of Kamloops, B.C. and 10 in the South Okanagan valley. Mountain pine beetle mortality was severe in the Thompson valley with over 95% of ponderosa pine larger than 30 cm dbh killed on all transects over a three year period. Associated western pine beetle (*Dendroctonus brevicomis* LeConte) attacks also caused some mortality. In the South Okanagan, there were very low levels of mortality from mountain pine beetle but western pine beetle killed patches of large trees. All stands had experienced varying degrees of disturbance in the past. Almost all ponderosa pines sampled were younger than 120 yr suggesting there was widespread severe disturbance between 1880 and 1910. Historical records indicate that there was logging throughout the range of ponderosa pine in the province at that time.

While stands were resilient in the past, ponderosa pine stands may disappear in some areas as aresult of the pine beetle. Where current stands are dense, the future stands may shift to interior Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) or grassland. More open stands have advance regeneration of ponderosa pine and may recover to a form a ponderosa pine stand. Impacts of these changes will be discussed.

5. Defoliating Insects as cross-scale factors in northern forest ecosystems

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Native forest insects come to the attention of foresters as pests; competitors for forest values and indicators or the cause of declining forest health. As we recognize larger spatial and longer temporal scales as the context of forest ecosystem management, our assumptions about the role of insect outbreaks requires re-evaluation. The science of ecosystem resilience offers a modern perspective on the organization and behaviour of complex structures such as forest ecosystems by casting insect outbreaks as cross-scale factors which influence the stability of forest ecosystems and the sustainability of the values they provide. Learning how to measure and analyze appropriately the influence of these cross-scale factors on forest dynamics will allow more informed interpretation of the risk of outbreaks in terms of costs and benefits of disturbance.

6. Mortality following forest tent caterpillar outbreaks and its effect on succession and residual tree growth

Benoit Gendreau-Berthiaume, Daniel Kneeshaw, Brian Harvey

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Forest tent caterpillar (FTC) is an insect defoliator that has an important impact on the boreal mixedwoods across Canada. Recently, many aspen stands have suffered important dieback and mortality following FTC outbreaks, drought or both of these disturbances simultaneously. This study evaluated when trembling aspen mortality occurred following an FTC outbreak in three trembling aspen dominated stands in Quebec and how these forests recovered following mortality. To estimate the time of death following the 1999-2002 FTC outbreak, we sampled disks from dead trees in 2009 and cross-dated their chronologies with a reference chronology built with cores from living trees. Recovery was evaluated by tree composition in 6 height classes (5-30cm, 31-60cm, 61-99cm, 1-2m, 2.1-4m and >4m). Smaller stems usually died first with 35% and 62% of dead stems < 17cm DBH dying before or during the FTC outbreak respectively. A larger number of individuals over >17 DBH died following the outbreak with 24%, 39% and 37% of dead stems sampled dying before, during and after the FTC outbreak respectively. Following mortality, residual balsam fir trees and balsam fir advance regeneration > 1m tall (in 2009) had rapid growth increases while balsam fir < 1m tall had less important growth increases probably due to the high density of shrub species. In all the height classes sampled shrub species had densities at least twice as high as tree species which indicates that shrub competition might slow the regeneration process following mortality in these stands.

7. Variations in intra-annual wood formation, and foliage and shoot development of three major Canadian boreal tree species

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To better understand how trees are reacting to the warming climate during a growing season, intra-annual growth of stem xylem, shoot and foliage of *Pinus banksiana*, *Populus tremuloides*, and *Betula papyrifera* was monitored in a boreal forest in Quebec. Xylem formation, shoot elongation and foliage expansion were measured at weekly intervals from May to September. Standardized residuals of their growth curves were used to identify climate-growth dependences. The onset and termination of xylem cell formation of *P. banksiana*, *P. tremuloides*, and *B. papyrifera* was detected on May 7, May 28, June 5, and August 9, August 16, August 16, respectively. Of the three species, *P. banksiana* had the earliest budburst (May 20) yet the latest completion date of the foliage growth (August 2); *P. tremuloides* had the latest budburst (May 27) yet the earliest completion date of the foliage growth (July 10); Compared with *P. tremuloides, B. papyrifera* had an earlier budburst (May 22) but later completion date of both extension and xylem growth (July 30). Air temperature positively affected shoots extension growth of the three species; Precipitation positively influenced stem growth of the two broadleaf species, whereas temperature positively impacted stem growth of *P. banksiana*. The results show that both environmental dependences and timing of growth processes differ strongly among co-occurring species, thereby possibly leading to different vulnerabilities to extreme climatic events. Under climate warming, tree species with short duration of shoot and foliage growth like *P. tremuloides*, might be more vulnerable to unfavourable conditions during leaf growth like droughts or potentially late frost in the future.

