# Fire and Forest Dynamics in Northern Boreal Forests

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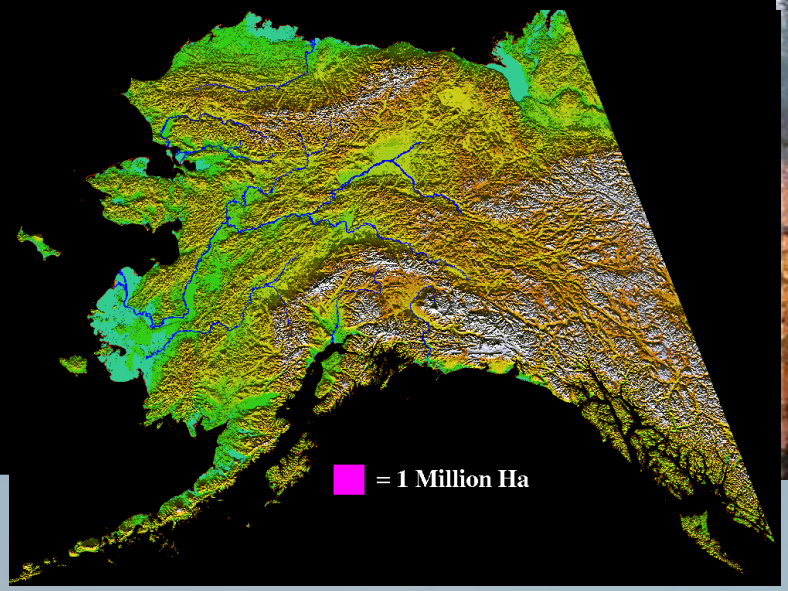
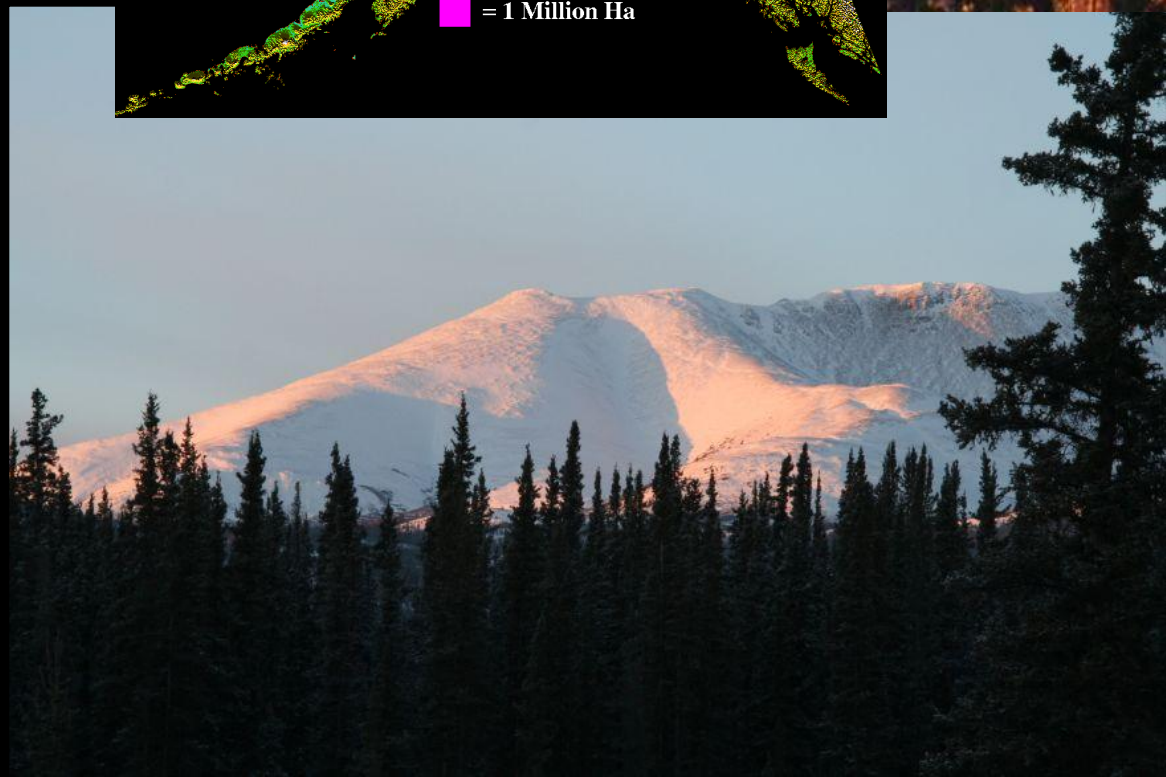
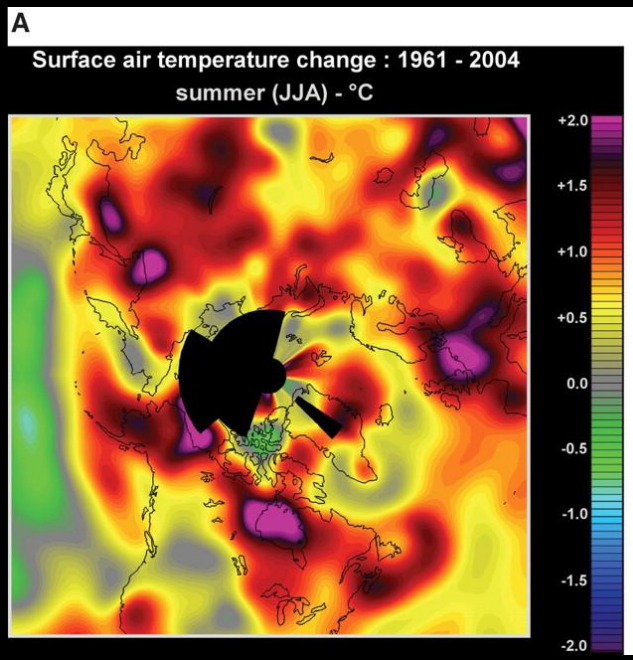
# Northern boreal forest

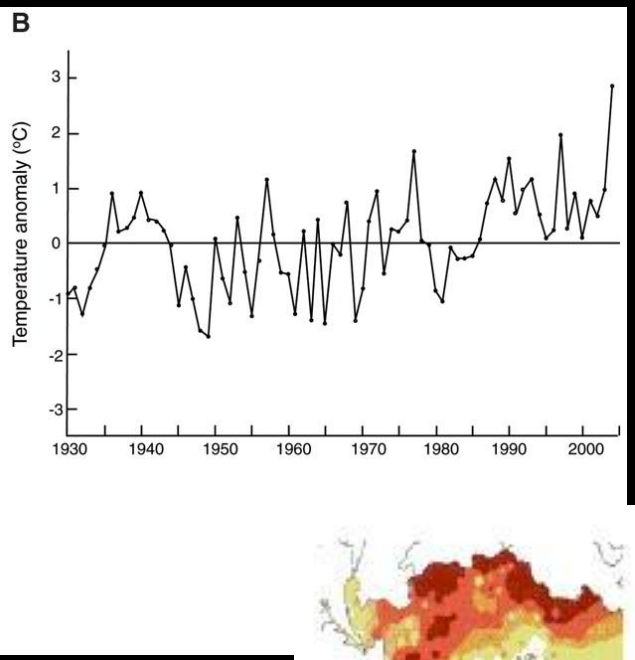
- Conifer dominated
- Cool soils, slow growth & decomposition
- Resistant to change?



