List of Abstracts (last updated June 2, 2017)

(Ordered alphabetically by last name of first author)

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If we plant, what should we plant? Matching seed sources to new climates

Climate change is generating a mismatch between tree populations and their local climates. Migration rates of tree species are an order of magnitude slower than the rate at which climatic niches are shifting, and populations already lag behind their historic environments. The long-held rule of thumb that trees planted should be grown from locally collected seed is becoming less effective for managing within-species genetic variation and adaptation to climate. Assisted gene flow (AGF, Aitken and Whitlock 2013), also known as climate-based seed transfer, is the practice of changing seed sources for reforestation within an existing species range to facilitate adaptation to new climates. While AGF is often discussed more broadly with assisted migration (AM) of species, the two differ in that AGF is mostly a genetic issue while AM raises broader ecological issues.

AGF can be used to increase the local frequency of pre-adapted individuals which has the potential to improve forest health and forest productivity under new climatic conditions compared to status quo seed sources. The genetic knowledge gained from a long history of provenance trial research with forest trees as well as more rapid genomics-based techniques and short-term seedling experiments can inform AGF (Aitken and Bemmels 2016). Research has consistently shown that populations of temperate and boreal species in western North America are most strongly locally adapted to low fall and winter temperatures, so AGF should match trees with near-future rather than distant-future climates to avoid cold injury. Other potential risks of AGF include uncertainty around climate change projections and disruption of local adaptation to non-climatic biotic and abiotic factors. Natural regeneration will provide some genetic buffering to risks of AGF. Results from a large-scale phenotypic and genomic study of adaptation to climate in populations of lodgepole pine (Pinus contorta) and interior spruce (Picea glauca, P. engelmannii and their hybrids) from across western Canada will be used to illustrate these issues.

D. Amsalu (1)

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The impact of land use and land cover changes on deforestation in Alberta from 2000 to 2010

The main objective of this paper was to quantify and characterize the effects of different land usechanges on deforestation in Alberta from 2000 to 2010 using Geographic Information systems (GIS) database from the Alberta Biodiversity Monitoring Institute (ABMI). The results revealed that about 1.8 million hectares of forests that account for 5.5% of the total forest land were cleared in Alberta over the period of 10 years. Approximately 90% of the forest loss was caused by the forest companies and forest fires, and only 2% was caused by the developmental activities such as oil and gas, and urbanization. On the other hand, on the agricultural land, there was a net forest gain of 0.2% due to increased afforestation efforts. The spatial map showed that the majority of the forest loss was concentrated in the north-eastern and north-western corners of Alberta, which was caused mainly by the forest fires. The forest loss in the central part of Alberta was caused mainly by the developmental activities that have been raising in the Edmonton-Calgary corridor over time.

S. Andrews-Key (1), C.P. Laroque (2), & M. Johnston (3)

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Vulnerability and adaptation to climate change in sustainable forest management and the forest industry in Saskatchewan

As the climate continues to change, forest ecosystems are experiencing stresses that have not been seen in the historical past. These changes are impacting many facets of forests in Saskatchewan and will have implications for forest practitioners and industry in their efforts to achieve sustainable forest management (SFM) objectives and goals. With this in mind, on a national level, the Canadian Council of Forest Ministers has recommended that it is essential to consider both climate change and future climatic variability in all aspects of SFM. Policy and management practices need to evolve in the face of an evolving climate. What does a changing climate and its impacts on forests mean for industry? Mistik Management Ltd. Manages 1.9 million ha of boreal forest in northern Saskatchewan. Mistik is dedicated to practicing responsible forest management that provides sustainable wood products and maintains healthy ecosystems and communities. Mistik realizes that in order to do this sustainably for the future, ongoing climatic changes need to be addressed. Current and future risks of Mistik's management area, including both the biophysical and management aspects of their practices need to be incorporated into forest management plans. Adaptive management tools and techniques are essential for Mistik to continue to adapt to the rapidly changing climatic conditions. A vulnerability assessment of their management area using a practitioner's guidebook developed by the CCFM is currently underway. Through this assessment, Mistik's adaptive capacity is also being analyzed. Based on the vulnerability assessment and the analysis of their adaptive capacity, we will work with Mistik on incorporating the results into their 20-year forest management plan.

M. Aquino (1), A. Velazquez (1), M. Acosta (1), & J. Etchevers (1)

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Carbon concentration variability in three tropical tree species of the Sierra Madre del Sur of Oaxaca, Mexico

In this research we measured carbon concentration (CC) in three native tropical tree species of the Sierra Sur of Oaxaca, Mexico. We analyzed the variation of CC in tree components (stem, branches, and leaves) for different tree size in Alchornea latifolia Sw, Cupania dentata DC., and Inga punctata Willd. The values obtained from the CC were lower than the assumed value of 50 % to estimate the tree biomass. In all three tropical species, CC in different components and sizes ranged from 43.9 to 49.3%. In general, we found that the leaves have significantly highest CC than branches and the stem, however, there are not significant differences about CC in tree size. The average CC in the stem, branches and leaves was 45.48 Â± 0.39, 45.20 Â± 0.22 and 46.41 Â± 0.38%, respectively. Hence, variations in CC should be considered to improve the accuracy of estimates of carbon content in tropical trees.Key words: carbon, biomass, Cupania dentata, Alchornea latifolia, Inga punctata

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Caribou habitat degradation under changing climate and fire regimes in northern Alberta

Habitat management across large regions represents a significant challenge for land managers, who must balance multiple species and populations against industrial development under accelerating climate change. While multiple tools exist for assessing habitat quality, few are suitable across regions larger than 1 Mha, and fewer still account for changes in land cover or disturbance processes with changing climate. In this study, we use an adaptive and modular spatial framework to assess the habitat quality of woodland caribou (Rangifer tarandus caribou) in a 6.37 Mha area in northeast Alberta under baseline (i.e., current) conditions and future conditions as predicted by 3 global circulation models. Topo-edaphically constrained projections of vegetation change are combined with projections of fire-regime change, as modelled using the Burn-P3 fire simulation model, to produce an index of caribou habitat quality, accounting for nutrition, predation risk, and landscape connectivity. Our results point to significant expansion of deciduous woodland and grassland cover, with dramatic decline of upland conifer and mixedwood forests. This corresponds to a dramatic decline in caribou habitat quality across the study area through limited nutrition and increased predation risk. While we forecast heavy habitat degradation in some areas, we also identify regions that are likely to serve as refugia retraining moderate to high habitat quality into the future. This information may inform the use of conservation resources to ensure that critical habitat is preserved into the future.

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Canopy disturbance history and structural complexity of a temperate deciduous forest

Stand structural complexity enhancement is an increasingly popular management objective, especially on public lands. Complex stand structures are hypothesized to support relatively high native forest diversity and be more resistant and resilient to disturbance. Complex structures are characterized by heterogeneity of tree size classes and tree architecture and the presence of deadwood. We know relatively little about the discreet disturbance events that drive structural complexity in oak-dominated stands. To help fill this void, we collected data in a stand on the Sipsey Wilderness of William B. Bankhead National Forest in northern Alabama. On our 20 0.05 ha fixed radius plots, we quantified live tree species composition and density, and measured and classified standing snags and logs. Live and dead trees were mapped on each plot to quantify horizontal structure metrics. We extracted two cores from all trees >10 cm diameter at breast height (dbh) to quantify age, recruitment pulses, and reconstruct canopy disturbance history. Species richness for trees on the site was 39, and Shannon-Weiner species diversity was 2.81 for trees, 3.01 for saplings, and 3.24 for seedlings. The stand was dominated by Quercus alba, but Ostrya virginiana was the most abundant species. The stand exhibited an inverse J diameter distribution with a q-factor of 1.7. Almost half (42%) of live stems occurred in the 5-10 cm size class. The largest recruitment pulse for Quercus was in the 1880s, and declined after 1910. Ostrya became abundant beginning in 1930 and continued to recruit into the late 20th century. Of the 96 Quercus trees cored, 97% of them exhibited at least one release event. The most severe disturbance event was in 1946, concomitant with the pulse of Ostrya. The recent trend of Ostrya (along with other shade-tolerant species) recruitment may inhibit future Quercus regeneration.

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Changes in bryophyte diversity and composition along a soil wetness gradient in managed boreal forests assessed using topographic indices

The availability of moisture is critical to the establishment, growth and distribution of many forest plant species, especially bryophytes due to their limited control over water loss and uptake. We assessed changes in diversity and community composition of bryophytes along a soil moisture gradient assessed using a topographic depth-to-water index derived from advance remotely sensed (LIDAR) digital elevation data in managed boreal mixedwood forests located in northwestern Alberta. Bryophytes (mosses and lichens inclusive) were sampled in permanent sample plots in an experimentally harvested landscape (the EMEND - Ecosystem Management Emulating Natural Disturbance experiment) that included a suite of forest harvesting treatments (clearcut vs 10, 20, 50, 75 and 100% (control) retention) in conifer-, mixedwood, and deciduous broadleaf-dominated forests. Our aim was to determine whether there is a significant relationship between DTW and bryophyte diversity, abundance, and composition and whether the relationship or patterns change with harvesting intensity. Early results show variation in bryophyte diversity and composition along the soil moisture gradient with particularly higher species richness in the wet than in the dry end of the gradient. Similarly, species composition varied with DTW. The relationship between DTW and bryophyte diversity and composition was also observed to vary with harvesting intensity. The results emphasize harvesting and soil moisture controls on bryophyte diversity patterns. The results of this study can provide insight into how a topographic wetness index based on remotely-sensed data can help us understand variation in bryophyte diversity and composition across the landscape and how this influences their sensitivity to variable retention harvesting. Thus, this provides a tool to inform placement of retention harvesting that could help better conserve bryophyte diversity.

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20 years later: Evaluating the recovery of soil mesofauna on the Long-Term Soil Productivity sites in the sub-boreal spruce zone

In 1994 we began a study of the short-term impact of soil compaction and organic matter removal on soil fauna communities in the Sub-Boreal Spruce biogeoclimatic zone of central British Columbia as part of the Long-term Soil Productivity Study. In the Long-Term Soil Productivity Study, three levels of organic matter retention and three levels of soil compaction were applied in a factorial design across a range of forested sites from the boreal in NE British Columbia to the subtropical in Louisiana. Responses to these treatments are intended to be monitored for the full timber rotation. One year after treatment application we found that densities of most taxa did not differ between uncut forest control plots and stem-only harvested plots while whole tree harvest and forest floor removal combined with heavy soil compaction significantly reduced densities of soil mesofauna. Loss of forest floor represented a substantial loss of habitat for most soil fauna and increased the impact of soil compaction and fluctuations in soil temperature and moisture. In the mesofauna community, relative abundances of prostigmatid and mesostigmatid mites increased with treatment severity while that of

oribatid mites decreased.In the intervening years, samples were collected from each site at 5, 10 and 20 years and provide us with a unique opportunity to evaluate the recovery of the soil mesofauna community. We present an assessment of long-term recovery of soil mesofauna community and attempt to see if our predictions from 1994 have come true.

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Wildlife response to energy sector recovery: The importance of sampling methodology

Vegetation disturbance via energy development, while spatially extensive results in relatively little forest loss but extensive forest fragmentation (i.e. edge effects). The consequences of forest fragmentation are varied amongst wildlife species with some species avoiding edges while others having their movement facilitated by linear features. How these effects are mitigated as vegetation regrows is not clear. Some of this uncertainty is
caused by variation in the response variable used among studies (i.e. abundance versus use), differences in the approach used to measure vegetation recovery (i.e. height, cover, proportional difference of line vs. forest height), and inherent variation in recovery rates amongst forest types. We review the state of knowledge about what level of vegetation recovery is required to consider energy disturbances recovered from a wildlife perspective.

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PlantWatch phenology data: tools for decision-making

The Alberta PlantWatch database comprises over 55K records spanning 3 decades. This ongoing citizen science survey tracks bloom and leafing times for 30 plant species: trees, shrubs and forbs. Analysis of 70 years of central Alberta plant data showed a 2 week trend to earlier bloom for aspen, and an increase in minimum February temperatures of 6 degrees.We present maps illustrating the timing progression of these 2 key phenophase events across Alberta ecoregions in early vs late bloom years. These data can contribute to understanding changes in length of the growing season, which affect carbon sequestration. As insects and plants both develop in response to rising spring temperatures, insect emergence timing can be predicted using plant phenology data.The PlantWatch database also provides tools for climate change adaptation. Forest data on spring plant phenology can guide decisions in management of forest biodiversity as well as restoration and reclamation. Major wildfire management costs in Alberta are associated with the spring season. The danger begins with snow melt, which coincides with the timing of Populus tremuloides (aspen) pollen shed, and ends with forest green-up and Amelanchier alnifolia (saskatoon) bloom.

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Where do the wood bison roam? Habitat selection of the Ronald Lake herd

Habitat selection is a behavioural process related to a hierarchy of factors and tradeoffs that influence an animal's decision to use various habitat types, and is often associated with temporal changes in environmental and biological conditions. These factors and tradeoffs include, among others, forage, predation, and insect harassment. Wood bison habitat use in relation to forage quality and quantity or aspects of predation has been well studied. However, an assessment of the factors and tradeoffs affecting habitat use are not well understood. Here we examine bison habitat use for the Ronald Lake herd, in northeastern Alberta, by assessing selection from GPS radio-telemetry and field studies of their habitat. This includes measures of habitat supply (forage) and biological and environmental factors potentially limiting habitat use and affecting requirements for health and survival. Forage quantity, biting insect activity, and measures of ground firmness associated with increased predation risk were measured in 3 focal land-cover types and 1 landscape feature: pine and deciduous forest, marsh meadow, and an esker unique to the Ronald Lake area. Nine sample sites were established for each land cover type and feature within a 12-km radius of Ronald Lake (n = 36 sites). Vegetation was measured by cover and biomass. Insect activity was measured using Tabanid and Malaise traps and sweep netting. Ground firmness was measured by bulk density and soil moisture and penetration depth. Marsh meadow has greater quantity of preferred forage (carex), biting insect activity, soil moisture and penetration depth, and lower bulk density than pine and deciduous forests, and esker. From these results, we suggest that in summer months bison observe a trade-off in the utilization of areas of high forage availability for areas of lower insect activity, firmer ground which may be important for the movement of bison in the presence of predators, and alternate foraging opportunities.

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Variable retention harvesting, biological legacies and ecosystem memory in relation to improving forest resilience

Biological legacies retain ‘ecosystem memory’ (EM) of pre-disturbance conditions that influences post-disturbance recovery and reorganization toward a pre-disturbance baselines (resilience). Therefore, the amount and quality of EM remaining after a disturbance directly influences resilience of the ecosystem. We investigate if ecological patterns established by three centuries of wildfires in a boreal mixedwood landscape in northwestern Alberta confer resilience to biodiversity after the application of variable retention harvest prescriptions. We first demonstrate that fire history explains the observed variation in pre-harvest tree basal area (BA). Sites with proportionally higher BA of shade tolerant softwood species exhibit longer times since high severity fires compared to sites with higher BA of shade intolerant hardwoods. Second, we show that pre-harvest species composition of seven biotic assemblages (bryophytes, herbs, shrubs, tree regeneration, songbirds, spiders, and carabid beetles) reflects the variation of pre-harvest BA established by fire history across the studied landscape. Finally, we compare the contribution of species-specific pre- and post-harvest BA to explaining the composition of these seven assemblages at two, five and ten years after harvest. Pre-harvest

BA had a persistent significant effect on all assemblages up to ten years after harvest; however, it had stronger effects than post-harvest BA on post-harvest understory plant and carabid beetle assemblages, while the opposite was true for spiders, songbirds and tree regeneration. We detected EM effects (as a function of pre-harvest BA) in all sampling years after harvest but temporal patterns varied according to taxa. Thus, post-harvest EM effects related to fire history are stronger for understory plants than for animals and can persist at least ten years after variable retention harvest. We suggest that management of biological legacies has positive impacts on retaining EM after harvest, increaseing overall resilience and sustainability of these mixedwood forests.

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Prediction of forest productivity and competing vegetation potential using wet areas mapping and topographic data derived from ALS data

Estimates of potential productivity are needed to guide management and as input to growth models used in forestry, but are not always easy to obtain. In this study we evaluate the use of ecological site information obtained from remote sensing in estimating forest site productivity and competing vegetation potential in the Lower Foothills Natural Subregion in central Alberta, Canada. LiDAR generated Digital Elevation Model (DEM) and Wet Areas Mapping (WAM) provided biophysical data at a 1 m resolution for the study area. Biophysical data collected in the field were strongly correlated with data obtained from remote sensing. In the first study relationships between environmental factors and Site Index (at base age 50) of three major commercial tree species (trembling aspen, lodgepole pine, white spruce) were examined. Depth-To-Water (DTW) index from WAM was found to be the major predictor of forest site productivity (SI), together with topographic variables such as slope, topographic position and surface curvature. WAM data by itself explained most of the variation in SI productivity. The best models explained up to 70% and 73% of the variation in aspen and lodgepole pine site index, respectively. Models for spruce (R2=0.31-0.44) were less robust, due to smaller samples size and limitations in the range of conditions that could be found for this species. The second study examined relationships between biophysical factors and abundance or height of bluejoint reedgrass (Calamagrostis canadensis) and other competing vegetation in recent cutblocks (3 to 4 years old). Results indicate that DTW and other variables can be used to predict potential cover and potential height of competing vegetation. Using environmental data derived from a LiDAR generated DEM and WAM provides a very cost-effective method for predicting and mapping both SI and competing vegetation potential. These techniques are valuable additions to our toolbox for precision silviculture.

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Restricted rooting space in mine reforestation

In order to re-establish closed forest cover on lands affected by anthropogenic disturbances, such as surface mining, reclaimed soils must be constructed so that they provide stable access to sufficient moisture and nutrients, to sustain stands of mature trees and understory vegetation. However, soil compaction and intense below-ground competition with herbaceous plants, two issues commonly associated with reconstructed soils, can restrict accessible rooting space and prevent access to resources. This can result in stunted trees with poorly developed root-systems that are pre-disposed to drought stress, windfall and attacks by pests and diseases. Fine-textured, rich-mesic soils are particularly susceptible to both of these concerns and while there are recognized ways to manage competition, attempts to alleviate soil compaction through mechanical means have produced varying results. The roots of some herbaceous plants have the potential to penetrate compacted soil layers, possibly offering a biological means to overcome physical restrictions. However, these potential benefits need to be weighed against negative effects from competition with planted trees. We examined the individual and combined impact of compacted soil and competing herbaceous vegetation on soil properties, resource availability and above and below-ground growth of aspen (Populus tremuloides Michx.) seedlings on a reconstructed mine soil affected by severe subsoil compaction. Our findings suggest that soil compaction had a limited effect on resource availability and seedling growth. In contrast, competition with smooth brome grass (Bromus inermis L.) strongly impacted aspen growth above and below ground. Smooth brome aggressively colonized available rooting space, while simultaneously lowering the availability of water and nitrogen. Consequently, aspen competing with smooth brome had smaller and shallower root-systems with much lower total root mass than aspen without smooth brome. This reduction in root mass was reflected in reductions in leaf area and stem mass, and to a lesser degree in seedling height.

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The evolution of grazing management within central Alberta's aspen forests

Aspen forests comprise an important, yet likely undervalued, component of grazing resources in the aspen parkland and dry boreal forest of central Alberta. Since European settlement, perspectives have changed markedly toward trembling aspen, with early studies reflecting that of an undesirable weed encroaching into grasslands on privately owned pastures, where it was shown to reduce herbage yield, decrease forage accessibility and subsequent grazing capacity. This thinking in turn, gave rise to extensive studies to identify and field test methods to control aspen during the late 60's through the 1980's. These investigations provided important insight into how aspen can be reduced or eliminated, including through the use of mechanical clearing, herbicide application, mob stocking with cattle, and the use of prescribed fire. Moreover, integrated strategies were shown to be most effective (and least costly) for containing trembling aspen, while simultaneously maintaining rangeland productivity. Subsequent studies during the 1990's and thereafter have demonstrated the positive contribution that aspen forests can make to livestock grazing, for example by providing a preferred source of habitat during the grazing season, and as an alternative source of critical forage during times of drought. Changes have also been evident in how trembling aspen are managed on public land.

Where cattle grazing occurs in conjunction with commercial forestry operations that rely on aspen, this in turn, has given rise to studies evaluating practical strategies to conserve aspen in a multiple use landscape. Controlled grazing trials in the boreal have revealed that forest harvest alters the availability, accessibility and use of forage by cattle. Simple adjustments to cattle grazing regimes such as using low stocking rates and deferring access into recently cut areas, can help ensure forest regeneration, and thereby simultaneously support both land uses. While our understanding of aspen forest ecology and response to grazing remains incomplete, existing knowledge provides a solid foundation on which to help manage and conserve this species on both private and public rangelands.

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Provincial forest management, a landscape approach to management of biological legacies

In Canada, provincial authorities are responsible for the development of forest management policies that are compatible with biodiversity conservation objectives. A major challenge for these organizations is to assimilate current scientific knowledge on ecosystem functioning, and boil it down to a few meaningful principles that can be readily integrated in harvesting regulations or guidelines that are comprehensible for all stakeholders. This challenge is compounded by the fact that contemporary scientific concepts are in constant flux and tend to emphasize non-linear ecosystem dynamics, whereas forest planning systems typically reward stability across very long time frames. This presentation will briefly present ecosystem management guidelines currently used in Québec, and some challenges ahead regarding the integration of forest resilience concepts.

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Overstory cohort survival in an Appalachian hardwood deferment cutting: 35 year results.

Deferment cutting is an uneven-aged regeneration method similar in implementation to the seed-tree method where a portion of the overstory is retained to provide seed for the new cohort. The two methods differ in that the overstory is retained for another half to full rotation, resulting in a two-aged stand for the deferment cutting. Various landowner objectives may be accomplished with this retained overstory such as providing wildlife habitat, increasing visual appeal vs clearcuts, increasing growth rates for the overstory trees, and providing shade for the new cohort. Careful consideration of residual trees, in both characteristics and harvesting, is necessary to improve the chances that individual trees will survive until the next planned harvest.

An experimental deferment cutting study was established on the Monongahela National Forest in the time period 1979-1984 and measured periodically to the present. Repeated tree measures spanning the approximately thirty-five year study period permitted a survival analysis of the overstory cohort. Two endogenous factors (dbh, species) and two exogenous factors (crown class, logging damage) were tested using a Cox Proportional Hazard model. Survival rates were high, with 93.9% of trees surviving (925 out of 985 trees). Trees injured in the regeneration harvest did not show increased risk of mortality, $p=0.86$. Crown class also did not contribute to increased mortality, $p=0.35$, as the majority of overstory trees retained were in the dominant and codominant classes. Six species, Liriodendron tulipifera L., Prunus serotina Ehrh., Quercus alba L., Quercus montana Willd., Quercus rubra L., Quercus velutina Lam., had sufficient sample sizes to test for species differences. However, species was not significant for survival, $p=0.11$. DBH was a significant factor in survival,

p<0.01, with larger trees having increased probability of survival. These results demonstrate that overstory trees in a deferment cutting can be acceptably maintained midway through the next rotation and likely until the next regeneration harvest.

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Does gap-based silviculture accelerate the development of old-growth characteristics?

Logging at the time of Euro-American settlement greatly reduced the extent of old-growth northern hardwood forests in the Upper Great Lakes region. Observational studies suggest differences in understory plant community composition between remnant old-growth and second-growth stands are related to differences in tree species composition, light transmission and coarse woody debris. Gap-based silviculture is thus often promoted as a method of restoring old-growth characteristics in younger second-growth forests. Yet, the historical legacy of clearcutting, increased deer population sizes, introduced species and changes in landscape structure may lead to unanticipated responses of plant communities and natural regeneration processes in the understory. Here I will synthesize near-term results from experimental treatments of canopy gap size and deer exclusion in the Flambeau River State Forest in north central Wisconsin (the Flambeau Experiment). Our studies show that although species richness increases asymptotically with canopy gap size, species composition varies among small, medium and large gaps – suggesting a range of gap sizes is required to maintain the greatest diversity of plant species in the ground layer. Increases in species richness were due to the colonization by both native and introduced species. The richness and productivity of introduced species comprised a small proportion of the community, and declined after peaking in the second year following gap creation. The productivity of forb, graminoid, shrub and vine species increased with canopy gap size and associated with soil moisture as well as light transmission. Deer herbivory decreased the productivity response of forbs and increased the productivity of graminoids, but deer did not affect the responses of vines or shrubs. Our results show how deer influence understory community responses to canopy gap size, and suggest that large gaps may hasten a transition from forb- to graminoid-dominated ground-layer plant communities in northern hardwoods forests.

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The rest of the story: measuring and managing complexity in understory plant communities

Managing forests as complex adaptive systems promises the maintenance of a broader range of ecosystem services in the context of changes in climate and disturbance regimes, but requires a holistic understanding of forest ecosystems, including linkages among various structural components, resources and environmental conditions. The structure of the forest overstory is not only critical for the ecosystem services provided by the overstory, but also intimately linked to those provided by the understory. The majority of plant species in temperate forests reside in the understory, which provides wildlife habitat and contributes to numerous ecosystem functions. Here I will provide an overview of indicators of complexity in understory plant communities. These include multivariate taxonomic- and functional trait-based metrics derived from field data, and integrate spatial metrics including spatial autocorrelation. Emerging technologies, such as terrestrial laser

scanning (LIDAR), may also be used to characterize understory complexity albeit with limited resolution. For improved taxonomic and functional resolution, georeferenced field data can be used in conjunction with LIDAR data in analyses of linkages between overstory- and understory complexity. Finally, I will show how relationships among overstory- and understory complexity can be used to develop silvicultural systems aimed at maintaining ecosystem services in the context of climate change.

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Constraints, filters and contingencies in forest recovery after disturbance

The complexities of plant community development do not usually lend themselves to interpretations that fit the general linear model for assessing multi-factorial influences. When evaluated under field conditions, many responses to a continuum of a single factor (such as temperature or competitive intensity) can be fit with a non-linear least-squares regression line, but would much more logically be fit with a ceiling function. That is, the factor under study may
be a limiting or constraining factor, but is not a driving factor of observed variability – other factors are limiting to the majority of the cases measured. Forest regeneration studies recognize that multiple factors are at play, with some more important than others at different stages of stand establishment and development. Germination, growth and early survival of trees may each experience the same environment quite differently. In other words, the success of any particular species as a forest develops can best be interpreted as a progression through a series of species-specific filters which themselves are undergoing shifts in selectivity. Other sequential dynamics are arrayed in space rather than time, such as light transmission through a canopy or the spread of an invasive species. Many factors are influential only on defined subsets of the data, subsets that may be difficult to recognize and stratify in advance. Long-term data sets and techniques such as classification and regression tree analysis (CART) may better represent the contingent realities by which biotic and abiotic factors influence reforestation and vegetation dynamics.Examples from a number of investigations into forest regeneration and vegetation change are illustrative of these points, while they also point to caution against over-interpretation.

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Allometric relationships to determine age in tropical forests: Towards improved estimates of annual rates of carbon sequestration

This study focused on development of allometric relationships for tropical trees in Senegal (West Africa) and Indonesia (Southeast Asia) as a new approach to lead to improved estimates of annual rates of biomass and carbon accumulation. A total of 57 trees from seven different tree species were selected from five different

protected forest areas of Senegal and tree age was determined through dendrochronological analysis. For Senegal, existing allometric models were screened through regression analyses in order to attain a best fitted species composite model in describing the relationship between age as a function of diameter at breast height (DBH), and age as a function of total tree height. A total of 407 trees from four different species were sampled in Indonesia and age was determined from plantation records. For Indonesia, allometric regression models were screened to identify the best relationship between age as a function of DBH from four different tree species and one species composite model.

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Pathosystems, spread, and temporal stages of beech bark disease in North American forests

Beech bark disease (BBD) is an intractable biotic disturbance that has caused heavy mortality of American beech (Fagus grandifolia) populations throughout the eastern US and Canada for over a century. Although BBD results from the accumulation of necroses in host phloem caused by pathogenic fungi (Neonectria ditissima or N. faginata), infection results from a predisposition process involving scale insects (Cryptococcus fagisuga [beech scale] and Xylococculus betulae) whose activities and importance varies with disease stage. After beech scale proliferates throughout a stand during the BBD advance front stage, disease-induced mortality of beech trees occurs during two successive stages: the killing front and aftermath. These stages are characterized by different pathosystems of Neonectria spp. infection and relative mortality level. In the killing front, beech scale predisposes trees to N. ditissima infections, which causes heavy mortality of overstory beech and root-sprouting responses from dead trees. Left in the wake of this mortality is the aftermath forest where few overstory beech remain, thickets of clonal sprouts dominate forest understories, and the BBD agents occur at reduced levels to cause low but persistent mortality. Recent work indicates that during this stage, BBD may develop from separate pathosystems of N. faginata, predisposed by beech scale feeding, and N. ditissima, predisposed by X. betulae feeding, infections. These infections are also variously predisposed by tree nutritional status and defensive chemicals.

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Rapid monoterpene induction promotes the susceptibility of jack pine to mountain pine beetle colonization but not to beetle-vectored fungi

Variation in chemical induction can drive tree susceptibility to and host range expansions of attacking insects and fungi. Recently, mountain pine beetle (Dendroctonus ponderosae; MPB) has expanded its host range from its historic host lodgepole pine (Pinus contorta) to jack pine (P. banksiana) in western Canada. Beetle success in jack pine forests likely depends upon the suitability of tree chemistry to MPB and its symbiotic fungi. In particular, how rapid induced defenses of jack pine affect MPB colonization and the beetle's fungi is unknown. In a field experiment, we compared differences in rapid induced phloem monoterpenes between lodgepole and

jack pines in response to various densities of Grosmannia clavigera, a MPB symbiotic fungus used to simulate beetle attack inoculations. Lodgepole pine had higher limonene and myrcene, but lower β-pinene, concentrations than jack pine. However, myrcene concentrations in jack pine increased with inoculation density treatments, while that in lodgepole pine did not respond to treatments. Furthermore, we compared the growth and reproduction responses of MPB's symbiotic fungi, G. clavigera, Ophiostoma montium, and Leptographium longiclavatum, grown on media amended with three biologically-important monoterpenes at concentrations reflecting two induction levels from each pine species. Myrcene and β-pinene amendments inhibited the growth but stimulated the reproduction of G. clavigera, whereas limonene amendments caused the opposite responses. However, the growth and reproduction of the other fungi were generally stimulated by monoterpene amendments. Overall, our results suggest that jack pine rapid induction could accelerate MPB aggregation on jack pine due to high levels of the pheromone precursor β-pinene, a positive feedback of the pheromone synergist myrcene, and low levels of defense-related limonene. Jack pine is likely as susceptible to the MPB-vectored fungi as lodgepole pine, indicating reduced symbiont activity due to monoterpene induction may not be a barrier to MPB colonization of jack pine.

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Complementarity of gymnosperms and angiosperms: disentangling the effects of phenology, leaf morphology, and temperature

In seasonal tropical forests, mixtures of evergreen and deciduous species are more productive than monocultures because they intercept more light throughout the year, reflecting complementary use of resources by functional groups possessing different traits. This suggests that temperate and boreal forests may also exhibit transgressive overyielding, due to the difference in phenology between gymnosperms and angiosperms. However, complementarity could also arise from differences in morphology between needle leaves and broad leaves. We assessed the complementarity of the main functional groups in the Swiss Alps, including a deciduous gymnosperm. We used a trait-based analysis of competition to determine whether: 1) trait differences reduce the intensity of competition between complementary functional groups; 2) complementarity is observed at both ends of the altitudinal temperature gradient. We found no evidence of complementarity between evergreen and deciduous species. In cold montane forests, however, broadleaf species reduced the suppression of needleleaf species, and vice versa. Thus, 50/50 mixtures of deciduous angiosperms and evergreen gymnosperms were more productive than monocultures, indicating that the complementarity is caused by differences in leaf morphology, not phenology. In contrast, no such complementarity was observed in warm lowland forests. These results have important implications for the management and modeling of mixed stands.

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The development of boreal forest associations for the Canadian National Vegetation Classification (CNVC)

The Canadian National Vegetation Classification (CNVC) is a hierarchical framework for describing patterns of vegetation at different scales, from global to local. It is a program that was initiated by Natural Resources Canada, Canadian Forest Service in 2000 and relies on strong partnerships with provincial and territorial government agencies. The CNVC uses data and expertise from each jurisdiction to develop vegetation units at various hierarchical levels. The units are ecological and reflect patterns of vegetation influenced by different drivers at the different levels, i.e., regional climate and biogeography at upper levels and stand-scale successional relationships and site factors at lower levels. The fundamental unit of the CNVC is the Association; a plant community type with consistent species dominance and overall floristic composition having a clearly interpretable ecological context. Associations have been developed from existing units of provincial and territorial vegetation classifications by combining plot databases from each jurisdiction into a nationally standardized database and correlating provincial units using phytosociological tables. Each Association has been reviewed and confirmed by a panel of ecologists with regional expertise. Associations are at a consistent level of taxonomic detail yet retain their links to existing provincial units. The classification provides a common language for studying and reporting on forest ecosystems throughout the boreal forests of Canada, and for inter-jurisdictional communication of ecological and regulatory information. An overview of the boreal forest classification will be provided, with emphasis on lower levels of the hierarchy, including examples of Associations and their edaphic and successional relationships. The hierarchy and list of CNVC units at various levels of classification are provided on the CNVC website: http:cnvc-cnvc.ca.