8. **Sway patterns of boreal forest conifers ten years after thinning**

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Tree sway and frequency of crown collisions play an important role in overstorey canopy dynamics. In stands with high densities and stem slenderness, collisions between tree crowns help to stabilize trees in high winds by the transfer of wind energy from one tree to another. This study re-examines the tree sway patterns of a stand of even-aged lodgepole pine *(Pinus contorta* var. *latifolia)* 10 years after thinning from below, in which 50% of stems were removed. The original experiment established in 1998, examined how tree characteristics (slenderness, height, diameter) and thinning affected tree sway patterns and associated crown collisions under high wind conditions. Pre-thinning sway patterns of the instrumented trees were circular in shape indicating the occurrence of many low intensity crown collisions with neighbors. After thinning, sway patterns were found to be elliptical in shape indicating that sway dynamics shifted after the treatment (Rudnicki *et al.* 2003).

Now ten years later, this research study sets out to evaluate how tree growth responses have affected tree sway patterns. Data suggest that tree sway patterns of the sensored trees have returned to pre-thinning, circular shapes implying that the boles of trees have adapted to the new wind regimes. We plan to measure eccentric growth along the boles to determine if compression wood was formed to stabilize the sway patterns of the trees following thinning. As well, we plan to map the crown interaction using GIS software to determine if a reduction in the number of intense crown collisions has occurred among sensored trees.

9. *Effects of site characteristics and Tree Ageing on Radial Growth and Wood Density of Thuja occidentalis* L.

Bouslimi Besma, Koubaa Ahmed and Yves Bergeron

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To ensure the sustainability of the Quebec forests, a suitable use of the available forest resources is crucial. Eastern white cedar *(Thuja occidentalis L.)* is a valuable timber species with both commercial importance and ecological values. Its potential for value-added applications and his availability, led us to study the characteristics of its wood and the sources of its variation. The main objective of this work was to study the site, inter-tree and within tree variations of growth, density, anatomical, chemical and mechanical properties of eastern white cedar wood. Ten sites were selected in the Abitibi-Témiscamingue region. Forty trees per site were randomly sampled to study the site variation of growth and wood density using X-ray densitometry. Fifteen trees were also sampled and harvested in three different ecological sites to study the site and within tree variations of selected anatomical, chemical and mechanical wood properties and to examine the effect of ageing on these attributes. The patterns of radial and longitudinal variations of ring width and density were established. In mature wood, ecological site, trees within site and growth year showed the most important effects on wood density and growth but cambial age had no significant effect on wood density for non aged trees. For aged trees, growth, wood density, anatomical, chemical and mechanical properties decreased substantially for wood formed at ages higher than 100 years. The variation of growth and wood density with site followed a latitudinal gradient. Northern stands showed higher density and slower growth compared to southern stands.

10. **Carbon, fire, and fuel management in fire-prone forests**

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When do fire management activities increase greenhouse gases emissions or sequestration? This presentation describes approaches for dealing with carbon stocks and flows while managing fire and a full range of natural resource values in fire-prone forests. In many dry-forest settings, fire has been a natural ecosystem process. In response to a changing climate, longer fire seasons and increased fire weather severity are anticipated, which may result in more fire ignitions, larger fires, and increased fire duration and severity.

To address climate change, relationships between fire management and carbon emissions and storage need to be understood. Carbon dioxide (CO_2) contributes to climate change. Forests emit CO_2 (and other gases) when they burn and decompose. Simultaneously, as they grow, unburned forests across the landscape (and areas re-generating after fires) take in atmospheric CO_2. This means that forests actively recycle CO_2. Use of fossil fuels also releases CO_2. However, underground fossil-fuel deposits have no such capacity for taking in CO_2 from the atmosphere.

There are ways of managing fire-prone forests to protect people and their communities, reduce costs (of fire-fighting, rehabilitating post-fire conditions, and regenerating new forests) while maintaining and protecting carbon stored in those forests. By reducing fuel hazards, other forest values can be maintained or protected; these include water and air quality, aesthetics, recreation, tourism, native vegetation and habitat, site productivity, and forest health. The presentation will compare the effects on carbon dynamics of three approaches that can be applied to fire-prone ecosystems: fire suppression, fuel reduction and restoration treatments, and Wildland Fire Use.

It will be challenging to strategically weigh tradeoffs when striving for maximum carbon pools and minimizing carbon emissions while addressing fuel hazards and fire risk and considering other forest values and climate change.