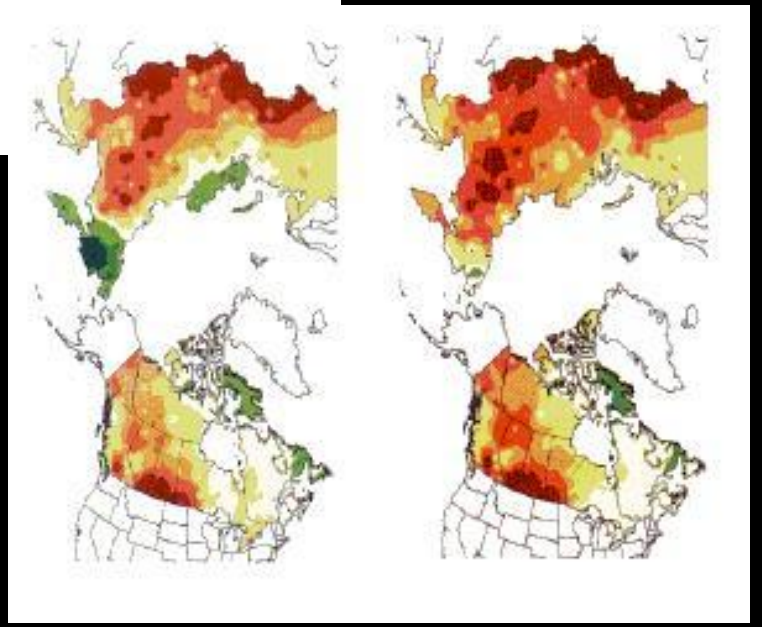



# Fire and Global Change




Chapin *et al.* 2005



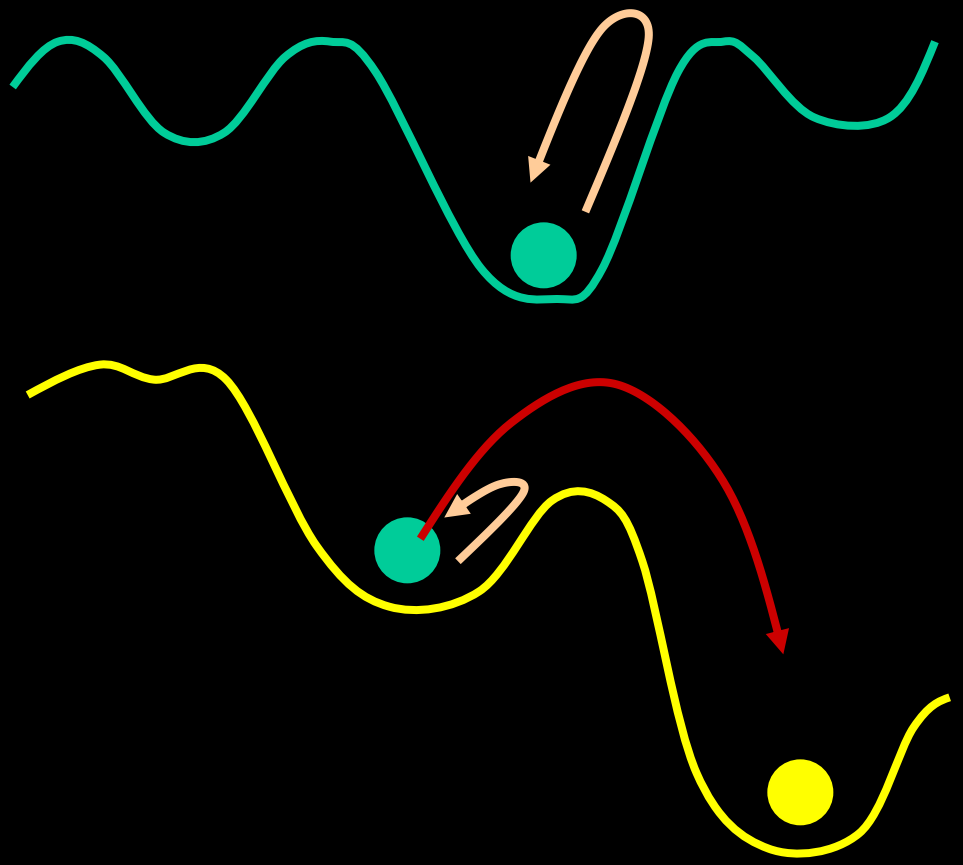
Stocks *et al.* 1998

Can we expect changes in forest composition?
What are those likely to be?