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Simulated forest dynamics in eastern boreal Canada from 1901 to 2012 using the LPJ-LMfire dynamic global vegetation model

Accurate estimation of net primary productivity (NPP), biomass and fire regimes and their sensitivity with climate variables is important for understanding fluxes and pools of terrestrial carbon under the anticipated climate change. The goals of this study were to (1) reconstruct the evolution of NPP, biomass and burn rates in forests of eastern boreal Canada during the last century using a regional ecosystem model, (2) verify the predictive skills of the model with other reported data covering from eastern Canada's boreal forests, and (3) determine the historical levels of resilience of these forests. We addressed these objectives using the dynamic global vegetation model LPJ-Lmfire implemented with four plant functional types (PFT) at the genus level (Picea, Abies, Pinus, Populus), constructed on the basis of the main tree species that dominate eastern Canada`s boreal forests. We ran the model using 10 km spatial resolution climate data in monthly time-steps for the period 1901-2012. Our modeled distribution of annual burn rates and mean total biomass across eastern boreal Canada agrees well with reported data. Despite a general increase in productivity from 1901 to

2012, largely related to the increase in atmospheric CO2 concentration, our simulations showed a stabilization of the mean total biomass across the study area during the last century. The capacity of the four studied PFTs to maintain in the same areas than in the past appears to be significantly compromised under climate change because our simulations showed that the rate of regeneration accidents, caused by disturbances, has doubled in the last 20 years.

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Climate change and weather impacts on aspen forest communities in the parkland and prairie region of southern Manitoba

Climatic sensitivity of white spruce (Picea glauca (Moench) Voss) was examined growing in association with trembling aspen (Populus tremuloides Michx.) at their southern limit of distribution in a transitional ecotone between the southern boreal forest and northern prairie region. The study was carried out in the Spruce Woods Provincial Park (SWPP) located in southwestern Manitoba, Canada. The dry regional climate restricted trembling aspen growth during the growing season via moisture deficiency and temperature induced drought stress. Warm, mild winters also negatively affected radial growth of trembling aspen. Growth of white spruce was moderated by conditions within the aspen stands as radial growth patterns showed low variability from year to year, a low common growth signal, and a stronger response to temperature than to precipitation. Nonetheless, the dry regional climate still restricted growth of white spruce during the growing season via temperature induced drought stress. The findings of the study for white spruce support the stress gradient hypothesis in which facilitative interactions between tree species are expected under harsher environmental conditions. Historical growth-climate relationships were also used to forecast growth of both white spruce and trembling aspen under future scenarios of climate change in the 21st century.

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Examining biodiversity in old forest and old growth forest stand structures using aerial laser scanning

The biodiversity of forests is integrally linked to the 3 dimensional structures inherit within each stand. Old growth forests are often assumed to provide the highest amount of structural diversity and therefore the highest contributing value on the landscape. However, current biodiversity indicators for forests are often premised on course ecological correlations and frequently derived from landscape level modeling. In this study, Aerial Laser Scanning was used, in combination with empirical data, to detect and develop metrics of biodiversity at the stand level. Structural complexity metrics include measures of coarse woody debris (cwd), vertical structural complexity, horizontal canopy closure and gap analysis , tree species richness, and others. Metrics were used to compare natural old growth and mature second growth forest stands. Our work was completed at the Aleza Lake Research Forest a forest that provides a high variety of natural and management

forest histories, with stand management starting in the 1920s. Results indicate that Aerial Laser Scanning (ALS) techniques are effective at detecting and characterizing ecologically relevant structural characteristics from various forest stands. Mature second growth forests provide for the highest degrees of structural complexity including the highest levels of vertical and horizontal diversity of live trees while providing high levels of cwd recruitment. Natural growth stands contained the largest individuals and the largest amount of coarse woody debris, and largest canopy gaps. While providing structural attributes that support biodiversity the structures mature second growth remain different from those of natural old growth forests. Out work indicates that the structural attributes based on disturbance histories are can be distinguished using ALS for the rapid assessment of forest stand biodiversity.

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Overstory and understory responses after thinning in 50-year-old Douglas-fir and Douglas-fir/western hemlock stands in Oregon

Forest management practices designed to restore or enhance late-successional structure for habitat values typically include provisions for the creation and maintenance of structural and compositional diversity within and among stands. In the Pacific Northwest, thinning and gap creation are often suggested as methods for enhancing complexity in forests with young, structurally simple stands. We assessed structural development and timber yields across a range of variable density thinning treatments to evaluate tradeoffs between habitat development and stand productivity. Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco var. menziesii) and Douglas-fir/western hemlock (Tsuga heterophylla [Raf.] Sarg.) stands were thinned at age 50 to different residual stocking levels, with and without gaps on medium or better (McDonald) and excellent (Blodgett) sites in western Oregon. Post-thinning basal areas ranged from 17 to 32 m2/ha in 98-211 trees/ha. Stands were underplanted with different conifer species, and vegetation management treatments included spraying and no treatment. Understory responses to thinning varied primarily by site and species group, given the range of pre-existing plant communities, and through time. In general, shrub cover increased after thinning, while forb cover increased initially after thinning and then declined. Though spraying effects were still visible 15 years after treatment driven by reductions in one dominant understory species, it had little effect on long-term development of structure at these overstory densities. The range of densities led to peaking of periodic Scribner and cubic volume growth at ages 60 & 90 years, with mean annual increment peaking after age 100 based on Organon model projections. Post-thinning stand growth was greatest with the highest residual basal area; percent growth was highest in the lowest densities. By age 65, some tree diameters had reached late-seral sizes. This long-term, replicated study shows that overstory thinning and understory treatments can be used to stimulate heterogeneous structure and composition development in these forests.

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Development and dynamics of young aspen-spruce mixedwood stands in western Canadian Boreal Forests

We will present results from a study designed to evaluate the effects of aspen and spruce densities on the long-term dynamics of mixedwood stands in the western Canadian boreal forest. This study was established as part of the Western Boreal Growth and Yield Project (WESBOGY) of the Forest Growth Organization for Western Canada (FGrOW). Eleven replicate installations have been established in western Canada. We will present and discuss results from recent analysis of spruce and aspen growth responses to the different treatments up to age 24. We will also present results from simulations with the Mixedwood Growth Model examining the effects of aspen and spruce density on the long-term dynamics of these mixtures.

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Dendroarchaeology reveals influence of early-European settlement on forest disturbance regimes in Virginia

Dendroarchaeological samples archived in historical buildings or wooden artifacts can be used to reconstruct forest conditions during European settlement of North America. In this study, we dated and examined the tree-ring records of white oak (Quercus alba) logs sampled from two buildings, a kitchen and slave quarters, from a large property in western Virginia. The kitchen was constructed from logs harvested after the growing season in 1845 and the slave quarters was constructed from logs harvested after the growing season in 1864. The tree ring record from both buildings revealed a forest that was heavily impacted by human activities. Regional events such as the French and Indian War were seen in the tree-ring record as a demographic peak in white oak establishment that occurred after European settlers abandoned agricultural lands during this period of warfare. Local events, such as harvesting trees for lumber for new building construction are recorded as growth releases in the residual trees indicating canopy disturbance. The dendroarchaeological samples from the two buildings reveal a forest in the 1700 and 1800s that was heavily influenced by human activity. It is anticipated that future partnerships between dendroachaeologists and dendroecologists has the potential to reconstruct disturbance regimes that pre-date European settlement to provide a perspective on Native American influence on forest conditions.

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Survival functions for nine western boreal and northern montane tree species

Logistic survival probability models were developed for nine tree species in western North America using Permanent Sample Plot (PSP) data from: six Canadian provinces and territories, the government of Alaska (USA), and four forestry companies; for a total of 1,354,237 trees within 11,700 PSPs. The survival probability of: white/Engelmann spruce, black spruce, lodgepole pine, jack pine, trembling aspen, balsam poplar, balsam fir, subalpine fir and tamarack was modeled using tree size (dbh), competition estimates (basal area of the larger trees by species group), climate normals, and the time elapsed between consecutive measurements. The results indicated that survival increased nonlinearly with tree size. The effect of competition on tree survival was related to the shade-tolerance characteristics of the species and to stand composition; with pioneer shade intolerant species (i.e. pines, deciduous and larch) being negatively affected by competition. Competition from larger Picea and Abies genera had stronger influences on survival than other species. Intraspecific competition also had significant effects on survival of the more shade-tolerant spruce and fir species. Increasing summer temperatures had a negative effect on survival of jack pine reflecting the fact that data for this species is largely from the southern edge of its range where drought stress is high. Effects of increasing temperature on balsam poplar and balsam fir reflected this species sensitivity to drought. Species more limited by cold temperatures such as sub-alpine fir, black spruce and tamarack larch responded positively to warmer temperatures. Moreover, species more susceptible to summer drought benefited by increasing levels of annual and summer precipitation including lodgepole pine, trembling aspen, balsam poplar and balsam fir.The predictive equations developed in this study will be incorporated into existing growth and yield models (e.g. MGM) to improve estimates of future stand conditions.

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Stand dynamics 11 years after retention harvests in Rocky Mountain lodgepole pine

Despite being one of the most widespread conifers of North America, lodgepole pine is typically managed under a narrow range of even-aged approaches. Variable-retention harvesting is one alternative that can create multi-aged stands to improve resistance and resilience to disturbances. In this study, we examine treated stands in Montana's Tenderfoot Creek Experimental Forest. Our experimental units were prescribed to 50% basal area retention given two levels of spatial patterns (aggregated or dispersed) and fire use (broadcast burned or not burned); nearby reference stands received no treatment. Our primary research question was: how does retention harvesting affect 11-year stand dynamics in a Rocky Mountain lodgepole pine forest? We monitored stand structure as well as overstory growth and mortality over the course of the study to address this question. Measures of stand density indicated that treated overstories have declined or exhibited no change since harvest, but were also more variable in aggregated treatments than dispersed treatments. Stand

diameter distributions revealed high variability both within and among treatment groups and highlight the wide range of conditions that managers should expect in implementing retention harvesting. When we examined individual trees in the recent measurement period, overstory tree growth in treatments was no different than in controls; however, growth in dispersed stands was 47% greater than aggregated, and unburned was 97% greater than burned (p-values=0.060 and 0.003). Regeneration abundance was no different by retention pattern, but was most concentrated in the openings associated with aggregated retention. Seedling annual height growth did not vary due to burning, but was greatest in aggregated retention stands (p-value=0.089). Finally, our mortality analysis showed greater tree death in stands that were broadcast burned. These results provide useful insight into patterns of stand change wherever retention harvesting is used, and is especially pertinent for those considering management of lodgepole pine.

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Estimating the collapse rate of boreal aspen stands

The phenomena of aspen stand collapse has been known since at least the 1930s, and has in some instances been linked to specific events such as drought and defoliation. However there have been no studies to estimate the frequency or prevalence of this event, or to model stand-level correlates of its probability. We report such a study, conducted over an area of roughly 100,000 sq km in northeast Alberta, Canada. We used a time series of forest inventory data to measure the fates of 1 756 mature aspen canopies identified in the first inventory (c 1980), as estimated from attributes for stands at the same locations in a later inventory (c 1995). Of these, 171 (9.7%) showed evidence of collapse or dieback as evidenced by a decrease in canopy height of at least 3m and a decline in canopy age of at least 20 years. We used mixed effects logistic regression to model the probability of collapse in terms of stand attributes while accounting for spatial autocorrelation due to the sample design (of points within stands within inventory maps within regions). The most significant variables were stand age and density. Collapse probability was inversely correlated to density class and increased with age reaching a maximum at ages of roughly 110 years. The mean collapse rate overall was 0.58%/yr, but this reached 1%/yr in stands 25-50% canopy closure, and 2%/yr in open stands (5-25% canopy closure). We discuss some implications of these results in terms of forest management planning and the ecological interpretation of forest inventory ages.

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Silviculture in the face of future uncertainty: is the past still relevant?

Global change represents the greatest challenge facing forest conservation and management efforts due to uncertainty in future conditions and an urgency to develop strategies that increase adaptive capacity and/or minimize ecosystem vulnerability. Increased emphasis on novel future conditions and dynamics has caused some managers and scientists to move away from management regimes based on historic knowledge of forest systems towards those focused primarily on anticipating future conditions. While this new focus is necessary, much can still be gained from examining and integrating an understanding of historic natural dynamics and

structures into management regimes aimed at addressing future environmental uncertainties. This presentation will highlight a series of retrospective and large-scale manipulative studies that apply dendrochronological, long-term inventory, and detailed ecosystem measurements to examine the impacts of past climate extremes and disturbance events and emerging stressors on the structure, composition, and productivity of a range of temperate forest ecosystems. Findings highlight that although conditions are changing, many elements of resilience emerge from compositional and structural conditions associated with historic, natural systems and underscore the continued relevance of ecological silviculture approaches as we continue to proceed into an era of managing for an uncertain future.

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Southwestern white pine seedling tolerances to a changing climate: Results from common gardens across an elevational gradient

Pinus strobiformis, southwestern white pine, is a high elevation 5-needle pine species important to the ecology of the American Southwest and Mexico. It is threatened by a changing climate (increasing drought, increasing temperatures), and by a non-native fungal pathogen, Cronartium ribicola (white pine blister rust). Southwestern white pine has a disjunct distribution, which could increase the amount of genetic variation in potentially adaptive traits. We are evaluating the geographic pattern and amount of genetic variation in traits that may be adaptive for tolerating a warmer, drier climate. To do this, a common garden experiment at 3 sites across an elevational gradient is underway. The common gardens are located in northern Arizona at elevations of 2057m, 2276m and 2688m, and vary by 4 degrees C in mean annual temperature. Seeds from 26 populations were collected from the species' range in Arizona and New Mexico and were germinated and grown in a greenhouse until planting into the gardens in fall 2015. We will present results on first-year seedling performance, including growth rate, water use efficiency, and mortality. Understanding genetic variation in these traits across the range of southwestern white pine and the magnitude of gene by environment interaction will provide insight into the long term prospects for maintaining southwestern white pine in the face of climate change.

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Edge effects of low impact seismic lines on upland forest plant communities in northern Alberta

Low Impact Seismic (LIS) techniques were developed to reduce the environmental effects of the oil exploration in Alberta. Although relatively narrow (~2-3 m) and constructed with light-weight equipment, the lines still cause forest fragmentation, and potential edge effects may substantially increase their footprint. We assess the effects of three to four year old LIS lines in the upland coniferous sub-boreal forest in NW Alberta by investigating the distance of influence from the line edges on plant species diversity and abundance, as well as on soil temperature, soil moisture, solar radiation, and percent cover of humus or deadwood. We also assess

whether orientation of the lines influences edge effects on plant and environmental responses, and we investigate plant and environmental conditions at the centres of the line. Species diversity and abundance of herbaceous plants were lower along the edges and up to 15 m and 5 m away from the edge, respectively, when compared to 25 m and 75 m away. Non-vascular plants were less diverse and abundant on the lines and along the edges in comparison to any distance away from the edge. As well, deadwood was more frequently encountered along and near the edges than in the interior forest. Soil temperature was higher on the lines and along the edges than in the adjacent forest, and soil moisture on the lines was about twice as high in comparison to the edges and adjacent forest. Line centres and edges also received more light in comparison to near-edge forest. There were no effects of line orientation on vegetation and environmental factors. With the evidence of existing edge effects present three to four years post-construction, long-term and regular monitoring of LIS lines is recommended, as active management and remedial reclamation actions may be required to put the recovery on the right trajectory.

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Black ash, emerald ash borer, and climate change: assisting the replacement of a foundational species

The introduced emerald ash borer (EAB) poses a tremendous threat to ash forests across the upper Great Lakes region of North America. Of particular concern is the impact EAB will have on the ecology and functioning of black ash (Fraxinus nigra) forested wetlands, which cover over 500,000 ha in Michigan, Minnesota, and Wisconsin alone, and represent the region's most common ash forest habitat. Black ash often occurs in relatively pure stands on poorly drained sites where it serves as a foundation species exerting a strong control over ecosystem structure and functioning. Correspondingly, extirpation of this species by EAB could have negative cascading effects, including dramatic rises in water tables and shifts in vegetation composition towards shrub- and graminoid-dominated wetlands with little to no tree component.

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Wetlands and riparian zones 101: definitions, delineation, and implications for ecosystem-based management

Wetlands and riparian areas occupy approximately 30% of the >2,000,000 km² of commercial boreal forests in boreal North America. These ecosystems provide unique and key biodiversity and ecological functions, and are arguably as important in providing ecosystem services (ES) as the aquatic and terrestrial ecosystems they interconnect. Wetland and riparian areas, although they are highly related, are managed as two parallel worlds by forest-specialists. Several reasons could be invoked to explain that. First, they belong to very different conceptual frameworks, wetlands being defined based on internal characteristics (water level, soil, vegetation) while riparian areas are defined essentially based on their location and functions (tri-dimensional ecotones of interactions). Wetland delineation is generally easy to do, the most important difficulties being at the edges of the wetland continuum, e.g. distinguishing between deep Vs shallow (littoral) waters and non-riparian treed

swamps Vs upland forests. Riparian zone delineation remains in its infancy, as there is still a lot of controversy about criteria to determine where it extends perpendicularly to the shore. Recent studies in intact forests of eastern boreal Canada showed that the riparian zone could be best delineated by a combination of environmental (macro- and micro-topography) and biological (vegetation) variables; and that it consistently breaks into three sub-zones (untreed wetlands, wet riparian forest and dry riparian forest). Developing a vision of the land-water interface that will better consider the complementary of the littoral zone, the three riparian sub-zones and the non-riparian wetlands is a prerequisite to reconcile wetland and riparian management in forest dominated-landscapes.

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Fire severity affects the spatial patterns of jack pine forests in nutrient poor boreal ecosystems

Wildfire is a major recurrent phenomenon in northern boreal ecosystems that has a profound impact on the pattern and heterogeneity of forest ecosystems. Jack pine forests on nutrient poor soils in the boreal region are fire adapted but their spatial stand dynamics in relation to fire severity is poorly understood. In this study, we examined the spatial patterns of tree regeneration, forest floor characteristics, abiotic conditions, and plant community composition after fire in stands of two pre-fire age classes (Old; > 65 years and Young; < 30 years) after two different burn severities (Moderate and Low) five years after the Richardson Fire in northern Alberta, Canada. Moderate severity burns were stand replacing with 75% overstory mortality, 25-50% forest floor consumption, and abundant tree regeneration while low severity burns were non-stand replacing. Using semi-variogram, spatial autoregressive models, and spatial point pattern analysis, we estimated spatial grain and patchiness of the measured variables and identified the factors responsible for spatial structuring of vegetation composition in different stands. Overall, moderate severity burns created more variability in soil properties and the plant community than low severity burns. However, low severity burns altered the spatial pattern of the canopy trees from aggregated to random in the old stand, and more patchy in the young stand. Tree regeneration in the moderate severity burns had an aggregated pattern in both young and old stands but at different scales. Charred forest floor cover, coarse woody debris cover, and soil temperature appeared to be the factors controlling spatial patterning in understory vegetation in the old sites, whereas light availability and soil moisture were the most significant factors in the young sites. Our findings suggest that the fire severity-spatial stand dynamics relationship in jack pine forests varies with pre-fire stand age.

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Effects of stand dynamics on resistance to climate anomalies and disturbance in the Canadian boreal forest

Canada's boreal forest covers approximately 55% of the country's land mass. These forests are both culturally and economically significant for Canadians, and also play a crucial role in the global carbon cycle. Recent

studies have attributed increased tree mortality and disturbance across the Canadian boreal forest to climate change. By modifying stand characteristics, forest managers have the capacity to increase the resistance and resilience of these forests to climate change and disturbance. To do so, a better understanding of the effects of forest dynamics--changes in stand structure, composition, and density over time--on forest responses to recent climate anomalies and disturbance is critical. In this work we use a Bayesian hierarchical state-space framework to separate long-term growth trends from inter-annual growth variability driven by climate extremes (e.g., drought) and disturbance (e.g., insect outbreaks) within boreal forests in Alberta and Quebec. Growth responses to climate extremes and disturbance are modeled as a function of stand characteristics such as age and size distribution, composition, and density using a space-for-time approach. This approach allows us to identify stand characteristics that minimize the effects of future climate extremes and disturbance across a broad geographic, soil, and climate gradient. In particular, results from this work will quantify and compare the effects of climate extremes and disturbance on forest growth responses in the Eastern and Western Canadian boreal forests. We hypothesize that the strong longitudinal precipitation gradient - with increasing water availability in the East - controls stand vulnerability to both climate anomalies and disturbance.

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Plant community composition and aspen establishment in response to seeding and weeding treatments on different reclamation soils

Reclamation efforts that promote the re-establishment of native tree and plant communities subsequent of large-scale oil sands mining land disturbances are crucial in restoring natural ecosystems. It is important that reclamation procedures capable of facilitating the establishment of native species be identified and put into practice. The objective of this research project is to determine plant community development and aspen seedling establishment in response to different combinations of soil types and experimental plant establishment treatments on an oil sands overburden waste area.Eighteen field plots, established in 2014, were re-monitored to compare plant community development and trembling aspen seedling density on 3 soil types (forest floor-mineral mix [FFMM], transitional, peat-mineral mix [PMM]) with 4 plant establishment treatments (seeding native species, weeding undesirable weeds, seeding & weeding, control). Soil type was found to be a dominant plant community driver, with FFMM and transitional soils showing higher species richness, diversity, and total vegetation cover than PMM, while PMM supported greater aspen seedling densities. Minimal weed establishment on transitional and PMM soils resulted in weeding treatments having no significant effect on plant community development; however, weeding on FFMM did result in the increased presence of native forb species, Galium boreale and Vicia americana. Additionally, seeding treatments resulted in the increased presence of Achillea millefolium on all soil types, and of Solidoga canadensis on FFMM. Future analysis will focus on identifying plant community development trends from the initial growing season to present, as well as determining the effect of soil type and plant establishment treatments on belowground microbial communities.

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Quantifying detection rates for understory vascular plant species using decoy field trials

Detection of vascular plant species during field surveys is rarely perfect, yet this issue is seldom considered in survey design and methodology. Given that plants are static, increased survey effort (time and/or area searched) likely contributes far more to detection success than would repeat visits, which are a common practice for animal surveys. The probability of falsely recording a species as absent may be affected by factors such as plant morphology and abundance, habitat type, or observer traits. We tested the influence of these variables under forested conditions using field trials with volunteer observers and planted decoy species. In 2014, we considered plot size, target species identity, and observer experience level. We observed low (<50%) detection rates in plots > 100m2 (10 x 10 meters), reduced success when searching for a cryptic species, and no influence of observer experience level. 2015 trials tested the influence of abundance and distribution of two target species across a constant plot size (33 x 33 m). We found that randomly arranged individuals of a cryptic species were 25 - 34% more likely to be detected than the same number planted in a clump, a detection rate of 0% for single individuals, and that detection patterns typically became apparent after ~30% of the survey plot had been searched. Given the observed poor detection success, particularly in plots of large spatial scale, we suggest search effort during plant surveys should be documented to assess the likelihood of imperfect detection. Widespread use of this simple protocol can develop our understanding of how detection success in forested areas varies with both habitat and species' traits, which is particularly important for species of scientific or conservation interest.

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Generalizing riparian hydrologic function in a heterogeneous landscape, Western Boreal Plain, Alberta, Canada

Canada's Boreal Plain (BP) eco-region is experiencing unprecedented development for forestry, oil and gas resources; escalating the need to understand the role of riparian areas in mitigating potential impacts of land use changes on water quantity and quality. We compared findings among local scale transect studies across differing surficial geologies at the Utikuma Region Study Area (URSA) to characterize variability in hydrological and biogeochemical processes of riparian areas located on major landforms and landscape positions typical of the BP. We found vegetation in riparian areas acted as hydrological linkages between uplands and aquatic systems; removing soil water and groundwater. Additionally, riparian areas translocated water to adjacent hillslopes regardless of groundwater function. The type and seasonality of flow path and variability in riparian function were related to interactions among sub-humid climate, surficial geologic landforms (texture) and topographic position within these landforms. Water table gradients from aquatic to upland regions were common and perched aquatic and wetland systems were observed in areas of contrasting soil texture. Riparian functions were highly variable in coarse textured outwash landforms and influenced by regional-scale flow systems and seasonal freezing. On fined grained lacustrine plain landscapes, riparian interactions were largely restricted to near surface discharge and recharge flow through. In contrast, on poorly drained and mixed

textured moraine landforms riparian systems were often isolated or interacted with recharge or perched flow systems. Our findings not only point to the need to improve our understanding of how riparian functions vary with geologic landform and groundwater or river network location, but also highlight the importance of vegetation interactions in controlling the water budget. Local and regional interactions should be considered in conceptual frameworks and modeling efforts that consider the role of riparian areas in mitigating any effects of land use practices in heterogeneous glacial landscapes.

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Ecosystem assembly ideas and their application in oil sands reclamation

Plant community succession and assembly both address the temporal dynamics of ecosystems after disturbances where succession focuses on the dynamics of a system following initial colonization and assembly deals with the arrival, establishment, and persistence of the suitable species in the ecosystem through the physical and biotic interaction. Thus, understanding the effects of reclamation treatments on plant community assembly and succession is an important step in developing realistic indicators and targets for reclamation of upland oil sands sites to forest ecosystems. The main goal of this study is to review ecosystem assembly ideas and their application in oil sands reclamation with theoretical and practical examples. Parametric and non-parametric multivariate tests and probabilistic model have been applied in examining effects of reclamation materials and treatments on establishment of vascular and non-vascular species, plant community assembly and succession. The initial results indicate that species composition, richness and diversity vary among reclamation treatments and differ from the natural forest stand. Effects of soil properties and reclamation treatments on species composition will be discussed. Outcomes of this study will assist in setting priorities for future reclamation research and in identifying operational activities for developing functional and productive forests.

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Building a better reclamation soil: Admixing peat, subsoil and biochar following surface mining in Northern Alberta

Surface mining of oil sands in northeastern Alberta is a large-scale disturbance with over 900 km2 affected so far. Extraction companies are required by law to return the environment toan equivalent land capability, but this has been challenging to quantify and to date, only one site has been certified as reclaimed. Restoring ecosystem function, including nutrient availability and uptake, might be a more realistic goal of reclamation. In a greenhouse study, we tested the effect of admixing subsoil with peat and biochar to make bioavailable nutrients, foliar nutrient concentration, and aspen (Populus tremuloides Michx.) productivity more similar to reclamation soil salvaged from forests. Brunisols and Luvisols, which are found in upland boreal forests in the Athabasca Oil Sands Region, have higher mineral soil content compared to the commonly used peat. Biochar is a native component of boreal forest soils in northern Alberta and has an effect on a variety of soil characteristics. In two separate tests, we compared different peat-subsoil admixtures, and biochar amended peat subsoil mixes to forest-floor-mineral-mix (FFM). Seedling productivity increased with admixing subsoil and

there was an overall positive effect of amendment with biochar. Findings suggest that peat-subsoil mixes did not provide sufficient amounts of P and Cu to seedlings. A lower K and Mn availability in peat-subsoil mixes was also identified and needs to be evaluated in further studies.

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Planning and operational approaches to the conservation and management of wetland and riparian areas in the Boreal Plains: The Al-Pac Experience

Since the onset of operations in 1993, Alberta-Pacific Forest Industries Inc. (Al-Pac) has been developing and implementing ecosystem-based approaches to managing the boreal forest ecosystem within Al-Pac's 6.4 million hectare Forest Management Agreement Area. This approach, while focusing primarily on the forested elements where Al-Pac operates, has necessarily included many considerations for the aquatic elements of this system including a combination of forest planning and operational practices at stand to landscape scales. Recent regulatory developments in Alberta, with landscape-based approaches to the management of aquatic ecosystems, include the new provincial wetland policy for forested areas and the Biodiversity Management Framework (BMF), a component of the Lower Athabasca Regional Plan (LARP). These strategic level approaches are delivered on the ground through a combination of regulatory and voluntary practices implemented at smaller scales (operating areas or site level). The Northeast Alberta Operating Ground Rules(OGRs), jointly developed by the Province and forest companies, address planning and operational considerations for harvest area layout, riparian management, stream crossings and other operational practices that would be associated with aquatic systems. In addition to the OGRs, Al-Pac has implemented many voluntary practices to address forest certification requirements or gaps to more fully integrate an EBM approach for these areas. This presentation will provide an overview of Al-Pac strategies and operational practices, including regulatory and voluntary approaches, implemented at varying scales to meet ecological management objectives. Case studies and examples will be used to illustrate how Al-Pac has integrated new knowledge and management tools into planning and operational practices including the identification and classification of wetlands, winter road BMPs (beneficial management practices), the conservation of high conservation aquatic forest values under Forest Stewardship Council (FSC) certification and road construction design and monitoring.

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Carbon sequestration in managed temperate coniferous forests under climate change

Forests are priorities for addressing climate change because while they are natural carbon sinks, mal-adaptation may turn them into net carbon sources. Management activities can potentially increase the magnitude of forest-based carbon sinks while also facilitating adaptation of forests to new climatic conditions. Understanding the potential impacts of climate change on the productivity and forest carbon dynamics is one way to support management decisions around adaptation. In this study we simulated the Copper-Pine

Creek valley in north-west British Columbia using the Forest Carbon Succession module of the landscape simulation model LANDIS-II. The model simulates growth, competition, and decay dynamics of above- and below-ground carbon pools and integrates fire and harvest disturbance extensions within the LANDIS-II family. The projections of impacts on productivity and carbon sinks were: positive for higher elevation forests where tree species were able to capitalize on warmer conditions and longer growing seasons but disturbance rates remained constant; negative for lower elevation forests where productivity declines but the harvest rate is higher and fire risk is higher compared to other parts of the landscape; and, negligible in mid-elevation forests. Forest carbon dynamics were found to be highly influenced by disturbance regimes. There may be opportunities for forest managers to adapt to climate change, increase productivity and carbon sinks at lower elevations by planting species or genotypes from warmer locations within the region.

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The effect of harvesting on the relationship between depth-to-water values and understory vegetation

Variable retention harvesting is becoming a popular alternative to clear-cut harvesting due to the assumption that it has fewer negative effects on biodiversity. Most studies have focused on the effects of the proportion of retained trees as well as the arrangement of the residual trees (i.e. aggregated vs dispersed retention) on the harvested landscape. However, critical information regarding where retention harvest patches should be placed is lacking. We investigated the utility of increasingly available fine-resolution remotely-sensed data (LIDAR) to help identify areas of high plant diversity or resilience and to guide managers in the placement of retention in managed landscapes. We conducted studies in the boreal mixedwood forests of northwestern Alberta, located within the experimental area of the Ecosystem Management Emulating Natural Disturbance (EMEND) experiment. We sampled four harvesting treatments (clearcut (2% retention), 20%, 50% retention, and unharvested control) in three forest types: conifer-dominated, mixedwood, and deciduous-dominated stands. Using mixed-effects models, we examined the relationship between depth-to-water (DTW) index (a moisture index based on remotely-sensed topographic values) and understory plant diversity, abundance, and composition 15 years after harvest. We found the relationship between depth-to-water and understory abundance and composition varied with harvesting intensity. Of the three forest types, conifer-dominated stands appeared to be the least resilient with harvesting affecting the relationship between depth-to-water values and most understory attributes. Our study emphasizes the utility of remotely-sensed LIDAR data to help managers understand patterns of biodiversity across forested landscapes and to identify areas of high sensitivity in forests managed with structural retention.

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A pan-Canadian approach for adapting sustainable forest management to a changing climate

Sustainable management of Canada's forests is a complex issue requiring decision makers to manage for multiple values over long time horizons. Understanding the impacts of a changing climate on forestry resources and operations, and implementing proactive and effective adaptation are essential to maintaining sustainable forest management (SFM) in the face of an uncertain future. While much attention has been given to climate change impacts on forests, efforts to move from adaptation theory to practice have just recently started within the Canadian forest sector. Early lessons learned in developing SFM adaptation plans and actions suggest the need for forest research scientists and forestry decision makers (e.g., planners, practitioners, operators) to work together in coproducing knowledge of climate change impacts and developing robust adaptation actions. Tools and frameworks for enhancing coproduction of adaptation knowledge and action have recently been produced and examples of their application are starting to emerge. In this session, I will present an SFM adaptation framework recently developed through the Canadian Council of Forest Minsters. The framework provides a structured decision-making approach for mainstreaming climate change into SFM planning and practices; and the framework calls for research scientists to work closely with forestry decision-makers throughout the adaptation process. I will provide examples of implementation of the framework within Canadian forest management contexts and share early lessons learned in applying the framework.

C. Elkin (1)

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Evaluating how landscape heterogeneity influences the resilience and recovery of sub-boreal forest diversity

The ecological resilience of forest stands, and the rate at which forest biodiversity recovers following harvest events, is expected to depend on the type and intensity of harvest but may also be influenced by stand topography and forest characteristics. We evaluated the relative importance of landscape characteristics on forest diversity, and the dynamics of biodiversity change following harvest, in sub-boreal spruce and sub-alpine fir forest in the central interior of B.C. Sample plots were established in early, intermediate and late stage stands that differed in their topographic complexity, and could be identifies as being free from past management, or were previously harvested over the past 60 years. At each plot forest information was measured at two nested spatial scales, thereby allowing us to evaluate within plot variance in forest diversity, and its correspondence with landscape variability. Commonly used diversity metrics were calculated using both species data as well as forest structural data, and used to evaluate alpha and beta diversity. All of the forest diversity metrics that we considered increased with stand age. However, the impact of harvest history on diversity varied depending on the metric being used and the age of the forest being considered. Late stage forests that were previously harvested generally had higher structural diversity, compared to non-harvested sites, but lower species diversity. With the exception of early stage stands, landscape characteristics accounted for a larger amount of the observed variation in forest diversity compared to harvest impact. Landscape heterogeneity evaluated at a larger spatial grain (1 ha) was a better predictor of species diversity, while structural diversity was better predicted by finer grain landscape characteristics. Our work suggests that

the recovery of forest diversity following harvest can be facilitated by considering landscape features across a range of spatial scales when doing landscape planning.

