Task D1: Effects of propagule dispersion on post-fire establishment & successional trajectories

- Johnstone, Hollingsworth, Ruess, Taylor, Mack

Summary of findings

- Role of mycorrhizal colonization: distribution of mycorrhizal taxa colonizing tree seedlings after fire, and impacts on seedling growth (PhD student Rae deVan-Taylor lab)
  - Ericoid mycorrhizae increase colonization of tree seedlings at sites with ericaceous shrubs and reduce tree growth
  - Abundance of preferred myco taxa appear to be limited (ascomycetes dominate colonization despite preference for basidiomycetes)

- Relative effects of moss microbiome, interannual climate, and canopy litter effects on moss-associated N-fixation (PhD student/PDF Mélanie Jean - Mack & Johnstone labs)
  - Distribution of N-fixing activity more limited by moss distribution than microbial availability (cosmopolitan)

- Lagged effects of environmental factors, fire history, and initial seedling recruitment on post-fire trajectories of forest canopy dominance (Johnstone, Mack, PDF Gerardo Celis)
  - Environmental controls and fire effects of broader importance than biotic interactions (herbivory, comp.)
Propagules and post-fire succession

Future directions

◦ What are your plans moving forward?
  ◦ Several papers are close to being submitted, Rae deVan is completing PhD thesis in 2019
  ◦ Fieldwork: Surveys of tree growth across RSN and other existing plots to improve data needed for modelling tree growth (Johnstone and Mack collaborating with Winslow Hansen)
  ◦ Analyses: Growth potential of alternate tree species from transplant experiments in 2004 burns
  ◦ Modelling: application of individual-based model (iLand) to explore impacts of fire-initiated alternate successional trajectories for landscape forest composition
    ◦ Currently in process of parameterizing iLand for Alaska (Winslow Hansen, Columbia PDF)
  ◦ Synthesis: Interannual and tree-to-tree variability in mast seed production (Jim Clark, Duke Univ.)

◦ What is limiting your efforts?
  ◦ Time & funding for personnel to complete data analyses and get papers written
Propagules and post-fire succession

Understanding cross-scale interactive effects

- Drivers of moss-associated N-fixation across scales
  - Effects of interannual climate variation > community effects
  - However, canopy litter effects on mosses and microbes distribution have strong effects on absolute amounts
  - Implies large interannual variation in N-fixation that is highly patchy according to forest type
- Mycorrhizal propagules affect post-fire tree growth
  - Not everything is everywhere - root colonization by preferred myco spp. is limited at some sites
  - Pre-fire legacy of ericaceous species can impact colonization
  - Propagule dispersal important for migrating lodgepole pine

- Temporal lags: material legacies of soil organic layer shape success of plant propagules
  - Filter for invasive species spread
  - Refugia or repository for soil microbes
  - Stabilizes plant community composition across disturbance cycles
Propagules and post-fire succession

Publications


◦ deVan, R. in prep (PhD thesis, Taylor lab)

◦ Johnstone, J., et al. Factors shaping alternate successional trajectories in burned black spruce forests of Alaska. in prep
Task D2: Examine the spatial patterning and strength of plant-herbivore interactions across the post-fire landscape in relation to plant growth, species dominance, successional pathway, and biogeochemical cycling (Kielland, Ruess, Genet)

Summary

Herbivory has plethora of effects on plants ranging from small changes in foliar chemistry to major shifts in root/shoot allocation patterns or outright mortality. Much of the recent work on plant succession has focused experimental and observational studies of spruce and aspen demography and the proximate factors that allow these species to flourish or suffer.

Height growth of spruce and aspen in response to herbivory is influenced by fire severity and browsing intensity. Height growth rate below and above 3 m differed between browsing intensities. Heavy browsing had a negative effect on annual height growth when individuals were below 3 m; there was no difference between browsing intensities once trees surpassed 3 m in height (Conway and Johnstone 2017).
### Salient findings

The intensity of herbivory is loosely a function of the plant-herbivore system in question; insects and snowshoe hares typically have drastic ‘disturbance’ effects, whereas moose exert more of a constant press (except at high densities). Herbivory may accelerate successional change (willow miners, moose) or it may reset/retard succession (hares–spruce). For example, hares can pretty near wipe out an entire (local) cohort of spruce seedlings, resetting the successional clock or slow height growth before the trees finally escape.