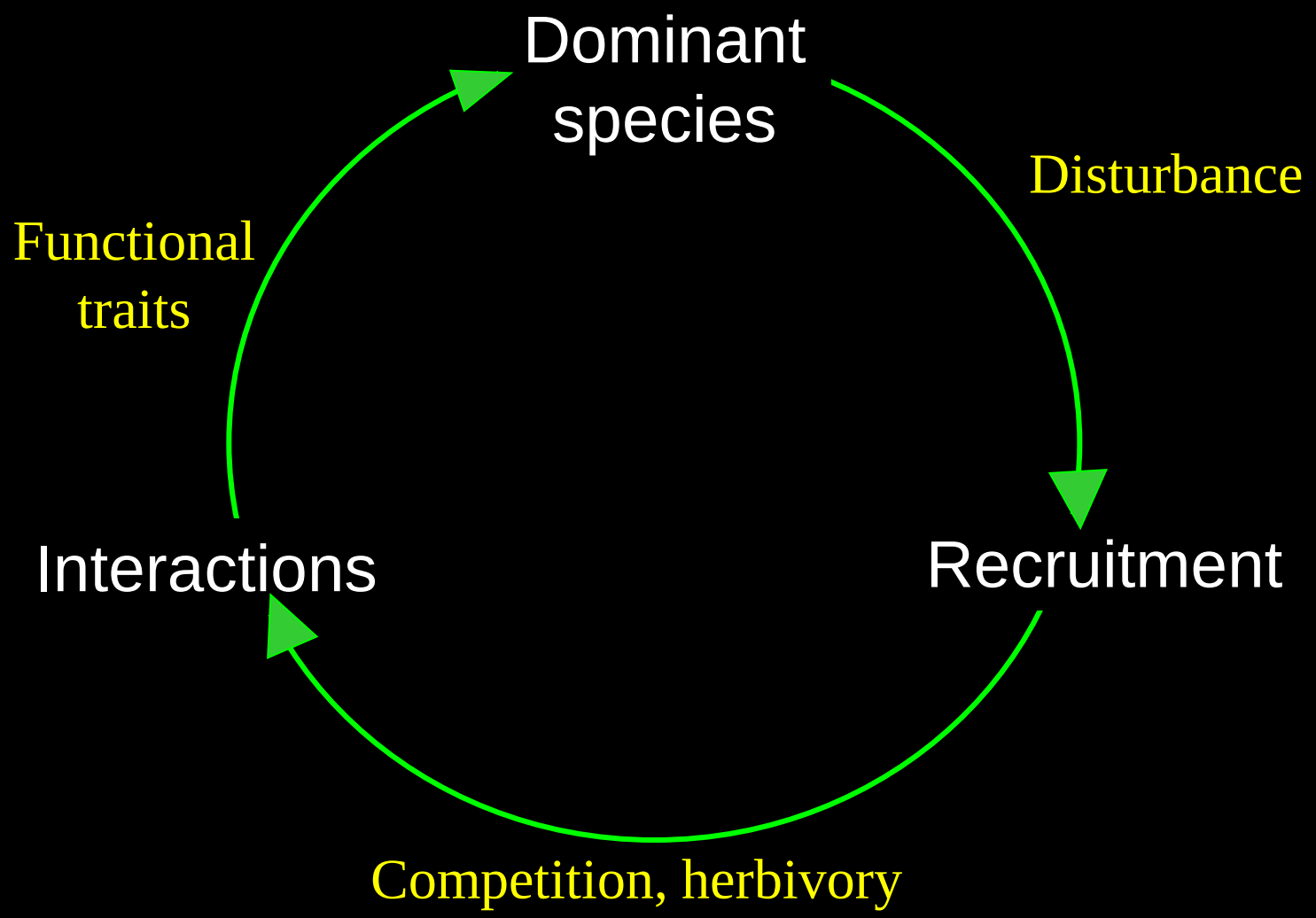
# Resilience and Response Dynamics

dynamic equilibrium

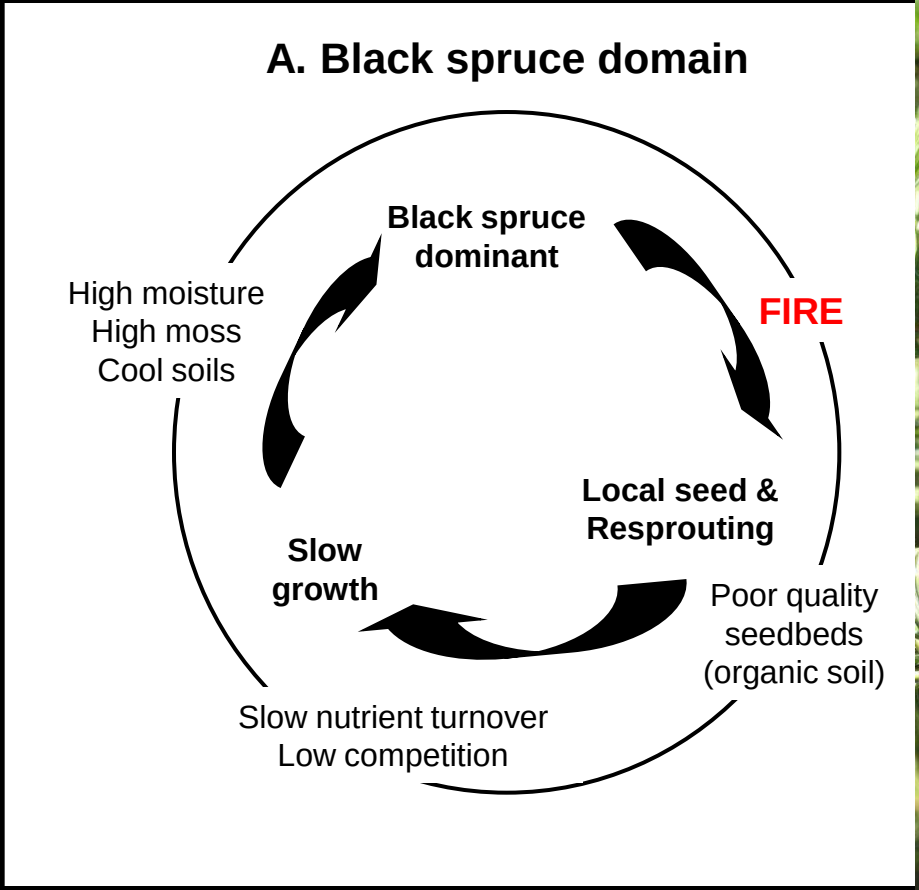
directional change



# Resilience & Ecosystem Feedbacks

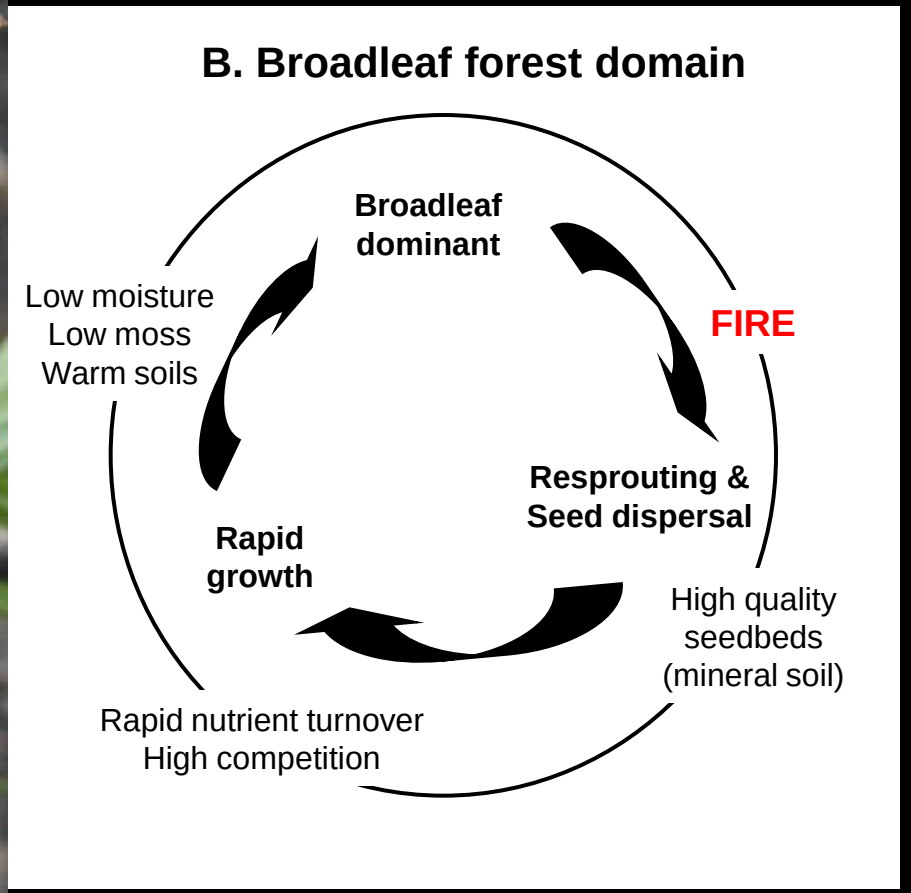


# Alternate successional cycles




Johnstone et al. 2010, *Can. J. Forest Research*

# Alternate successional cycles




Johnstone et al. 2010, *Can. J. Forest Research*

# How do fire characteristics shape patterns of forest resilience?

- Why study fire?
  - Ubiquitous in western boreal region
  - Sensitive to climate
  - Post-fire recovery determines future forest composition

# Fire and successional trajectories in black spruce forests

# Fire severity affects seedbed quality

Burning of organic soils influences patterns of post-fire recruitment

# Patch effects of fire severity

Low severity (organic)

- Poor seedbeds
- Recruitment requires high seed inputs
- Favors serotinous conifers