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Disturbance recovery of understory plant communities in natural and reconstructed boreal aspen stands

Forest fires play a fundamental role in structuring the landscape of the western boreal forest and, consequently, boreal aspen communities are highly adapted to disturbance. A clonal tree species, trembling aspen (Populus tremuloides) will typically regenerate from root suckers following forest fire but is also capable of reproducing via small, wind-dispersed seeds. On land reclaimed following oil sands mining in northeastern Alberta, aspen forests are naturally regenerating from seed in contrast to nearby fire-origin stands that are regenerating from root suckers. This study compares the relationships between developing deciduous canopies and understory vegetation communities five years following disturbance for aspen stands originating from forest fire (sucker-origin) and from land reclamation activities (seed-origin). Across all stand types, understory biomass was negatively related to aspen stem density, likely due to canopy shading. However, there were different understory responses to developing forest canopies between natural and reclaimed sites with overall understory species richness, forb richness and forb cover all positively related to stem density on natural sites but negatively related to stem density on reclaimed sites. The opposing trends seen with forb cover and richness are particularly interesting and point to forbs inhibiting the establishment or growth of aspen seedlings on reclamation sites. In contrast, forb cover and richness were associated with greater densities of aspen suckers in the fire-origin stands where an open seed bed was not required for establishment. Although precise mechanisms underlying the observed relationships are difficult to determine, it is clear that different processes are influencing plant community development in reclaimed, seed-origin aspen stands as compared to those of fire-origin stands regenerating via root suckers.

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Quantifying forest structural complexity: approaches, metrics, and a conceptual framework

Ecological forest management often explicitly includes promotion of complexity as a goal, but definitions of forest complexity can vary greatly depending on the system in question or the ecological functions that are of interest in determining management targets. We explore different conceptual frameworks that have been employed to describe and quantify forest complexity including factors such as tree spatial arrangement, canopy structure, community complexity (species and functional trait diversity), heterogeneity in resource distributions, and spatial and temporal variability in measurable ecosystem functions. Although many valuable structural complexity indices have been developed around these factors and combinations of them, protocols for quantifying complexity in forests and comparing resulting metrics among stands are not standardized. We

discuss the literature around quantification of complex patterns in 2D and 3D from the fields of image analysis, landscape ecology, and complexity science. Although forest complexity can be defined in many ways, characterizations based on complexity in the three-dimensional arrangement of structural and functional elements and resource environments within forest stands may be particularly valuable. Emerging technologies such as terrestrial laser scanning, hyperspectral image-LiDAR fusions, and drone-based imaging are greatly expanding the potential tool-kit for quantifying the arrangement of structural and functional elements (and the physiological and morphological traits of these elements) and corresponding gradients in resource availability. A conceptual framework and standardized metrics for evaluating the effects of silvicultural treatments on complexity will be useful in predicting treatment impacts and designing new treatments to promote these complexity and resilience.

C.D. Fang (1), & P.G. Comeau (1)

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The effects of red alder density on growth of Douglas-fir and western redcedar

In 1992 and 1994, long-term studies of mixed red alder-conifer plantings were established in southwestern British Columbia to examine: 1) the effects of differing initial densities and proportions of red alder (Alnus rubra [Bong.]) on the survival and growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western redcedar (*Thuja plicata* Donn.); 2) the relationships between growth of conifers and red alder densities (at both the individual tree and plot stand level); and, 3) the effectiveness of various distance dependent and independent competition indices and the influence of assessment plot radius. This study includes: 1) additive experiments established at four locations with different amounts of red alder (0, 50, 100, 200 and 400 red alders per hectare) planted with Douglas-fir and western redcedar; and, 2) replacement series experiments at two locations where mixtures of Douglas-fir and red alder were planted in five proportions (1.0:0, 0.5:0.5, 0.25:0.75; 0.11:0.89, 0:1.0) at a density of 742 tph. In this poster we will summarize and discuss results from measurements collected 15 to 22 years after establishment of these mixtures.

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Do landform and topography affect the degree of overlapping between wetlands and riparian zones? A study in eastern Canada

The forest-dominated landscapes of Quebec extend over 540,000 km² of plains, low, medium and high hills, and mountains, where regional average annual temperature varies from -2.0 to +2.0°C and annual rainfall from 800 to 1300 mm. It is estimated that wetland and deepwater habitats cover respectively 12% and 11% of these landscapes. These percentages vary considerably across landscapes, passing from 4% in the mountainous areas of the Gaspésie peninsula to 40% in the Abitibi Claybelt. Riparian zones occupy on average 32% (range 18-50%) of these landscapes according to unpublished data of the Ministry of Forests, Wildlife, and Parks of Quebec. We conducted a study aimed at determining the degree of overlap between wetlands and riparian zones across forest-dominated landscapes of Quebec. We selected 10 of the 153 Regional Landscape Units of the province using a stratified approach: two in plains (average slope 0-3%); two in low hills (3-5%), two in medium hills (5-

8%), two in high hills (8-23%) , and two in mountains (>23%). Our results suggest that less than the half of riparian zones (as defined in Quebec) is wetland but that more than the half of wetlands are riparian. At the time of writing this abstract, we had not yet determined whether the proportions of riparian Vs non-riparian wetlands and the proportions of wetland Vs upland in riparian zones vary independently from each other. Obviously, there is a need for a better integration of management riparian management guidelines and wetland conservation measures to through an integrated approach to the management of the land-water interface.

C. Farnden (1)

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Influences on tree growth of soil capping material over deep deposit tailings sand

Tailings sand is the primary residual material left after the extraction of bitumen from oil sands ore, and is a major constituent material of reclaimed landforms following mining. In preparation for revegetation treatments, tailings sand landforms are capped with combinations of surface soil, subsoil and/or peat salvaged during the mine operation to provide a suitable soil medium for ecosystem development. Research and monitoring to date suggests that ecosystems equivalent in productivity to the pre-disturbance landscape can readily be supported on these reclaimed landforms. This presentation will focus on inferences regarding forest growth from a 20-yr capping thickness experiment (3 thicknesses x 3 tree species x 3 replications) and a fertilizer trial in a jack pine stand of similar age and on similar soil material.

E. Fien (1), S. Fraver (1), A.Teets (1) & D. Hollinger (2)

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Factors influencing tree mortality risk in a late-successional conifer forest in central Maine, USA

Understanding tree mortality and its role in driving ecological processes is imperative when characterizing forest stand dynamics and forecasting future stand development. Mortality drives ecological process by altering community structure and composition and by regulating nutrient cycling. Furthermore, increasing mortality rates, perhaps associated with a changing climate, introduce uncertainty in forecasting future forest structure and dynamics, that necessitates an improved understanding of the characteristics that place individuals at risk. Despite the prevalence of late-successional forests in the north-eastern United States few long-term studies have been conducted to characterize tree mortality in these forests. We are studying tree mortality in a late-successional coniferous stand at the Howland Research Forest of central Maine, USA. Our study focusses on a three-ha plot, established in 1989, where all trees > 3 cm in diameter were mapped and measured. The plot is being re-inventoried to determine tree mortality risk as a function of species, size, neighborhood crowding, canopy size, and local soil moisture. First, we will determine the mortality rate for all species and assess how species survival rate has changed over time.Then we will determine the relative importance of the above-mentioned variables in modelling mortality risk. These findings will add to the knowledge of tree mortality in late-successional forests of the region, and may point to the need for more sophisticated parameters to describe mortality when modeling stand-level growth and predicting forest dynamics.

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Growth and yield of fast-growing plantations of Pinus chapiensis at Tlatlauquitepec, Puebla, Mexico

A growth and yield prediction system was built using a set of 44 permanent plots established in 2013 and re-measured in 2014 on a Pinus chiapensis plantation at Tlatlauquitepec, Puebla, Mexico. The growth and yield prediction system was fitted using a Seemingly Unrelated Regression method (SUR) as a set of simultaneous equations. Dominant height and site index were better described with polymorphic curves derived from the Hossfeld IV model. Models for basal area, mortality and total volume explained 80.9 % and 99.9 % of the total variation observed. Yield table indicate that at high productivity sites (site index 18 m, base age 8 years) maximum volume rotation (MVR) was estimated to happen at 17 years with a yield of 473 m3 ha-1 (28 m3 ha-1 yr-1). The expected volume yield at average site index (14 m/8 years) is 454 m3 ha-1 (23 m3 ha-1 yr-1) at 20 MVR. Low productivity sites (10 m/8 years) produce 442 m3 ha-1 (18 m3 ha-1 yr-1) at a 25 years MVR.
Keywords: Algebraic difference, Pinus chiapensis, Dominant height, yield prediction and projection, Seemingly Unrelated Regression.

J.R. Foster (1), & A. d`Amato (1)

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Forecasting migration rates of montane species under climate change with a spatially dynamic vegetation model

Montane forest species are vulnerable to climate change, challenging land-managers who must prioritize protected areas for conservation. Sub-alpine spruce-fir forests in New England illustrate this challenge. Forests of Abies balsamea and Picea rubens are predicted to recede to higher elevations as temperatures increase. Warm-adapted species are predicted to expand upward. Yet satellite imagery has shown that the extent of subalpine forests has remained stable or expanded downward over the past 30 years of warming. We hypothesize that movement of the subalpine forest boundary has responded more to disturbance dynamics, from wind, harvests and insect outbreaks, than to recent changes in climate. We ask how disturbances help or hinder migration and the development of refugia for montane species in the Green Mountains National Forest (GMNF) in Vermont, USA. We simulated future forest conditions using the landscape model LANDIS-II under a combination of four global circulation model (GCM) projections. We tested whether spruce-fir forests shrink as expected and identify where spruce-fir persists as potential climate refugia for conservation. Growth and establishment of subalpine A. balsamea and P. rubra were sensitive to the range of GCM projections; increasing or decreasing on different soil types and topographic positions. In spite of this variation in vital rates, the extent of P. rubra proved resistant to projected changes in climate, though composition of its codominants shifted between 2010 and 2100. A. balsamea and Betula papyrifera var. cordifolia were more sensitive and became less dominant toward the end of the century. Abundance of these short-lived species diminished in synchrony, as current forests approached senescence at the same time that climate change exceeded thresholds suitable for their continued establishment. Fine-scale landscape simulations helped identify potential climate refugia for montane spruce-fir forests providing an opportunity to direct conservation efforts towards areas with the highest likelihood of success.

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Understory response to invasive shrub removal techniques in hardwood forests

In managed forests, efficiently and effectively controlling invasive plants while promoting native species is a growing challenge. In eastern hardwood forests, invasive shrubs reduce herbaceous cover and diversity and suppress native tree regeneration. Manually removing invasive shrubs can be effective, but is time-consuming, labor-intensive, and often expensive. Mechanized removal with a skidsteer-mounted mulching head (e.g. Fecon®) may expedite the restoration of heavily invaded forests. However, unlike the common cut-stump method (cutting shrubs at the base and treating stumps with herbicide), mulching heads substantially disturb top soil and leave a layer of woody mulch. The widespread invasive shrub Amur honeysuckle (Lonicera maackii) forms dense thickets in forest understories and, therefore, presents an ideal system in which to test the effects of mulching heads on understory vegetation communities. We tested the effects of mechanized vs. cut stump removal in a factorial design with residual woody debris removed from half of the mechanized removal plots and added to half of the cut-stump plots in hardwood forests of central Indiana. Both treatments similarly improved the total cover and floristic quality of herbaceous species as well as the diversity of woody seedlings, but diverged in their effects on native and honeysuckle seedling abundance. Whereas the cut-stump treatment increased the abundance of native seedlings and only moderately increased honeysuckle seedling abundance, mechanized removal greatly increased the abundance of honeysuckle seedlings and did not increase native seedling abundance relative to invaded sites. Mulch deposition inhibited honeysuckle seedling recruitment, but did not significantly affect other aspects of the understory community. While mechanical treatments may be more efficient for large-scale shrub removal, our results suggest that they perpetuate recruitment of the same woody invaders they are removing and hamper restoration efforts by diminishing recruitment of native seedlings.

C.M.A Franklin (1), S.E. Macdonald (1), & S.E. Nielsen (1)

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Effects of prescribed burns and partial harvesting on understory vegetation in boreal mixedwood forests

Natural disturbance emulation is increasingly being used in sustainable forestry to help mitigate the negative effects of clearcutting on biodiversity. In the boreal forests of western Canada, wildfire is the predominant natural disturbance. Green-tree retention harvesting is a partial harvesting technique used in forest management to retain stand structural diversity post-harvest. The application of prescribed burning to areas treated with green-tree retention harvesting may emulate the influence of wildfires in managed forests more effectively than harvesting alone. We compared vascular understory plant diversity, abundance, and composition between forest stands subjected to green-tree retention harvesting (10% retention) with and without prescribed burning 13 years post-harvest. Research was conducted in three different forest stand types (deciduous dominated, mixedwood, conifer dominated) at the large-scale "Ecosystem Management Emulating Natural Disturbance" experiment located in northwestern Alberta. Burned areas had higher species richness and greater cover of rhizomatous and wind-dispersed species compared to the unburned and untreated areas. Effects of treatment on vegetation were similar amongst forest stand types. Our results

suggest that prescribed burning post-harvest benefits some fire-adapted species and that these effects can still be seen over a decade after harvest. Thus the combination of prescribed burning with variable retention harvesting could be considered a useful option in forest management that aims to emulate natural disturbance.

J.F. Franklin (1)

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Ecosystem continuity: the critical role of biological legacies in nature and in management

The most important feature of forest disturbances is the biological and physical legacies that remain; effectively these represent the ecological memory of the preceding ecosystems that have occupied the site. The biologically-derived elements, including living organisms and dead organic materials, are critical in determining the developmental patterns and richness of the post-disturbance ecosystem. Most fundamentally, biological legacies provide for continuity of biota, function, and structure between forest generations. Amazingly the goal in traditional even-aged forest management included intentional elimination of biological legacies! Ecologically-based management embraces legacies to sustain biota, function, and structure through harvests, thereby providing continuity between forest generations.

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Stand dynamics and structure of old-growth black ash stands in northern Minnesota, USA

In Minnesota, USA, black ash often forms pure or nearly pure stands in poorly drained landscape positions. A recent ash decline throughout the region, as well as the potential spread of the emerald ash borer (EAB), could result in the loss of a major forest type in this region. Observations from the region raise concerns that the loss of overstory black ash may transform these forests to open shrublands dominated by alder, willow, and graminoids. Despite the wide distribution of black ash ecosystems, little is known about their natural stand dynamics. The lack of this information hinders our ability to forecast the future of this forest type following its potential demise and to develop effective conservation efforts. Our objectives were to (1) quantify the natural range of variability in structure and composition in old-growth black ash forests and (2) characterize the recruitment and historical disturbance dynamics of these forests. To this end, we sampled six old-growth black ash sites to assess structure (including age structure) and past disturbance using standard dendrochronological procedures. Preliminary results indicate that black ash had fairly continuous recruitment over time, with recruitment peaks coincident with drought and/or canopy disturbance. Disturbance rates fluctuated markedly through time, but remained relatively low, suggesting small-scale and occasional moderate-scale disturbances. Temporal patterns of recruitment and disturbance suggest a possible coupling with local hydrologic regimes. Given the current scarcity of ash recruitment, and under the scenario of widespread black ash mortality, appropriate management strategies would include underplanting with non-ash tree species to maintain the current hydrologic regime and perpetuate forest cover in these systems.

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Conservation strategies for native forest plant communities affected by invasive earthworms, deer, and fragmentation

Understory plant communities in hardwood (maple and oak) forests of the Lake States (Minnesota, Wisconsin, Michigan) USA, were historically lush with high species richness. In recent decades, these plant communities have become highly degraded, with either low native plant species richness, or very sparse plant communities. These dramatic changes have been caused by high deer populations (due to landscape fragmentation) and European earthworm invasion. Some forests have 'lawns' of a few native sedge species, especially Carex pensylvanica, and C. pedunculata, while others are invaded by exotic plant species such as common buckthorn (Rhamnus cathartica), Tatarian honeysuckle (Lonicera tatarica) and garlic mustard (Alliaria petiolata), which are facilitated by the earthworms. Furthermore, the exotic shrub layer and stem exclusion stage of development of most stands, which originated after clearcutting during European settlement, lead to low light conditions and slow growth rates of native plants. Thus, there are four stress factors: deer grazing, low light, competition with exotic plants, and European earthworms. Furthermore, the lack of seed source is a factor for native plant species, as the standing crop of plants was eliminated by the stress factors. Three of the four stress factors (deer, low light, abundance of exotic plants) can be managed at the stand level with current knowledge, and reducing their impacts is likely to allow restoration of many native plant species via seeding and planting, as nurseries specializing in native plant species are becoming common in the region. A few native plant species probably cannot tolerate the presence of European earthworms and may require special conservation strategies. However, restoration of lush native plant communities is possible in Midwestern hardwood forests.

B. Frey (1)

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Stand structure and regeneration of American beech at its southern range margin

American beech (Fagus grandifolia Ehrh.) is an important shade-tolerant component of mature hardwood stands across eastern North America. In the southern U.S., mesic, late-successional mixed hardwood forest types with a component of American beech have been greatly reduced, and are considered a forest type of high conservation concern. However, few studies have evaluated stand structure or regeneration of American beech in its southern range. This study examines stand structural characteristics and regeneration of American beech within mature, mixed-hardwood stands growing in loessal deposits of west-central Mississippi. The study sites were dominated by an overstory of cherrybark oak (Quercus pagoda Raf.), yellow poplar (Liriodendron tulipifera L.), sweetgum (Liquidambar styraciflua L.) and white oak (Q. alba), with an intermediate canopy of American beech. Stand structure indicates an intermediate distribution of diameters for American beech, but with a clear absence of sapling-sized (<5 cm diameter) and few large (> 30 cm diameter) individuals. Regeneration measurements indicate low densities of American beech regeneration, with germinants representing a high proportion of its seedling bank. Results suggest recruitment limitations in recent years, contributing to a lack of small diameter individuals. A partial-cutting treatment is providing further opportunities for evaluating recruitment and growth of residual American beech, and an on-going

regeneration survey coupled with spatial and dendrochronological assessment of stand structural conditions will improve insights into regeneration and persistence of American beech following harvest disturbance. Findings from this work should enhance our knowledge of regeneration dynamics of American beech in its southern range, and improve efforts to maintain it as an important component of complex, mesic-hardwood forest types in the southern U.S.

M.T. Garrison-Johnston (1), J.A. Cale (2), S.A. Teale (3), & J.D. Castello (3)

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Nutritional physiology influences host tree susceptibility to BBD

The American beech-Neonectria relationship became pathogenic following the introduction of the invasive beech scale ~1890, but the onset of nitrogen (N) pollution in the late 1800's may have also played a role in the success and spread of BBD. Human activities have increased atmospheric N inputs to forests in the northeastern USA by at least 5- to 10-fold since the onset of industrialization. In theory, increased N availability results in greater demand for, and thus lower availability of, phosphorus (P). In a recent study of second-growth forests in central NY, high N relative to P in tree tissue was associated with increased Neonectria infection, suggesting that nutrient imbalance between N and P is a previously unrecognized factor in the development and behavior of BBD in aftermath forests. Furthermore, low P and high N:P more strongly predisposed trees to infection by N. faginata than N. ditissima. An improved understanding of the nutritional and physiological aspects of BBD may be important in our ability to manage this disease.

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Planning for the future with beech bark disease: A synthesis of research gaps and management questions

Findings presented during this session and by other researchers suggests that in BBD aftermath conditions, disease agents interact with each other and their environment in ways neither observed nor anticipated from earlier studies of initial (e.g. advance front and killing front) disease behaviors. Previously unrecognized factors such as atmospheric pollution and nutrient imbalances may exacerbate tree susceptibility to this disease. A clearer understanding of BBD agent behavior, disease progression and impacts, and interactions between biotic and abiotic factors is needed to support the development of management options aimed at ameliorating economic and ecological consequences of disease-induced forest change. We will discuss new concerns of a re-emergence of heavy mortality in some aftermath forests and present critical knowledge gaps and key considerations to help inform future BBD research and management programs.

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How do different forest management strategies influence soil microbial communities and do they persist over time?

Uneven-aged management has become increasingly popular over the past few decades in order to sustain a wide range of ecosystem services. Although we have a good understanding of the impacts of even and uneven-aged management on vegetation composition, productivity and different groups of fauna such as mammals, arthropods and birds, little information is available on the influence of these management strategies on soil microbial communities, especially over the long-term. The objectives of this study were to 1) assess and compare soil microbial communities (bacteria and fungi) right after clear cutting and partial cutting and 20 years later and 2) determine the relative importance of stand structure, plant community composition and soil properties in driving soil microbial community structure. During the summer of 2016, we collected soil samples of the first 15 cm in both recently and 20-year old clear-cut and partially cut, as well as in unlogged stands. Species and functional diversity of the microbial communities (bacteria and fungi) of the soils were determined respectively by next generation DNA sequencing 454 (FLX+) and substrate induced respiration methods (MicroResp). We additionally assessed vegetation composition, coarse woody debris, topography and determined the physical (water holding capacity, texture) and chemical properties of the soils (nutrients, pH). Results of the difference in soil microbial communities in response to harvesting treatments as well as potential environmental drivers of any observed changes will be presented and the implications of these results for forest management will be discussed.

A. Girard (1), S. Saunders(2), K. Lertzman (3), B. Buma (4), P. Alaback (5), & H. Klassen (6)

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A comparative analysis of structural characteristics in old-growth coastal temperate floodplain forests

We studied the structure and composition of high bench Sitka spruce (Picea sitchensis) floodplain forests across a latitudinal gradient from Southeast Alaska to Southwestern Vancouver Island, British Columbia. Considerable research exists on Sitka spruce floodplain forests to the south of this region, but there is less information from Vancouver Island north. Trees, snags, vegetation cover, and downed woody material were measured in eleven permanent sample plots established in the early 1990s as part of a transboundary partnership in the Pacific coastal ecoregion. We use multivariate analysis to examine latitudinal trends in stand structure and elucidate relationships between composition, structure, and site variables. Analyzing these forests across a latitudinal gradient allows us to distinguish between stand-specific attributes and regional trends in structural and compositional features, and allows an examination of latitudinal gradients between seasonal and perhumid rainforest. This study establishes a regional baseline and is part of a long-term study of stand structure and dynamics across this gradient.

A. Gomez-Guerrero (1), W.R. Horwath (2), L. Silva (3), T. Doane (2), A. Correa-Diaz (1), L. Castruita-Esparza (4), & J. Villanueva (5)

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Intrinsic water use efficiency of tree forest species at different sites in Mexico

The combination of dendrochronology and isotopes analysis (13C and 18O) helps to understand past changes in intrinsic water use efficiency (iWUE) and climatic effects on forest ecosystems. The strength of dual measurements of 13C and 18O in tree-rings rely on their independence in the plant physiological process; while 13C is more related to CO2 fixation and atmospheric exchange process, 18O provides insights on the source and quantity of water at the leaf level. From other side, tree basal area and tree ring indexes coupled with climate data help to identify wet and dry periods and analyze them accordingly changes intrinsic water use efficiency (iWUE). Together these analyses provide a retrospective insight on past and future climate impacts on tree growth.In this work we present information of tree-ring and isotope analysis of Pine, Bald Cypress, Fir and Douglas-fir trees sampled at different sites in Mexico. Sampling sites encompass a transect on the Pacific of Mexico, and other sites at the States of Chiapas, Mexico, Colima, Durango, Chihuahua and Baja California. We discuss the trends in iWUE for different sites and forest species in Mexico.

S. Greenler (1)

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Spatial variation in regeneration in small shelterwood gaps and surrounding forest matrix in the Central Hardwood Region

Canopy heterogeneity results from inherent landscape characteristics, such as slope, aspect and soil type, and transient environmental conditions created by weather and disturbances, either natural or anthropogenic. In particular, disturbances dramatically alter the forest understory microenvironment, causing lasting compositional shifts in the regeneration layer and future forest canopy. However, past understory conditions that led to current desirable overstory communities are no longer observable or measurable, making them difficult to recreate. Silvicultural methods that strive to directly emulate, or even incorporate aspects of, a system's natural disturbance regime can regenerate stands with high ecological and economic value. In many regions of eastern North America, gap- or group-based silvicultural techniques can create understory conditions that extend far beyond the harvest edge into the surrounding forest matrix. We studied how orientation (N, E, S, W) within and outside of small shelterwood harvest gaps influenced the spatial arrangement of competitive seedlings in four factorial treatments: 2- or 3-stage group shelterwood, with or without prescribed fire in southern Indiana. Two years after harvest, we found that competitive seedlings of some species displayed dramatic spatial variation on a fine scale. The greatest abundance of competitive (defined as within 25% of the tallest nearby competitive seedling) Quercus sp. seedlings occurred in the forest matrix on the eastern side of the shelterwood harvests, while the lowest abundance was in the southern matrix. Competitive Sassafras albidum regeneration was generally higher within the group harvest than the

surrounding matrix, but was markedly highest in the northern matrix, where maximal light filtered through the shelterwood opening into the matrix understory. For species-centric management, predicting fine scale regeneration patterns can inform optimal arrangement of harvest areas and direct limited resources for post harvest management. Understanding how regeneration varies spatially in and around forest canopy openings is critical to reconstruct how past disturbances shaped current overstory composition and how present management will influence composition and heterogeneity of future forests.

L. Gustafsson (1)

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Research and practice in forest conservation and restoration in north Europe

Northern European forest landscapes have long been heavily impacted by industrial forestry, homogenizing structure and composition, and causing declines in many species populations. Clearcutting is the prevailing harvesting regime, with some stands entering their second or even third clearcutting cycle. This type of forestry is at the extreme end of an intensity gradient, using natural tree species, in a circumboreal context. As such it may be of interest in discussions of future forest use in other regions. Further, nitrogen deposition and increasingly dense stands have caused a change in forest floor vegetation. Over recent decades, though, forest and environmental policies have increasingly stressed other goals than wood production, leading to a need to identify new solutions that balance different values. Certification has been a strong driver of change in forest management since large proportions of forestland are under certification schemes of FSC or PEFC. Three main approaches to increase structural diversity, and thereby improve conditions for biodiversity and to sustain ecosystem functions, are to 1) increase the area of protected forests, 2) modify management regimes to include integration of conservation measures in daily forest operations, i.e., retention approaches, and 3) to restore important processes and habitats. In my presentation I will elaborate on these three components by demonstrating results from research studies but also by showing examples from practical conservation and forestry. I will discuss differences between northern Europe and North America regarding land-use history, forest states and socio-economic conditions, but also draw upon similarities.

A. Hamann (1)

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Assisted migration in reforestation: risk of action versus risk of status quo management

How reliably can we guide assisted migration of forestry species through seed use guidelines in commercial reforestation programs? Such management interventions tend to entail the risks of unintended consequences, and several conditions should be met before implementing assisted migration to address climate change. We bring together results from genetic field trials, remote sensing, tree ring research, and landscape ecology to develop assisted migration prescriptions for western North America. Our intention is to develop more dependable guidelines by synthesizing information from a variety of experimental and empirical data from long-term field trials and historical ecology approaches.

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Applying emerging technologies to applied forest ecology and forest management planning

Stand structure has long been recognized as a key driver of forest productivity. Traditionally, however, measurements of 'structure' have been justifiably restricted to stand attributes practical to measure, such as stand size and age. These attributes formed the basis for decades of management prescriptions consisting primarily of selective thinning to favor certain age or size classes. Additional components of stand structure also drive forest productivity but before now have been difficult and time consuming to measure, limiting their usefulness in helping shape forest management prescriptions. However, a new generation of forest mensuration technologies is emerging, allowing forest scientists to easily and accurately measure a broader suite of stand structural characteristics including community structure (species diversity and evenness), trait structure (diversity and distribution of plant/leaf functional traits), and canopy physical structure. We will present a brief survey to the several emerging technologies likely to have numerous applications in forest ecology and forestry planning. Ground-based remote sensing techniques such as terrestrial lidar systems (TLS) and multispectral photogrammetry provide data on the spatial arrangement of canopy elements and the types and distribution of leaf traits. These technologies provide unprecedented levels of structural detail at the plot-scale. Aircraft and unmanned aerial systems (UAS, i.e. "drones") can deploy a wider range of lidar methodologies (first/last return, full waveform, single photon) as well as hyperspectral imaging systems; both techniques produce information on forest structural and functional characteristics across the landscape. Satellite-borne forest monitoring technologies are advancing at comparable rates and now include space-based lidar, high-resolution spectral imaging, and solar induced fluorescence (SIF) to provide information at regional, continental, and global scales. We will discuss these emerging technologies, their likely impacts on the ability of forest scientists to measure important forest structural characteristics, and discuss their potential influence on our understanding and management of forests.

K. Harper (1), C. Staicer (2), L. Gray (1) & A. Westwood (2)

(1) Dalhousie University, School for Resource and Environmental Studies; (2) Dalhousie University, Department of Biology

Biodiversity and ecosystem functioning of forested wetlands across Atlantic Canada

Forested wetlands are an integral but understudied part of the broad landscape of Atlantic Canada. Because of their complex vegetation structure and wide range of hydrologic and edaphic conditions, forested wetlands display both high biodiversity and a relatively unique set of ecosystem functions. Our project takes a multifaceted approach to increase knowledge about forested wetlands in Atlantic Canada while addressing the conservation efforts required to protect this habitat and its biodiversity from various human impacts. Our long-term goals are to determine the variety of forested wetlands and their sensitivity to different anthropogenic changes, to inform conservation efforts and to enable the reduction of impacts from land use and climate change on forested wetlands. We will investigate spatial and temporal dynamics of forested wetlands, develop a characterization of their different types, assess biodiversity including species of interest and compare

ecosystem processes among the different wetland types. Preliminary results from pilot studies indicate that some bird species at risk such as the Canada Warbler, Olive-sided Flycatcher and the Rusty Blackbird favour forested wetland habitats that can be predicted by using Nova Scotia's Forest Ecosystem Classification system; including interactive effects of wetness and forest type in species distribution models improved model accuracy for these species. Although patterns of vegetation across transitions varied for different forested wetland types and adjacent ecosystems, most boundaries between forested wetlands and upland forest were demarcated by an abrupt edge of Sphagnum moss cover. Knowledge gained can be used to provide insight into natural and anthropogenic processes influencing forested wetlands, to inform best management practices, and to serve as a framework for the conservation of forested wetlands.

S. Harrisson (1), & T.T. Work (2)

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Impacts of partial cutting on the resilience of ground beetles assemblages in the boreal forest

Uneven-aged management has been advocated as a means to maintain resilience in managed forests. In contrast to even-aged management, which results in relatively homogenous stands, uneven-aged approaches management (partial cutting) such as shelterwood or multicohort harvesting may maintain structures consistent with uncut forests, and may better maintain species assemblages but require more frequent interventions. For biodiversity, the capacity of species assemblages to recover before successive stand interventions is a direct measure of resilience in managed forest ecosystems that may be used to improve future management strategies. We compared ground beetle assemblages collected in pitfall traps in clear-cut, shelterwood and multicohort harvests with uncut forests using a replicated randomized block design. All stands were harvested during the winter of 2007-2008. Beetles were sampled in 2009, 2010 and 2016 to evaluate the speed with which beetle assemblages recovered after harvests and to quantify any resilience associated with partial cut harvesting. We compared abundance, species richness and composition of beetles among harvest treatments using a combination of generalize linear models, rarefaction and multivariate analyses. Immediately after harvesting, ground beetle abundance was greatly reduced in clear-cuts and both partial harvest treatments as compared to uncut forests. We also observed significant differences in beetle composition between clear-cut, partial cut and uncut treatments initially after harvest. In 2016, these differences in ground beetle abundance between harvested and uncut stands persisted. Among partial cuts, we did not detect significant differences in abundance of ground beetle between multicohort and shelterwood harvests. In fact by 2016, ground beetle abundance in clear-cuts surpassed levels observed in either partial cutting treatment. Thus nearly a decade after harvesting and after collecting more than 10 000 ground beetles, we observed little evidence of recovery in multicohort and shelterwood stands in stark contrast to other studies.

J. Hart (1) & L. Cox (2)

(1) University of Alabama, Department of Geography and Environmental Science(2) University of California, Berkeley, Department of Environmental Science, Policy, and Management

Incorporating intermediate-severity disturbances in oak stand development

We propose a model for the development of closed canopy oak (Quercus) stands. Our proposed model of oak stand development incorporates the influence of intermediate-severity canopy disturbance events, provides for the possibility of multiple developmental pathways, and does not narrowly define an endpoint given the stochastic nature of natural disturbances. The proposed model differs from the current oak stand development model in three primary ways. First, our proposed model acknowledges more than one mixed stage of development after an intermediate-severity disturbance based on the pre-disturbance condition and disturbance agent. Second, we suggest that these discrete mixed stages may progress in their development along different pathways and stands may be structurally dissimilar when they reach the complex stage. Third, we contend that the complex stage of development in oak stands is not achieved in the absence of the mixed stage because the return interval of these events is shorter than the period required for oak stands to reach the complex developmental stage.