The legacy of these events can be found in the tree age structure reflecting the asynchrony in the recruitment dynamics of hares and spruce (below).
Understanding cross-scale interactive effects

Both insect and mammal herbivory unfold from the scale of a plant to the landscape, and data on long lived plants leave a ditto legacy. Snowshoe hares represent a significant filter to plant recruitment and survival under the right/wrong conditions. Whereas spruce seedlings may be especially vulnerable during post-fire succession due to increased deciduous cover, snowshoe hares also occupy habitats where spruce are increasingly expanding such as the altitudinal and latitudinal tree line.
Future directions

- Recruit personnel that will continue field work related to herbivory (some of us are getting increasingly creaky (and cranky).
- Incorporate USFS aerial flight data on plant pathology and possibly remote sensing data to map insect outbreaks.
- Expand current vegetation models to include different kinds of herbivory (e.g., insects, mammals, summer, winter) in different successional/disturbance settings and climate/ecologic hot spots.

Limitations: Maintenance support of infrastructure, field vehicles.
Task D3. Determine the consequences of a changing fire regime and fire-driven permafrost thaw for biogeochemical connectivity between past and present ecosystems


- Combustion of legacy carbon indicates ‘unprecedented’ disturbance severity
- Shifts NECB over the fire cycle
- Only evident in young-burned stands

- Spruce stands that retained legacy soil organic layers returned to spruce decade after fire
- Stands that lost this legacy transitioned to deciduous dominance

- Stands that transition to deciduous store more C at 100 years despite deeper burning/greater combustion C loss
- Accumulate N faster; acquisition of deep N?

- Ericoid and ecto spp use fungi to acquire deep N

- Tundra test bed at Healy and Toolik
- Rooting depth = deep N acquisition for non-myco spp
Future directions

◦ What are your plans moving forward?
  ◦ Examine whether acquisition of permafrost N can explain rapid accumulation of N in deciduous stands
  ◦ Evaluate rooting depth of conifer versus deciduous trees across RSN sites (young, intermediate, old)
  ◦ Examine depth profile of mycobionts on roots and compare to deep bulk soil (Hewitt, Taylor)
  ◦ Test for differential deep N foraging between conifer and deciduous species with root and mycorrhizae traps

◦ What is limiting your efforts?
  ◦ Time, personnel, and money
  ◦ Need to write new grant. Won’t happen for another year.
Task D3. Determine the consequences of a changing fire regime and fire-driven permafrost thaw for biogeochemical connectivity between past and present ecosystems

How do these findings inform our understanding cross-scale effects, interactions or feedbacks?

- Combustion of legacy carbon crosses temporal scales; old carbon loss can shift NECB over the disturbance cycle; controls over depth of burning crosses spatial scales.

- Deep burning that removes the legacy of past ecosystems can shift successional trajectories and potential alter the coupling of deep soil with surface processes.

- Legacy nitrogen may subsidize current productivity.

- Spruce recruitment is a local process, but hardwood seed rain is a regional process.

- Biogeographic idiosyncrasies, like pine expansion, might alter these cross-scale dynamics.
Task D3. Determine the consequences of a changing fire regime and fire-driven permafrost thaw for biogeochemical connectivity between past and present ecosystems


Task D4: Examine the interactions among changes in climate, permafrost, and vegetation on soil water retention, hydrologic partitioning, and stream export of C and N across upland boreal forest catchments

- Jones and Harms

A brief summary of findings related to the task

- Stream water chemistry is related to permafrost extent with dissolved organic carbon (DOC) concentration higher in stream draining watersheds with extensive greater permafrost extent, whereas nitrate concentration is lower.

- Wildfire in catchments results in lower DOC concentration and elevated nitrate.

- Across interior AK, DOC concentration is inversely related to catchment slope, whereas nitrate concentration is directly related (Harms et al. 2016).