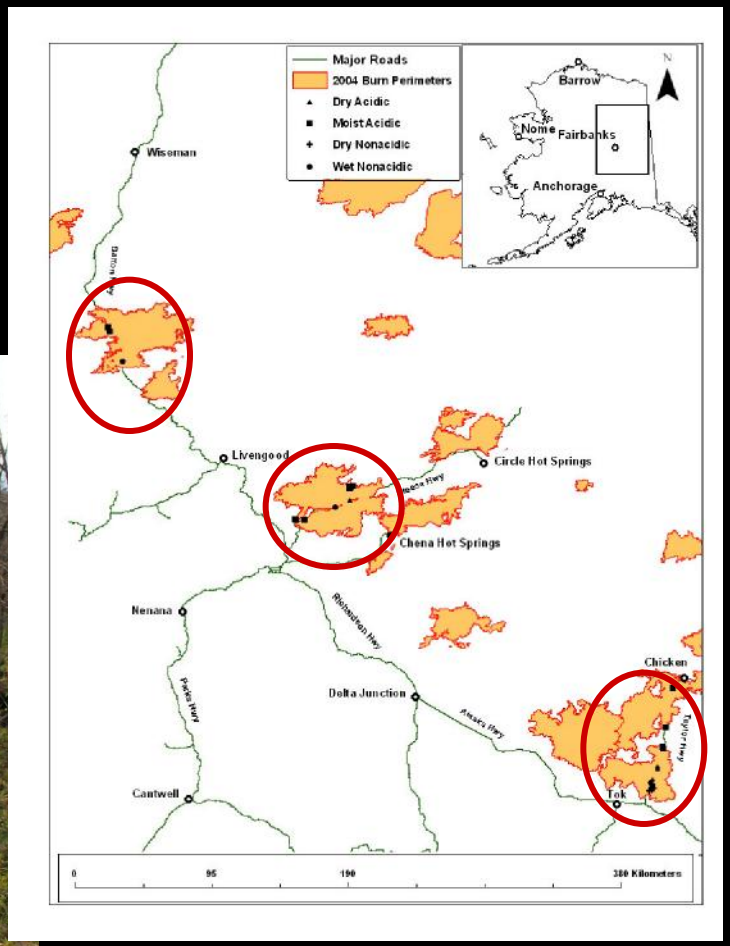
High severity (mineral)

- Higher quality seedbeds
- Creates opportunities for deciduous establishment


How does this influence forest dynamics across heterogeneous landscapes?

# Fire severity and post-fire recovery

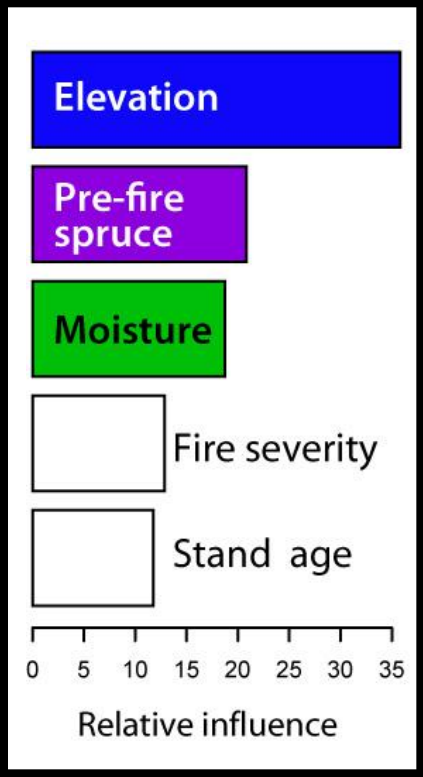
- Alaska 2004 fires
- 90 black spruce sites
- Initial stand recovery