11. The impact of pre-fire cover type on the post-fire composition and structure of upland forest in the boreal mixedwood region of Alberta

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In this a study we examined the influence of pre-fire cover type on composition of post-fire regeneration in Alberta. Measurements were collected in five selected fires. Within each of these fires, areas with pre-fire dominance by white spruce (C), and by conifer- (CD) and deciduous- (DC) dominated mixedwoods and pure decidous (D) cover types were identified and sampled. In all 10 – 13 year old fires the unstocked proportion of plots averaged 9% in deciduous (prefire) stands and 43% in coniferous stands. However, when using a lower height limit of 0.3 m, 5.6% (D) to 23% (C) of plots would be considered unstocked. The proportion of plots stocked after the fire was positively correlated with pre-fire abundance of the deciduous component. Overall, the mean conifer density was much lower (3,570 trees/ha) than the mean deciduous density (12,225 trees/ha). There was a high level of variation in regeneration density between fires as well as between pre-fire cover types within each fire. The *Populus tremuloides* and *P. balsamifera* potential crop trees were tallest in the DC (pre-fire) stands (average 5.13 and 4.34 m, respectively) while white spruce were tallest in the CD stands (average of all trees 0.76 m) 10 to 13 years after the disturbance. In terms of stocking and density, pre-fire deciduous stands showed the quickest recovery while mixedwood stands had taller trees. In all cases the pre-fire conifer stands showed the lowest abundance of regeneration. n this presentation we will present results from this study and discuss their implications to regeneration, sustainable management, and ecosystem resilience.

12. The impact of cattle grazing on aspen regeneration on crown lands in western Manitoba

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In North America there has been an increasing appreciation for the value of trembling aspen (Populus tremuloides Michx) as a source of timber. Moreover, aspen stands and the understory vegetation that they support also provide valuable forage for livestock and wildlife. Timber harvesting and cattle grazing are often done on the same area of land, though not simultaneously. The purpose of this project is to summarize the effects cattle grazing has on regeneration numbers and forest health in post-harves aspen stands in the aspen parkland of western Manitoba.

Stem density, tree health, and understory diversity are compared in nine grazed and nine ungrazed sites spread across a 12 year harvesting chronosequence. Experimental design consisted of three stand age classes (2-3 years, 5-8 years and 9-11 years-old), of either grazed or ungrazed harvested aspen stands. Environmental data were collected to establish supplementary correlates of species performance. These variables included soil compaction, soil texture, drainage class and an index of grazing pressure.

13. Height growth of white spruce following hardwood release

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In the western boreal forest the two primary species, trembling aspen (*Populus tremuloides* Michx.) and white spruce (*Picea glauca* [Moench] Voss) usually occur in mixtures, with spruce overtopped by aspen until late in natural stand development. Competition between these species for light and other resources makes it difficult to determine the true site productivity of white spruce since it often impossible to select a true competition-free white spruce tree. Existing site index curves for white spruce ignore effects of aspen competition on spruce. This study attempts to evaluate the true site index for white spruce released from aspen canopy. I used plots established by the Canadian Forest Service in the 1950's in control (mixedwood) and aspen removal (spruce retention) treatments across the mixedwood boreal forest in Saskatchewan and western Manitoba. These plots have been re-measured approximately 5, 10, 30, 50 and 60 years following treatment. I sampled trees from the buffer region north of each plot to reconstruct detailed height growth trajectories using stem analysis. The stem analysis work and the historical measurements will provide data for reconstructing site index curves quantifying potential gains in site index for released white spruce stands compared to white spruce in the mixedwood. We will present preliminary results illustrating the magnitude of the competition release. Understanding the trade offs in growth of single vs. multiple species will be beneficial to forest managers who are interested in sustainable management of this region.

14. The Effect of Physical Interactions and Understory Light Conditions on Long-term Stand Dynamics in White Spruce and Aspen Boreal Mixedwoods

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Aspen and white spruce mixedwood forests are widespread across western Canadian boreal forests. About 50-80 years after disturbance the slower growing white spruce starts to grow through the aspen canopy and is subjected to physical abrasion by aspen swaying on windy days. Abrasion and reduced light levels can negatively affect understory spruce. This study examined the importance of physical interactions and competition for light on the growth of white spruce into aspen canopies.

The research was conducted in CFS white spruce release plots established in 1951-1954 in Saskatchewan. Detailed tree data and hemispherical images quantified spatial variation in understory light conditions and crown architecture. The effect of physical abrasion of spruce by aspen on spruce mortality and growth was determined. Light levels around each spruce tree were estimated using the LITE model (Comeau 2002) and correlated with spruce survival and growth.

Physical abrasion has a significant effect on spruce growth and mortality, with a three-fold reduction in volume increment for trees with moderately to severely damaged leaders, compared to undamaged trees. Variations in understory light levels had a lesser, though still significant, influence on spruce growth. Current emphasis in boreal mixedwood management is on retaining "intimate mixtures" following variable retention harvest and regenerating stands to meet a variety of ecological and management objectives. White spruce trees growing in close proximity to aspen are negatively influenced by physical abrasion. Stand tending operations may be required to remove these close competitors, while retaining some deciduous trees on site for ecological benefits.