- Within streams, DOC retention is greatest for DOM enriched in phosphorus (Mutschlecner et al. 2017)
Task D4: Examine the interactions among changes in climate, permafrost, and vegetation on soil water retention, hydrologic partitioning, and stream export of C and N across upland boreal forest catchments

Future directions

◦ What are your plans moving forward?
  ◦ Nitrous oxide ($N_2O$) emissions from the boreal forest (M.S. student Melanie Burnett)
  ◦ The interactive effects of inorganic nutrient, dissolved organic matter, and light availability on autotrophic and heterotrophic activity (M.S. student Sophie Weaver)
  ◦ Interaction between nutrients and ectoenzymes on dissolved organic matter decomposition (M.S. student Marie Schmidt)
  ◦ Long-term trends in stream water chemistry in the boreal forest (Christina Baker and Jones)
  ◦ Temporal trends in stream chemistry across biomes (NCEAS working group)
  ◦ Hydrologic partitioning in boreal forest catchments

◦ What is limiting your efforts?
  ◦ Funds to support high-throughput analysis of trace gases and isotopic analysis of $N_2O$
Task D4: Examine the interactions among changes in climate, permafrost, and vegetation on soil water retention, hydrologic partitioning, and stream export of C and N across upland boreal forest catchments

How do your findings inform understanding cross-scale interactive effects?

- Thaw influence on nitrate export from upland streams may result in fertilization and increased productivity of coastal ecosystems
- Permafrost/vegetation distributions and wildfire history at larger spatial scales determine spatial and temporal dynamics of stream chemistry and biotic communities

From Soranno et al. 2014
Task D4: Examine the interactions among changes in climate, permafrost, and vegetation on soil water retention, hydrologic partitioning, and stream export of C and N across upland boreal forest catchments

Publications and datasets


◦ Rüegg, J. et al. 2015. Baseflow physical characteristics differ at multiple spatial scales in stream networks across diverse biomes. Landscape Ecology


Planned publications


◦ Webster et al.: Permafrost and fire influence on temporal patterns in biogeochemistry of boreal headwater catchments

◦ Webster, Harms, Chapin, Johnstone, & others: Catchment hydrobiogeochemistry indicates ecosystem resilience
Task D5: Determine influences of vegetation and permafrost thaw on soil C storage and soil water retention and hydraulic properties (Turetsky, Schuur, Mack, Kane)

The goals of this task are to
1) Build from D4 activities at CPCRW and extend across the site network
2) Explore relationships between soil carbon and water storage and how this relates to the temperature and moisture sensitivity of soil carbon mineralization
3) Serve as a tool for integration between D3 and D4
Ongoing activities: series of short and long-term incubation experiments to explore variation in soil organic matter quality across the site network. Need to link these results into D3 results.
Future activities: Build a soil hydrophysical database for boreal soils, starting with the site network. Start with site attributes and soil properties that relate to soil hydrology. Start to quantify water retention under lab and field conditions.

Lab based soil water retention curves (pressure plate method)

Monitor soil moisture with depth for representative soil profiles under field conditions
D6: Use global change experiments situated in contrasting upland and lowland ecosystems to determine ecosystem responses to changes in permafrost extent and surface hydrology

Schuur and Turetsky

**CO₂ and CH₄ exchange:** Upland tundra (CiPEHR; warming, drying), and fen (APEX; lower water table, interannual var.)

**Upland:** Ecosystem C balance net uptake first stimulated by warming, then net release; CH₄ persistent

**Wetland:** Ecosystem C balance resilient to flooding and drought cycles
D6: Use global change experiments situated in contrasting upland and lowland ecosystems to determine ecosystem responses to changes in permafrost extent and surface hydrology

Future directions

- **CiPHER**: Transition point in experiment. New proposal for final phase submitted to DOE TES Mar 2019; (LTREB, ANS)
- **APEX**: New infrastructure upgrades; LTREB; ...
- What is limiting your efforts?
  - Good field work is hard; good field manipulations are harder
D6: Use global change experiments situated in contrasting upland and lowland ecosystems to determine ecosystem responses to changes in permafrost extent and surface hydrology

**Cross-scale interactions:** Experiments and observations identify interactions between warming, permafrost thaw, surface hydrology across geomorphological gradients
D6: Use global change experiments situated in contrasting upland and lowland ecosystems to determine ecosystem responses to changes in permafrost extent and surface hydrology

2018 Publications:


Task D7: Characterize patterns and drivers of recent changes in regional distributions of key plant pathogens, assess pathogen effects on plant growth, community composition, and successional dynamics, and predict future impacts on ecosystem function at regional scales. (Ruess, Lori Winton, USDA State and Private Forestry; Gerry Adams, U Nebraska)

Inventory of >18,000 trees across 8 ecoregions indicates that:

Infection is widespread across interior AK

Infection is higher on smaller DBH trees, and increases with total aspen basal area and average aspen DBH, which is our best indicator of stand age.