# 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

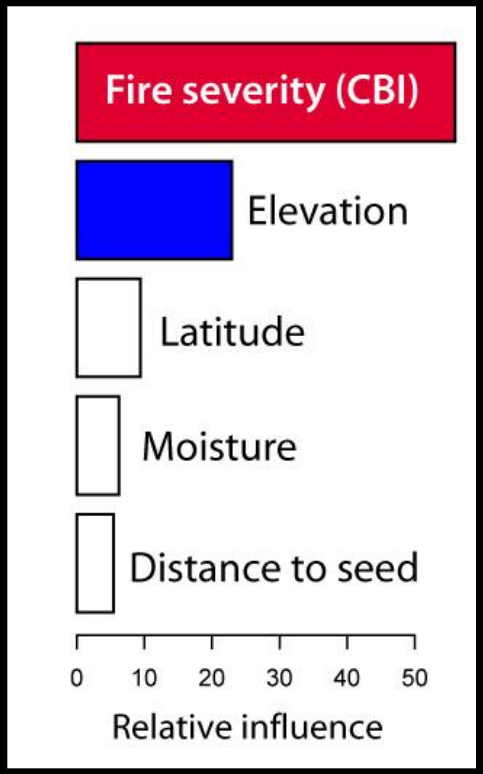
# Spruce seedling density




Boosted regression tree, prediction error=0.54

Johnstone et al. 2010, *Global Change Biology*

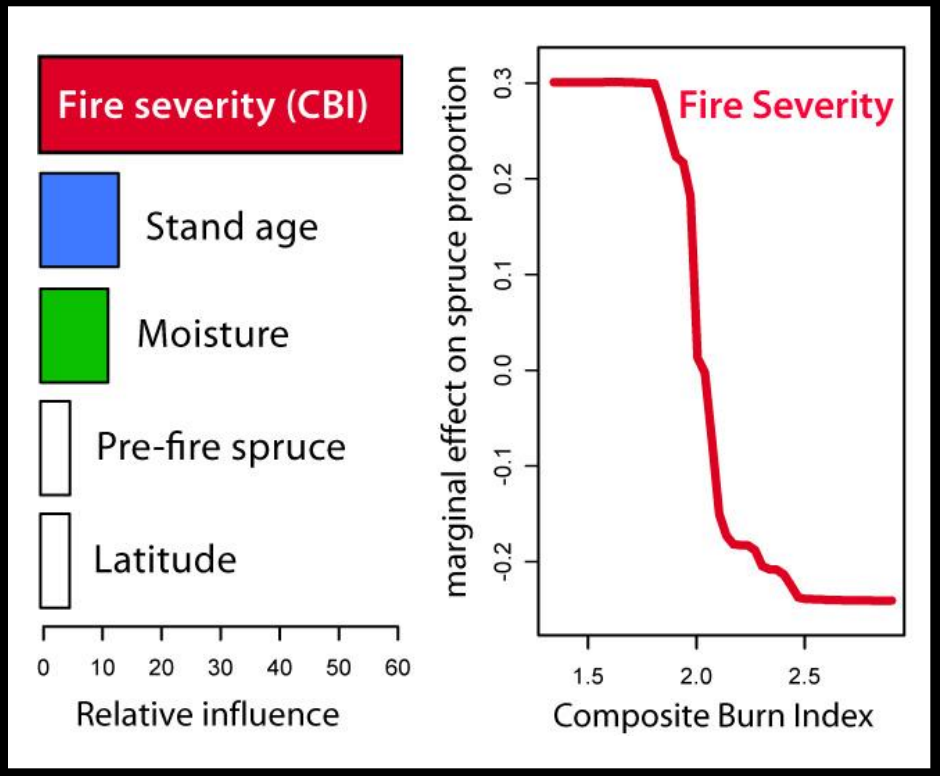
# Deciduous seedling density




Boosted regression tree, prediction error=0.44

Johnstone et al. 2010, *Global Change Biology*

# Relative spruce dominance: Recovery of spruce trajectory



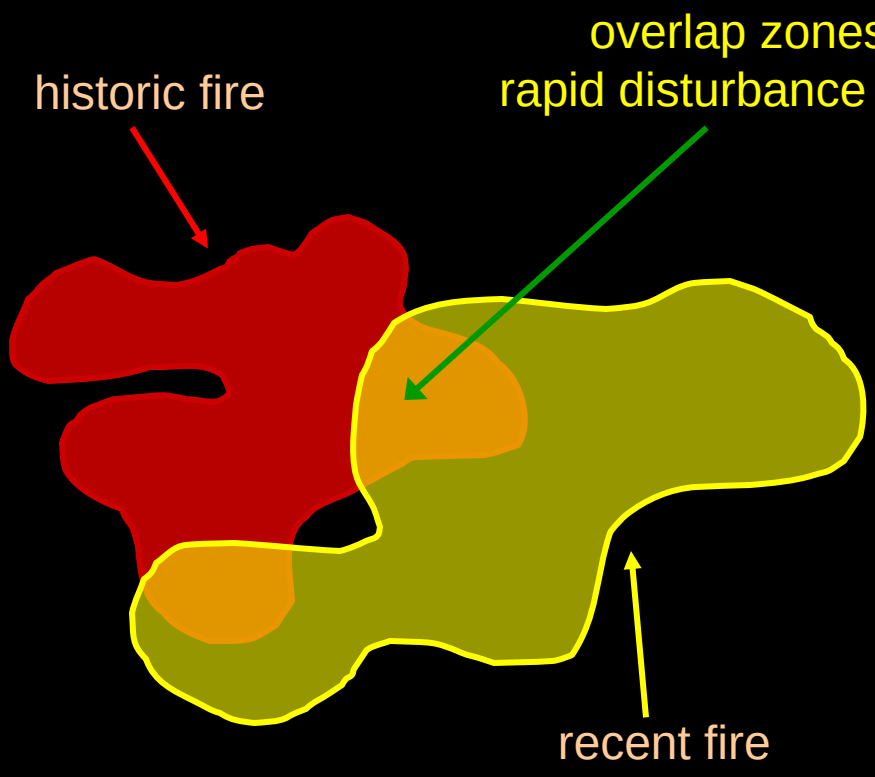

Boosted regression tree, prediction error=0.42

Johnstone et al. 2010, *Global Change Biology*

# Controls on spruce forest resilience

- Severe fires reduce the competitive advantage of spruce and favor deciduous species
- Severe fires alter soil microclimate
- Site moisture
  - Warm, dry soils favor aspen
  - Severe fires are also more likely
- Young stands vulnerable to change

# Studies of fire frequency using overlapping fires



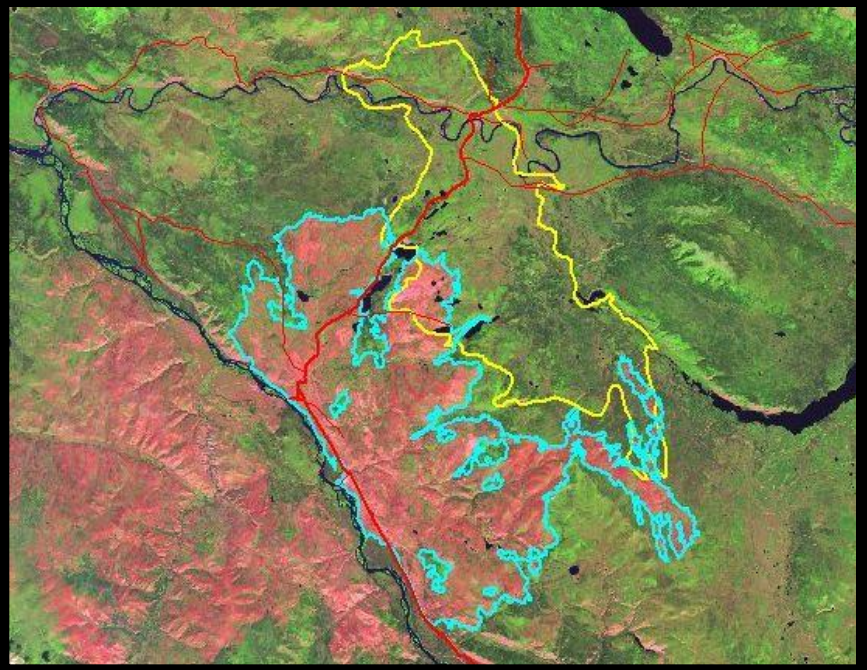



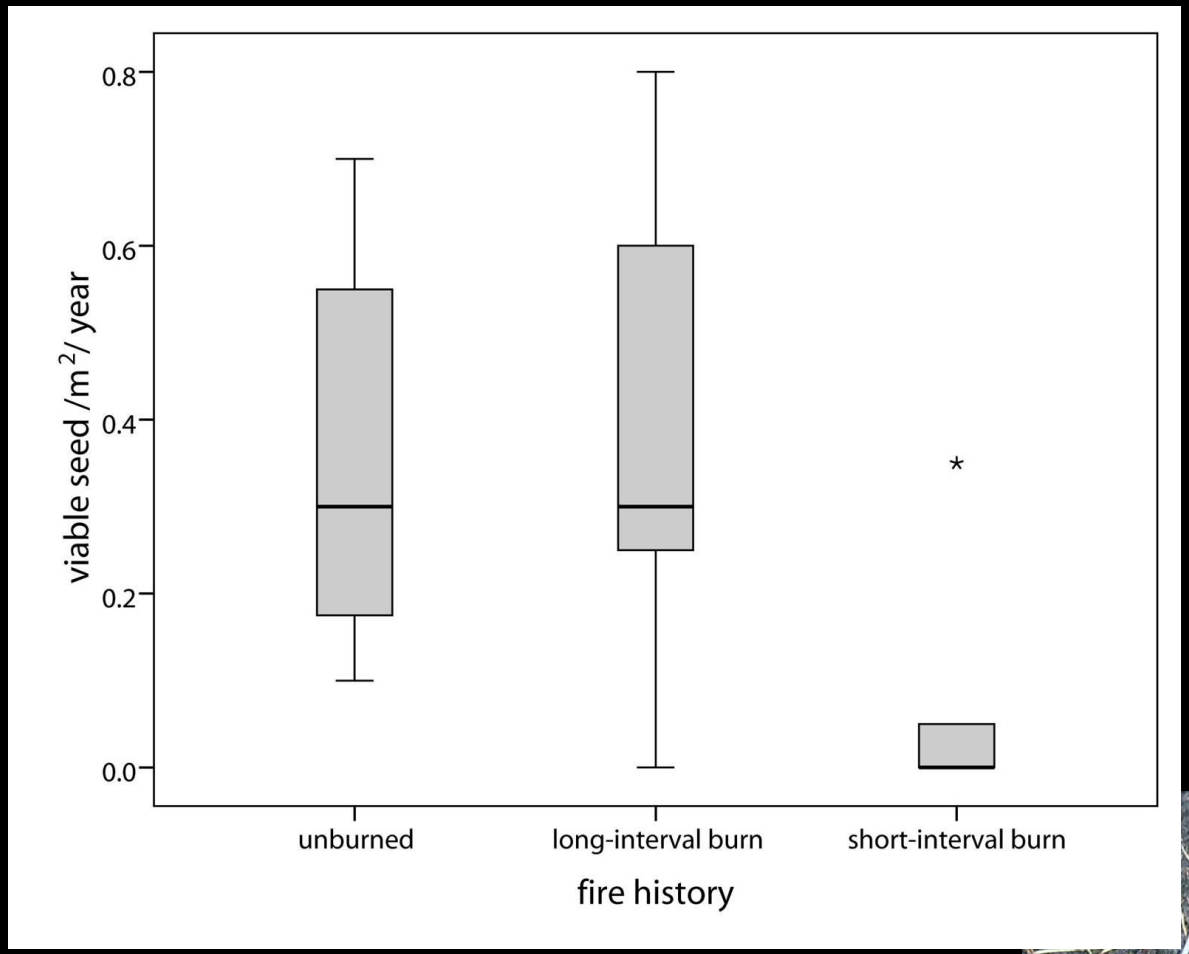
image courtesy of David Milne, Yukon Gov.