A. Hedrich (1), P.C. Rogers (2), R. Howell (3), & S. Petersen (4)

(1) Utah State University, Merrill-Cazier Library; (2) Utah State University, Western Aspen Alliance, Ecology Center and Wildland Resources; (3) Brigham Young University; (4) Brigham Young University, Plant & Wildlife Sciences

North American aspen science is on the map: accessing research through a spatial lens

Increasingly, natural resource managers rely on instantaneous access to ecological materials to stay apace of rapid developments in the field. An online forest ecology database that is the result of a collaboration between Brigham Young University and Utah State University allows for spatial exploration and analysis of research on trembling aspen, Populus tremuloides. Working with a large aspen bibliography created and updated by the Western Aspen Alliance at Utah State University, Brigham Young University partners are creating an online interface that displays the location of published aspen papers. Information can be found by navigating in the GIS or searching within bibliographic information for research studies. Forest ecologists can easily find aspen-related works around the world, see what kind of research is being done in different regions, and investigate the progression of aspen research over time. The poster describes the status and attributes of this developing project, as well as some of the challenges encountered to date. This spatial platform for bibliographic data offers innovative connections to salient forest ecology information for scientists and land stewards.

J. Hjältén (1), T. Work (2), J. Andersson (2), T. Ranius (3), F. Stenbacka (1), & H Ekvall (4)

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Bioenergy extraction and saproxylic biodiversity: strategies and thresholds for stump harvesting

A range of conservation measures, based on legal demands or certification requirements, are implemented in today's forestry to mitigate the negative effect of forestry on biodiversity. A potential drawback in this conservation work is the increased interest for biofuel extraction from forest to reduce our dependence of fossil fuels and thus mitigate climate change effect. Slash and stumps earlier left to decay after final harvest can potentially provide large amount bioenergy and commercial harvesting have started in some countries. However, our knowledge on how this type of bioenergy harvest can influence biodiversity, e.g. saproxylic (wood living) organisms is limited. We present results from projects aimed at: determining the extent to which low stumps are utilized by saproxylic beetles and whether the beetle assemblages in low stumps are similar to those of other dead wood substrates (i.e. high stumps and logs); identifying thresholds for stumps harvest at stand level; and optimising stump harvest to balance economic output and biodiversity conservation. We found low stumps created at final felling support as many beetle species and individuals per volume dead wood as other dead wood substrates and that they are therefore overlooked as important and abundant substrates for wood living organisms. We used species accumulation curves to identify thresholds for stump harvesting and these results suggest that if 75% of the stumps are harvested about 25% of the saproxylic beetles will be lost from a clear-cut. However, if more that 75% of the stumps are harvested the species loss will increase very fast. The optimization modelling suggest that there is an optimal size of stumps that should be left at stump harvesting but that this size depends on the revenue from stumps harvest and this will be further discussed.

J. Hoage (1), L. Roussaeu (2), T. Porter (3,4), L. Venier (4), N. Basiliko (1), & M. Hajibabaei (3)

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Developing a metabarcoding strategy for soil mesofauna to monitor the ecological impacts of intensified biomass harvesting in forestry

Forest biomass is a renewable resource that has recently been promoted as an economical green alternative to fossil fuels for energy production. However, limiting the accessibility of biomass for decomposition could impact soil fertility and reduce future forest productivity. The response of soil biological communities to environmental impacts can be monitored and related to soil quality. Soil mesofauna are bioindicators that have been notoriously difficult to study traditionally. With molecular methods, the power and efficiency of soil biomonitoring can be enhanced and standardized for large-scale applications. High-throughput sequencing technologies allow for the characterization of native communities from environmental DNA samples. The goal of this research is to develop a standardized protocol for metabarcoding soil mesofauna and apply this to The Island Lake Biomass Harvest Research and Demonstration Area. The site was established in 2011 to assess the

impact that biomass removal has on forest sustainability and contains a randomized plot design with 5 replicates of 4 intensifying biomass removal treatments. Individual mesofauna specimens were collected from the area for identification and barcoding to identify the absence of local organisms in sequence databases. Soil core samples were taken from across the site in 2015 and 2016 to assess the spatial, temporal and experimental variability of mesofauna through amplicon sequencing of phylogenetic barcodes. A kit-based soil DNA extraction protocol with an amended chemical flocculation step was selected for the enhanced removal of organic contaminants from the humic-rich soil samples and provided an average 64 ng/µl of amplifiable DNA. 4 phylogenetic barcodes have been targeted for PCR amplification and Illumina sequencing: 2 invertebrate CO1, the eukaryote 18Sv4 and fungal ITS2 rDNA regions. Using this approach, changes in biodiversity and function of the soil food web caused by increased biomass removal may be efficiently identified and related to the future sustainability of biomass harvesting practices.

A.R. Hof (1), C.C. Dymo (2) , & D.J. Mladenoff (1)

(1) University of Wisconsin-Madison;(2) Government of British Columbia

Effects of intentional alteration of tree species composition on forest carbon pools in the face of climate change

Climate change and intensive forestry can largely alter forest dynamics and provision of ecosystem services. Adaptation of forest management practices can mitigate negative effects of climate change but may positively or negatively affect other ecosystems services. Thorough assessments of possible impacts of management adaptation strategies are therefore needed. One strategy is planting alternative tree species, but its effect on forest carbon pools is largely unknown. Harvest levels and species diversity will likely also depend on the planting strategy chosen. We used a spatially explicit forest landscape modelling framework to simulate the impact of planting alternative tree species as a forest management strategy to adapt to ongoing climate change on a temperate coniferous forest in British Columbia, Canada. We investigated impacts on tree species diversity, harvest levels and carbon pools, under different climate change scenarios for 100 years and found that impacts are largely dependent on the climate prediction model chosen. We further found that current stocking standards led to low species diversity, low NPP and mediocre levels of carbon stocks. In contrast, a diversification planting regime lead to a more diversified forest and was often superior in increasing carbon stocks and lead to the highest NPP. Planting more lodgepole pine (Pinus contorta) than at present also appeared to be a good alternative since it led to high carbon stocks, NPP and harvest levels, albeit to low tree species diversity. There are however many risks and uncertainties associated with lodgepole pine stands, especially in the face of climate change.

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Recent decline of white spruce growth in drought-affected areas of western Canada

Over the past 15 years, conditions have been exceptionally dry across large areas of western North America, including central and northern Alberta. This has led to widespread impacts on forests across the region and poses a major concern for the future, given model projections for continued warming and drying under human-induced climate change. We conducted tree-ring analysis at a total of 75 pure stands of white spruce (Picea glauca) across Alberta and west-central Saskatchewan to examine the impacts of recent climatic drying on the growth of this important boreal tree species. Allometric equations were used to calculate annual growth in aboveground tree biomass (G_BM) from ring width measurements. The results showed a notable reduction in the growth of white spruce across the study region that coincided with the onset of anomalously dry conditions at the start of the 21st century. For all stands, mean decadal G_BM declined by 16% between the 1990s and the 2000s, and the decline exceeded 40% in 12 of the sampled stands in central and northern Alberta. Based on our analysis, climatic drying was a significant factor driving spatial variation in the observed percentage growth decline in mean decadal G_BM. Subsequent analyses of the subset of 40 stands that were sampled across Alberta's managed forests in 2015 revealed that white spruce growth had declined even further as drought conditions intensified during 2012-2015. Overall, there was a 38% decrease in mean G_BM between 1997 and 2015, but surprisingly, the percentage decrease was not significantly different for young, productive stands compared with older, less productive stands. Thus, stand ageing cannot explain the observed decline in white spruce growth, suggesting that these forests are at risk if the trend toward more frequent, severe drought continues in the region.

K. Hossain (1) & P. Comeau (2)

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Characterizing light across a strip-cut shelterwood in mixed conifer forest of ICH

A strip shelterwood trial was initiated at Burton Creek, Southern British Columbia in 1994 to investigate seedlings establishment and growth response in relation to microclimate gradients. Two small (50 m wide by 150 m long) clearings were created in a mixed stand dominated by Douglas-fir, western redcedar, and western larch. The long axis of each clearing was oriented east-west. As a result of this orientation a gradient of light conditions exists going north to south in each clearing. Since light is the key driver of many ecological processes, our study aims at evaluating several light estimation techniques reported in the literature in the context of this experimental condition. In this study we compare: 1) Hemispherical photography; 2) Lai-2000 plant canopy analyzer; and, 3) Instantaneous measurements of below canopy PPFD (hourly average) using mid-summer averages of different durations of sunny and overcast sky conditions. We also attempted to understand how these techniques correlate with growing season (May to September) light levels. This study will contribute to a better understanding of why certain techniques perform better than others in this area and will help in selecting the most appropriate method.

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(1) Utah State University, Ecology Center and Department of Wildland Resources; (2) University of Alberta, Department of Agricultural, Life, and Environmental Sciences; (3) New Mexico State University, Department of Plant and Environmental Sciences

A seedling-based approach to aspen restoration in the western US

Traditional silvicultural practices to regenerate aspen focus on inducing asexual suckering, but these methods can reduce genetic diversity over time and are limited to existing stands. Planting of nursery-grown aspen seedlings for restoration has proven effective in mined-land reclamation in the boreal forests of Canada, but protocols have yet to be developed for the western US where seedling establishment may be more challenging. Here, preliminary results from an ongoing study testing seedling-based aspen restoration in southern Utah will be discussed. Survival during the first growing season varied substantially between locations, and mortality was dominated by rodent herbivory and early summer drought. Additionally, uneven responses among seedling sources in the nursery suggest further protocol optimization will be necessary for western US aspen. Despite these initial challenges, further refinement of seedling-based aspen restoration techniques in the western US could prove to be a useful supplemental tool for increasing resilience through active management of this keystone species.

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Investigating silvicultural systems for promoting tree diversity in managed Lake States northern hardwoods

Sustainable forest management must be informed by a fundamental understanding of how organisms interact with their environment. In northern hardwood forests of the Lake States, widespread, long-term application of single-tree selection has reduced structural and microenvironment heterogeneity, consequently leading to declines in trees species diversity. It has been suggested that implementing a greater variety of silvicultural techniques which mimic the full variety of historically-occurring disturbances, within the natural range of variability, may restore structural and microenvironment heterogeneity. The objective of this research is to investigate the response of northern hardwood stands to a greater variety of silvicultural systems. Specifically, six treatments will be implemented: 1) uneven-aged management control; 2) shelterwood with high canopy retention; 3) shelterwood with low canopy retention; 4) irregular shelterwood with high canopy retention; 5) irregular shelterwood with low canopy retention; and 6) patch clear-cut. Prior to treatment application, 108 plots were surveyed in Michigan's Upper Peninsula for two consecutive seasons. Plant community patterns were assessed and compared to environmental conditions such as litter depth, coarse woody debris volume, soil water content, and canopy openness. Prior to treatment application we detected few differences in plant community structure, environmental variables, or interactions among these factors across our sites, findings which further suggest little heterogeneity in the current state of this northern hardwood stand. Our research will build upon the conceptual framework of successional dynamics in managed forests, and insights from this research will be used to design alternative techniques for sustainably regenerating northern hardwood stands, and increasing landscape heterogeneity in northern hardwood forests of the Lake States.

A. Hussain (1), & N. Erbilgin (2)

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Host defense: productivity and spread of mountain pine beetle in novel jack pine habitats

Mountain pine beetle (Dendroctonus ponderosae Hopkins; MPB) success is linked to overcoming host tree defenses. The eastward expansion of MPB brings it in interaction with boreal jack pine (Pinus banksiana Lamb.) which is naive to MPB. Jack pine is often faced with droughts and nutritional deficiencies. MPB however, is known to prefer stressed and weakened trees. Building on these facts, this research explores how host defenses vary through different growing conditions and how MPB host colonization and dispersal are subsequently affected. Preliminary results show that Grosmannia clavigera, a MPB associated fungus produces longer lesions in trees on dry sites. Chemical analyses of phloem tissues will further validate how such gradients affect the balance among different chemical defenses and how nutrients and carbohydrate reserves are utilized in mediating these responses. Simulating MPB, different inoculation densities of G. clavigera will be used to determine why some trees succumb to a limited number of beetles. Spatial patterns in pine defense mechanism will be studied by investigating induced defenses. The study will contribute to understanding if trees in certain growing conditions are more vulnerable, if some trees are phenotypically more resistant and if inducible responses and volatile signaling can be used as vulnerability signatures.

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Evidence of biotic resistance to nonnative invasions in eastern U.S. forests: A macroscale study

Biological invasions and their impacts are likely to increase with the expansion of global commerce, making the need to identify key drivers and regulators of invasion greater than ever. One of the most enduring, and tested, hypotheses for explaining invasions is the “biotic resistance hypothesis”, which postulates that communities having greater biodiversity are less invasible because they have fewer unfilled ecological niches. Using data from 42,626 Forest Inventory and Analysis (FIA) plots from forests of the Eastern United States, we tested for associations between native trees and invasive plants that would suggest the presence of biotic resistance. Specifically, we wanted to determine (1) whether native communities are resistant to biological invasions at macroscales; (2) which biodiversity metrics are most reflective of biotic resistance at these scales; and (3) the degree to which the direction these metrics varies with scale and/or location. In addition to tree species richness, we quantified native tree biodiversity in ways that incorporate the evolutionary relationships among co-occurring species. Evolutionary diversity metrics generally increase as species become less evolutionarily related, potentially signifying greater diversity not only in known functional traits, but also in unidentified phenotypic traits that may be of ecological importance. In this study, evolutionary diversity measures were estimated using a phylogenetic tree of life of 397 native

native tree biomass and evolutionary diversity, but not species richness, is negatively associated with invader establishment and dominance, and thus indicative of biotic resistance; (2) evolutionary diversity limits invader dominance more than it does invader establishment; and (3) greater biotic resistance to invasions exists in and around the Appalachian Mountains and in parts of the Midwest. As forests and the services they provide are increasingly harmed by invasive plants, these findings will have implications for both invasive species management and policy.

K Illerbrun (1)

(1) Alberta Biodiversity Monitoring Institute, University of Alberta

Cultivating receptivity: Creating engagement through citizen science and outreach at the ABMI

The Alberta Biodiversity Monitoring Institute is an independent organization that tracks changes in Alberta's wildlife and habitats. As part of its mandate, the ABMI seeks to motivate and enable others to practice responsible resource management. In this talk, we highlight the development and realization of ABMI initiatives aimed at fostering engagement and increasing uptake among users from government, industry, and the lay public. First, we briefly discuss the appetite for impartial data on Alberta's biodiversity that led to the ABMI's establishment. Land-use decisions that are based on best scientific practices can minimize environmental impacts while, in effect, providing land users with a 'moral license to operate'. This was a key factor in the ABMI gaining the early support of government, industry, and environmental NGOs. Second, we introduce several recent ABMI projects, including NatureLynx, a citizen science and outreach initiative; the Adopt-a-Camera Program, a user-collaborative monitoring program; and the ABMI Data and Analytics Portal, which provides direct access to ABMI data. We discuss the organization's hopes and objectives for each, along with challenges and lessons learned. Overall, these initiatives try to put power into the hands of users, whether stakeholders or the public. In doing so, they aim to highlight and amplify both the intrinsic and applied value of what the ABMI does—gaining trust and cooperation and, ultimately, reaffirming the organization's own 'moral license to operate'.

J.Iqbal (1)

(1) Woodlands North

Development of the restoration roughness index (RRI) as a standardized measure of restoration

The exploration and production of energy resources across Alberta's forested landscape has affected ecosystem structure and function leading to a requirement for restoration of the industrial footprint. While there is an active, adaptive effort being put forth by industry, there remains a lack of a defined end state for a restored site. In other words, what is a measurable definition of restoration status? Moreover, while there are a number of definitions for similar activities such as reclamation, or environmental monitoring, a standardized method to determine the status of a restoration project is required so activities can be conducted in sync with exploration, resource development, reclamation, and integrated forest management in general. Any method considered to determine the restoration status of a site must be based on reliable principles that are repeatable, quantifiable, auditable, and have the ability to work across a wide array of cover-types present throughout the northern

forested landscape. Surface roughness is a measurable characteristic of a forested site that is positively correlated to a tempered micro-climate, improved microsite quality and frequency for natural germinants and seedlings. Enhancing surface roughness through operational activities will reduce erosion, reduce travel ease and speed for predators, and encourage forest regeneration. Cenovus Energy and Woodlands North have developed a model that uses spatial statistics as a method to standardize, define and quantify surface roughness as one of the criteria to predict restoration status. The Restoration Roughness Index (RRI) is a measure that will enable regulators and industry to accomplish two objectives currently lacking in restoration of disturbances. The preliminary results from a site analyzed in northeastern Alberta indicate that the model has great potential to help in both the planning stage to determine which areas on the landscape require restoration and also to provide a measure of restoration upon completion.

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Identifying drought tolerant lodgepole pine populations using growth analyses and a dual-isotope approach

Choosing drought-tolerant seed sources for planting may help to reduce the risk of forest maladaptation under climate change. Identifying suitable populations is therefore a necessary step prior to assisted migration implementation. Here, we assess drought tolerance of populations of lodgepole pine (Pinus contorta), a wide-ranging conifer in western North America. We combine growth data with a dual-isotope approach to analyze samples taken from a large provenance trial. Within this trial, long-distance seed transfer simulates climate change, while our planting sites in southern British Columbia also captured a drought that occurred in 2002 and 2003. Northern populations may be most at risk under climate change and drought since they showed poor growth, lower water use efficiency and limited stomatal plasticity. In contrast, populations from British Columbia's central and southern interior regions showed better growth, higher water use efficiency and a stronger stomatal response to changing environmental conditions. While seed sources from more southerly areas in the United States were relatively drought tolerant, this tolerance may be better explained by wood anatomy rather than stomatal conductance (functional wood analyses currently in progress). Implications of these results to assisted migration are discussed in the poster.

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Understory response to 17 years of controlled deer hunting in Indiana state parks

Negative effects of overabundant deer populations have been widely observed in the understories of natural areas and managers have enacted hunting programs to control populations and allow recovery of vegetation communities. However, few studies have examined whether recovery has occurred following sustained hunting. In the 1990s, hunting was initiated to reduce deer populations within Indiana state parks. In 2010, we resampled 108 plots established in 1996/97 across 15 state parks and five historically hunted reference areas

to assess how understory vegetation responded to 17 years of hunting. We measured herbaceous-layer species cover along transects and tallied woody regeneration within nested plots. We calculated species richness (S), evenness (E), and Shannon-Weiner diversity (H') in 1996/97 and 2010 for herbaceous cover and regeneration density. Changes in herbaceous-layer composition across environmental gradients were examined using nonmetric multidimensional scaling (NMS). We observed greater increases in herbaceous-layer cover in parks than in reference areas and S and H' increased significantly in parks, but not reference areas. NMS ordinations revealed unidirectional changes in composition between parks and reference areas with the composition of parks becoming more similar to that of reference areas through time. Park size, cumulative deer harvest, initial deer abundance, and recent average of harvest/hunter effort were significantly correlated with ordination scores in four out of five natural regions. Browse-sensitive functional groups increased in cover while that of exotic species decreased. Both parks and reference areas displayed large increases in the density of small seedlings (<50 cm height), but only parks displayed an increase in the density of large seedlings (50-200 cm height). Species richness increased significantly in all height classes in parks, but only for large seedlings in reference areas. These results suggest that hunting has allowed recovery of degraded vegetation communities.

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Fuels and fire behavior in mixed-conifer forests of the Sierra Nevada

The aim of this study was to measure fuel loads in old-growth stands of the northern Sierra Nevada of California, and to create custom fuel models based on local data. It was found that stands that were dominated by a large sugar pine (Pinus lambertiana) had higher loads of fine fuels than stands that were dominated by a large ponderosa pine (Pinus ponderosa), likely due to differences in branch morphology between the two species. When fuel loads were related to other stand structure variables, it was found that basal area showed a negative correlation with 10-hr fuels in ponderosa-dominated stands, and trees/hectare showed a negative correlation with 1-hr fuels in sugar pine-dominated stands. This unexpected result is hypothesized to be related to lower relative wind speeds in denser stands. Large 1000-hr fuels were found to be most consistently related to stand structure of any fuel size, possibly because stand structure influences levels of mortality and large fuels are mostly created by mortality events. When compared with standard fuel models, both the sugar pine stands and the ponderosa pine stands showed significantly different fuel loads from the ones predicted by the models. When fire behavior simulations were run, the TL8 model (long needle litter: a model selected to represent the long needle pines) tended to show the most extreme fire behavior, followed by the sugar pine model. The TL3 model (moderate load conifer litter: a model selected to represent the many short needle firs in the area) was mostly in between the two custom models in predicted fire severity, and the ponderosa model was often lowest severity. This suggests that fire behavior may change when moving between stands with different dominant species, and that current standard fuel models may not accurately represent fire behavior in the area.

M. Johnston (1)

(1) Saskatchewan Research Council

Integrating climate change adaptation into forest management in the Canadian forest sector

Climate change is increasingly recognized as an important factor in Sustainable Forest Management (SFM) in Canada. Both government and the forest industry are exploring ways of incorporating climate change into their SFM policies and practices. Research is providing more detailed scenarios of climate change impacts, and many jurisdictions are making that information available to forest managers through publications, web pages and workshops. As part of a multi-sector review of current adaptation practices, The Forestry Working Group of the Canadian Adaptation Platform recently produced a State-of-Play report summarizing current efforts by jurisdictions to incorporate climate change impacts and adaptation into SFM. In this presentation I will give an overview of current adaptation programs and activities among SFM practitioners in government, industry and NGOs. I will also offer some thoughts about where adaptation needs to go in the forest sector, particularly with regard to opportunities for mainstreaming climate change into Canadian SFM.

T. Jones (1) & J. Fera (2)

(1) Ontario Ministry of Natural Resources and Forestry, Science and Research Branch; (2) Natural Resources Canada, Canadian Forestry Service

Biomass harvesting in the Great Lakes - St. Lawrence Forest: Sustainability of increasing utilization in shelterwood harvests

Large tracts of the Great Lakes St. Lawrence (GL-SL) forest region consist of low quality, degraded mixed wood stands. These stands are often left unmanaged due to the high cost of regeneration back to healthy and productive states. With the emergence of the forest bio-economy and demand for forest biomass, this study examined the economic, operational, and ecological sustainability of using a forest biomass harvest as a means of restoring these degraded stands. The study, carried out at several sites across Ontario's GL-SL forest, comprised three shelterwood harvests occurring under mixed wood forest conditions. Each harvest utilized two harvesting methods, tree length (current recommended practice) and full tree (biomass/high utilization), and a no-harvest control. Ecological impacts were assessed using data collected from permanent research plots, while data from time of motion studies and the operational and economic analyses. Early results indicate that ecological impacts do not differ significantly between the full tree and tree length harvest treatments. Economic and operational results indicate that additional profits can be realized through a full tree harvest. These results suggest that forest managers could use biomass harvesting as a tool to rehabilitate degraded, low-value stands while providing useful biomass feedstock. In addition, results from this study will be used to support biomass policy development in the Great Lakes-St. Lawrence forest region and enable further diversification of the forest industry and the bio-economy in central Ontario.

C. Jones (1), S. Bachma (1), V. Lieffers (1) & S. Landhäusser (1)

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Rapid aspen and understory plant recovery following forest floor protection on temporary drilling pads

Oil Sands Exploration (OSE) practices cut the forest and move surface soils to establish flat, temporary drilling pads for the exploration of the oil sands layer. The usual construction of an OSE pad entails stripping off the top soil layers and stockpiling it off the site during leveling and drilling. After drilling is completed, the site is recontoured and the topsoil is placed back onto the site. OSE practices therefore represent a unique disturbance regime, providing a great challenge for the re-establishment of a diverse post-reclamation forest environment. We compared protecting the original forest floor under a layer of subsoil during the leveling of drilling pads with the current practice of stripping off the forest floor and topsoil and placing it back on the site (Rollback) in the re-contouring of the reclamation phase. We assessed the extent of surface disturbance, soil temperature, the density and height of aspen regeneration, and the recovery of the understory community in the first and fifth growing seasons. Aspen suckers were tallest, had the highest density, and had better survival in the first year when the forest floor was protected compared to the standard Rollback treatment. By the fifth growing season aspen suckers still had not established on the Rollback treatment. The understory community of the forest floor protection areas was more like that of a traditionally clearcut aspen stand than the Rollback treatment in both years measured. While the vegetation community of the forest floor protection areas was dominated by forest understory species, the Rollback treatment was dominated by various non-forest associated species, including some aggressive shrub and herbaceous species. The study indicates that protection and the careful uncovering of the forest floor should be a preferred strategy for temporary drilling pad construction and their subsequent reclamation in aspen-dominated boreal forests.

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The role of mycorrhizal fungi in constitutive and induced defenses of lodgepole pine

Recent mountain pine beetle outbreak in lodgepole pine stands of western Canada has had cascading effects on below-ground communities, especially that of ectomycorrhizal fungi. As root-inhabiting plant symbionts, these fungi are critical determinants of successful pine regeneration after major disturbances. Specifically, these fungi promote resource acquisition and resistance in developing pine seedlings. Indeed, seedling health declines follow a loss of ectomycorrhizal fungi due to forest mortality from mountain pine beetle outbreaks. However, how pine seedlings differentially respond to individual or a community of ectomycorrhizal fungi is unknown but could elucidate methods to promote healthy post-disturbance pine regeneration. This project investigated such responses by examining constitutive and induced defensive chemicals as well as growth parameters of greenhouse-grown lodgepole pine seedlings that were either susceptible or resistant to mountain pine beetle attack and whose roots were colonized by individual or a combination of ectomycorrhizal fungi. A laboratory experiment was also conducted to assess ectomycorrhizal competition on artificial growth media. This research will reveal the relative importance of individual and communities of ectomycorrhizal fungi in determining pine seedling health and resistance factors

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Establishment of ectomycorrhizal fungal communities following reclamation

As part of restoring diversity and ecosystem function, ectomycorrhizal fungi are an important component of forest restoration following reclamation. Moreover, the inclusion of reference ecosystems is critical in measuring restoration 'success', and should include not only the target ecosystem, but also those representing steps along the successional pathway in the absence of disturbance from mining. We compared the assembly of ectomycorrhizal fungal communities in reclaimed and reference ecosystems. Reclamation included placement of three soil types, peat, forest floor material, and subsoil, a mix of salvaged B and C soil horizons, on overburden. Representative boreal forest, which varied in above-ground disturbance over otherwise intact soils comprised reference ecosystems. Specifically, reference models included: 1) mature jack pine (Pinus banksiana) with forest floor intact, 2) trees removed and forest floor intact, and 3) trees and forest floor removed. In May 2012, seedlings of three host species (Populus tremuloides, Pinus banksiana, and Picea glauca) were planted to assay soils for ectomycorrhizal fungi in reclaimed and reference treatments. Subsets of these seedlings were harvested in August 2013 and 2015, and fungi colonizing roots were identified using molecular techniques. Two years after planting, communities of ectomycorrhizal fungi colonizing seedlings on reclaimed sites slightly differed from those assaying soils of reference models. Four years after planting, however, fungal communities diverged. While the removal of trees from reference ecosystems did not cause a pronounced change in the composition of fungal communities, the loss of the forest floor did. With respect to the reclaimed treatments, fungal communities fell on a trajectory unique from those observed at the reference ecosystems. Four years following afforestation on reclaimed sites, the ectomycorrhizal fungal community not only differed across soil types, but also varied from the reference sites selected to represent a reset of succession.

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A tale of two Neonectria: Dynamics of N. ditissima and N. faginata in the aftermath forests on the Monongahela National Forest, West Virginia, USA

In North America, beech bark disease (BBD) occurs when beech stems previously infested with the exotic scale insect, Cryptococcus fagisuga, are colonized by one or more phytopathogenic fungi, primarily Neonectria faginata and Neonectria ditissima. Previous studies on the Monongahela National Forest in West Virginia and elsewhere documented a unidirectional progression in which N. faginata eventually supplanted N. ditissima as the dominant pathogen in the BBD complex with complete replacement within as few as 7 years. More recent studies in Maine indicate that N. ditissima, an endemic pathogen that also causes perennial target cankers on numerous hardwoods, can be maintained and contribute to BBD even in aftermath forests when other highly susceptible hardwood tree species were present. Together these data may indicate that following transition from the killing front to the aftermath forests, relationships between N. faginata and N. ditissima may be more dynamic than previously thought, with possible implications for BBD epidemiology and disease agent evolutionary pressures. To test this hypothesis, beech stands located on the Monongahela National Forest,

including plots initially established and monitored by Houston from 1982-1994, were revisited in Fall 2016 and bark disks sampled to permit culturing and single spore isolations from five perithecia from each of four bark disks taken from five beech and one non-beech host across four spatially segregated plots. A total of ten single spore colonies per perithecia were plated and grown out for one month for morphological confirmation. Incidence of N. faginata and N. ditissima was recorded by plug, tree, and plot. Representatives for each species will be retained for genetic analysis and molecular confirmation. Results of this study should uncover whether individual contributions of N. faginata and N. ditissima vary across the West Virginia landscape and if factors such as non-beech hosts influences these relationships.

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Experimentally testing silvicultural strategies that promote stand structural complexity in northern hardwood forests

Forestry practices emphasizing stand structural complexity are of interest in many temperate regions of North America because of their potential to enhance carbon storage and provide a range of co-benefits. Our long-term research is evaluating silvicultural treatments promoting late-successional forest diversity, structure, and dynamics in northern hardwood-conifer forests. We test the hypothesis that aboveground biomass development (carbon storage) is greater in structural complexity enhancement (SCE) treatments when compared to conventional selection systems (single-tree and group) modified to retain elevated structure and emulate natural disturbances. Manipulations and controls were replicated across 2 ha. units at two study areas in Vermont, USA. Over two pre- and 13 post-treatment field seasons, we employed a variety of sampling techniques to quantify structural complexity, regeneration, and biodiversity responses. Data on aboveground biomass pools (live trees, standing dead, and downed wood) were collected pre- and post-harvest then again a decade later. We used the Forest Vegetation Simulator to project "no-treatment" baselines, allowing measured carbon responses to be normalized against differences in site characteristics affecting tree growth. The integrated quantification approaches taken in this study have produced a well-rounded, empirical and model-based picture of ecosystem responses. Ten years after harvest, measured aboveground carbon in SCE units was 15.9% less than simulated no-harvest baselines, compared to 44.9% less in conventional treatments. Results from multivariate models indicate treatment as the strongest predictor of aboveground C storage followed by site-specific variables. Diversity for late-successional herbaceous plants increased significantly in SCE units and decreased significantly within group selection units. Fungi and salamander populations were strongly associated with microsite characteristics and increased significantly under SCE. Structural enhancement treatments have the potential to increase carbon storage in managed forests. They offer alternatives for adaptive management integrating carbon, climate mitigation, timber revenue, and late-successional biodiversity and habitat. Applications include old-growth and riparian restoration, carbon management, and low intensity commercial management.

C. King (1), E. Wilely (1), & S. Landhäusser (1)

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Carbohydrate remobilization and suckering potential of aspen roots following severe disturbance

Nonstructural carbohydrate (NSC) storage and remobilization are important processes that allow trees to temporarily maintain a negative carbon balance and recover from disturbances that kill aboveground tissue and/or limit carbon uptake. However, the carbohydrate remobilization process in trees remains poorly understood. In particular, it remains unclear which tissues are the main sources of NSC reserves and how much of NSC pool can be remobilized in older tissues. This knowledge is needed to determine the relationship between pre-disturbance carbohydrate storage and recovery potential (i.e. sucker growth).To determine the extent to and the spatial/temporal pattern in which carbohydrates are remobilized following a severe disturbance, we collected root segments (1-3 cm diameter; ~10-35 years old) from a mature trembling aspen (Populus tremuloides Michx.) stand and allowed them to sucker in a dark growth chamber. Roots were harvested either when: 1) sucker growth stopped or 2) all suckers met the criteria for death. Sucker growth and initial and final carbohydrate concentration of the xylem and phloem were measured.Total sucker weight increased with root volume and initial root NSC mass. After controlling for volume, growth was more strongly correlated with initial phloem NSC than xylem NSC concentration. As sucker growth progressed, though xylem NSC was depleted more than the phloem (68% vs 45% of initial levels), more total NSC was removed from the phloem (~4x that of xylem) due to its much greater initial NSC mass. At sucker death, xylem still contained ~2-3% and phloem contained ~10-14% NSC.These results suggest that the phloemâ€”an often overlooked carbohydrate poolâ€”contains a large and important carbon reserve pool for regrowth following disturbance. However, the high levels of carbohydrates remaining in the root suggest that a large portion of NSC ”mostly sugar”may be unavailable for remobilization.