Smaller diameter trees in older stands are particularly vulnerable to the canker, and most are dead from the disease. However, small diameter trees in younger stands are almost completely devoid of canker.

Most of trees with canker are either dead or dying

Reinventory of RSN plots suggest the disease was likely well underway when plots were first inventoried, and is still spreading within stands.
Fungi isolated from infected trees, grown in culture, and DNA sequenced suggest *Nakazawaea wyomingensis* as a putative causal agent. Additionally, microbial community analysis using metagenomics also shows this yeast abundant in cankers yet absent in healthy trees. We have initiated greenhouse experiments infecting boles with culture isolates, and will be infecting trees within experimental plots this summer.

We have initiated an experiment to test whether shade increases vulnerability to infection among young trees in young stands. In 2018, replicate plots (20 x 25 m) were set up, and spring 2019, 30% shade cloth will extended above the canopy at a height of 15m. Damage/inoculation treatments will be imposed in TRMT and CTL plots this summer. Disease and AGNPP are being monitored in all plots; would like to use transcriptomics to assess the up- and down-regulation of defensive chemistry.

During the summer of 2019, we will begin measurements of shoot growth rates of black spruce in Gerstel River RSN plots to assess how changing aspen overstory is influencing dominant understory species.
Task D7: Characterize patterns and drivers of recent changes in regional distributions of key plant pathogens, assess pathogen effects on plant growth, community composition, and successional dynamics, and predict future impacts on ecosystem function at regional scales.

Disease spread / aspen resistance and survival

Landscape/Stand Conditions
- Stand Age & structure
- Light & soil moisture
- Disturbance history

Plant and Pathogen Genetics

Phenotypic defense traits:
- Relative growth rate
- Chemical defense
- Hypersensitive response

Recruitment

Suckering

Root/Shoot Partitioning

Slow-Killing Canker in Big Trees

Fast-Killing Canker in Big Trees

Disease Resistance and Survival

Long-term impacts on ecosystem function

Warming & ALM

Vertebrate Herbivory

Aspen running canker

Aspen Mortality

Black spruce growth & dominance in mixed stands

Fire regime

- Rates & patterns of C storage
- Litter chemistry/ Nutrient cycling rates
- Permafrost-hydrology interactions
- Flammability

Spring, 2019
Task D7: Characterize patterns and drivers of recent changes in regional distributions of key plant pathogens, assess pathogen effects on plant growth, community composition, and successional dynamics, and predict future impacts on ecosystem function at regional scales.

Data sets: yes, not uploaded
Manuscripts: in prep
Task D8: Examine the direct and interactive effects of insect herbivores and vertebrate browsers on plant growth, biogeochemical cycling, and vegetation development in early successional stands

Diane Wagner, Knut Kielland, Roger Ruess

Direct effects of herbivory

- Ongoing monitoring of aspen insect herbivory (since 2004)
- Tree ring, remote sensing: aspen leaf miner (ALM) reduces photosynthesis and growth (Boyd et al. 2019 in rev; Juday et al. in prep.)
- ALM damage has negative effect on water status (Wagner, Burr in prep)
- Willow leaf blotch miner also decreases growth of susceptible host species (Wagner & Doak 2018)
- Browsing effects on aspen growth depend on fire severity (Conway, Johnstone 2017)

Interactive effects of insect herbivory and browsing

- Insect herbivory initially reduced productivity & offtake by browsers (Allman et al. 2018)
- Vertebrate browsers exert much stronger control over community development than insects
Task D8: Examine the direct and interactive effects of insect herbivores and vertebrate browsers on plant growth, biogeochemical cycling, and vegetation development in early successional stands

Future directions
- What are your plans moving forward?
  - Impacts of aspen leaf mining across range of water availability
  - Continued collaborative work on physiological effects of leaf mining
  - Browsing x insect herbivory experiment – continuation ~3 years max
Task D8: Examine the direct and interactive effects of insect herbivores and vertebrate browsers on plant growth, biogeochemical cycling, and vegetation development in early successional stands

How do your findings inform understanding cross-scale interactive effects?