# Repeat fires alter tree regeneration



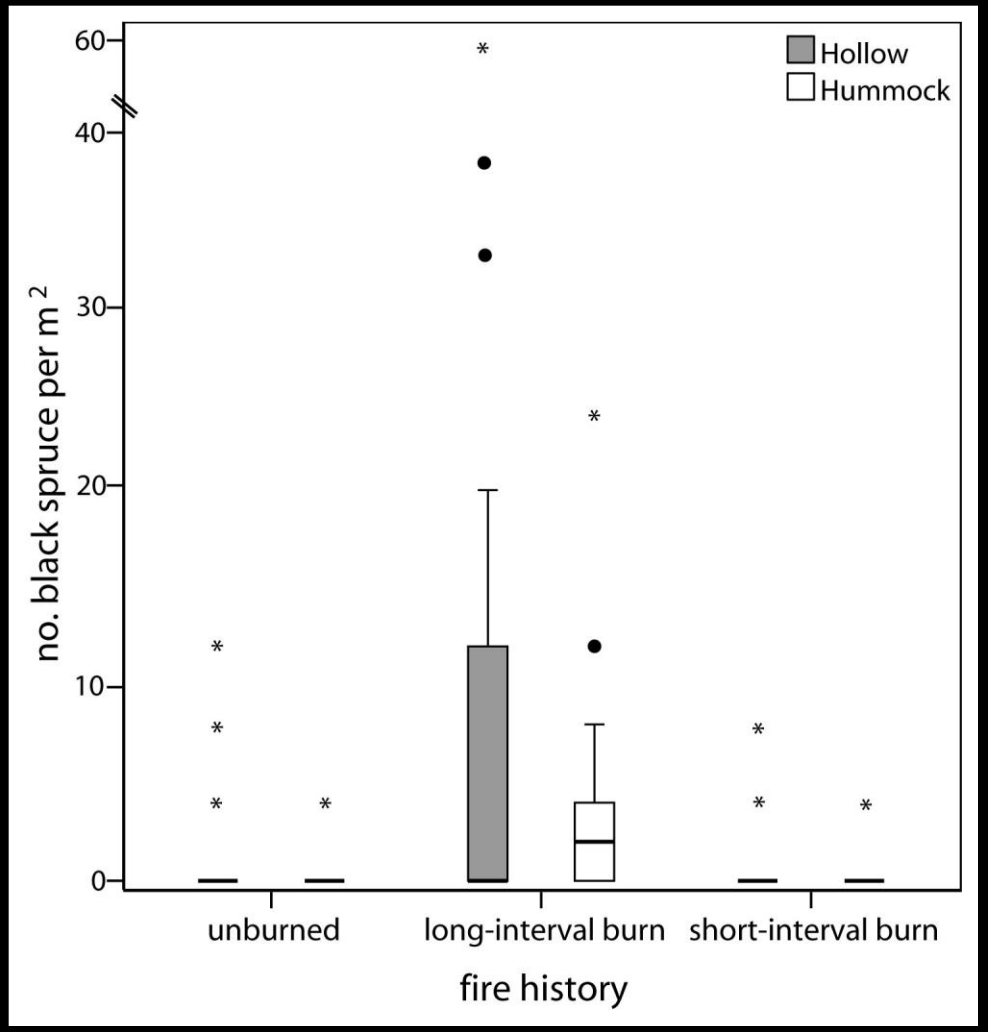

Johnstone & Chapin 2006, *Ecosystems*

# Seed rain




Brown & Johnstone, unpublished

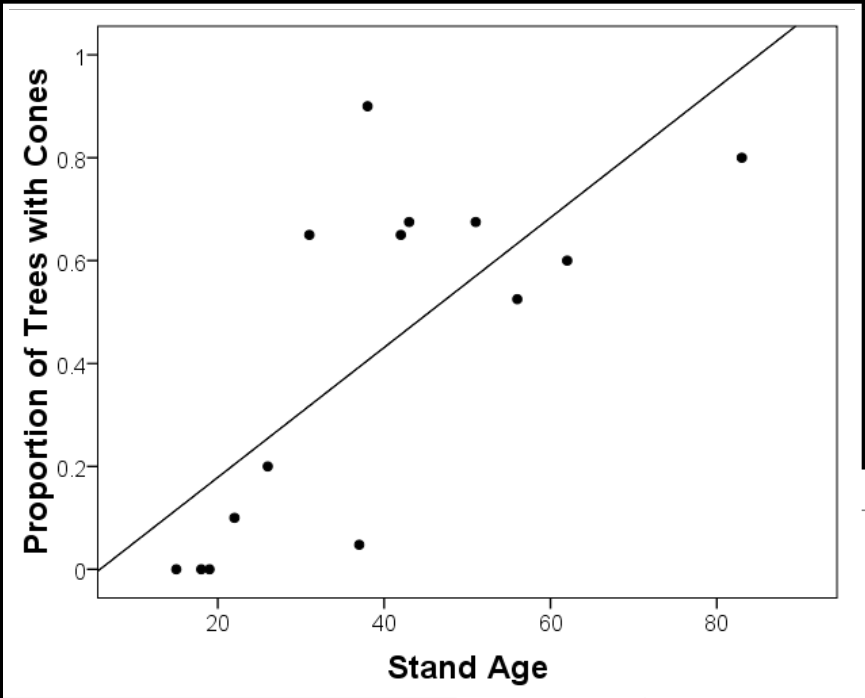
# Seedling establishment




Brown & Johnstone, unpublished

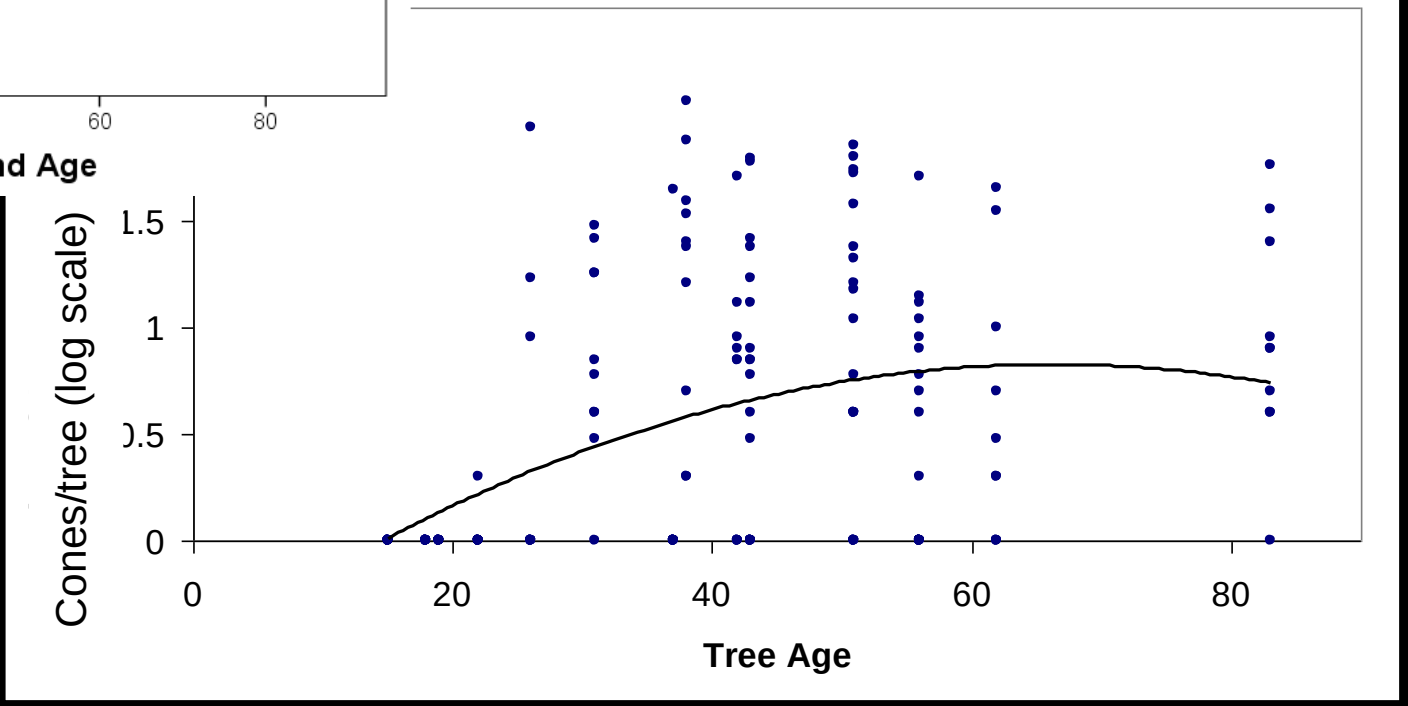
# How old does a stand need to be before there is sufficient cone production to support regeneration?