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Catastrophic wind and salvage harvesting effects on woodland communities

Compounded disturbances may result in novel forest successional and developmental patterns. We investigated the effects of post-wind disturbance salvage harvesting, a unique compounded disturbance of which the ecological consequences are unresolved, in fire-restored longleaf pine woodlands of the Alabama Fall Line Hills, a characteristically biodiverse and rare ecosystem. We developed floristic inventories and collected plot-level data in areas undisturbed, wind-disturbed, and compound-disturbed (wind + salvage) to compare disturbance-mediated differences in (1) physical site conditions, (2) woody plant composition and structure, and (3) the composition and abundance of ground vegetation (herbaceous and woody plants more than 1 m in height). Nonmetric multidimensional scaling (NMS), PerMANOVA, and Indicator Species Analysis revealed distinct differences in ground vegetation across disturbance categories. The biophysical drivers most correlated with differences in species assemblages were volume of coarse woody debris, sapling density, percent canopy cover, and basal area. Wind-disturbed plots had the greatest species richness and diversity of saplings and ground vegetation, and were characterized by indicator species with unique habitat requirements. Indicator species of compound-disturbed plots were mostly generalists with broad habitat requirements. We posit that salvage harvesting reduced habitat heterogeneity engendered by the wind disturbance, thereby

reducing species diversity on compound-disturbed plots. Thus, we recommend leaving patches unharvested within salvaged stands to support stand-scale plant diversity. Interestingly, regeneration of longleaf pine, the most desirable species in the system, increased with cumulative severity. Nonetheless, longleaf pine saplings and seedlings were markedly outnumbered by other species in all disturbance categories, indicating that these woodlands likely need prescribed fire or other competition reduction measures for recovery toward longleaf pine dominance.

W. Klenner (1)

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Stewardship approaches to forest management of dry interior forests in British Columbia in an era of uncertain climate

Concerns about the effects of climate change on terrestrial ecosystems have existed in the scientific literature and popular media for over 30 years. I assessed the likely effects of climate change on forested ecosystems in BC using literature reviews and landscape-level climate change modelling using a range of assumptions about the nature of climate change, the effects of climate on vegetation and succession, and interactions between climate, natural disturbances and management. The literature and our model projections were characterized by high levels of variability and hence, considerable uncertainty around the effects that climate change will have on dry forests in the interior of BC. Under certain climate change/natural disturbance assumptions, old-growth forests will almost disappear in a century. Other climate change scenarios have little effect on the amount of old-growth forest beyond their reduction via harvest. Due to the many potential risks to ecological, economic and social values, risk-averse management to address climate change should include: 1. Clearly defining desired conditions and identifying areas of greatest concern, 2. Landscape-level coordination and planning to achieve large-scale objectives, 3. Active management to create diverse forest age, species and structural conditions, 4. Recognition that as disturbance severity increases, so does the probability of ecosystem change and the unwanted departure from existing or historic conditions, 5. The need to implement strategic fuel management, and 6. Systematic monitoring and a clear application of adaptive management principles to evaluate the efficacy of specific practices.

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Native pathogen-induced changes in jack pine have cascading effects on the invasive mountain pine beetle and its interactions with resource-sharing insects

With recent range expansions of species due to climate change, it is important to understand the impact of natural disturbances on exotic species. Our research investigated the expansion of mountain pine beetle (Dendroctonus ponderosae) into the novel host jack pine (Pinus banksiana), which is an ecologically and economically important component of the Canadian boreal forest. We identified the impact of induced host defense compounds due to the infection of a widespread native parasitic plant (dwarf mistletoe, Arceuthobium

americanum) on the success of mountain pine beetle and its associated fungi. We also tested the impact of dwarf mistletoe-induced changes on interactions among mountain pine beetle and the community of resource sharing insects. There was a non-linear defense chemical response from dwarf mistletoe infection, with increasing chemical concentrations at moderate severities and decreasing concentrations at high severities. Host susceptibility to mountain pine beetle-associated fungi was negatively affected by the dwarf mistletoe-induced changes in chemical defense concentrations. Furthermore, the reduced phloem thickness from dwarf mistletoe infection had a negative impact on mountain pine beetle developmental success. Finally, dwarf mistletoe infection reduced the competitive advantage of the subcortical insect community on mountain pine beetle performance. We discuss implications of these interactions between natural biotic disturbances and mountain pine beetle in regards to its range expansion in boreal forest and identification of forest susceptible to mountain pine beetle.

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Applying principles of ecosystem memory to restore resilience in heavily managed forests of Fennoscandia

North European forest management has centuries-long history, but particularly the era of intense forestry since the mid-1900s has strongly affected forest structures and biota. In Finland and Sweden, for instance, several hundred species have become threatened because of forestry. Certain key features of "natural" forests are of particular importance for these species, but due to the intensive forestry these are usually rare in an average managed forest. These features include large-sized dead wood, exceptionally old tree individuals, tree-species mixtures, and their spatio-temporal continuities. The scarcity of such “little grey cells” weakens ecosystem memory and thus the post-harvest recovery of forest ecosystems. However, after recently acknowledging biodiversity loss, North European forestry has begun to retain modest levels of live and dead trees in cleared stands. In this presentation, I will evaluate evidence about the functioning of such features – and more generally retention forestry – in supporting ecosystem memory, and suggest further improvements for forestry to better support threatened and specialized species. Any retention supports at least some forest key features and their associated species, but many taxa require considerable amounts and continuous availability of these features. Applicable improvements in forestry include flexibly-applied gap-harvesting techniques (multiple-cohort, continuous-cover or variable-retention forestry) and improvements in stem-density variation, tree-species mixtures and dead wood. Still, perhaps the biggest obstacles for increasing these key features or for applying harvesting methods other than clear cutting include public attitude, insufficient training of forest professionals and, until recently, legislation.

J. Kwak (1), M.A. Naeth (1), & S.X. Chang (1)

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Ten years of elevated nitrogen and sulfur deposition did not affect microbial and enzyme activities and nitrogen transformation in a boreal mixedwood forest

Oil sands mining in northern Alberta, Canada, emits large amounts of NOx and SO2 to the atmosphere, which will eventually return to the surrounding forest ecosystems. This study was conducted to determine changes in microbial and enzyme activities and nitrogen transformation rates in a boreal forest soil in response to ten years (2006-2015) of elevated levels of nitrogen (N) and sulfur (S) depositions. The experiment had a two (0 and 30 kg N ha-1 year-1, as NH4NO3) × two (0 and 30 kg S ha-1 year-1, as Na2SO4) factorial design with three blocks. The forest floor and the mineral soil (0-15 cm) samples were collected in October 2015. Microbial biomass, enzyme activities related to N cycling, and soil respiration rates were measured to evaluate the responses of soil microbiological properties. A laboratory incubation experiment using 15N isotopic dilution was conducted to evaluate gross N transformation rates. Elevated N and S depositions did not affect soil chemical and microbiological properties, suggesting that the soil in the studied boreal forest was resistant for ten years of elevated levels of N and S deposition. Gross N mineralization, nitrification and immobilization rates were not affected by N and S deposition. Gross N mineralization (0.54-0.62 and 36-49 mg N kg-1 day-1for mineral soil and forest floor, respectively) and gross NH4+ immobilization (0.39-0.57 and 10-19 mg N kg-1 day-1for mineral soil and forest floor, respectively) rates were tightly coupled in both soil layers. Gross NO3- immobilization rates (20-32 mg N kg-1 day-1) were significantly greater than gross nitrification rates (9-20 mg N kg-1 day-1) in the forest floor. Our results suggest that the studied boreal forest soil was resilient or resistant for N and S deposition and considering the current N and S emission and deposition rates in northern Alberta, it will take a long time to cause negative effects on forest ecosystems.

D. Kweon (1), & P. Comeau (1)

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The maximum size-density relationship for trembling aspen

Maximum size-density relationships (MSDR) were developed for pure stands of trembling aspen (Populus tremuloides Michx.) in Alberta and Saskatchewan, Canada. These relationships define the maximum number of trees that can be supported in a stand when trees are any particular size. Stochastic frontier function regression was used to estimate the static self-thinning line and a linear mixed-effects model was used to determine the average dynamic self-thinning line from repeated measurements. Climate variables obtained from Climate WNA were included in our models. The static thinning line was steeper than Reineke's slope (-1.605) and the slope value of the average dynamic thinning line was not different from -1.605. Frost free period, summer heat moisture index, and mean coldest month temperature negatively influence the position of the static thinning line because these climate variables are linked to increases in evapotranspiration and drought exposure. For the average dynamic thinning line, summer heat moisture index has a negative effect on the intercept and no effect on the slope. Our models are potentially useful in characterizing and modeling variation in stockability and relative densities of aspen stands in Saskatchewan and Alberta. Results also suggest that increasing summer dryness related to climate change may decrease the carrying capacity and productivity of aspen stands in portions of this region.

M. Kwiaton (1(

(1) Ontario Ministry of Natural Resources and Forestry (OMNRF)

Examining effects of disturbance type and intensity on deadwood dynamics in jack pine dominated stands: a FVS-DbD modelling exercise

Standing and downed deadwood is a major component to forest dwelling species and their habitat requirements. Therefore, deadwood volume is widely used as a surrogate for forest biodiversity. Natural and human caused disturbances affect the patterns of deadwood availability throughout the life cycle of a forest stand and depending on the species requirement can influence species richness and thus biodiversity at various stages of stand development. The Forest Vegetation Simulator (FVS) is a live-tree growth model that was used for projecting forest stand dynamics using various forest management alternatives and natural disturbance scenarios. The mortality outputs from FVS were than used as inputs into a deadwood dynamics (DbD) model calibrated for jack-pine dominated stands. The DbD model was used to track the standing deadwood (snags) as it decays altering its structural composition and converts to downed deadwood through snag breakage or snag fall. The model continues to track the downed woody debris, in five-year increments as it decays and eventually becomes incorporated into the forest soil profile. As a "proof-of-concept" to model deadwood supply under different disturbance types and intensity (typical tree-length harvest, intensified biomass harvest, wildfire, and post-fire salvage) were examined at various stages of stand development and projected over 150 years to examine and compare deadwood dynamics in these alternate disturbance scenarios.

S. M. Landhäusser (1), S.E. Macdonald (1), & V.J. Lieffers (1)

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Drivers of spatial and temporal patterns in vegetation during spontaneous early colonization of boreal reclamation sites

Industrial activities such as surface mining in the circumpolar boreal forest result in significant and severe disturbances to ecosystem structure and processes. Reclamation methods must facilitate the re-development of basic ecosystem functions such as carbon, nutrient, and water cycling. However, re-establishing these processes also requires the development of soils and establishment of tree canopies and associated plant communities. Often the placement of cover soils and planting of trees is part of the forest reclamation process; however, the establishment of the associated forest understory vegetation is often left for spontaneous regeneration that will depend upon legacy propagule banks or migration from adjacent undisturbed areas. In this presentation we will explore some of the drivers of early vegetation establishment and development on boreal forest reclamation sites. We draw from a range of studies to provide a clearer picture of the effects and importance of different variables influencing the initial establishment and early development trajectories of vegetation on reclamation sites. We will examine the response of vegetation diversity, cover, and composition across time and space in response to landform topography, presence of trees, cover soil types and their propagule legacy, and the importance of microtopography, such as surface roughness and coarse woody debris. Insight into such effects can be used to inform future approaches to facilitate rapid and successful establishment of native understory vegetation communities on boreal surface mine reclamation sites.

T.A, Larsen (1), S.E. Nielsen (2), & GB Stenhouse (1)

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Nutritional ecology of grizzly bears in a multiple-use landscape and its effects on density, survival, and recovery

Human factors threaten the persistence and long-term conservation of grizzly bears in Alberta's multiple use landscape. Empirical data suggests that roads compromise grizzly bear survival with local populations declining when road density increases. Management actions focused on recovery of grizzly bears have therefore focused mostly on limiting road development within core grizzly bear range. However, there is also evidence that grizzly bear populations are influenced by bottom up (food supply) processes. Research from western North American suggests that bear densities vary at local and regional levels due to complex interactions between human factors that influence both human-caused mortality risk of bears and their food supply. In particular, forest harvesting has the potential to increase food supply and therefore positively influence the health (body growth and condition) of grizzly bears therefore contributing to growth and maintenance of self-sustaining populations when human-caused mortality is kept low. Recent research in west-central Alberta has linked available digestible energy of ungulates and fruit to local abundance of grizzly bear. Areas of high relative bear density tend to be associated with forest disturbances from the energy and forestry sectors demonstrating an association with early seral habitats. The purpose of our paper is to highlight past research on the nutritional ecology of grizzly bears and contrast this to density, survival, and food supply. We then discuss potential linkages to industrial land use activity in relation to the management, recovery, and long-term conservation of this threatened species.

A.J. Larson (1), & R.T. Belote (2)

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Forest structure and fuel loads following single and repeat fires in mixed-conifer forest

Since the early 1980s managers have allowed many lightning-ignited fires to burn with minimal interference in forests of the Bob Marshall Wilderness in northwestern Montana, USA. Substantial portions of this landscape burned twice between 1985 and 2015. We used this contemporary active fire regime to investigate fire-effects and post-fire fuel loads, tree regeneration, and forest structure in mixed-conifer forest communities. Short-interval reburns decreased surface fuel loads relative to once-burned and unburned sites, with the strongest effect on the coarse woody debris (more than 7.6 cm dia). Black carbon ``the carbon fraction of charcoal”on was approximately twice as abundant at in reburn patches compared to once-burned patches. Reburns decreased tree seedling density relative to once-burned sites, but we found limited evidence of widespread transitions to non-forest communities. Reburns of sites that burned in an initial high-severity fire had the lowest surface fuel loads and lowest live tree and seedling densities. However, tree seedlings, primarily Pinus contorta, were almost always present at low densities, even after repeated high-severity fires. Our analyses suggest that the study forests are highly resilient to repeated wildfires. While post-reburn succession back to closed canopy, high-biomass forests will likely be much slower than for once-burned sites, most reburned sites nevertheless appear to be on a trajectory back to tree-dominated conditions. This contrasts with recent investigations of reburns in the Sierra Nevada and Southwest, where reburns frequently caused transitions to shrubfields and grassland.

N. Lauer (1) & J. Zwiazek (1)

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Effects of pH on salt tolerance in white spruce, tamarack and trembling aspen

Revegetation of land disturbed by oil sands surface mining in northeastern Alberta can be hindered by elevated soil pH and salt levels found at reclamation sites. In this study, the tolerance of white spruce (Picea glauca), tamarack (Larix laricina) and trembling aspen (Populus tremuloides) to elevated pH and salinity was investigated. Seedlings were maintained in liquid culture for 50 days while being exposed to three pH levels (5, 7, and 9) with three separate NaCl concentrations (0, 30, and 60 mM NaCl) in a factorial design for a total of 9 treatments. For white spruce, elevated pH caused decreases in leaf iron. Elevated NaCl induced decreases in leaf nitrogen, iron, total chlorophyll content, net photosynthesis, and net transpiration. However, elevated pH and NaCl did not induce mortality or changes in biomass. For tamarack, elevated pH and NaCl caused decreases in leaf nitrogen, iron, total chlorophyll content, net photosynthesis, net transpiration, and total biomass. For trembling aspen, elevated pH and NaCl induced mortality as well as decreases in leaf nitrogen, iron, total chlorophyll content, net photosynthesis, net transpiration, and total biomass. Furthermore, aspen exhibited a lower leaf sodium content compared to other species. Both tamarack and aspen exhibited an increased root:shoot ratio in response to stress. Multivariate statistical analysis revealed that all species exhibited a common pattern in response to stress. This intriguing trend is hypothesized to be caused by the trees' perception and response to stress rather than the consequence of living in a stressful environment. A potential mechanism will be discussed. Ultimately, this information could be used for reclamation efforts of lands disturbed by oil sands surface mining in northeastern Alberta, especially lands affected by elevated pH and salt levels.

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Twenty-four years of birds: long-term effects of forest fragmentation and recovery on boreal bird communities

The Calling Lake Fragmentation Study is a long-term, collaborative experiment in northern Alberta's boreal forests, supported through a partnership between Alberta-Pacific Forest Industries Inc. and the University of Alberta. Established in 1993, and encompassing ~120 sq. km of older, mixedwood forest, the core experiment involved the creation of forest fragments 1, 10, 40, and 100 hectares in size, through forest harvesting in adjacent areas. The fragments were either completely isolated by surrounding cutblocks, or left connected by riparian forest corridors to unharvested forest. Control sites were established in an extensive tract of unharvested forest within the study area. While many short-term experimental studies of forest fragmentation on boreal birds took place shortly after this project began, we have now accumulated 24 years of avian point count data, giving us an unprecedented opportunity to study long-term effects of forest fragmentation on boreal bird populations. We report here on how the boreal songbird community and focal boreal songbird species have responded over 24 years to the initial logging, including the trajectory of recovery, and explore to what extent changes in boreal bird populations at Calling Lake are due to these factors.

V. J. Lieffers (1), R.T. Caners (1,2), V. Crisfield (2,3) & H. Ge (1)

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Re-establishment of hummock topography promotes tree and vegetation regeneration on highly disturbed moderate-rich fens

Winter exploration of oil sands deposits underlying wooded fens mostly eliminates the hummock-hollow topography on drilling pads and the ice roads leading to them, after their abandonment in spring. Recovery of the specialized bryophytes and vascular plants especially conifers on these disturbed peatlands is thought to depend on the recovery of hummock topography. In late winter, numerous large blocks of frozen peat (1.5 x 1.5 m) were lifted out of the flattened drilling pads and positioned beside their excavated hollows; this was done on six pads within a large fen complex in northeast Alberta. Four years later, the condition of the mounds and the regeneration of vegetation were assessed on these elevated mounds compared to adjacent flattened areas of the pads. Mounds and flattened areas differed substantially in terms of the vegetation they supported; mounds were important habitat for a number of species that were less tolerant of conditions on flattened areas. Conifer seedling density was more than five times higher on mounds than the mostly flat, flood-prone areas between them, and seedling density was positively related to mound height and strength of seed source. Mounds on some of the pads were heavily eroded; these pads had peat with higher humification, and operationally these pads were also treated in late winter when peat was thawing and fractured into pieces during mound construction. Developing a large volume of elevated substrate that persists until natural hummock-forming mosses can establish is thought necessary as the primary substrates for recruitment of trees and a range of peatland bryophytes and vascular plants, and for the recovery of the habitat for the threatened woodland caribou of this region.

V. Lieffers (1), D. Sidders (2), T. Keddy (2) & P. Blenis (1)

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Fifteen year growth of planted spruce in variable retention mixedwoods: site preparation and stand composition

As a part of the Ecosystem Management Emulating Natural Disturbance (EMEND) experiment in Northern Alberta, survival and growth of planted white spruce (Picea glauca (Moench) Voss) were assessed in both deciduous-dominated (D-dom) primarily mature trembling aspen (Populus tremuloides Michx.), and conifer-dominated (C-dom) mixedwood stands. Three overstory retention levels (clearcut; 50% and 75% retention) and four site preparation methods (high speed mixing, mounding, scalping and no treatment) also were evaluated. In C-dom stands, 50% and 75% retention reduced spruce growth and survival compared to clearcutting. In contrast, in D-dom stands, spruce performed best in the 50% retention, with stem volume at year 15 being at least double that of any other treatment in the experiment. Across all sites, soil mounding and mixing treatments produced spruce that were ~30% taller than those in the control or scalping treatments. Importantly, rates of height increment between years 11 and 15 were still much greater in the mounded and mixed plots for both the entire spruce population and for top height spruce. The best site index estimate for

regenerated spruce occurred in the D-dom, 50% retention, soil mixing treatment and was close to that of the best stands in Alberta Boreal Forests. Natural regeneration of deciduous trees was greater after clearcutting and was reduced with partial harvest.

E.B. Lilles (1), A. Dhar (2) & K.D. Coates (3)

(1) BC Ministry of Forests, Lands and Natural Resource Operations; (2) University of Alberta, Department of Renewable Resources; (3) retired from BC Ministry of Forests, Lands and Natural Resource Operations

Retention level affects dynamics of understory plant community recovery in north-temperate coniferous forests

Retention forestry is replacing clearcutting as the dominant silvicultural practice in many parts of the world. Higher levels of retention are thought to promote faster and more complete ecological recovery after logging, but this hypothesis has not been sufficiently tested. In this study we examined understory plant community dynamics in 0%, 40%, 70% and 100% retention stands for 24 years after harvesting at the Date Creek Research Forest near Kispiox, BC. This research forest has a before and after control experimental design with four replicates of each retention level. We used the similarity of vegetation cover, diversity and composition to the pre-harvest and unharvested condition as an indicator of ecological integrity. Departures in understory vegetation (cover, diversity and composition) from pre-harvest levels were greatest at 0% retention, intermediate at 40% retention, and smallest at 70% retention. The cover of non-vascular cryptogams, which dominated the forest floor in unharvested stands, decreased sharply with decreasing retention level but had recovered within 10 years in the 40 and 70% retention treatments. The cover of vascular species increased gradually with decreasing retention level and although the cover of early seral species peaked and began to decrease to unharvested levels in all treatments by year 16, the generalist species continued to expand their cover at year 16. Most late seral vascular species showed a neutral or positive response to decreasing retention and only two species, Platanthera orbiculata and Oplopanax horridus, remained negatively affected by the 0% retention level at year 24. Although these vegetation responses did support the hypothesis that higher retention levels enhance ecological recovery after logging, in this ecosystem where a few moss species dominate at low light levels, lower retention levels were necessary to stimulate the growth of most vascular species and to increase diversity.

K. MacAfee (1)

(1) Natural Resources Canada - Canadian Forest Service - Canadian Wood Fibre Centre

Silviculture toolkit for re-establishing forest cover

The Canadian Forest Service of Natural Resources Canada is working together with the Canada's Oil Sands Innovation Alliance (COSIA) to produce a silvicultural toolkit that will improve return to forest cover on areas disturbed by oil sands exploration activities and operations. This project focuses on in-situ sites as well as seismic lines and other linear disturbances. The objective of this project is to help educate reclamation planners about the value of good silviculture practices and to create a toolkit that will support site-level decision making associated with forest land reclamation and return to forest cover.This two year project (April 20to March

2018) is currently finishing its first year of deliverables, which include guidebooks that cover topics related to site assessment and preparation, and regeneration techniques. Several factsheets have been developed covering techniques and topics that can directly be applied in the field. In addition to written and published material, videos are being produced that clearly show successful reclamation and restoration activities. To link all this material together, and help with applying the right techniques at the right sites and the right time, we are developing a web-based, decision making tool. The subject topics and the format of the tools are developed in collaboration with industry, based on their needs and preferences. The poster will provide an overview of the project, its key deliverables, and describe how it meets industry needs to return their disturbed sites to forest cover.

Z.G. MacDonald (1), I. Anderson (2), J.H. Acorn (3), & S.E. Nielsen (4)

(1) University of Alberta, Department of Renewable Resources

Using butterfly assemblages on lake islands to assess applications of insular biogeography to the conservation of terrestrial biota

Ecologists have been fond of insular metaphors since the publication of the theory of island biogeography. A priori parallels between oceanic islands and habitat patches suggest that habitat fragmentation (decreasing patch size and increasing patch isolation) reduces species diversity. Indeed, early works concluded that fragmentation effects were of great conservation concern. However, recent research suggests that negative relationships between fragmentation and species diversity are artefacts of habitat loss because total habitat area may correlate positively with species diversity, and negatively with degree of fragmentation. In this study, we used butterfly assemblages on islands of Lake of the Woods, Ontario, Canada to decouple habitat fragmentation from habitat loss and test two competing hypotheses: (1) the island effect hypothesis, which suggests that decreasing patch size and increasing patch isolation reduces landscape-level species diversity; and (2) the habitat amount hypothesis, which suggests that patch size and isolation have little effect on species diversity, and only the aggregate amount of habitat matters because patch edges do not delimit populations. Existing methods that control for habitat loss were used to test for effects of island size on butterfly species richness. Constraining these analyses to different ranges of island sizes demonstrated that fragmentation-species diversity relationships were scale dependent, questioning the viability of broad-scale approaches. Generalized linear models were also used to test the combined effects of island isolation, vascular plant diversity (proxy of resource availability), and habitat diversity on butterfly species richness. Our islands approximate oceanic archipelagoes in many ways, while maintaining a scale of fragmentation more consistent with patches on landscapes fragmented through human activity (e.g., insular woodlots within an agricultural matrix). Observed patterns in butterfly diversity supported the habitat amount hypothesis. We conclude that it is principally the scale of separation of habitat from non-habitat that questions the validity of the island effect hypothesis.

E. Macdonald (1), L. Schroeder (1), J. Steinke (1), & V. Lieffers (1)

(1) University of Alberta, Department of Renewable Resources

Beyond beetle: Natural regeneration after mountain pine beetle outbreaks in Alberta

The unprecedented outbreak of the native pest, mountain pine beetle (MPB), in Alberta presents government and industry with the challenge of deciding upon post-attack management for dead or partially dead lodgepole pine stands. These stands represent a diversity of ecosite types. We examined natural regeneration of pine and spruce in lodgepole pine-dominated forests for a variety of ecosite types in west-central Alberta. We examined stands that had experienced heavy mortality due to MPB attack six to eight years prior to sampling and had low densities of other tree species in the canopy or as advanced regeneration. Only about one third of sites had any evidence of lodgepole pine regeneration post-MPB. On sites that had some regeneration, seedling densities varied from 25/ha to a maximum of 200/ha. Drier and poorer ecosites had a greater probability of occurrence of some regeneration and higher densities when regeneration did occur. Regeneration densities, however, were always low. Richer and moister ecosite types had no or very few seedlings; these sites were dominated by heavy understories of herbaceous (and sometimes shrubby) vegetation cover. Low densities of white spruce and black spruce seedlings were also found on several sites. Rich moist stands will experience a regeneration delay following MPB attack and they may stay in a forb- or shrub-dominated phase. We are further exploring variation in serotiny among sites and variation among ecosite types in the severity of MPB-caused mortality. Results from this research can help us understand the potential for successful lodgepole pine regeneration in these forests and is critical to understanding their successional future, and to deciding upon management options for them.

M.D. MacKenzie (1), J. Hogberg (1), S. Dietrich (1), & J. Battigelli (1)

(1) University of Alberta, Edmonton, AB

Can reclamation of above and belowground processes be measured with a functional similarity index?

Oil sands mining in northern Alberta reduces ecosystem function to zero. Industry is legally required to return the environment to “equivalent land capability,” which has been interpreted to mean productivity. To date, this has proven challenging to quantify and the criteria and indicator systems commonly applied to sustainable forestry may not work for this purpose. To measure reclamation success, we need a better understanding of the ecosystem ecology of intact systems in the region, including how these communities respond to disturbance. I would also suggest that we need to apply soil science methods and community ecology based on the principles of the edatopic grid, with a better understanding of how to quantify the nutrient regime axis. Over the last 5 years, my lab has been examining natural and reclaimed upland forest ecosystems using a variety of modern techniques including: ionic resin analysis, for soil nutrient availability; phospholipid fatty acid analysis and community level physiological profiling, for microbial community structure and function; simultaneous thermal analysis, for soil organic matter stability; and spatial statistics, for measuring the effect of interactions. Things we've learned to date are that not all reclamation substrates are created equal, the boreal forest floor is alive, and that space can be used as a surrogate for unmeasured variables. This presentation will focus on our recent development of a functional similarity index and where we can go from there.

D. MacKenzie (1) & M. A. Naeth (2)

(1) Vertex Resource Group Limited; (2) University of Alberta, Department of Renewable Resources

Surface soil handling and storage impacts on plant propagules and establishment of native plant communities

Conservation of forest surface soil is critical for development of self-sustaining forest ecosystems on post-mined land. Salvaging the surface soil from upland boreal forests received little attention in the past and was often not required. Research has shown forest surface soil provides an economical, diverse and abundant source of native propagules and an important source of nutrients and soil fauna. Salvage depth affects soil quality and potential for in situ propagules to emerge. Salvaging too deep will dilute the propagule and organic matter content of the forest floor with underlying mineral soil; however, salvaging too shallow may not provide sufficient root to soil contact for successful emergence of vegetative propagules. Optimal salvage depth is impacted by various factors such as soil texture, donor source location and reclamation objectives. Salvaged surface soil should be directly placed if native vegetation establishment is desired, as stockpiling surface soil for even short periods of time reduces viability of most boreal plant species and causes substantial changes to soil chemical properties. Viability of seeds within stockpiles can be managed in the short term by altering stockpile size and timing of construction. Optimal placement depth and distribution of surface soil is also dependent on many factors including salvage depth, substrate quality and reclamation objectives. Data from field research at operational and plot scales are presented to support best practices. Various adaptive management practices developed from theory, research and operations to help reduce negative impacts on soil quality and viability of native propagules are discussed.

L. Mao (1), J. Dennett (1), C.W. Bater (2), P. Tompalski (3), N.C. Coops (3), D. Farr (4), M. Kohler (5), B. White (2), J. J. Stadt (2), & S.E. Nielsen (1)

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Using airborne laser scanning to predict plant species richness and assess conservation threats in the oil sands region of Alberta

Timely and cost-effective monitoring of biodiversity across large areas is a major challenge, yet an important component of monitoring programs that inform policy and conservation strategies. Recent advances in Airborne Laser Scanning (ALS) provide new opportunities to simultaneously measure vegetation structure and terrain morphology at fine spatial scales. However, there is limited research on whether ALS metrics correlate with biodiversity measures. Here we used vascular plant data from 283 quarter-hectare (50 m X 50 m) plots from the boreal forest in northeast Alberta, Canada to evaluate the potential for ALS-derived metrics in explaining species richness patterns for vascular plants, as well as for four growth forms: herbaceous (including forbs and graminoids) and woody plants. We found canopy height from ALS was the most consistent and important factor positively related to local patterns in vascular plant species richness. Multivariate regression models of ALS-derived metrics explained 20% to 35% of the variation in species richness among vascular plant and the four subclasses. When considering the current distribution of in situ oil sands leases in the region,

vascular plant richness inside of the leases are higher than those outside of the leases. Areas delineated for woodland caribou conservation had lower average plant richness suggesting that caribou conservation will do little to protect hotspots of plant diversity in Alberta's boreal forest. Our results highlight the value of using fine-scale measures of ALS-derived vegetation structure to explain, predict, and potentially monitor local plant diversity for a high latitude forested ecosystem.

A. Mathison (1), A. Schoonmaker (2), & M.D. MacKenzie (3)

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Ensuring plant diversity and restoring soil function in disturbed landscapes: hitchhiking native forbs with white spruce

The objective of this study was to determine the above and belowground effects of companion planting native herbaceous species (fireweed (Chamerion angustifolium) and showy aster (Eurybia conspicua)) with a white spruce seedling. We evaluated the success of this approach with reference to other landscape-level disturbance types: wildfires and forest harvesting. In this study, the following questions are addressed: 1. Can we produce mixed-container stock of white spruce that is comparable or better than singly produced white spruce seedlings? 2. What is the effect of stock type on the growth of the native forb species, while co-grown with spruce? 3. Does the established forb impact vegetation dynamics (reduce competition) of other undesirable species in the immediate vicinity of the white spruce seedling?4. Does the presence of a companion forb have an effect on microbial function in the root zone, and how does it compare to microbial function in the root zone surrounding similar aged white spruce seedlings in sites of a similar age recovering from a wildfire or forestry operations?Laboratory analysis of plant and soil samples is ongoing. However, after two growing seasons this study clearly shows that it is possible to successfully establish co-grown native forbs concurrently with white spruce seedlings. Where site conditions are good (adequate site preparation, low initial vegetation competition during year of establishment); both species of forb (fireweed and aster) demonstrate excellent growth and fireweed showed strong evidence of spreading substantially beyond the point of planting. Compilation of additional belowground results may provide further support and additional benefits in terms of restoration of key functional indicators belowground.

G.J. McDermid (1), S. Chen (1), C. Feduck (1), M.F. Wu (1), J. Hird (1), T. Tan (2), S.E. Nielsen (2), J. Linke (1) & G. Castilla (3)

(1) University of Calgary, Geography Department; (2) Univ. of Alberta, Department of Renewable Resources; (3) Natural Resources Canada, Canadian Forest Service

The role of UAVs in linear disturbance restoration and monitoring, contributions from the BERA project

Restoration of seismic lines and other legacy features in the boreal forest requires reliable tools for measuring and monitoring vegetation structural attributes at a variety of scales. Of particular interest is the role of unmanned aerial vehicles (UAVs): an emerging remote-sensing platform that fills an observation gap between ground measurements and piloted aircraft. In this presentation, we report on the accuracy and costs

associated with measuring vegetation height, percent cover, and stocking density: three key metrics associated with restoration planning. UAV-based spectral data and photogrammetric point clouds produce estimates comparable to field surveys (e.g. normalized RMSE of 9.08% for vegetation height; 83% accuracy for conifer seedling detection), but require specialized workflows and awareness of appropriate phenological windows. Handled appropriately, these technologies present an effective strategy for complimenting existing ground protocols and a powerful foundation for survival assessment and establishment surveys.

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Life after reclamation: Quantifying ecological recovery of wellsites in Alberta's forested lands

Evaluation of reclamation success is based on an objective of returning this anthropogenic footprint back to a functional ecosystem that shares similar ecological properties to what was historically present there. To this end, it is important to understand how reclamation practices can affect reclaimed soil and the subsequent trajectory of vegetation and other biota as they recover in reclaimed areas. Recovery of ecological conditions (i.e., vegetation and soil properties) at wellsites in Alberta may continue long after a reclamation certificate is issued, but the status of this ecological recovery is not currently tracked or documented. Towards the goal of increasing our understanding of ecological recovery on reclaimed wellsites, I will present research findings from the Ecological Recovery Monitoring Program, a new monitoring initiative that is measuring the recovery of soil and vegetation indicators on certified reclaimed wellsites. In forested lands, spatially-distributed soil samples were collected from each wellsite (ranging between ~10-50 yrs post-certification) and adjacent reference habitat for four soil depths. We measured pH, electrical conductivity, total organic carbon, and bulk density. We also quantified plant community patterns (% cover by species for vascular plants, species censuses for vascular and non-vascular plants, and lichens). In general, we found significant differences for soil properties on the wellsite compared with adjacent reference conditions for at least one soil depth (e.g., bulk density, pH). Plant communities also differed between wellsites and adjacent reference conditions across the gradient of ages post-certification that we studied. There was some evidence of younger wellsites reclaimed under evolving practices being more similar to reference conditions compared with older wellsites. The findings of our study and development of a long-term monitoring program for reclaimed wellsites in Alberta will improve our ability to adaptively manage into the future by providing novel insights into the trajectories of ecological recovery.