15. Silvicultural options for mixedwoods and their implications

Phil Comeau and Mike Bokalo

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Mixedwood stands composed of combinations of trembling aspen and white spruce are an important and prominent stand type in the boreal forests of western Canada. By virtue of their greater species and structural diversity and their reduced vulnerability to fire than pure spruce stands they are more resilient than pure spruce stands. Aspen can also facilitate establishment of white spruce through reducing other competing vegetation and providing protection from winter injury and frost. However, aspen also competes with white spruce, reducing its growth rate end extending the length of a spruce rotation (while potentially increasing spruce wood quality), and the presence of dense aspen cover can increase hare browsing of young seedlings. In this presentation we will explore some of the yield, economic and ecological implications of some silvicultural options that are intended to accelerate spruce growth into the main canopy. These options include selective spot and thinning treatments, as well as banded and cluster planting treatments.

16. Climate change and silvicultural options: caught between a frost and a hot place?

Andrew Park

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Attempts to project the future growth, disturbance rates and migration of forest trees have proliferated as evidence for global warming has accumulated. Under the influence of this research, forest managers expect that forest operations will have to change in a warmer world. Although a few adaptation projects have been initiated, the avenue from problem analysis to sustainable forest management in a warming world remains unclear, and the future is fraught with “unkown unknowns”. Under these circumstances, the management goal of maintaining “resilient” forests within historic boundaries of “natural” variation may lose relevance as the changing climate stretches the elasticity of current ecosystems towards the limits of resilience.

In this presentation I argue that excessive focus on “resilience” fails to capture the integrated forest ecosystem responses that will occur as global warming proceeds. A more useful approach to achieve understanding will be to investigate suites of whole ecosystem properties operating at different scales. Investigations of ecosystem inertia (resistance to change), alternative trajectories (especially climatically induced bifurcation points), elasticity and persistence merit detailed and individual attention. Insights into these ecosystem-wide processes can be enhanced by investigations of individual tree responses to climate change. In this context, there is strong evidence that species phenologies are already responding to warming temperatures. Species also display idiosyncratic growth responses to enhanced CO2 that range from 500 percent greater growth to 50 percent growth reduction, underscoring the possibility that “no analogue” species communities may be better adapted to future conditions than most forest types that are currently managed.

17. Beautiful plantations: how to make them more ecologically resilient

Christian Messier, Alain Paquette and Conny Garbe

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Plantations are increasing all over the world due to the extremely high yield we can get from them. They can also, in some cases, produce many useful other ecological services such as quality water, carbon sink, habitats for many creatures, etc. Yet, they are heavily criticized by many for their monotonous structure and function that harbor low biodiversity. In this talk, I will discuss how we could design better plantations at various spatial scales that could not only provide better ecological services, but also be more resilient to threats due to global change. I will also present a new worldwide network of high density functional diversity plantations that are set up to help us design more productive and resilient novel forest ecosystems. The core approach is the establishment and monitoring of a series of experimental high-density tree communities of single and mixed native and exotic species in three different areas in north-eastern America and in one area in Poland.

18. Evaluating functional resilience of ectomycorrhizal fungal communities

Melanie Jones and Lori Phillips

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Ectomycorrhizal fungal communities are highly diverse, even within a single forest stand, yet we know little about functional diversity amongst species within these communities, nor the response of functional traits to disturbance. Given the assimilative nature of fungal nutrition, and the importance of ectomycorrhizal fungi to both host nutrition and nutrient cycling in forest ecosystems, secretion of enzymes involved in the catabolism of organic macromolecules can be considered an important functional attribute. In two separate studies, we assayed ectomycorrhizas for up to eight hydrolytic or oxidative enzymes in order to test the resilience of this functional trait to fertlizer inputs or disturbance by wildfire or clearcut logging. Enzyme profiles at the scale of the ectomycorrhizal community (i.e., activities averaged across ectomycorrhizas formed by different fungi) varied little in response to wildfire or clearcut harvesting, or to long-term fertilization. This occurred even when the species composition of the fungal community changed. Instead, it was the fungal species forming the mycorrhiza that seemed to drive differences in enzyme profiles amongst root tips on an individual seedling. Furthermore, response of enzyme activities to fertilization depended on the fungal species colonizing the roots. These results indicate that functional complementarity exists amongst ectomycorrhizal fungi within a community, and that this, in turn, can contribute to functional resilience of the community to major disturbance or perturbation.

19. Complexity, adaptability, diversity, resilience – making fuzzy concepts operational

Klaus Puettmann

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The presentation highlights the benefits, insights, and shortcomings of viewing forests as complex adaptive systems (CASs). I will relate CAS to recent advances in resilience and the diversity-stability debate. Throughout the talk I will emphasize how such "fuzzy concepts" can be useful when making practical silvicultural decisions.