# Cone Production




n=14, p<0.001, r=0.723

n=170, p<0.001, r=0.360

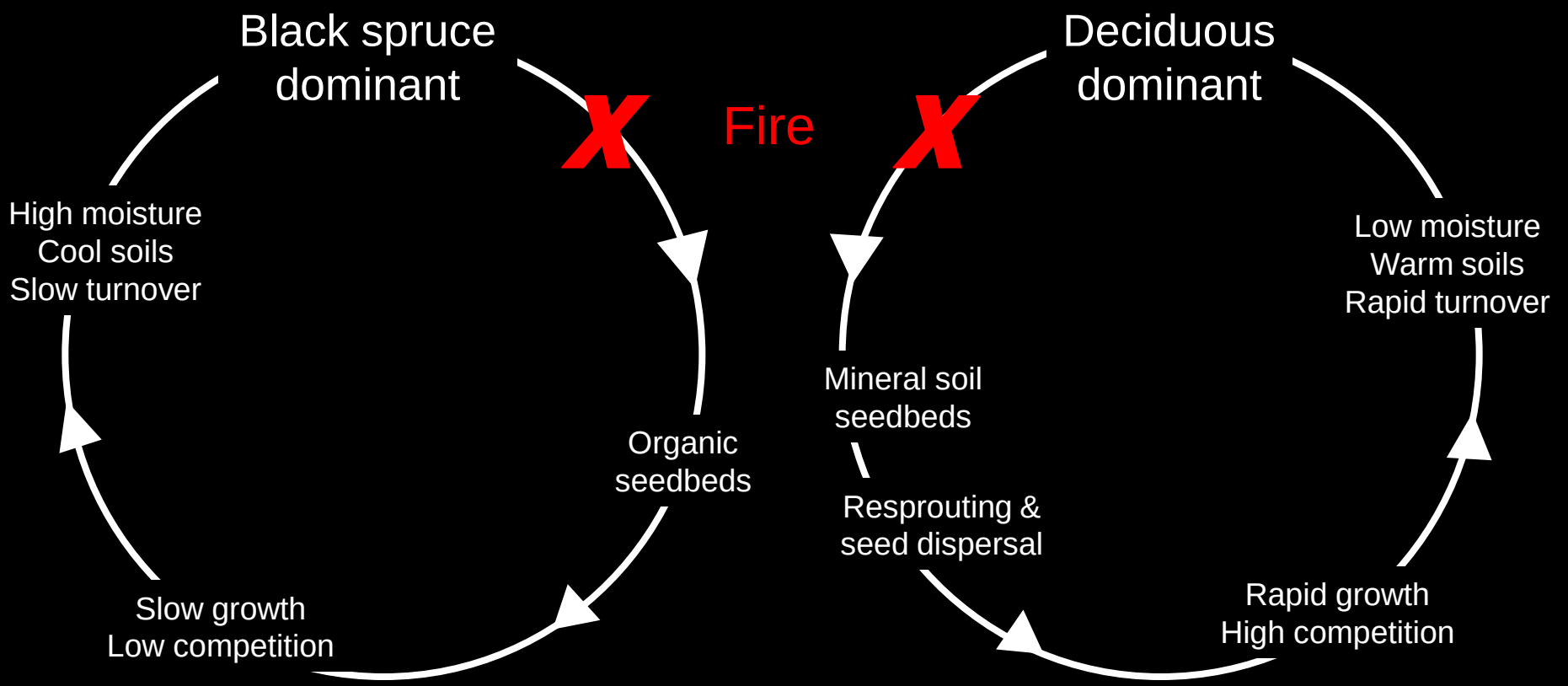



Viglas & Johnstone, unpublished

# Fire interval effects

- Repeat fires interrupt conifer regeneration cycles
  - Reduced cone production
- Confers a regeneration advantage to wind-dispersed seeds
- Net effect is to shift trajectories to deciduous dominance

# Shifts in resilience cycles



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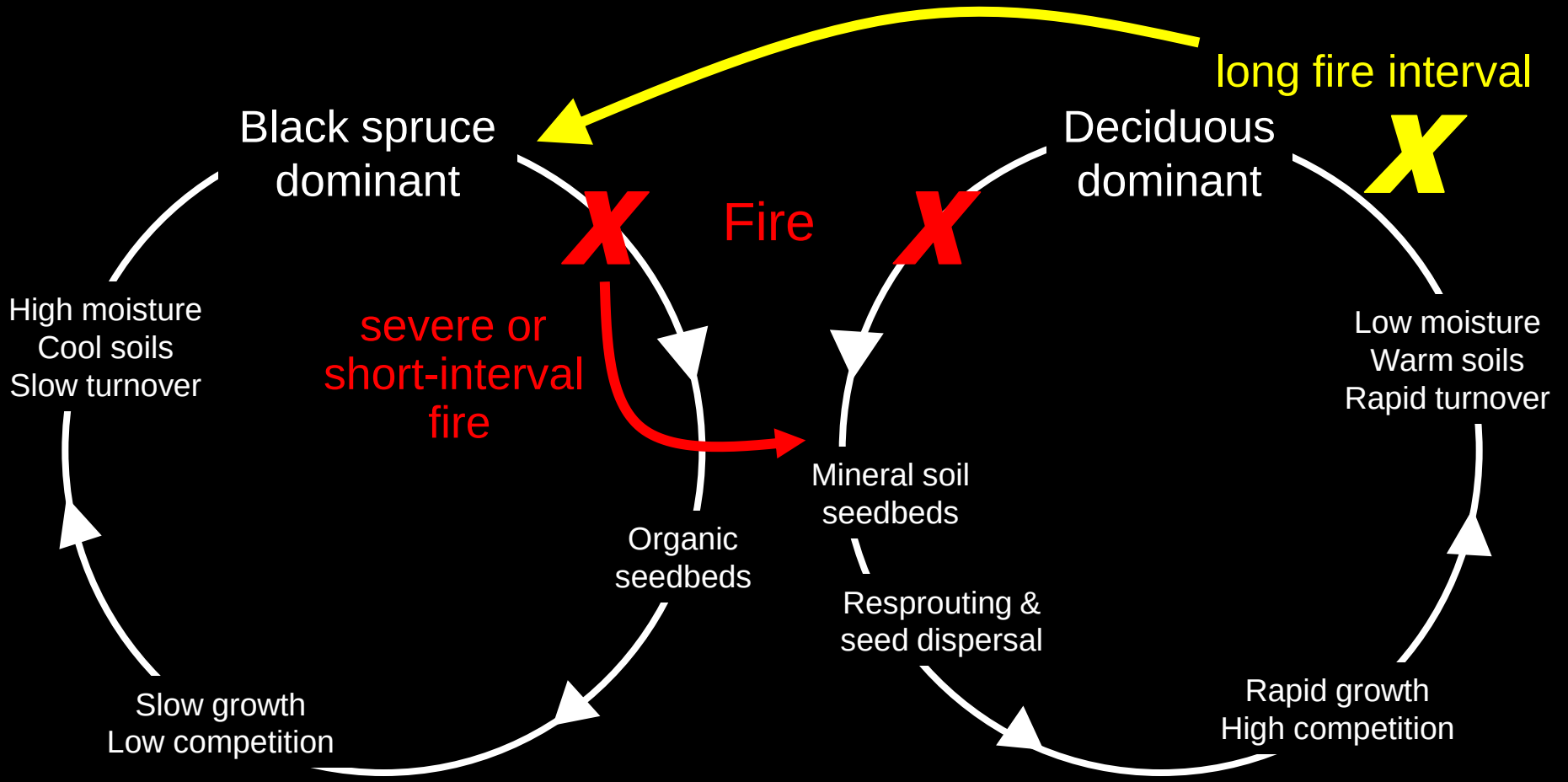