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Soil microbial structure and function in natural and reclaimed surface-mined boreal forest soils of the Athabasca oil sands region

Surface mining in the Athabasca oil sands region (AOSR) has resulted in full ecosystem removal, thereby returning the landscape to early successional stages. Functioning ecosystems require soil microbial

communities capable of proficiently carrying out biogeochemical cycles, including decomposition and mineralization processes. Consequently, understanding the effects of surface mining and current reclamation techniques on soil microbial community function is essential to ecosystem management ensuring long-term sustainability of our forest ecosystems. The objective of this research was to determine how the structural and functional diversity of soil microbial communities may develop in reclaimed soils. This was accomplished by assessing microbial communities in a chronosequence of reclaimed soils and comparing them to their mature natural counterparts in dominant stands of the region (trembling aspen and white spruce). Twenty sites were selected in the AOSR to investigate how tree cover (aspen vs. spruce) and time since disturbance (8 to 31 years) influenced soil microbial structure and function. Microbial biomass and structure were quantified using phospholipid fatty acid (PLFA) analysis. Microbial functional diversity was determined using multiple-substrate-induced respiration (MSIR). Results indicate that total PLFAs (nmol/g soil) increased from the younger (8-11 years) to the older (17-31 years) reclaimed stands, where levels became comparable to those in natural stands. In addition, microbial community structure (mol % PLFA) and function (CO_2 respiration) in the 17-31 yr reclaimed stands were more similar to those in the natural stands than in the younger reclaimed stands. In contrast, tree cover did not have a significant affect on microbial structure or function.

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Forest legacy-based mine reclamation methods for facilitating recolonization of soil biological communities

In mine reclamation, substrates available for use as growing mediums (e.g., tailings, subsoil) often lack the desired physical, chemical and biological properties. This presents a challenge for attaining mine closure land capability objectives. Facilitating recolonization of soil biological communities in these substrates can promote soil development, nutrient cycling, and establishment of native vegetation. This study tests the potential for forest ecosystem legacies to enhance recolonization of soil microbial communities and improve vegetation establishment following mining disturbance. To test this, a full factorial randomized block design field trial using Picea engelmannii x glauca (hybrid white spruce) forestry stock seedlings was established at the Mount Polley Mine, BC, encompassing areas of tailings deposition and scoured zones of exposed till that resulted from the 2014 tailings dam embankment breach. Factors included were site preparation, native forest soil transplants (active forest legacies), and spatial connectivity with the adjacent undisturbed forest (passive forest legacies associated with soil biota ingress and mycorrhizal network connectivity).Preliminary analysis of first growing season data suggests that soil transplants improved seedling survival and vigour, and site preparation increased vigour, although neither factor affected aboveground growth. Initial results of a supporting greenhouse trial using field site substrates indicate that the soil transplant effects can be partially attributed to the biological component (tested through sterilized versus unsterilized soil), which increased seedling vigour and chlorophyll fluorescence (a measure of stress), providing a benefit beyond the native soil physiochemical characteristics. First growing season treatment effects may have been masked by the nursery seedlings' high vigour and prior fertilization. Ongoing monitoring will track soil biota establishment and provide refined results for treatment effects on the soil food web, root microbial communities, and seedling above- and belowground traits. These results are anticipated to inform best practices for mine reclamation and rehabilitation of severely disturbed terrestrial ecosystems.

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Microtopographic features and substrate selection influence the early establishment of vegetation from a legacy soil seedbank on

The availability of plant propagules and appropriate growing conditions are crucial for re-establishing plant communities after severe disturbances. The legacy seedbank from salvaged topsoil is an excellent source of plant propagules, however, only 50% of its species are expressed following conventional reclamation. We hypothesize that seedbank expression is limited by the diversity of microsites and appropriate growing conditions. In this study we evaluated the role of substrate type, heterogeneity, and microtopographic features on legacy seedbank expression. In an operational-scale field experiment we manipulated topographical characteristics and substrate materials at different scales using two soil materials. In two treatments, forest floor material (FFM) salvaged from upland forests was placed to form a levelled surface or parallel ridges (~0.5m height). In the third treatment, alternating FFM and peat mineral mix (PMM) salvaged from lowland (peatland) forests were placed in large loose piles (1.5m ~7m3).Enhancing site microtopography and substrate heterogeneity significantly increased abundance and species richness of vegetation establishing from seedbanks of salvaged soil materials. Placing alternating piles of PMM and FFM resulted in the highest vegetation abundance, diversity, soil moisture, and recruitment of forest species not originally detected in soil seedbanks. The low-lying areas between piles or ridges had the highest soil moisture and species richness in these treatments, and both piling and ridging produced broader vegetation communities than the levelled surface. These results highlight the importance of microtopographic variability at different scales and their impact on the expression of the legacy seedbank in contrasting surface soil materials.

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Drivers affecting tree performance on upland areas of a reconstructed watershed

The restoration of forest ecosystems is a complex, multi-step process that is subject to topographic and climatic conditions that drive the redevelopment of soils, hydrology, and biota. A priority in reclamation of disturbed lands is rapid redevelopment of forested landscapes as the quick development of a continuous tree canopy helps suppress establishment of weedy forb and grass species, which can significantly hinder tree survival and growth. Site conditions such as soil and topography are important factors regulating vegetation development in reclaimed landscapes, particularly in northern latitudes. In this study, we examined the growth performance of tree seedlings planted on upland areas of a reconstructed watershed in the Athabasca oilsands region. We explored establishment, early growth and canopy development of jack pine (Pinus contorta) and aspen (Populus tremuloides) in response to coversoil material, vegetation cover, topography, reclamation practices (planting density, coarse woody debris), and edaphic variables. Data were collected from 2013 to 2016 and analyzed using common statistical tests and structural equation models. Survival of planted seedlings was high for both species, four years after planting. Disparities in height growth were largely related to differences in edaphic conditions between coversoils. The direct and indirect effects of changes in edaphic conditions and vegetation cover over the years explained a significant portion of the observed performance of the seedlings.

Additional effects of reclamation practices are indirectly affecting tree performance via alteration of the soil water supply, highlighting the effects of reclamation practices on successful tree development.

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Altitudinal trends of Ridge Top Forest Structure and Carbon allocation in Western Himalaya, India

We assessed the forest structure, biomass production and carbon storage of various ridge top forests (RTFs) along altitudinal and climatic gradients. For this we selected five altitudinal ranges m asl i.e., (i) < 2000 (ii) 2000-2500 (iii) 2500-3000 (iv) 3000-3500 (v) >3500 in the Bhagirathi basin of Western Himalaya India. A total of 57 woody tree species belonging to 49 genera and 33 families were observed in all ridge tops, amongst which highest species richness (32 species) was recorded in the RTFs situated below 2000 m asl and lowest (3 species) in the RTFs situated above 3500 m asl. Highest total biomass and C stocks were recorded in the ridge top forests situated between 3000-3500 m (581±17.7 Mg ha-1 and 261±7.9 Mg C ha-1), followed by the RTFs between 2500-3000 m (531±6.8 Mg ha-1 and 239±3.05 Mg C ha-1), 2000-2500 m (504.5±5.4 Mg ha-1 and 227±2.4 Mg C ha-1), >3500 m (432.3±11.2 Mg ha-1 and 194.5± 4.4 Mg C ha-1), and lowest on the RTFs situated below 2000 m (429.4±4.04 Mg ha-1 and 193±1.8 Mg C ha-1). Our results revealed that percentage contribution of Above Ground Biomass Density (AGBD) increased with increasing altitude, whereas the Below Ground Biomass Density (BGBD) decreased with increasing altitudes.

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Effects of elevated CO2 and temperature on peatland community composition and structure

Peatland communities that dominate high latitudes are increasingly at risk from global climate and environmental change. These communities play an important role in the global carbon cycle as they store significant amounts of carbon in deep peat soils and are a source of methane. We studied plant communities under the tree layer in the Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) experiment. SPRUCE explores two major drivers of global change: elevated CO2 and elevated temperature. Temperatures are raised +0, +2.25, +4.5, +6.75, and +9°C above ambient. Deep peat heating began in fall 2014, aboveground warming treatments were applied in August 2015 and CO2 treatments in June 2016. We surveyed vegetation <1 m tall in summer 2014, 2015 and 2016. We compared percent cover by species across treatments and analyzed community composition using ordination. We found no effects on community composition or structure after one year of deep peat heating. However, we found shifts in community composition one year after aboveground heating began. Both shrubs and graminoids (grasses and sedges) increased in abundance in the warmest treatments. These changes in community structure and composition have the potential to create feedbacks to the carbon cycle, such as increased drying and decomposition with increased abundance of shrubs or increased methane release with increased sedge abundance.

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Frost imprints in tree-rings to assess cold adaptation in Pinus contorta

The movement of genotypes towards northern latitudes and higher elevations can be used to address climate change. This strategy may, however, temporarily expose tree populations that are adapted to warm conditions to cold and frost damage. Here, we study cold adaptation of tree populations using a novel methodological approach: frost imprints in tree-rings visible as blue rings (failed lignification) and frost rings (cambium damage). Blue rings occur when temperatures during xylogenesis fall below freezing, preventing the lignification process from being completed. Frost rings occur when the cambial initial cells are killed by freezing. This causes a discontinuation of radial cell rows and a zone of irregularly shaped tracheids. Genotype and environmental effects were partitioned by analyzing 28 years of lodgepole pine (Pinus contorta) trees grown in a genetic provenance trial series. We found strong genetic population differences in susceptibility to blue and frost rings. Northern boreal populations showed the least cold damage, followed by sub-boreal populations from central BC, and southern populations in Canada and the United States. Cold imprints in the form of blue rings generally occurred in years with cool and short growing seasons. Frost rings occurred almost exclusively in combination with blue rings and were only present while trees were under 13 years of age. Our study highlights the necessity of considering the risk of frost damage in assisted migration prescriptions to address climate change and explores new methodologies to do so.

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Beech scale advance and regional forest dynamics in the northern forest

Invasions of individual non-native phytophagous insect species are known to affect growth and mortality of host trees, but the combined impacts of multiple invasions on forest dynamics over large regions has not been studied extensively. In this study we integrate geographical data describing historical invasion spread of the beech scale (Cryptococcus fagisuga) with regional forest inventory data collected by the US Forest Service's Forest Inventory and Analysis program to quantify the impact of this pest species. Across the northern forest the magnitude of impacts from beech bark disease range from the “aftermath” forests of New England to the “killing front” that is currently occurring in Wisconsin. Additionally, impacts of other major pests including hemlock woolly adelgid (Adelges tsugae), gypsy moth (Lymantria dispar), and emerald ash borer (Agrilus planipennis) are quantified and compared to beech bark disease for context. This analysis indicates that the timing of regional impacts of these insects on their hosts can occur very quickly or surprisingly slow, but all act to change regional forest succession pathways. Because many of the species commonly co-occur in eastern North American forests, invasions are altering the current and future composition of large forest regions through their impacts. Such results demonstrate how forest insect invasions can profoundly modify forest dynamic processes, resulting in short-term reductions in biomass stocks and long-term changes in forest ecosystems.

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The effects of in-bush chipper debris on leachate chemistry, tree seedling survival and growth, and soil microclimate.

In-bush chipping is a common practice across northwestern Ontario (i.e., producing 3.8 million m3 of white chips annually), which generates considerable roadside waste and has resulted in poor tree seedling regeneration. A series of simple experiments (field and laboratory trials) were conducted to investigate the potential causes for this poor regeneration. Suggested causes include: production of leachate high in phenolic compounds that may impede seed germination, and reduce seedling vigour and growth; physical barrier to seedling root penetration into a suitable rooting medium; and altered soil microclimate conditions. From a 2-yr. lysimeter study, it was shown that a considerable amount of phenolic-rich leachate is produced from fresh (1-yr-old) chipper debris piles. Although volume and concentrations were lower under older, more decomposed piles (8-yr-old), concentrations remained elevated compared to incoming rainfall. These high phenolic concentrations did reduce vigour (poor root and cotyledon development) in germinating black spruce seed. Based on a 16-wk greenhouse pot study, watering with phenolic-rich leachate did reduce relative growth rates in jack pine seedlings. Results from an outplanting trial, showed that 4th year seedling growth and health were reduced in both jack pine and white spruce seedlings planted directly into the debris piles, with this reduction more evident on the fresh piles likely due to the influence of poor planting medium, high phenolic concentrations in leachate, and altered soil microclimate conditions. It is recommended that forest management practices that increase debris carry back during logging operations, combined with double pass site preparation with power trenchers through spread-out (<20cm thick) debris piles be employed to reduce the effects of debris piles on soil microclimate conditions, improve drainage, and increase tree seedling regeneration success.

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Quantifying northern mixedwood soil nutrient availability 50 years following biomass harvesting

Given interest in using forest biomass as an alternative, or `green', energy source compared to fossil carbon, there is the potential not only for enhanced carbon sequestration from biomass production, but also climate change adaptation through shifts in species composition. Whole-tree harvesting (WTH) serves dual roles to extract both forest biomass for energy as well as for commercial wood products. However, because WTH reduces the amount of woody residue returned to the forest floor, there are concerns about long-term reductions in nutrient availability on productivity in regenerated stands. An on-going long-term study established in 1964-65 on a northern mixedwood stand within the Penobscot Experimental Forest in Maine, USA was repurposed to address these concerns. Composition prior to treatment was dominated by Picea glauca and P. rubens, in mixture with other softwood and hardwood species. Treatments applied 50 years prior included WTH, conventional stem-only harvesting (SOH), and prescribed burning following SOH (SOHB).

Objectives of this study were to compare long-term, stand-level productivity among treatments and define soil nutrient availability and uptake, while also accounting for site conditions following treatments. Stand structure, composition, aboveground carbon stock, mineral soil nutrient concentrations, and foliar nutrient concentrations were estimated on 16 fixed-area research plots, to address these objectives. For plant-available nutrient measurements within the mineral soil, we installed ion exchange resin membranes (IERMs) at the bases of two red maple (Acer rubrum) and two balsam fir (Abies balsamea): two dominant species of the regenerated stand. Foliage samples were then obtained from the upper third portion of their canopy, targeting the current year growth. Initial findings from this study suggested reduced productivity on SOH sites with greater O horizon thickness, though growing stock did not significantly differ across harvest methods. Overall, these finding suggest limited differences in nutrient availability and uptake across these harvesting methods.

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Anticipation ecology: Determine when and how to initiate forest restoration and reclamation

As anthropogenic climate change, invasive species, and resource and land management decisions change rapidly, there has been a reconsideration of the strict notion of restoring or reclaiming ecosystems like forests in order to return them to some historical state. The measurements used to monitor forest ecological integrity and impact of ecological restoration and reclamation have also been questioned as to whether they ask the right questions or yield pertinent information. There is a desire – and a necessity – for scientists to be able to anticipate and detect relevant changes in forest ecosystems in order to intervene and prevent a forest ecosystem from crossing an ecological threshold to a new and likely undesirable state. Where forests have already crossed such thresholds, the path to restoration or reclamation is not usually a simple matter of removing the impacts that caused the change and if the change is economically or ecological irreversible, then the task is to determine how to manage for a novel ecosystem that provides most of the ecosystem services and structures that once existed. In this plenary talk, I will discuss how restoration ecologists are using functional traits and change detection techniques to anticipate best practices for prevention of undesirable shifts or, failing that, how to use these approaches to restore and reclaim forest ecosystems. The ecological approaches have to be congruent with appropriate environment and resource policy and governance – and given the current political milieu in too many countries, the policy realm may present the greatest challenge to implementing effective forest restoration and practice.

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Patterns in seismic line vegetation recovery and landscape restoration planning in Alberta's oil sands

Seismic lines that are used to map Alberta's oil sands fragment habitats and increase movements of organisms that may alter biotic interactions, including wolf-caribou relationships. With woodland caribou being threatened, restoration of seismic lines has become a high priority. However, active restoration that focuses on forest recovery through site preparation and planting is expensive (~$12,000 per km), particularly when considering the total extent of seismic lines in the region (e.g. >55,000 km of 2D lines in northeast Alberta). This makes widespread restoration untenable and its effectiveness largely unknown. Critical to prioritizing where active restoration should occur first, is to better understand patterns of natural recovery and utilizing a passive restoration strategy that requires time, but no direct costs. Here we discuss the potential value and extent of the passive restoration strategy by examining environmental factors and site conditions that promote natural patterns of tree recovery, including wildfire. Recovery to a 3 m height was positively related to depth to water, unless excessively dry where recovery was attenuated. Sites most limited in tree recovery were treed fens and bogs where a high water table and simplified topography on lines restrict tree recruitment. Many sites were predicted to naturally recover to a 3 m height within 30 years in upland sites if recreational activity on lines is managed. On dry jack pine sites, wildfires increased tree recruitment on seismic lines, doubling tree density on seismic lines compared to adjacent forests when fires were moderate to high severity. Active restoration projects should therefore consider where natural recovery and wildfires are unlikely, assess the cost-benefits of active to passive restoration strategies, and more broadly prioritize where limited restoration dollars are spent.

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The impact of mountain pine beetle and mountain pine beetle management on caribou and grizzly bear food supply

The mountain pine beetle (Dendroctonus ponderosae, MPB) is one of the most destructive agents of pine (Pinus spp.) forests in western North America. To mitigate the impacts of MPB, the Alberta government has implemented a strategy of increased timber harvest of susceptible stands and a manual cut and burn program that targets newly infected trees. Prescribed fire is another management treatment being implemented, but primarily in areas where timber harvest is not possible. Landscape changes associated with MPB and MPB management have the potential to impact species-at-risk like woodland caribou (Rangifer tarandus caribou) and grizzly bear (Ursus arctos). In particular, changes to understory vegetation that result from MPB management could influence the availability of food resources such as terrestrial lichen for caribou and berry producing shrubs for bears. To address this concern, we modeled the occurrence and abundance of food resources based on vegetation surveys conducted within forest stands with varying levels of MPB infestation and within forest stands where three management treatments (timber harvest, cut and burn, and fire) were implemented. We focused vegetation surveys within five caribou ranges of the foothills and boreal forest of Alberta where grizzly bears also occur. We will discuss the changes in caribou and grizzly bear food supply resulting from MPB infestation, timber harvest, cut and burn, and wild fire. In addition, we will discuss the integration of the food models into a tool for predicting the potential consequences of MPB management on caribou and grizzly bear food supply.

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Release response of black spruce and white spruce due to overstory lodgepole pine mortality following mountain pine beetle attack

Advance regeneration is present in many lodgeople pine stands in Alberta. When the overstory pine canopy is killed by Mountain Pine Beetle (MPB), the growth of this advance is likely to increase. Understanding the growth response of these understory tree species is needed to improve mid-term timber supply projections and management decisions. To quantify the growth (diameter, height, height/diameter ratio) responses of black spruce and white spruce to lodgepole pine mortality, sample trees of black and white spruce advance regeneration were selected from 7 lodgepole pine dominated stands (5 attacked; 2 control) in the Foothills Region of western Alberta. Measurements were collected 7-8 years after MPB attack across a wide range of spruce height and stand densities. Analysis was done using mixed model analysis of variance (ANOVA) and mixed model linear regression. Result indicates that there was an increase in both diameter and height growth after MPB attack; however, this increase in growth was delayed for about four years. Both spruce species had similar height response and their height/diameter ratio decreased after release, partly as a result of increased understory light associated with loss of needles in the pine canopy. In addition, the diameter and height growth responses of both spruce species were strongly related to density, prerelease growth and initial size.

B. Palik (1), & A. D'Amato (2)

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Operational-scale experiments: connecting scientists with managers using real world forestry

Connecting natural resource managers with the latest scientific information is an important step in the adaptive management process. However, doing this successfully assumes that the scientist fully appreciates the needs of the manager; that is, the scientific information being provided is actually something the manager wants to know. A disconnect in this process can arise because a scientist working on natural resource problems often must straddle the fence between addressing important scientific questions, that peers find interesting and that are worthy of publication, versus addressing pressing problems faced by natural resource managers, which may not always be viewed as highly important or compelling by the scientific community. One approach to straddle this fence successfully, that is, pursue quality science while addressing the needs of managers, is to engage managers early and sincerely in the development and implementation of operational-scale experiments. These are experiments that occur at spatial scales relevant to managers and that include commercial timber harvesting as treatments, but can also be used to address compelling scientific questions. Pursuing experiments in this way fosters continued involvement of managers in the full scientific process, better allowing useful information to find its way into the manager's toolbox. The USDA Forest Service, Northern Research Station, working with university and agency partners, has a rich history of using operational-scale experiments to engage managers in the scientific process, better ensuring that current scientific information gets put into practice. We will highlight several examples of these experiments from northern Minnesota that have been used to address questions related to ecosystem restoration, biodiversity management, climate change adaptation, long-rotation forestry, and other issues. Findings from this work

have served to advance our scientific understanding of forest patterns and processes in managed landscapes and have revealed unexpected outcomes when experimental treatments are operationalized in a true management context.

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Transitioning red pine forests to a warmer, drier future: assisting the replacement of an iconic forest type

Climate models for northern Minnesota, predict warmer temperatures, increased winter precipitation, and substantially reduced growing season precipitation. In addition, the prevalence of disturbances, including bark beetles and root disease, may increase. For the iconic Great Lakes pine forests this may translate into reduced habitat for many species, including Pinus resinosa, P. banksiana, Abies balsamea, Picea glauca, Populus spp., and Betula papyrifera. A high probability of changes in composition and structure for this forest type has prompted the USDA Forest Service to explore adaptation approaches that will maintain forests on the landscape, while maintaining composition and structure that are socially acceptable and ecologically sustainable. The Adaptive Silviculture for Climate Change (ASCC) experiment is an operational-scale effort that explores adaptation options that convey resistance or resilience to climate change and other future stressors, as well examines approaches that transition these forests to future climate-adapted species using assisted migration and range expansion. The ASCC transition treatment in Minnesota uses an irregular shelterwood to create a range of microclimatic conditions, along with planting of species predicted to be future climate-adapted. Selection was based on climate envelop models, provenance studies, and evaluation of functional similarity to current species. Several species are currently minor components of the forest type, including Quercus rubra, Q. macrocarpa, Acer rubrum, and Pinus strobus, while others are found in the next southern climate zone, including Quercus alba, Prunus serotina, and Carya cordiformis. The transition treatment includes Pinus ponderosa, a dry site-adapted pine with similar morphology and disturbance ecology as P. resinosa and that is adapted to mild, wet winters and hot, dry summers. While the transition treatment pushes the envelope of what is considered operational practice, the treatment is generating the kind of on-the-ground results that are needed to assess adaptation options for forests in the face of climate change.

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Growth and financial assessment for plantations of Pinus patula Schiede. ex Schltdl. et Cham. at Zacualpan, Veracruz, Mexico

A growth and yield timber prediction system, that includes thinning regimes, was built using a network of 50 re-measured plots on a chrono-sequences of Pinus patula plantations at Zacualpan, Veracruz, Mexico. Dominant height was modeled using polymorphic curves derived from the Schumacher-Korf model. A fully compatible prediction and projection system was used to model basal area, total volume and mortality. Diameter distribution was simulated using a three parameter Weibull function. To simulate thinning, the

Reineke density index was used in combination with models that describe thinning effect on basal area. The results suggest that in the region exist four site indexes (SI): 10, 15, 20 and 25 meters at base age 15 years. Volume rotation at average SI (20 m) was estimated at 14 years, with an estimated yield of 251 m3 ha-1 and a mean annual increment of 18 m3 ha-1 . Models suggest that best thinning ages occurs at 7 and 11 years with a final harvest at 21 years. Financial rotation without thinning (discount rate, i=7.5 %) occurs at 19 years. The internal rate of return (IRR) is 20.1 % and the benefit-cost ratio (BCR) of 2.52. On the same SI conditions thinned options allow for an IRR of 29 % and an RBC of 3.0.Key words: Growth and yield timber, thinning, financial viability, Pinus patula.

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An overview of assisted migration in forestry

Assisted migration (AM) is the intentional movement of individuals to locations that are projected to be suitable for sustained survival and growth under ongoing climate change. Since its conception, AM has been a contentious issue as it challenges the longstanding paradigm of managing species within geographic range limits and thus exposes ecosystems to the potentially devastating impacts of invasive species. However, over the past decade, different forms of AM have emerged – each with its own distinctive features and risk levels. In this presentation, we provide an overview of the AM concept and examine how it has evolved in recent years. In particular, we explore AM in the context of commercial forestry operations – which provide a unique opportunity to practice AM across millions of hectares annually in North America, with a focus on moving populations of widely distributed commercial tree species within current range limits. Several jurisdictions have started to move ahead with this relatively mild form of AM via changes to seed movement policies and practices. Finally, we present new findings from forest genetics trials that suggest there is significant resilience to climate warming in northern tree populations – a phenomenon that could be leveraged in a low risk forest regeneration strategy to promote populations that are both local to the planting site and productive under a warming climate.

D.L. Peterson (1), & J.E. Halofsky (2)

(1) U.S. Forest Service, Pacific Northwest Research Station; (2) University of Washington, School of Environmental and Forest Sciences

Real-world forest adaptation: Moving from information to implementation in the western United States

Climate change vulnerability assessments and adaptation strategies now cover a large area of public lands in the western United States, and federal agencies are putting climate-smart management and planning into practice. The most common applications are land management plan revisions, environmental impact (NEPA) documents, restoration, and monitoring. The most common application is at the interface of hydrology and roads. Assessments provide the information needed to spatially identify a sustainable road system (and other infrastructure) in the face of increasing floods in areas where snowpack is declining, thus saving tens of millions of dollars in potential damage. Projected stream temperature data are being used to determine where viable coldwater fish habitat will persist, and to set priorities for riparian restoration. Projected snow data are being used to identify where skiing will continue to be a recreation activity in the future, and where additional

demand for hiking and camping may occur. In addition, we have developed the Climate Change Adaptation Library to assist managers in identifying adaptation strategies (general) and tactics (on the ground). The Library contains over 500 options for vegetation, wetlands, wildlife, water resources, fisheries, recreation, and ecosystem services that can be used directly in planning and management.

D. W. Peterson (1)

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Restoration treatment effects on wildfire severity and post-fire vegetation recovery

Dry forest restoration treatments have been applied in dry coniferous forests of western North America to improve forest health and make forests more resilient to wildfires. Recent studies have demonstrated that restoration treatments, particularly those that involved prescribed burning, have been effective at mitigating wildfire behavior and effects. However, there are almost certainly fire weather thresholds beyond which restoration treatments are rendered ineffective. Beyond greater tree survival, restoration treatments may improve post-fire soil stability and recovery of understory vegetation by facilitating the establishment and persistence of fire-tolerant woody and herbaceous plant species that can rapidly re-sprout following fire, provide soil cover, and compete with exotic plant species. The 2014 Carlton Complex was the largest wildfire event in Washington State history, and much of the fire area burned under extreme weather conditions with explosive fire growth. Because the Carlton Complex burned over many recent fuel treatments, it offered an opportunity to evaluate if and how restoration treatments mitigated fire severity in this extreme wildfire event. Here, we report results from the first two years of a research project investigating restoration treatments effects on fire severity during the Carlton Fire and the combined effects of restoration treatments and fire severity on post-fire understory vegetation cover and biodiversity.

D. W. Peterson (1)

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Climate-growth relationships in Pacific Northwest conifers: accounting for variability within stands and across environmental gradients

Climate-growth relationships have typically been described for mean chronologies at the stand or larger spatial scales, either as a basis for subsequent reconstruction of past climatic variability, or to better understand environmental controls on tree growth. However, accurately forecasting forest responses to future climate change may require a more detailed understanding of variability in tree growth responses to climatic variability within stands, among species, and across environmental gradients than can be obtained from mean growth chronologies. I demonstrate an individual tree-based approach to describing and testing hypotheses about climate-growth relationships that uses mixed effects statistical models to describe variability in responses to climate within and among populations. Using previously published data from subalpine conifers in the Pacific Northwest, I show that climate-growth relationships can vary significantly within and among stands and that this variability can be partially attributed to tree and site characteristics.

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Do large carnivores use riparian zones? Ecological implications for forest management

As part of forest management guidelines, most North American jurisdictions require the preservation of forested areas adjacent to streams and rivers (i.e. riparian zones). Forested buffer strips with restrictions on timber harvest and road-building (i.e. riparian buffer zones) were originally implemented to protect aquatic functions and resources. Riparian buffer zones now also target terrestrial habitats and wildlife. Even so, forestry managers who implement guidelines seldom consider the value of riparian zones (RZs) for large carnivores, partly due to a lack of data available. Our objective was to understand the role of riparian zones and riparian buffer zones for large carnivores in managed boreal forests. We used nine years of GPS telemetry data (2007-2015) from radio collared grizzly bears in west-central Alberta, Canada to quantify both the use (i.e. the amount of time grizzly bears spend in RZs) and selection (i.e. use in relation to the available riparian habitat) of RZs. We examined the effects of season, sex, distance class (0-30 or 30-60 m from streams and rivers), and the surrounding forest (harvested versus non-harvested) on use and selection of RZs. We found grizzly bears spent 19.1% of their time within 60 meters from streams and rivers. Selection of RZs declined relative to the distance from streams and rivers (10.8% within 0-30 m and 8.4% within 30-60 m). During summer, grizzly bears selected RZs in harvested areas and avoided them in non-harvested areas. There was no difference in selection of RZs in harvested areas between males and females; however, in non-harvested areas, females avoided RZs and selected RZs less compared to males. These results suggest that riparian buffers provide valuable grizzly bear habitat in multiple-use landscapes. Forest management practices can support grizzly bear habitat conservation efforts by implementing riparian buffer zones in identified grizzly bear habitat and considering grizzly bear habitat use of RZs and riparian buffers as one component of riparian zone management.

B.D. Pinno (1), & S. Das Gupta (1)

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Coarse woody debris applications in oil sands reclamation impact plant community and soil properties

Coarse woody debris is an important component of natural forests and is now being used in oil sands land reclamation to enhance diversity and as a longer term store of organic matter. However, the impact of woody debris on reclaimed ecosystems may vary depending on the amount applied and the soil it is applied to. We studied the impact on the plant community and soil properties of 4 levels of woody debris (none, low, moderate, high) on two reclamation soils (forest floor-mineral mix and peat-mineral mix) and two natural benchmark soils (recently burned and mature). Many significant differences were observed among soil types in terms of the plant community and soil processes but fewer differences were attributable to the woody debris. However, overall native plant species diversity decreased with high woody debris cover while native species cover decreased with moderate debris cover on forest floor-mineral mix and high debris cover on peat-mineral mix. Cover of non-native species on the reclaimed soils greatly decreased with even low debris cover while the regeneration density of woody plants was unaffected by debris cover on all soil types. Soil nutrient supply rates and soil moisture were significantly different among soil types but there were no differences among debris treatments while soil temperature decreased inversely with woody debris cover. A positive relationship

between C mineralization rate and woody debris cover was also found in both the reclaimed and benchmark sites. Overall, a low (up to 30% ground cover) woody debris application appears to be optimal for maintaining native plant species diversity and soil processes while controlling undesirable plant species.

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Growth, N retranslocation, N uptake and foliar 13C in white spruce seedlings in response to nursery fertilization and field weed control

Early establishment of seedlings is often affected by low nutrient availability caused by strong understory vegetation competition in reclaimed soils in the oil sands. Management practices such as nursery fertilization, field weed control and fertilization could help improve early establishment of planted seedlings and reclamation success. We studied the growth, foliar 13C, nitrogen (N) retranslocation within seedling components, and plant N uptake from the soil in white spruce (Picea glauca [Moench] Voss) seedlings planted on a highly competitive reclaimed oil sands site in a field experiment for two years. Nitrogen retranslocation was traced using 15N-labeling in the seedlings. On average, 78% of the total N demand of new tissue growth in the first year and less than 50% in the second year were met by N retranslocation. Exponential fertilization during nursery production increased the biomass root:shoot ratio but not nutrient reserve in the seedling. In the field experiment, percent height and root collar diameter growth were increased by exponential fertilization with no effects on N retranslocation. Weed removal increased the growth of seedlings by increasing soil N availability resulting in greater N uptake from the soil and N retranslocation within the seedlings in the second year after outplanting. Further research is needed to optimize the nursery exponential fertilization regime for white spruce seedling production. We conclude that vegetation management by weed control can improve the early growth of white spruce seedlings planted on reclaimed soils and facilitate land reclamation in the oil sands region.