- Dynamics of herbivory have changed over time
- Pattern and impact of herbivory may respond to, and be dependent on, landscape position and climate
  - Conway & Johnstone 2017; Boyd et al. in prep.
- Herbivory and pathogen impacts on aspen may oppose environmental changes favoring aspen expansion
- Aerial forest damage surveys now include LTER sites, will help us apply results at larger scales

![Graph showing area damaged by Aspen leaf miner from 1975 to 2015.](Source: Forest Health Conditions Reports)
Task D8: Examine the direct and interactive effects of insect herbivores and vertebrate browsers on plant growth, biogeochemical cycling, and vegetation development in early successional stands

Publications


Wagner D, Burr SJ (in prep.) Damage to aspen caused by the outbreak leaf miner *Phyllocnistis populiella* increases vulnerability to water stress.


Task D9: Determine how post-fire stand age and area influence aspen’s susceptibility to insect herbivory and impact the population dynamics of an outbreak insect herbivore. P. Doak & D. Wagner

Aspen leaf miner population trends

- % leaf mining
- Eggs/leaf
- Surviving pupae/leaf

Aspen defense differs with tree size

- Proportion leaves with extrafloral nectaries
- Foliar phenolic glycosides (mg/g) (Young et al. 2010)

Leaf miner survival differs with tree size

- % leaf mining
- Eggs/leaf
- Surviving pupae/leaf
Task D9: Determine how post-fire stand age and area influence aspen’s susceptibility to insect herbivory and impact the population dynamics of an outbreak insect herbivore

Future directions
- Within stand differences between short and tall
- Aspen leaf miner oviposition, survival and production across stand types
  - Geographically paired early and late successional stands in interior Alaska
  - Scaling: leaf level to stand level production of aspen leaf miners

What is limiting your efforts?
- Money – yes
- Personnel – yes
- Time – yes
- Field vehicles – yes
- Logistics – yes
Task D9: Determine how post-fire stand age and area influence aspen’s susceptibility to insect herbivory and impact the population dynamics of an outbreak insect herbivore

Cross-scale interactive effects.

Differences in aspen defenses
Differences in phenology
Proximity to overwintering sites

Fire frequency & severity

Aspen on the landscape: stand age & area

Aspen leaf miner abundance
Herbivore pressure
Aspen resilience to damage

Aspen leaf miner herbivory & contribution to population dynamics
Task D9: Determine how post-fire stand age and area influence aspen’s susceptibility to insect herbivory and impact the population dynamics of an outbreak insect herbivore.

Publications

Tundo G, Doak P & Wagner D. *In prep.* The impact of tree developmental stage on oviposition and survival of the aspen leaf miner.


Task D10: Examine population dynamics of snowshoe hares and their spatial synchrony across a latitudinal boreal transect in relation to the abundance and space use of their primary mammalian predators (Kielland)

The trajectories of snowshoe hare abundance regarding the amplitude and period are quite similar across the monitoring areas from the north (GAAR) to the south (Tetlin). Maximum density estimates from both pellet plots and MRC range from 1-5 hares/ha, but the pellet grids (7 grids x 50 plots) exhibit substantial variation within a given site.
Understanding cross-scale interactive effects

- Our animal population studies have both temporal (~20 years) and spatial dimensions (~1000 km) across physiographic and climate gradients.
- Across the study areas in the eastern Interior to the Brooks Range snowshoe hares respond to similar environmental cues in terms of breeding and molting, but the greater variability of weather patterns (and climate warming?) in the North render hares more vulnerable to both camouflage- and trophic mismatch.

Data accumulating from the Lynx Project where BNZ LTER collaborate with F&WS and NPS illustrate the scale of movements by these animals. We hypothesize that such large-scale movements represent an important factor in the population dynamics of lynx in Alaska.
Future directions

The work on animal population ecology has an inherent monitoring component - long-term population dynamics - but within this frame work we are addressing a range of ecological issues:

**Snowshoe hares:**
- Seasonal variation of nutritional status of hares in relation to survival
- Camouflage mismatch of hares in relation to climate change
- Controls over spatial distribution of hares in relation to resource supply (food, minerals)

**Lynx:**
- Model habitat use and spatial ecology in relation to fire scars
- Identify the frequency and magnitude of lynx dispersal and the characteristics of movement corridors
- Model movement behavior of lynx in relation to life history events
- Model energetics of foraging behavior of lynx in different habitats
- Abundance estimation of unmarked animals using remote cameras

**Limitations (besides imagination):**
These activities are resource intensive in terms of implementation, personnel, data acquisition, and equipment.


