Fire and Succession in Northern Black Spruce Forests

Dr. Jill Johnstone
Department of Biology
University of Saskatchewan
Northern boreal forest

- Dominated by black spruce
- Cool soils & slow growth
- Highly flammable
- Dynamics of change?
Succession & Ecosystem Feedbacks

- Dominant species
- Recruitment
- Competition, herbivory
- Interactions
- Functional traits
- Disturbance
Black spruce ecology

Serotinous cones - seed source for regeneration after fire

Picea mariana forest
Black spruce succession cycle

A. Black spruce domain

- Black spruce dominant
- Local seed & Resprouting
- Slow growth
- Slow nutrient turnover
- Low competition
- High moisture
- High moss
- Cool soils
- Poor quality seedbeds (organic soil)

FIRE

Johnstone et al. 2010, *Can. J. Forest Research*
How do fire characteristics shape the resilience of spruce succession cycles?

• Why study fire?
  – Ubiquitous in boreal North America
  – Sensitive to climate
  – Post-fire recovery determines future forest composition
1. Fire severity and post-fire recovery of black spruce forests
Fire severity affects seedbed quality

Burning of organic soils influences patterns of post-fire recruitment
Experimental effects of fire severity

Low severity (organic)
- Poor seedbeds
- Recruitment requires high seed inputs
- Favors serotinious conifers

High severity (mineral)
- Higher quality seedbeds
- Creates opportunities for deciduous establishment

Johnstone & Chapin 2006, Ecosystems
How does this influence forest recovery across heterogeneous landscapes?
Fire severity and post-fire recovery

- Alaska 2004 fires
- 90 black spruce sites
- Initial stand recovery
Field Data

• Environmental conditions
  – Potential site moisture
  – Elevation
  – Potential insolation

• Pre-fire stand structure
  – Stem density
  – Stem basal area

• Fire severity
  – Composite Burn Index (CBI)
  – Residual organic layer depth

• Post-fire recruitment
  – Tree seedling density
  – 4 years post-fire
Spruce seedling density

Boosted regression tree, prediction error=0.54

Johnstone et al. 2010, *Global Change Biology*
Deciduous seedling density

Boosted regression tree, prediction error=0.44

Johnstone et al. 2010, *Global Change Biology*
Relative spruce dominance: Recovery of spruce trajectory

Boosted regression tree, prediction error=0.42

Johnstone et al. 2010, Global Change Biology
Controls on spruce forest recovery

• Fire severity
  – Dominant control on deciduous recruitment
  – Driven by seedbed quality
  – Creates opportunity for deciduous-dominated stands to replace spruce stands

• Spruce recovery is favored by low severity, wet sites, and older forests
2. Impacts of increased fire frequency

*Picea mariana* forest in North Yukon (64 ° N)
Studies of fire frequency using overlapping fires

historic fire
overlap zones: rapid disturbance return
recent fire

image courtesy of David Milne, Yukon Gov.
Fire frequency in N Yukon
Seed rain


~80 years between fires

15 years between fires
Seedling establishment

How old does a stand need to be to support post-fire regeneration?
Surveys of black spruce stands
Cone Production

Viglas, Brown & Johnstone 2013, *Canadian Journal of Forest Research*
Seed Production

![Seed Production Graphs]

**A**
- Cones $\cdot m^2$
- $r = 0.83, p < 0.001$

**B**
- Seeds $\cdot m^2$
- $r = 0.81, p < 0.001$

**C**
- Viable seeds $\cdot m^2$
- $r = 0.78, p < 0.001$

$n = 158, r = 0.27, p < 0.01$
Fire interval effects

• Short-interval fires interrupt conifer regeneration cycles
  – Reduced cone production
  – Failure of conifer regeneration

• Vulnerable up to ~80 years

• Short-interval fires can shift succession to alternate vegetation types
Future scenarios for successional shifts

- Historic regime

- Increasing severity
- Increasing frequency
- Decreasing BS seed

- Decreasing moisture

[Diagram showing changes in tree types and fire regimes]
Fire-mediated changes in succession cycles

Chapin et al. 2013, Novel Ecosystems
Why is this important?

• Changes in northern forest cover affect:
  – Carbon storage
  – Energy and water transfer
  – Wildlife and subsistence resources
  – Future disturbance risk (fire & insects)
Conclusions

• Fire is both catalyst and driver of change
  • Critical post-fire regeneration phase
  • Both frequency and severity shape future succession

• Fire severity
  • Effects on seedbed quality and relative success of competing species

• Fire frequency
  • Effects on seed production of serotinous conifers
Acknowledgements

Collaborators:
Carissa Brown
Terry Chapin
Teresa Hollingsworth
Michelle Mack
Ted Schuur
David Verbyla
Jayme Viglas