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Project CAPTURE: A U.S. national prioritization framework for tree species threatened by climate change and other threats

A variety of threats, most importantly climate change and insect and disease infestation, will increase the likelihood that forest tree species could experience population-level extirpation or species-level extinction during the next century. Scientists and managers from throughout the United States Forest Service have cooperated to develop a framework for conservation priority-setting assessments of forest tree species. The Project CAPTURE (Conservation Assessment and Prioritization of Forest Trees Under Risk of Extirpation) framework is data-driven and guided by expert opinion, and allows for the quantitative grouping of species into

vulnerability classes that may require different management and conservation strategies. The first application of this framework uses trait data and predictions of expected climate change pressure to categorize and prioritize 339 native tree species for conservation, monitoring, management and restoration across all forested lands in the contiguous United States and Alaska. This categorization is based on risk factors relating to the species' (1) exposure to climate change, (2) sensitivity to climate change, and (3) capacity to adapt to climate change. We used K-means clustering to group species into seven classes based on these three vulnerability dimensions. The most vulnerable class encompassed 35 species with high scores for all three vulnerability dimensions. These will require the most immediate conservation intervention. A group of 43 species had high exposure and sensitivity, probably requiring conservation assistance, while a group of 69 species had high exposure and low adaptive capacity, probably needing close monitoring. This assessment tool should be valuable for scientists and managers determining which species and populations to target for monitoring efforts and for pro-active gene conservation and management activities. The Project CAPTURE framework is being applied separately for an assessment of the threats to North American tree species posed by pest and pathogen infestations, and for tree species in Hawaii and Puerto Rico.

M. Proulx (1)

(1) University of Alberta, News & Media Relations

Re-writing the way universities share science with the public by shifting away from traditional approaches

With traditional media in decline during the past few years, it's been more and more difficult to get mainstream media coverage of new scientific discoveries. The media landscape has changed dramatically with the evolution of the internet and the ever-increasing use of social media platforms. While it's harder to get coverage, it's never been easier to publish and distribute news online than it is today. There has been a proliferation of web sites and news articles being distributed on social media platforms like never before. News consumers are increasingly getting their news from a much wider variety of other sources.
All of this – the changing media landscape, the decline of traditional media, the ease to post and share stories online – gives organizations such as the University of Alberta an unprecedented opportunity to share our story with the world. But it means we have to shift how we have traditionally done things. The presentation will discuss how traditional media relations can be enhanced to include the delivery of our scholarly news directly to a broader audience. I will discuss the strategies and tactics the university is adopting to reach this goal, through a brand journalism approach.

M. Pyper (1)

(1) Fuse Consulting Ltd

Using drones and dialogue to inform new approaches to resource management

Forest management in Canada has made a dramatic shift in approach, moving from a system that prioritizes only fibre, to one that recognizes the importance of a range of ecosystem values. The concept of ecosystem-based management has therefore emerged as a leading forest management approach. However, despite progress scientifically on the topic of ecosystem-based management, the term is frought with different interpretations of what it actually means. These varying interpretations can inhibit dialogue with the public about current and future practices that might otherwise improve the sustainability of forest management. To

overcome this, the Healthy Landscapes program at fRI Research, based in Hinton, AB, developed an interactive website to discuss the concept of ecosystem-based management. The site, www.lessonsfromnature.ca, summarizes over 20 years of research into a series of bite-size key messages. It leverages several science communication techniques: using drones and an engaging interface to take users into the field to see modern forest management, interviews with key scientists to capture opportunities and uncertainties, and illustrations and animations to communicate key ideas. In this presentation, we will showcase how the Healthy Landscapes program is using the Lessons From Nature website to engage in dialogue with stakeholders about the opportunities and challenges of ecosystem-based management. The website itself will serve as a neutral baseline and will aid in developing two-way conversations with stakeholders about applying new research findings.

J.C. Rodriguez Ramos (1), J.L. Beck (1), E.G. Fellrath (1), J.A. Cale (1), S.W. Simard (2), JC. Cahill (3), J. Karst (1), & N. Erbilgin (1)

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Safeguarding pine forests against climate change-associated disturbance patterns: Using soil fungi to promote regeneration vigor

Forest recovery following disturbance is tied to soil fungal communities. Saprotrophic fungi mineralized organic nutrients into plant-accessible forms, mycorrhizal fungi facilitate the vigorous and healthy development of tree seedlings, and phytopathogenic fungi reduce density-dependent competition among seedlings. Disturbance-induced forest morality can alter fungal communities and as a result affect dependent forest regeneration. Understanding how individual and cumulative biotic and abiotic disturbances alter the effects of soil fungal communities on seedling health is critical to developing methods promoting forest regeneration under predicted climate change-associated increases in disturbances such as wildfire and mountain pine beetle (Dendroctonus ponderosae; MPB) outbreak. We seek to develop such methods for lodgepole pine (Pinus contorta var. latifolia) forests in an ongoing study using field surveys as well as greenhouse and field experiments to answer several research questions. Soil collected from lodgepole pine stands in Alberta that have been disturbed by wildfire, logging, MPB, and MPB plus logging, or collected from paired non-disturbed (control) stands are being used with genomic techniques to identify the composition of fungal communities to answer (1) how do fungal communities respond to different disturbances and (2) how edaphic factors influence these responses. A greenhouse experiment with lodgepole pine seedlings grown in pots inoculated with field soil will use biomass assessment and stable isotope probing to investigate (3) how fungal community composition affects seedling growth and belowground carbon allocation. Another greenhouse experiment of similar design will use metabolomic profiling of pine seedlings treated with defense-related hormones to investigate (4) how fungal community variation affects the production of secondary metabolites involved in pathogen and insect resistance. A field experiment investigating potential dose-dependent effects of soil-transfer and inoculated outplanted seedlings on fungal community composition investigates (5) whether disturbance-altered fungal communities can be remediated. We present current results and progress toward answering our research questions.

D.E.B. Reid (1), N. Bu (1), A. Rogers (1), J. Shuter (1), T. Avgar (2), G.S. Brown (1), J. Hagens (1) , S.G. Newmaster (3), B. Patterson (1), I.D. Thompson (4), & J.M. Fryxell (3)

(1) Ontario Ministry of Natural Resources and Forestry; (2) University of Alberta; (3) University of Guelph; (4) Natural Resources Canada

Managed stands providing woodland caribou habitat in Northwestern Ontario: Stand characteristics and landscape context

We assessed stand characteristics within broad forest cover types across two large study areas in northwestern Ontario. Both areas are located on the Ontario Shield, but differ in terms of the amount of area affected by forest management, and the densities of important predators (wolves), alternate prey species (moose), and the density of roads. We used GPS collar locations from 126 animals to determine which cover types were used disproportionately to their availability. We also compared stand conditions within cover types between used and available habitats. Stand characteristics were generally consistent within cover types between the two study areas, and there were few differences between harvest origin and natural origin stands. Consistent with previous research conifer dominated cover types (Conifer Upland, and Treed Lowlands) were used most by caribou, although other habitat types were used in both study areas. Conifer-dominated stands with abundant lichen and low shrub densities, generally considered ideal winter habitat, were important to woodland caribou during the snow free months. Within the managed landscape, a number of individual woodland caribou home ranges included harvest origin stands. Those that were used tended to have significantly higher biomass of ground lichens, and harvest origin stands had lower basal area. Combined with insights gained through this large-scale collaborative project regarding the impacts of linear disturbances, predation by wolves, and apparent competition with moose, our work indicates harvested and regenerated forests can provide suitable habitat for woodland caribou. The presentation will highlight silvicultural approaches that can be used to identify and maintain high value woodland caribou habitat within a landscape, which is also managed to provide valuable wood products.

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Cranberry blue butterfly: habitat use and response to in situ oil sands developments in the Alberta boreal ecoregion

Information on North American populations of cranberry blue butterfly (Plebejus optilete yukona) is scarce. In Alberta less than 20 locations of the species are documented, generally in boreal treed bog and fen habitats. Oil sands underlie a vast section of the Alberta boreal biome and cranberry blue populations may be affected from the widespread extraction of this reserve. In situ extraction (subsurface wells) is required to extract oil from much of the area, causing less habitat loss, but more habitat fragmentation when compared to oil sands surface mining. Fragmentation for in situ disturbances is primarily linear, in the form of cleared corridors (seismic lines). In 2015 we discovered new cranberry blue populations in forests affected by in situ oil sands developments. Given this species' rarity and poorly-understood biology, we studied these populations in 2016 with respect to association with various environmental factors and responses to in situ oil sands disturbances.

Specifically, we stratified 120 sample sites on the basis of soil wetness and forest height, measured with LiDAR techniques, and disturbance type (3-m wide seismic line, 9-m wide seismic line and well pad vs. control undisturbed forest). We used generalized linear models to predict cranberry blue presence as a function of the interaction of natural and anthropogenic factors and ranked support of models using Akaike Information Criterion. Cranberry blue was observed in 35 sample sites and was associated with wet habitats and open areas surrounded by forests of shorter canopy height. Seismic line disturbances did not appear to negatively affect this species, while well pads had a strong negative effect on speciesâ€™ occurrence. Therefore, larger in situ oil sands disturbances, such as well pads, should avoid semi-open wet treed fens and bogs that are habitat to cranberry blue butterflies, but the seismic lines themselves do not pose a threat.

C. Robles (1), A. Velazquez (2), V. Reyes (2), D. Rodriguez (3), J. Etchevers (2), & H de los Santos (2)

(1) Comision Nacional Forestal; (2) Colegio de Postgraduaos; (3) Universidad Autonoma Chapingo

Effects of fire on basal area relative increment of Pinus hartwegii Lindl. in the Izta-Popo National Park, Mexico

The recent Mexican policies regarding the use of fire in forest ecosystems, involve the necessity of developing applied research to justify utilization of fire for managing fire-dependent ecosystems. This study aims to evaluate the effect of fire on basal area relative increment (BARI) in Pinus hartwegii young trees, growing in a protected forest of Central Mexico. We assessed and compared the effects of a medium-to-high intensity fire (MHIF) that occurred in March 2013, a prescribed burning of low intensity (PBLI) applied in April 2013, and a no-treatment area (NT) with no indication of recent fire occurrence. In summer 2014, we collected two increment cores samples out of 100 pre-selected young trees (less than 12 m height), and three shoots by crown section (9 samples by tree), corresponding to the 2013 growth period. Treatments were analyzed with ANOVA and analysis of covariance, and with Tukey test for means comparison. Results indicate that BARI was 9.6 % at the PBLI, which was significantly different ($P<0.05$) from the other treatments, 5.5 % and 7.3 % for MHIF and NT, respectively. These increments are mainly explained by the percentage of crown damage (18.2 % for PBLI, and 62.8 % for MHIF), and by the average increment in biomass of the most recent growth period, which also showed significant differences between the low and the upper crown sections of trees in PBLI, respecting the other two areas. Our results also confirm previous findings from other studies conducted in the same region, that suggest that trees located in sites with PBLI have higher photosynthetic efficiency and better re-allocation of carbohydrates. Our results could be used to develop strategies for fire management in similar ecosystems in central Mexico.

P. Rogers (1) & B. Pinno (2)

(1) Western Aspen Alliance, Wildland Resources Department and Ecology Center, Utah State University, (2) Canadian Forest Service, Natural Resources Canada, Northern Forestry Centre

Applied functional ecology in quaking and trembling aspen: one size does not fit all

Trembling aspen (Populus tremuloides) occurs across the continent, but varies geographically in functional ecology. The driving management paradigm in forest ecology hinges on crafting stewardship practices to match tree, forest, and system processes. To the degree we understand their ecology, it is assumed that the probability of recovery and renewal following management actions will be heightened if we can emulate environmental characteristics, including disturbance, climate shifts, and ambient conditions. This practice requires a close link between science and management: to establish links and feedback loops between experimental and field practice. An advantage of such an approach over taxanomically-driven classification schemes is that for most foresters there is an inherent understanding of environmental factors (i.e., water availability, common disturbances, plant-animal interactions, climate) that are easier to gain than botanical skills required to identify aspen's vegetation types. This presentation will provide a wide-ranging overview of thee functional types framework as applied to western North American aspen. We will describe principal functional types, then suggest management approaches groomed to local regional applications. The presentation touches on what we call "barrier" to functional aspen management, such as herbivory, climate change, and past management practices. We stress the 'framework' aspect of this schema; clearly geographic variants should be added to improve on the system as science and practice develop.

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Long-term regeneration dynamics in northern hardwood forests of the Northeast United States

Silvicultural systems for northern hardwood forests of the northeast United States are predicated on an ability to reliably secure natural regeneration of desired species. Our ability to regulate the composition and stocking of preferred species has been greatly challenged in recent decades by invasive pathogens such as beech bark disease, high levels of herbivory, and changes in climate regimes. Understanding regeneration dynamics is further complicated by limited knowledge of impacts following repeated even- and uneven-aged management. Long-term silvicultural studies (> 20 years) in the Adirondack Region of New York provide a unique opportunity to explore the variation in seedling and sapling recruitment after single-tree selection and uniform shelterwood cutting, as well as forest evolution under changing overstory conditions. Results synthesize repeated measurements and emphasize the importance of control efforts in forests with a heavy component of American beech (Fagus grandifolia). Additionally, analysis highlights the utility of shelterwood systems to maintain desired species such as sugar maple (Acer saccharum) and yellow birch (Betula alleghaniensis). We will consider results in the context of long-term forest dynamics and future uncertainty in environmental and management conditions.

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Spatio-temporal and functional approaches clarify the successional trajectory of a dry tropical forest

Distributed widely in the Keys and southern Everglades, tropical hardwood forests are among the most biodiverse of the region's communities, but the factors that drive their successional dynamics on the limestone rocklands they inhabit are not well understood. In 1993, a National Audubon Society research team used a chronosequence approach to document species positions along a Key Largo successional gradient of ~100 years, and found a pattern of replacement of deciduous trees by evergreen taxa. However, assumptions associated with the space-for-time replacement inherent to chronosequence designs may result in imperfect projections of the species dynamics that take place at individual locations, and might provide a misleading view of successional forces. In order to explore the methodological question, and to sharpen understanding of the ecology of these forests, we resampled 19 of the 23 original sites in 2013. The second survey allowed us to test whether species changes over two decades on individual sites matched compositional predictions based on the initial chronosequence. It also enabled us to test the robustness of these predictions with respect to community-level leaf traits, i.e., specific leaf area, leaf N and P concentrations, carbon isotope content, and metrics of leaf longevity and canopy deciduousness. We found that the chronosequence effectively predicted changes in composition at individual sites, but the magnitude of change was overestimated, especially in the oldest stands. At the stand level, abundance-weighted leaf traits also continued the trajectories suggested by the chronosequence, but change was less than anticipated. Trends in individual leaf traits painted a complex picture, perhaps reflecting responses to an environmental sequence in which light levels declined while the availability of belowground resources increased. By integrating chronosequence and permanent plot elements into our design, we gained a more three-dimensional view of forest succession on limestone surfaces in seasonal tropical environments.

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Long-term responses of soil mesofauna communities to woody debris biomass harvesting in an eastern Canadian boreal forest

In Canadian boreal forests, woody debris biomass is regarded as a new source of bioenergy. However, sustainable management of this natural resource requires an understanding of potentially negative effects of its harvesting on forest ecosystems. Soil mesofauna, especially Collembola and Oribatida, which contribute to the forest ecosystem functioning (e.g. litter decomposition) depend on woody debris as micro-habitats. Our study aimed to determine the long-term effect (20 years) of biomass harvesting with associated disturbances on the taxonomic and functional structure of the communities of both these groups. Collembola and Oribatida were sampled from the forest floor in a gradient of four biomass harvesting treatments that included uncut coniferous forest, trunk only, full tree (trunk, top and branches) to full tree with stump plus forest floor harvesting applied 20 years ago in five experimental sites in northern Ontario. We observed a clear

modification of the taxonomic structure of both groups with reduced species abundance, species richness and a modified composition in all harvested treatments as compared to unharvested stands. Oribatida communities also showed a modified functional structure through a shift from large surface-dwelling species towards small-sized, soil-dwelling species in response to harvesting intensity, especially in the two more intense harvesting treatments. Changes in forest floor moisture and in the volume of woody debris in treatment plots were the environmental factors explaining most of the variation in community structure of both groups. Thus, soil mesofauna communities were clearly modified after 20 years due to woody debris harvesting beyond the trunk only harvesting practice in the Canadian boreal forest.

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No support for long-term effects of commercial tree-stump harvest on understory vegetation

Intensification of forestry may further increase the threat that forestry already imposes on biodiversity. The recent re-introduction of stump harvest in Swedish forestry clearly represents such intensification. Stump harvest not only decreases the available habitat for organisms living on dead wood, but also causes soil disturbance that can potentially alter understory diversity. In this study we capitalized on the large-scale stump harvest (c. 10000 ha) that took place during the period from 1977 to 1989 in south-central Sweden. In 2013, we performed vegetation surveys in forest stands where stumps were harvested and in conventionally harvested reference stands. Twenty-four to 36 years after stump harvest we found no differences in species richness and composition of vascular plants and mosses between the two categories of stands. We conclude that our study lends no support for any long-term effects of stump harvest on understory vegetation. The lack of differences between stump harvested and conventional clear-cut stands may be due to that the additional disturbance effects generated by stump harvest were overridden by the strong disturbance effects already imposed by the standard forest management, i.e. clear-cutting with subsequent soil scarification.

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Simulating the impact of bioenergy extraction on habitat suitability for species on a landscape scale

Wood can, in theory, become a major source of bioenergy and, if used as replacement for fossil fuels, contribute to mitigating the anticipated temperature rise. However, there may be large-scale and long-term effects of bioenergy extraction on important habitat structures for forest biodiversity that we are currently not aware of. Without this knowledge, it is very difficult to provide recommendation on future bioenergy extraction strategies. We evaluate the large-scale and long-term effects of biomass extraction on biodiversity of saproxylic (wood living) species by using a spatially explicit forest landscape modelling framework to simulate different bioenergy extraction strategies on a 125km2 large boreal forest landscape in the counties of Västra Götaland and Värmland in Sweden. This landscape is dominated by Norway spruce (Picea abies), Scots pine

(Pinus sylvestris), and silver birch (Betula pendula) and representative of boreal forests in large parts of Northern Europe. We investigated impacts of different initial levels of dead wood and of implementing different harvest and bioenergy extraction strategies for 100 years on dead wood availability and the suitability of the resulting habitat for saproxylic species as well as on carbon pools and fluxes. The different strategies include a no harvest strategy, and several strategies to retain different percentages of the aboveground and belowground woody biomass to simulate e.g. stump harvesting. Preliminary results show that different initial levels of dead wood have smaller effects on habitat suitability for saproxylic species then different bioenergy extraction strategies. When larger proportions of the woody biomass are retained in the field, more dead wood is available and saproxylic species should benefit. With our results, we aim to provide a tool to balance conflicting goals between climate change mitigation and biodiversity conservation.

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Spatio-temporal pattern in plant communities along hydrology gradient in Everglades Tree Islands

In the Everglades, tree islands are complex ecosystems where a range of vegetation assemblages are arranged along hydrologic and soil nutrient gradients. In these islands temporal changes in flooding regime often result in a spatial shift in community composition along the gradient and determine the trajectory of community succession. We examined the interaction between hydrology and vegetation over a 12-year period in three southern Everglades tree islands. Using the Everglades Vegetation Succession Model (ELVeS) tool, we also modeled effects of alternative changes in hydrologic regime under five restoration scenarios considered in the Central Everglades Planning Project (CEPP). We hypothesized that drier condition in recent decades would result in an increase in the dominance of woody plants, especially flood-intolerant species, over herbaceous and flood-tolerant woody species, ultimately causing a shift in the boundaries between plant communities. Moreover, we also expected that the magnitude and direction of change in tree island communities at the landscape scale would reflect regional variation in hydrologic conditions predicted under different restoration scenarios. In most of the transects and/or plots in bayhead forest and bayhead swamp portions of islands, the relative abundance of flood-tolerant species like Annona glabra and Salix caroliniana declined, while that of moderately-tolerant species like Chrysobalanus icaco, Ilex cassine, and Ficus aurea increased over the study period. In these islands, the effects of inter-annual variation in hydrology over the previous decade resulted in small shifts in the boundaries among communities. Model results predicted widespread changes in one of the four regions tested, with drier conditions associated with several restoration scenarios resulting in large increases in the extent of bayhead forests over bayhead swamps and marsh vegetation. These results suggest that tree islands are dynamic successional communities whose expansion or contraction over time depends on the strength and duration of changes in hydrologic conditions.

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Can access roads impact carbon dynamics of boreal forested peatlands by altering enzyme activities?

Canadian boreal forest is interspersed with both forested and open peatlands, mostly bogs and fens, which have a significant carbon stock (~550 Gt) in the form of peat and biomass. The carbon is stored due to lower decomposition rate favored by low enzymatic activities (phenol oxidase and hydrolases), low pH, high water table, anoxic conditions and phenolic material accumulation. Enzymes produced by fungi, bacterial communities and plants are macromolecular biocatalysts that stimulate the rate of reaction and organic matter degradation. In peatlands, oxygen limitation to phenol oxidase reduces phenolic material degradation, and the accumulated phenolics suppresses hydrolase activities the process is known as the enzymatic latch mechanism. However, the mechanism can be altered by the road networks constructed for the exploration and extraction of natural resources (e.g. forest products, oil sands, and natural gas). The access roads fragment peatlands and alter local hydrology that can either enhance or reduce enzyme activities, ultimately altering carbon cycling. To understand the impacts of roads on peat enzymatic activities, we studied both forested bog and fen peatlands near Peace River, Alberta. Samples were collected in August 2016 along transects extending 20 m from the road on both upstream and downstream sides. Preliminary results indicate that the roads have potential to bring changes in peat enzymatic properties. In road-induced lowered water table (drier) areas of peatlands both phenol oxidase and hydrolases activity was stimulated, which indicates the potential for enhanced CO2 emissions. In contrast, in flooded areas enzyme activities were suppressed due to anoxia and increased phenolics concentration. The study suggests that peatland road crossings can reduce peat accumulation rate by opening the enzymatic latch in boreal peatlands. The outcomes of the study can assist decision makers in both restoring degraded peatlands and minimizing the impacts of disturbances.

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A unique industry collaboration to recover threatened caribou habitat in the boreal forest

Boreal populations of woodland caribou are listed as Threatened federally under the Species At Risk Act, and provincially in a number of jurisdictions across Canada. In Alberta, caribou ranges overlap extensively with valuable oil, gas and timber resources, and these industry sectors (among others) are implicated in caribou declines. The federal caribou Recovery Strategy identifies habitat restoration and conservation targets for individual caribou ranges. Habitat management is recognized as a foundational element of caribou recovery, but because caribou are wide-ranging nomadic species, it is most effective when coordinated over large landscapes or regions. In northeastern Alberta, a group of oil sands and forestry companies have formed a unique collaboration - the Regional Industry Caribou Collaboration (RICC) - and is working to coordinate habitat restoration, effectiveness monitoring, and research activities across entire caribou ranges. Specific objectives of the RICC include: (i) coordinating restoration of industrial footprint in priority areas within the Cold Lake caribou range, (ii) supporting and leading scientific research on caribou ecology and caribou-predator-landscape relationships, (iii) implementing habitat restoration treatments on linear features (seismic

lines, trails) and monitoring effectiveness and wildlife responses to those treatments, and (iv) supporting government-led caribou range and action planning processes.

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Shifts in community composition, but not richness, of ectomycorrhizal fungi are driven by host identity and cover soils on mine reclamation sites

Restoring forest ecosystems is an important objective of reclamation on sites mined for oil in northern Canada. Tree diversity, in particular, is often manipulated on reclaimed sites through targeted planting of species native to the region. Mixed stands (comprised of conifer and hardwood species) may promote species richness in organisms interacting with trees, such as ectomycorrhizal fungi (EMF). In exchange for carbon, EMF provide their tree hosts with essential nutrient and water uptake. Hosts colonized by a more diverse EMF community can improve tree health and growth. However, there is debate on whether mixed stands have synergistic or additive effects on ectomycorrhizal fungal diversity. In other words, is the sum of the parts greater than the whole? We planted three tree species (Populus tremuloides, Pinus banksiana, and Picea glauca) in single and mixed species stands on three cover soil materials (forest floor material, peat and subsoil) placed over overburden. Three years later, we harvested the seedlings and EMF colonizing roots were identified using molecular techniques. The community composition of EMF was different among the cover soils and tree species. Importantly, the species richness of EMF in the mixed stands was not different from the richness of the combined single species stands. In consequence, there was no synergistic effects on EMF community richness from planting trees in mixtures.

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Shifts in the nutrient limitations of tree growth and N fixation along steep atmospheric N deposition gradients in Norway spruce

A major challenge facing biogeochemists will be understanding how atmospheric N deposition (AND) affects the chemical stoichiometry of biological processes in forest ecosystems. For example, AND may fertilize trees, but at the same time down-regulate biological nitrogen fixation (BNF) by cyanobacteria found in mosses. Changes in both processes (i.e. forest growth and BNF) will in turn affect the biological demand of other nutrients. For example, AND may cause a shift in the N-to-P limitation of trees, or a shift in the stoichiometry of P and metal cofactors limiting nitrogenase activity of cyanobacteria. Here, we report on a study where these questions were addressed by sampling along steep AND gradients along five busy roadsides in Northern Sweden. In May 2016, 15-20 trees were fertilized at each site with either N, P or N+P. Needles were collected in September 2016 and analyzed for dry mass as well as N and P concentrations. Using these data, we derived a novel index to assess the relative N-to-P limitation across AND gradients. On both dates, we established strip

plots parallel to the road at 0, 10, 50 and 100 m from the roadside. Pleurozium schreberi moss was randomly collected in tufts, bulked into a single sample per plot and transported to the Swedish Agricultural University in Umeä. Moss subsamples were then amended with either Mo, P, Mo+P or left non-amended. These were then incubated for 24 h and analyzed for potential BNF using the acetylene reduction method. Preliminary results reveal that BNF increases significantly with roadside distance, while total BNF varies considerably between sites. On some sites, Mo+P stimulated BNF but only on plots with the highest BNF rates. Taken collectively, our data provide evidence that AND from anthropogenic sources may cause shifts in the chemical stoichiometry of boreal forest processes.

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Topographic controls on soil respiration in the boreal forest

Soils of the boreal forest have been estimated to contain 471 Pg of carbon. Much of this carbon accumulates as part of the forest floor, which hosts the majority of biogeochemical activity in the soil. Heterogeneity of topography and forest structure in this ecosystem gives rise to significant spatial variation in soil moisture and temperature regimes - features that are critical to soil respiration fluxes as well as soil organic carbon stocks. The objective of this research was to assess the spatial variability of soil moisture and temperature controls on soil respiration in the boreal forest. We measured soil respiration at distinct topographic positions on a mixedwood hillslope during the 2016 growing season. Forest structure was quantified and soil profiles were described to assist in the interpretation of spatial variation on soil respiration. Respiration measurements were taken from the forest floor and exposed mineral soil in order to partition forest floor respiration from the entire soil profile. Respiration fluxes from the total soil profile ranged from 0.69 to 9.90 mol m-2 s-1 while the exposed mineral soil ranged from 0.12 to 2.88 mol m-2 s-1. Topographic position had an effect on CO2 efflux of the total soil profile as well as the exposed mineral soil. Although upslope positions respired more, there was a higher contribution from the forest floor at downslope positions. In lower slope positions, the forest floor thickness and canopy cover increased. Soil development was least pronounced on the shoulder and midslope positions, and gleying appeared to be the dominant soil forming process at the base of the slope. If upslope soil temperature and moisture conditions migrate downslope either because of harvest activities or climate change, then the carbon stored in the forest floor could be released into the atmosphere.

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Monitoring reclamation success with the forest floor recovery index manual and app

In the oil sands region of the boreal forest, the forest floor accumulates thick organic horizons due to low decomposition rates. The forest floor is the site where above- and belowground processes interact, influencing decomposition, the structure of the soil community and stand productivity. The Forest Floor Recovery Index (FFRI) aims to monitor ecosystem recovery using changes in forest floor properties during stand development following reclamation. Forest floor data were collected throughout the Central Mixedwood subregion of Alberta from 93 plots ranging in age from 0 (post-fire) to 100 years representing a range in ecosite types.

Results were used to develop the FFRI manual and app. The manual and app presents a simplified forest floor classification system using photographs and descriptions to illustrate examples of 19 forest floor types, differentiated according to composition and dominant horizons. Users are provided with guidance to determine a Recovery Index Score, specific to each ecosite, through comparison of site data to reference data. Modelling results are used to provide guidance on tree biomass inputs required to develop natural forest floors.This approach provides a useful tool for monitoring recovery of forest soils that have been disturbed by oil sands development activities (surface mining and in-situ) and reclaimed.

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Changes in utilization and travel along linear features by woodland caribou, moose and two predators following mechanical site preparation

Seismic exploration, used to identify and delineate oil and gas deposits, typically results in a land surface footprint of long linear trails cut into the forest. These lines intersect with other lines creating a fragmented linear network across the landscape. The LiDea (linear deactivation) project aims to restore landscape level ecological processes by reducing line-of-sight, trafficability and stimulating regeneration to increase the rate at which linear features are eliminated from the landscape using silvicultural techniques such as mechanical mounding and coarse woody debris additions. While increasing the rate of habitat recovery should reduce wildlife usage in the long-term, the effect of these reclamation methods in the near-term is an important consideration. In order to measure and document these short term changes in wildlife usage of seismic lines as travel corridors following restoration treatments, Woodlands North set up wildlife cameras along treated and untreated seismic features in the Cold Lake Air Weapons Range. In this presentation we quantify relative usage of treated and untreated seismic lines and travel speed by four large boreal species Ursus americanus, Canis lupus, Rangifer tarandus and Alces Alces. A total of 5785 independent observations were captured over the course of the monitoring program. Treatment intensity had a significant effect on all species examined, and we found a consistent pattern of lower use of treated lines compared to untreated lines for all four mammal species. The rate of decline in usage was species specific, with some species usage rates dropping at light treatment levels, while other species only responding to very high treatment levels. In terms of travel rates, increasing treatment intensity was negatively correlated with travel speed. Overall this study demonstrated that mechanical site prep can be an effective strategy for reducing wildlife use of linear features, but its effectiveness is likely species specific.

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Aspen stability and regeneration dynamics in isolated mountain ranges of the Great Basin, U.S.A

Aspen can form both seral and stable communities, yet in many regions of the western U.S. aspen stand dynamics remain poorly studied. We sampled aspen stands in three mountain ranges in the northern Great Basin, where conifer species and their abundances differ, potentially leading to divergent regeneration and successional dynamics. Our primary objectives included: 1) determining whether tree age and size class structures suggest that aspen communities are seral or stable at stand- and landscape-scales; 2) estimating the

role of fire, browsing, and other disturbance in shaping aspen stands; and 3) determining if temporal patterns of cohort establishment are correlated with climate and might influence aspen persistence. At the landscape scale, aspen tree size classes strongly fit negative exponential distributions. Age structures of individual stands were variable, but most exhibited continuous to semi-continuous age class distributions and had higher proportions of young to old trees. Few plots contained evidence of fire, and relationships between dead and live trees also suggest that most stands were not initiated by stand replacing fire. However, several stands had even, unimodal or bimodal age class distributions that suggest past stand-initiating events. High browsing pressure was correlated with a reduced proportion of aspen suckers reaching recruitment heights. Six climate variables were moderately or highly correlated with annual aspen establishment, especially during years prior to establishment. Minimum winter temperature (averaged for a 5-year period) prior to establishment explained most of the variance in aspen establishment densities over time. These preliminary results suggest that aspen in our study area are generally self-replacing and not dependent on fire for regeneration, but browsing can impede recruitment rates, and antecedent climate variability creates conditions conducive to successful regeneration. Developing a better understanding of these disturbance-regeneration dynamics at local and landscape scales can help to guide management and conservation strategies for aspen

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Wetland and aquatic conservation and management practice in the Boreal Shield: The Tembec experience.

Tembec is a manufacturer of forest products – lumber, pulp, paper, and specialty cellulose – and a global leader in sustainable forest management practices. All the forests directly managed by Tembec are FSC® certified. Principal forest operations are located in two land types: the great northern clay belt of northeastern Ontario/northwestern Quebec, and the rocky Canadian Shield to the south. While wetlands are common throughout the boreal, extensive peatlands dominate the claybelt region in the north where rivers are typically shallow, slow flowing and have highly seasonal flow regimes. As natural resources are a provincial jurisdiction, Ontario and Québec have unique forest management regimes. The terms and conditions set out in the laws and regulations as well as in the guides of best management practices differ between provinces. The Règlement sur les normes d'interventions in Québec compared to the Forest Management Planning Manual (FMPM) and the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (Stand and Site Guide) in Ontario propose different approaches to aquatic and wetland protection. In the Boreal, the location and dynamics of wetland ecosystems have a profound influence on the possibility and timing of forest operations. Our primary source of information comes from provincial forest resource inventory data. Recent developments in Ontario have led to the inclusion of Ecological Land Classification (ELC) information within forest resource inventories that will greatly enhance our knowledge and inform best management of wetland ecosystems within our tenure. The alternative available data vary widely between the different management units within and between provinces: LiDAR pilot project, digital elevation model or large-scale research projects results. Despite the variety of tools available, there is much to be done in terms of using these sources of information to implement best management practices related to water quality on all our managed forests.

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Regulatory and voluntary best-management practices for wetlands and riparian zones in boreal commercial forests: Synthesis and gaps

In Canada, management of watersheds and wetlands is a provincial mandate, but some federal legislation plays a role in influencing management. Increasingly, actions outside the regulatory framework are being undertaken to enhance the conservation and management of riparian areas and wetlands (e.g. through forest certification schemes). Here we will review regulatory frameworks and best-management practices available to operators related to wetlands and riparian conservation across the boreal ecozone of Canada. The focus of this review is forest management on Crown forests where wetland and riparian area management is applied to various forest practices including silvicultural prescriptions, forest management planning, and water resource management. While most provincial regulations stipulate a distance from water that must be respected during all management activities, the widths themselves are variable (15 – 110 m). Interpretation of and use within buffers is also variable, with some jurisdictions allowing activities within buffers, but stipulating a "vehicle free" zone. Finally, the activities that are permissible within vary as well. The application of BMPs near waterbodies has received much research attention, although the focus has largely been on watercourses, lakes and more rarely, open water or marsh wetlands. Increasingly it is being recognized that treed wetland systems require special attention, particularly wetlands that move water across the landscape such as fens and swamps. While riparian buffer zones have a wealth of values (interception of sprayed chemicals, sediment and nutrient filtering), other practices are also commonplace (e.g., minimizing skidding during wet weather, and the reduction of soil disturbances). While the overall regulatory and BMP frameworks available across the country are robust, variation across regulatory jurisdictions and the need to expand protection of a wider range of wetlands, the application of BMPs by operators could lead to inconsistencies in the way that wetlands and other waterbodies are conserved across the Boreal landscape.

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Genetic improvement of larch for Canadian prairies

Larch (Larix spp.) has been used extensively for Canadian agroforestry, particularly shelterbelts in western Canada, for over 100 years. Agriculture and Agri-Food Canada (AAFC) has been involved in breeding and selection of Larix since 1908 when it establish one of the first plantations of Siberian larch (Larix sibirica Ledeb.) in Canada. Through breeding, selection and progeny testing researchers at the AAFC in Indian Head, Saskatchewan has developed the improved seed strain 'Lindquist' Siberian larch. The release of this strain significantly improved the performance of larch planted on non-agricultural land in non-forest environments. A major obstacle for improvement of Siberian larch in Canada was low genetic variability of Siberian larch breeding populations. To address this issue, Canadian researchers began, in 1985, a series of seed collection missions to central Siberia. Importation of larch gene resources continued in 2003 through participation in the International Family Test of Eurasian larch species organized by the Swedish University of Agricultural Sciences in Umea, Sweden. The International Family Test of Eurasian larch species trial, including Larix sukaczewii Dyl.,

Larix sibirica, Larix gmelinii Rupr. and Larix cajanderii Mayr. from 17 provenances, was established in Saskatchewan at two sites in 2004. Nine year data showed significant differences in performance of provenances. The best performing provenance according to height growth was Sukachev's larch (Larix sukaczewii) from the Nizhnij Novgorod region of Russia. Overall the best performing species was Siberian larch.

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Effects of mountain pine beetle attacks on understory vegetation in lodgepole pine forests in western Alberta

Mountain pine beetle (MPB) is a native forest insect that is expanding into unprecedented areas at higher elevations and further east into west-central Alberta, where lodgepole pine forests differ from historical MPB habitat. To understand the effects of MPB attack in Alberta we conducted an experimental study in lodgepole pine-dominated forests in west-central Alberta. MPB attack was simulated by stem injections with glyphosate, which induced chemical girdling of the trees resulting in a pattern of mortality that closely resembles that following MPB attack. Treatments included: high mortality (100% of trees treated), medium mortality (30% of trees were treated), simulated salvage logging operation (clearcut), and untreated control (three replicates of each). During MPB attacks, pine needles turn red (red-attack) and begin to fall, and most foliage is lost within 2-3 years (grey attack). Stands were sampled for understory vegetation, soil moisture and nutrient availability, and percent canopy cover one year prior to disturbance (2008), the year of treatment (2009), one-year post-treatment (2010) during red-attack stage, and five and seven years post-treatment (2014 and 2016), by which time the stands had transitioned to grey-attack stage. Mixed effects models and ordination were used to examine responses of understory vegetation to the above- and below-ground changes that arose due to tree mortality induced by the treatments. In the first post-treatment year of the simulated MPB treatments the only change was a slight increase in soil moisture. Canopy cover and light had begun to change by five years post-treatment and this was followed by some changes in understory vegetation. Changes in the simulated salvage logging treatment were immediate and dramatic. Understanding how MPB-disturbed tree canopies in Alberta impact understory vegetation and lodgepole pine regeneration can help us understand the transformations in forest composition, structure, diversity, and successional pathways that may develop on this changing landscape.

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A century of landscape change in the southern Rocky Mountains and Foothills of Alberta

We used 137 historical repeat oblique photography pairs from the Mountain Legacy Project (originals taken in 1913, repeat images in 2008) to quantify vegetation change over 320,000 ha in the southern Alberta Rocky Mountains since the beginning of the 20th century. We developed new methods to overlay a spatially referenced grid on the photographs, classified vegetation into seven distinct categories (closed canopy conifer-, broadleaf deciduous-, or mixedwood-forest, open canopy woodlands, shrublands, grasslands and meadows,

non-vegetated), and assessed vegetation change between the two time periods. We found that closed canopy coniferous-, broadleaf deciduous-, and mixedwood- forests have increased on an area basis by 35%, 45% and 80% respectively relative to a century ago, while concomitantly the area covered by grasslands and open canopy woodlands declined by 25% and 39% respectively. Only 9% of the landscape was in an earlier successional state, while 28% was in a more advanced successional state in 2008 as compared to 1909. More than 87% of the area that was in an earlier successional state in 2008 occurred in areas that had known disturbances (timber harvesting, wildfire, anthropogenic disturbance) between the two time periods. Most change occurred in the Montane and Subalpine Natural Subregions (42% and 26% respectively in a more advanced state). The loss of open canopy woodlands is acute across the entire landscape. Grassland and meadow losses are most acute in the Subalpine and Alpine Natural Subregions. There was an increased probability of vegetation change to a more advanced succession condition at higher elevations and in areas receiving lower amounts of solar insolation. As time since fire or harvest increased, sites were more likely to have returned to (or gone past) its pre-disturbance successional stage. The changes observed are consistent with what we would expect to see due to lengthening of fire return intervals.

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Using historic landscape vegetation structure for ecological restoration: effects on burn probability in the Bob Cree

Montane regions throughout western North America have seen large scale forest encroachment on grasslands, bringing a concomitant increase in the probability of high intensity wildfire. Many agencies are planning ecological restoration activities under the assumptions that restoring historical landscape conditions will reduce the probability of high intensity wildfire. We used the Bob Creek Wildland in southern Alberta to test whether historic landscape restoration would: a) reduce burn probability, b) change the spatial pattern of burning; and c) change the distribution of fire sizes. We used historical photographs to reconstruct the vegetation composition from 1909 (historical restoration scenario) and compared this to the current vegetation composition of the landscape (baseline scenario). The historical restoration scenario involved changing the vegetation composition of the Wildland to its 1909 condition while leaving the surrounding landscape in its current (2014) condition. We used the Burn-P3 model to determine burn probabilities, and fire size distributions in both scenarios. Modelling revealed that the mean burn probability of all fires was only very marginally reduced by changing the vegetation (1.3% reduction), however, the overall spatial pattern of burn probability changed considerably. When we considered only high intensity wildfires, we found that the mean burn probability of the landscape was reduced by nearly half (44.2% reduction) in the historical restoration scenario, and many areas had burn probabilities that were 20% or less than they were in the baseline scenario. In areas where the fuel changes resulted in accelerating the rate of spread of fires in the historical restoration scenario we found that the raw burn probability rose, and in areas where the fuel changes resulted in lower rate of spread the probabilities were lower.

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Impact of access roads on peatland greenhouse gas exchange

Access roads criss-cross the boreal forest related to resource extraction and transportation. Given that 30% of the boreal forest is peatland, these access roads frequently cross peatland ecosystems, potentially altering ecosystem function. Peatlands are longterm sinks of atmospheric carbon dioxide (CO2) and globally important sources of methane (CH4); fluxes of both these greenhouse gases may be impacted by ecological, chemical and hydrological impacts linked to access road construction. We measured plot-scale CO2 and CH4 fluxes in peatlands along transects perpendicular to, and crossing both a winter road and two semi-permanent access roads near Peace, River, AB. Clearing of trees and peat compression on winter roads led to warmer and wetter conditions resulting in significantly higher CH4 emissions from the winter road footprint on the peatland. Placement of mineral soil fill on semi-permanent access roads created a damming effect, flooding areas upstream of the road and leading to drying on the downstream side; however, the impact varied between the sites. Spatially variability in greenhouse gas fluxes was high across the site, but CH4 flux was clearly increased in areas affected by flooding near the road. The potential impact of access roads on regional peatland greenhouse gas exchange will also be discussed.

C. Swanston (1)

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Real-world forest adaptation: Tools, examples, and lessons from the Northwoods

The Climate Change Response Framework (CCRF; www.forestadaptation.org) in the United States spans 20 states in the upper Midwest and Northeast and was launched in 2009 to help people meet their land stewardship goals while minimizing climate risk. The emphasis of the CCRF on stewardship goals represents a subtle but important shift in focus to people and their values, as opposed to climate change and its effects. It has involved thousands of people and over 100 organizations, and published six ecoregional vulnerability assessments with more than 150 authors. The CCRF developed a climate planning tool, the Adaptation Workbook (www.adaptationworkbook.org), for use along with ecosystem vulnerability assessments and a diverse “menu” of adaptation strategies to generate site-specific adaptation actions that meet the explicit conservation objectives of the landowner or resource manager. These tools have been integrated into an Adaptation Planning and Practices workshop that leads organizations through this structured process of designing adaptation tactics for their projects and plans. This approach has generated more than 200 intentional adaptation demonstrations in real-world land management projects on federal, state, tribal, county, conservancy, and private lands. In each case, landowners and resource managers pursued adaptation actions that reflected their own values, needs, constraints, and opportunities. This presentation will consider lessons learned in moving from information to implementation with diverse stakeholders across a diverse landscape.

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Aquaporins are involved in the amelioration of hypoxic aspen (Populus tremuloides) root hydraulics

Hypoxia caused by flooding is a great challenge for terrestrial plants. Ethylene plays a profound role in plant responses to flooding, but we still know very little about the effects of ethylene on aquaporin-mediated water transport in hypoxic plants. In the present study, the physiology and gene expression of aquaporins was investigated in aspen (Populus tremuloides) seedlings exposed to hypoxia and treated with exogenous ethylene. Methods: Roots of hydroponically-grown aspen plants were subjected to aeration, aeration with exogenous ethylene, hypoxia, and hypoxia with exogenous ethylene treatments. Physiological measurements included gas exchange, photosynthetic light responses, and leaf chlorophyll fluorescence measured with an infrred gas analyzer. Root hydraulic conductance was measured with a high-pressure flow meter, and root oxygen concentrations were determined with an oxygen microsensor. Root porosity was estimated by a pycnometer method and mRNA expression profiling was measured by qRT-PCR. Main Results: Hypoxic seedlings showed lower gas exchange, light-saturated net photosynthetic rate (Pn), effective quantum yield, root hydraulic conductance and root oxygen concentrations. Exogenous ethylene also significantly enhanced Pn and transpiration rates. qPCR results showed that hypoxia had significant effect on PtPIP1;2, PIP2;1, PIP2;2 and PIP2;5 transcript levels and significant effects of exogenous ethylene on PtPIP2;4 expression was detected by the two-way ANOVA. Root oxygen concentrations also increased with ethylene treatment compared to non-ethylene treated hypoxic plants, and this may partly be due to increased Pn. Conclusion: Our results suggest that exogenous ethylene may enhance root water transport in hypoxic plants through the effect on aquaporin expression. The enhanced root water transport by ethylene is likely responsible for the increase in Pn which, in turn, may have a positive effect on plant aeration.

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Linking forest carbon sequestration with annual CO2 flux

Forests play a pivotal role in the terrestrial carbon cycle by sequestering and storing carbon in woody biomass. By converting atmospheric CO2 to long-lived biomass, forests can mitigate the effects of elevated atmospheric CO2 by offsetting emissions from burning fossil fuels. Technological advances have allowed researchers to measure forest-level CO2 exchange (flux) using relatively non-invasive techniques, namely eddy flux towers. The eddy flux technique utilizes air currents to continuously measure net CO2 exchange at the forest canopy - atmosphere interface. However, there are important knowledge gaps concerning the relationship between CO2 flux and tree growth. These knowledge gaps exist in part because most eddy-covariance towers have not been operating long enough to determine how these factors co-vary through time. The purpose of this study is to clarify the relationship between CO2 flux measurements and landscape level aboveground biomass increment. The study benefits from the second longest running eddy flux tower in the US (Howland Experimental Forest, Maine; flux data back to 1996), which provides a data series long enough for robust analyses of these relationships. A three hectare spruce/hemlock forest has inventoried and a subset of the trees (10%) have been cored to estimate annual carbon mass increment. Our results demonstrated strong

correlations between carbon mass increment and annual CO2 flux measurements summarized from previous-year fall to current-year fall, an improvement from calendar year summaries. Further, our results suggest tree growth was lagged one year behind CO2 flux (i.e., assimilated CO2 was not allocated to growth until the following year) for about the first half of the time-series, but later became synchronized with current year assimilation. Understanding this link will strengthen our understanding of forest CO2 exchange and the terrestrial carbon cycle.

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Using dendrochronology to explore tree growth in Alberta's rocky mountains under a changing climate

In addition to providing insights into historical events such as fires, the study of dendrochronology can also provide insights into past changes in climate and extreme weather events. Changes in environmental factors such as precipitation and temperature will influence how tree rings develop, resulting in narrow or wide rings, numerous or few resin canals and changes in density of tracheids. The advanced regeneration in the understory of mature forests provides an underutilized component of the forest tree community that can be used to explore climatic patterns across decades. This study examines how climate has influenced growth of advanced regeneration of three conifer species, Abies lasiocarpa, Picea engelmanii, and Pinus contorta, found in the Rocky Mountains of Alberta. In our poster we will describe the differences in climatic patterns observed among the three species and among the different time periods (up to 50 years) since their establishment. This study provides novel insights into the ecology of lodgepole pine forests in the face of changing climate conditions, demonstrating the important knowledge that can be gained from measuring the tree rings of understory saplings. This information in turn can be applied to exploring future successional trajectories of these forests under both changing climate and shifting disturbance regimes.

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Effects of land reclamation treatments on the establishment and productivity of trees on a reclaimed oil sands mining site

The reclamation of mined or disturbed areas in the oil sands region of northern Alberta aims to re-create a functioning forest ecosystem similar to the pre-disturbance boreal forest. Part of that goal is re-establishing native tree species on reclaimed soils. Tree establishment, productivity, and their ecological drivers were studied on a former overburden soil dump reclaimed in 2011 with four different reclamation treatments (two soil types x two fertilization levels). Peat-mineral mix (PMM) and forest floor-mineral mix (FFMM) were used as cover soils and two levels of fertilisation were applied (no fertilisation and 200 kg/ha N over two years). White spruce (Picea glauca) seedlings were planted while aspen (Populus tremuloides) regenerated from wind-blown

seeds. For comparison, we also studied a reference natural site that burned the same year the reclaimed site was established. Overall, after six growing seasons, trembling aspen regeneration and growth was greatest on PMM soils with no fertilization (average 13,600 stems per ha and 183 cm tall) but both density and height were reduced with early fertilization, likely due to an increase in competing vegetation. Aspen density and growth were significantly lower on FFMM (average 3,500 stems per ha and 85 cm tall) and there was no impact of fertilization on these soils. In comparison, the natural reference site had a density of 30,000 stems par ha and average aspen height of 245 cm. White spruce height growth was not different between soil types (average height of 62 cm) but there was a significant negative effect of the fertilizer treatment when combined with PMM. Further analysis will be performed to identify what are the most important factors influencing the growth of both species.

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Challenges of utilizing municipal compost as an amendment in boreal forest reclamation on nutrient poor sites

Forested regions throughout the world envelop mineral and energy resources that lead to industrial disturbance due to resource extraction. Reconstructed subsoils of low fertility and organic carbon are common when trees are planted on forest reclamation sites following open pit mining because there is often not enough salvaged topsoil material to cover all areas. Municipal compost (urban kitchen and backyard waste) as a reclamation amendment is known to increase soil fertility, decrease bulk density, and increase water holding capacity. These improved soil conditions, however, are often accompanied by an increase in competing invasive and agronomic species that significantly reduce tree establishment on forest reclamation sites. In this study, we explored the use of compost as an amendment to poor subsoils for boreal forest reclamation at a large open-pit coal mine near Edmonton, Alberta, Canada. This project utilizes a novel application (layered) technique in which compost incorporated into subsoil (25 cm layer) is covered with a poor mineral subsoil (20 cm cap). This gives tree roots access to compost while remaining concealed from quick establishing, shade intolerant species. In 2015, a six hectare site was constructed and in 2016, 5,000 stems/ha of Populus tremuloides, Picea glauca, and Pinus contorta were planted. In 2016, the entire site experienced the establishment of a soil salinity tolerant, invasive annual (Kochia scoparia). This species dominated and heavily competed with trees in plots with compost. There was a relationship between mineral soil cap thickness and Kochia performance indicating that a cap of 40-50 cm is likely more effective. The soil analysis from 2016 indicated high electrical conductivity (EC) and sodium adsorption ratio (SAR) values in the compost layer suggesting that compost is salt-affected and may limit tree growth. Tree mensuration will occur before bud flush in April of 2017 and again in August.

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Biodiversity response to biomass harvesting; the Island Lake Biomass Harvest Experiment

We evaluate the response of biodiversity to biomass harvest, at the Island Lake Biomass Harvest Experiment in jack pine forests in northern Ontario. The experiment included a gradient of 4 biomass removal treatments ranging from tree-length harvest to full-tree biomass harvest with forest floor removal as well as 3 reference conditions (young harvest origin stand, old fire origin stand and early post-fire stand). We measured soil characteristics, microclimate, vegetation and faunal components of the biodiversity (microbiome, soil fauna and epigaeic arthropods) and provide an overview of the results from 6 studies. Overall we observed little impacts from full-tree harvest over tree-length in most groups suggesting that removal of branches and other harvesting residuals are having little effect on biodiversity. However more intensive removal such as blading and in some cases stump removal had significant impacts on soil fauna and epigaeics. Two primary factors driving faunal differences were the amount of deadwood and the degree of forest floor disturbance. In addition to changes in abundance and composition, we also evaluated fecundity of ground beetles to determine whether reduced numbers were accompanied by lasting impacts on population dynamics. We compared the proportion of gravid and mature females as well as clutch size of gravid females among harvesting treatments of 3 common ground beetle species. The proportion of fecund and mature females did not differ among biomass removal treatments for any of these species. Clutch sizes for fecund females did not differ among treatments for 2 species, however, female P. coracinus had fewer eggs in full-tree or stumped treatments than tree-length or bladed sites. In general, most results suggest that full-tree harvesting does not differ from less intensive tree-length harvesting. We also explored multi-trophic analysis to investigate the effects of biomass removal on several ecological communities simultaneously and in relation to litter decomposition.

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Low tree regeneration diversity: Can the legacies of forest and deer management practices be overcome with new management approaches

Summarizing the results of several studies in northern Michigan, USA, we show that tree diversity and density in the regeneration layer of northern hardwood forests is limited by many factors, with complex interactions among harvest intensity, deer herbivory, and competition from non-tree vegetation strongly affecting the transition from established seedling to sapling. Specifically, the combination of high deer populations and small single-tree selection harvest gaps, which have dominated northern hardwoods management for decades, are strongly negatively impacting tree diversity and density in the regeneration layer. Compared to smaller gaps, larger gaps can provide favorable resource environments for a wider range of species, while the dense vegetation that develops within them can protect trees from deer herbivory. However, the rapid establishment of dense non-tree vegetation also competes with developing tree seedlings. In addition, tree regeneration can be stymied by the recalcitrant legacies of past forest management and high deer populations, including highly competitive advance tree regeneration and dense mats of Pennsylvania sedge (Carex pensylvanica). Given these circumstances, we predict that some combination of larger harvest openings, treatment of existing vegetation/establishment substrates, and/or time-sensitive artificial augmentation of seed/seedling populations, could increase the diversity of tree regeneration in northern hardwood forests, with specific prescriptions informed by current vegetation structures and local deer densities. We are currently testing these predictions with a manipulative 144-site silvicultural systems project.

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Simulated nitrogen and sulfur deposition effects on litter decomposition: a microcosm study

Litter decomposition rates are affected by many abiotic and biotic factors such as climate, soil properties, litter chemistry, external nitrogen (N) and/or sulfur (S) availability, and soil microbial activity. Elevated levels of N and S deposition from oil sands activities can change soil properties and litter chemistry, which are directly related to litter decomposition and carbon cycling. The objective of this study is to investigate how litter chemistry and soil properties affect litter decomposition (CO2 emission) rate under N and S additions. The hypotheses of this study are 1) N addition will increase litter decomposition due to the high lignin content; 2) S addition will decrease litter decomposition due to the suppressive effect of the added S on microbial activities. A simulated N and S deposition experiment were set up in 2006 in a mixedwood boreal forest in northern Alberta with two levels (0 and 30 kg N/S ha-1 yr-1) of N or S were applied to form four treatments: control (CK), N application (+N, applied as NH4NO3), S application (+S, applied a Na2SO4), and +NS application (+NS). Forest floor and aspen litter samples were collected in 2015 to conduct a laboratory incubation experiment. In the lab incubation experiment, newly senescenced aspen leaves were applied on the surface of the forest floor. Soils were incubated for a period of 100 days, and gas samples were taken at days 1, 2, 4, 7, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, and 100 and analyzed on a gas chromatograph to determine litter decomposition rates. This

study will help us better understand the mechanisms among soil properties, litter chemistry, and litter decomposition rate, which affected by ten years of simulated N and S deposition in a boreal forest ecosystem in northern Alberta.

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Managing aspen in the US Southwest: developing resilience through regeneration

Quaking aspen (Populus tremuloides) across the West has been declining in recent decades and climate models indicate that its range will decrease in the US Southwest in the future. With high mortality rates in the overstory and low recruitment of understory aspen, the resilience of aspen in the Southwest is uncertain. Regenerating aspen in the US Southwest can be challenging and often includes significant management efforts. Historically, managers relied on natural regeneration by suckering to regenerate aspen stands. Artificial regeneration of aspen as a supplement to natural suckering or where natural regeneration has failed may be key to restoration and resilience of aspen in the southwestern landscape.

Understanding under what circumstances natural regeneration thrives is equally important, including whether management strategies such as jackstrawing (felling overstory trees to impede ungulate movement and reduce browse) are effective for successful regeneration. National forest managers in northern Arizona have been planting aspen propagated in the greenhouse and tracking post-planting success, as well as monitoring natural regeneration on an array of sites and differing management strategies. We will present on the management challenges associated with sustaining aspen in the Southwest followed by results from experimental plantings and natural regeneration surveys.

A recent study found that apparent resistance to browse is likely site-specific, as all regeneration planted from apparently resistant genotypes at new sites were deemed unhealthy 1-3 years post-planting, while between 26-82% of control clones in fenced exclosures nearby remained healthy. Surveys of natural regeneration indicate that natural regeneration abundance following severe wildfire may be enough to surpass browse pressure by elk. Jackstrawing increases regeneration abundance but fails to remove browse pressure, resulting in fewer aspen stems than the fenced exclosures. Sustaining aspen in the southwestern landscape into the future will be challenging and require continued dedication and collaboration to be successful.

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Silviculture through the lens of forest complexity

Design goals for silvicultural systems have historically tended towards simplification and regulation of natural systems. The reasoning behind these design choices often grew out of a desire to emulate the perceived productivity and efficiency of conventional agricultural systems. Examples abound of successful efforts to

reduce the complexity of native forests, but unfortunately many of these efforts belatedly have been recognized as undermining the resilience and possibly the long-term productivity of forest ecosystems. Similarly, as our understanding and appreciation of the myriad ecosystem services provided by forests has grown, single-commodity approaches to forest management are increasingly viewed as insufficient. Consequently, silviculturalists and forest managers are exploring ways to reintroduce parts that were previously thought to be "seemingly useless", and mange for rather than against complexity. In this talk, I'll draw on examples from the northern Lake States and argue that sustaining the yield and enhancing the resilience of native forests are intractably intertwined. Achieving these goals, however, will require a combination of new, rediscovered, and reimagined approaches.

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Implementation of ecosystem-based management for the maintenance of forest resilience and ecosystem memory

The concept of ecosystem memory and the use of ecosystem based management to maintain it in a managed forest remain as ideas without their successful implementation on the ground. In Northern Alberta, the landscapes have historically been shaped through the influence of natural disturbances such as wildfires and insects and disease. With fire being the dominant disturbance in the north, these natural disturbances have resulted in forests with conditions and patterns that have left our forests healthy and able to support and maintain their diversity of life. Flora, fauna, soils and water resources have all persisted through those cycles of natural disturbances and have illustrated the resilience that ecosystems are capable of when key features and elements are retained on the landbase. In this presentation, I will highlight how DMI has utilized ecosystem based management over the past twenty years in order to maintain the resilience of the forest. More specifically, I will show how our understanding of natural disturbance patterns has been used to drive our ecosystem based management approach, from the strategic level through to the operational level.

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Recent effects of warming on hybrid spruce and Douglas-fir growth on sites with contrasting soil moisture regime

Effects of climate change on tree growth in ecosystems limited by cold temperatures remain unclear; in some cases growth may increase, but because warmer temperatures can increase water stress, growth may decline. As climate changes in the sub-boreal spruce zone in central British Columbia, hybrid spruce a dominant but drought-intolerant species is predicted to decline over much of its range. To see if this shift is already evident, we examined recent trends in tree growth in this region across sites varying in water availability due to

differences in climate (dry/warm vs moist/cool) and soil moisture regimes (mesic vs xeric). We collected tree cores for tree ring width (RW) and Î´13C analysis and root samples for carbohydrate analysis from 10 trees each of spruce and Douglas-fir, which may eventually replace spruce on some sites.Over the period 1961-2010, temperature increased significantly by ~0. °C/yr with no trend in precipitation. During this time RW declined for spruce at all sites except the moist/cool-mesic, with the greatest decline occurring at the dry/warm-mesic site. For Douglas-fir, RW only declined at the moist/cool sites. Root NSC and average RW were lowest at the dry/warm-xeric site for both species, and between sites, root starch was positively correlated with recent growth. 13C was also least negative for spruce at the dry/warm-xeric site, indicating greater water stress. Between sites, average RW declined with increasing 13C in spruce but not Douglas-fir.Recent growth declines suggest spruce is vulnerable to warming temperatures at all but the wettest sites. Douglas-fir is coping much better with the warming climate, even at the driest site where growth and root NSC are substantially lower. However, the growth decline of Douglas-fir but not spruce at the moist-mesic site indicate that spruce on wetter sites is not yet in decline.

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Seedling recruitment dynamics on decaying coarse woody debris

Recent evidence suggests that northern hardwood forests are on an unprecedented trajectory towards lower species diversity. Several tree species are now less abundant in the overstory, and forest understories are typically dominated by only a few large seeded, shade tolerant, deciduous species. One factor often cited as contributing to declining regeneration diversity is the prolonged application of single-tree selection harvesting. While the majority of work on this topic has focused on the effects of low light availability on seedling recruitment, less is known about the effects selection harvesting has had on important seedling establishment substrates, such as heavily decayed coarse woody debris (CWD). CWD is considered a favorable microsite for seedling establishment due to its high moisture content and elevated position off the forest floor. This latter function may be particularly important for several declining small-seeded species, as smaller seeded species are generally considered more vulnerable to several factors that threaten survival on the forest floor. Nevertheless, evidence from three separate experiments suggests that not all tree species are capable of providing favorable CWD for seedling survival, and that not all seedling species are capable of long-term survival on CWD. Sugar maple, a species promoted by selection harvesting, consistently provided low quality substrate for seedling establishment and performed poorly on CWD as a seedling. In contrast, conifer species, which have declined under selection harvesting, generally provided favorable substrate for seedling establishment, and survive better than deciduous species as seedlings on CWD. Nitrogen availability appears to be an important underlying mechanism for CWD favorability, as seedling development was positively associated with N content. Mycorrhizal facilitation also appears to be an important mechanism for some seedling species on certain CWD species. Collectively, these findings suggest restoration efforts that consider CWD as a generic entity may not achieve the desired regeneration response.

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Beech bark disease in Canada: current impacts, outlook and management efforts

For over a century, beech bark disease (BBD) in northeastern North America has been killing and severely damaging beech. The impact of BBD on forest management has been challenging, requiring forest managers to juggle a wide array of issues, including loss of biodiversity and wildlife habitat, changing forest composition, identification of potentially resistant or tolerant trees, safety issues, and development of suitable silviculture management practices. Forest management efforts have primarily focused on controlling beech advance regeneration, reducing the proportion of beech basal area, prioritizing stands affected or threatened by BBD, and maintaining diversity and beech's important ecological values. Developing practical silvicultural approaches, with and without herbicides, to effectively manage beech populations and root sprouts continues to be most challenging. Severely diseased stands within the killing front are subject to beech snap and pose a serious safety risk and economic challenges to forest operations, parks and campgrounds. Continuing low market value for beech timber has contributed to the difficulties in managing for BBD. Foresters indicate that cutting only beech in sanitation cuts, or selective cutting of beech in stands with more that 20 percent beech, is often not economically viable. In one jurisdiction, attempts to develop a beech wood flooring market were dismissed, due to fears of developing a market, only to be faced with the uncertainty of future beech wood supply. Forest managers continue to look for silvicultural methods to employ in beech stands before and during standard harvesting operations, to ensure that site productivity and ecosystem values of beech are not lost.

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There are limited impacts of the full-tree harvest on colonization and emergence dynamics of saproxylic beetles in residual stumps

Residual wood left following harvest (including large branches, slash and stumps) is the primary ecological legacy for saproxylic organisms in managed forests. However, increased interest in the development of sustainable feedstocks of bioenergy may lead to significant ecological impacts for saproxylic organisms. For example, removal of branches through full-tree harvesting will reduce overall volumes of deadwood habitat as well as disrupt colonization/extinction dynamics in more recalcitrant deadwood such as stumps. As a consequence, a sustained loss of species is predicted that will continue well beyond the initial biomass removal- a phenomenon termed 'extinction debt'. We compared arrival and emergence rates of saproxylic beetles from residual stumps over three years (4-6 years post harvest) that were located in replicated experimental plots where branches had been removed through full-tree harvesting or were left on site following stem-only harvesting. We collected over 9000+ individual beetles representing more than 300 species using both sticky traps and emergence traps placed on/over stumps. We found few examples of species whose colonization/emergence dynamics were strongly affected by the initial removal of deadwood suggesting that use of stumps by saproxylic beetles is, at least initially, largely independent of surrounding residual

deadwood. However, we did observe changes in colonization/emergence dynamics of individual species over the three sampling years which we attribute to changes in stump quality. In some cases it is possible to see rapid changes in dynamics, whereby species initially have high colonization rates followed by a rapid exodus in the following year. Current models of extinction debt do not incorporate changes in habitat quality and address only habitat loss. However, based on the relatively rapid shift in colonization/emergence dynamics over three years, we suggest there may be little indication of prolonged species loss through extinction debt from full tree harvesting.

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South Bison Hill Research Watershed: Science-based guidance on the appropriate soil capping thickness for reclamation of Clearwater overburden

Reclamation in the oil sands mining region involves the construction of new landforms comprised of substrates with unique risk profiles. An appropriate soil capping thickness is often a key strategy to mitigate these risks and to provide adequate soil quality to meet the intended equivalent land capability target(s). In the open pit mining process Syncrude Canada Ltd. (Syncrude) must remove overburden to access the oil sand deposit. At the Mildred Lake mine operation the overburden is predominantly Clearwater Formation containing a high proportion of silt and clay (>70%) with elevated salinity (mean electrical conductivity ~10 dS/m) and sodicity (mean sodium adsorption ratio ~17). Large, out-of-pit overburden disposal areas are constructed and reclaimed with the intent of establishing a predominantly upland boreal forest community. The soil placement objective on this landform is to provide an appropriate soil capping thickness that provides sufficient soil-water to support the targeted forest vegetation community, while also accounting for the potential of salinization and sodification of the soil cover from the underlying overburden.The South Bison Hill Research Watershed (SBHRW) study is multi-disciplinary and collaborative research project that began in 1999 with a central objective to provide science-based guidance on the appropriate soil capping thickness on Clearwater overburden. The results of a synthesis and assessment of 14 years of research and monitoring at SBHRW are presented, as well as the recommended soil capping thickness for future Clearwater overburden reclamation at Syncrude.

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Are the survival, growth, and defense of residual overstory lodgepole pine trees affected by post-mountain pine beetle stand conditions?

Mountain pine beetle (MPB, Dendroctonus ponderosae) populations have increased since they crossed the Rocky Mountains between British Columbia and Alberta and arrived in northern Alberta in 2006. Millions of mature lodgepole pine (Pinus contorta) trees have been killed, while only few residual overstory mature lodgepole pine trees and non-host tree species, such as spruce and poplar, are remaining in beetle-killed

stands. However, the health conditions of residual lodgepole pine trees are unclear and it is unknown whether the residual pine trees will continuously provide seeds for the next generation of pine forests or they will be prone to attacks and colonization by other insects and diseases. Thus, studies on the future of residual pine tree conditions in these disturbed landscapes are urgently needed. My research is focusing on: (1) investigate if pest insects and diseases will target residual trees and increase their abundance across the gradient of MPB-caused mortality in post-MPB stands; (2) characterize if primary tree traits, such as growth and defense, will be affected by the changes in stands, particularly with the rate of tree mortality; (3) determine if the changes in post-MPB stands cause residual trees particularly vulnerable to attacks by pests due to changes in growth/defense relationship. My results will determine whether the future of lodgepole pine trees in Alberta is in great risk. An understanding of variability in risk will be useful for prioritizing areas for management intervention by identifying areas with higher and lower risk for future pest attacks. These predictions can help inform approaches for post-MPB management and sustainability of pine sites in Alberta.