# Why is this important?

- Changes in forest cover affect:
  - Carbon storage
  - Energy and water transfer
  - Wildlife and subsistence resources
  - Feedbacks to future fire behavior

# Fire severity and succession: Impacts on future fire behavior

- High fire severity transforms black spruce to deciduous forest
- Deciduous forest has lower flammability

➢ Can fire-initiated changes create a negative feedback to climate-driven increases in fire activity?

# ALFRESCO simulation experiment

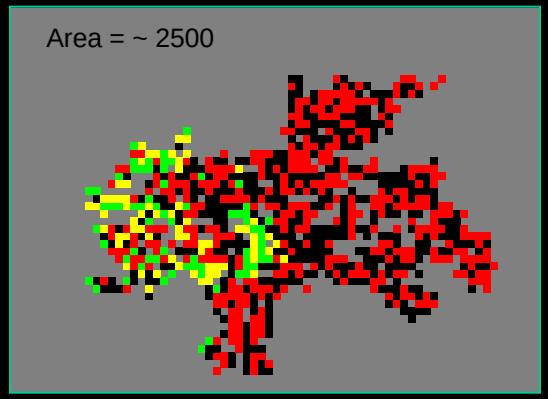
- Spatial simulation model for boreal landscapes
- Succession influenced by fire severity
- 3 Severity Scenarios:
  - Low (LSS): All fires burn with low severity (spruce trajectory)
  - High (HSS): Maximum extent of high severity (decid. trajectory)
  - Mix: Intermediate scenario
- High and moderate scenarios of climate warming

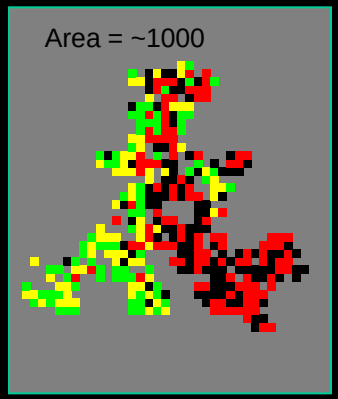
**KEY:**

Green & Yellow = Low Sev.

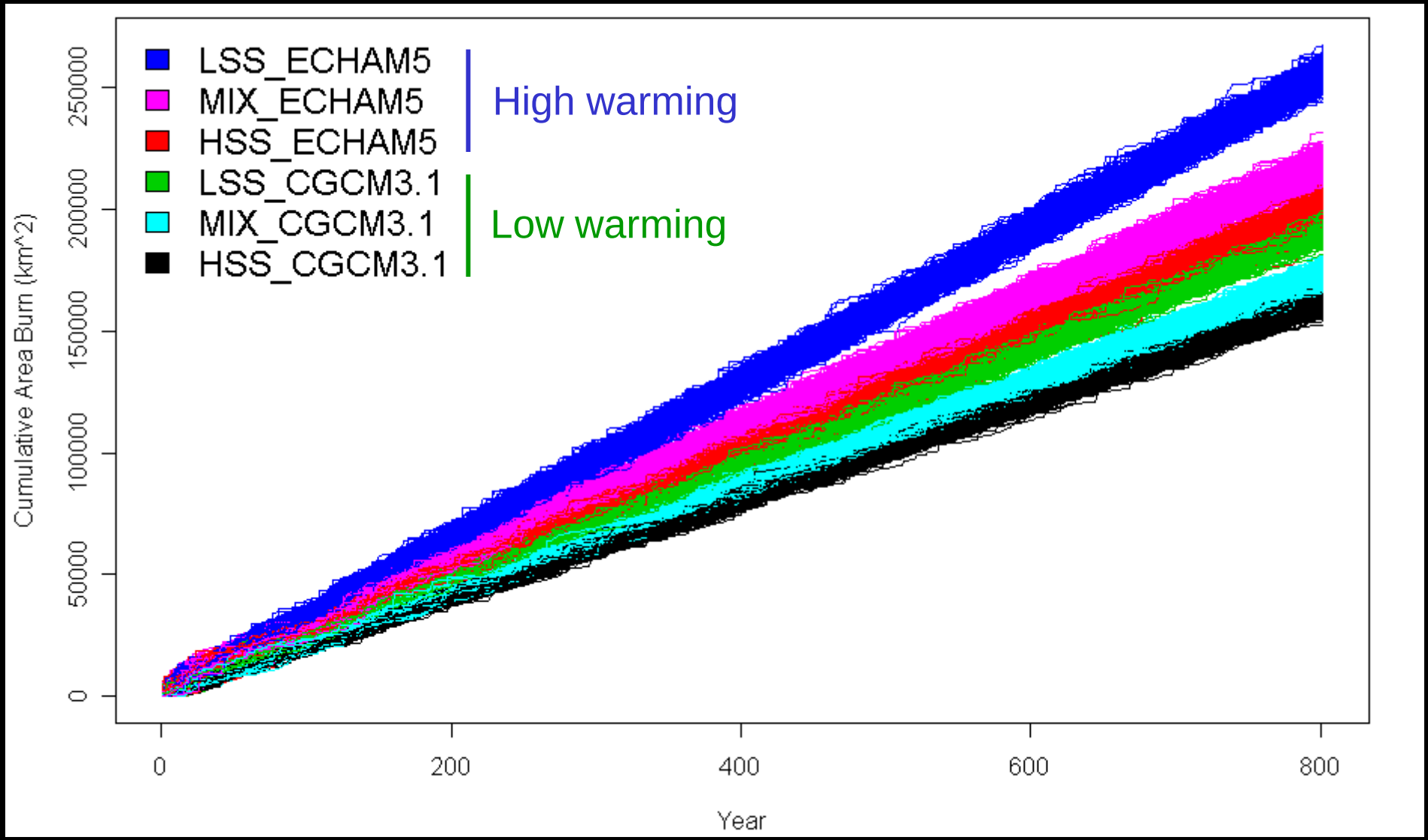
Red = High Sev. in HSS

Black = High Sev. in Mix + HSS



# Cumulative area burned

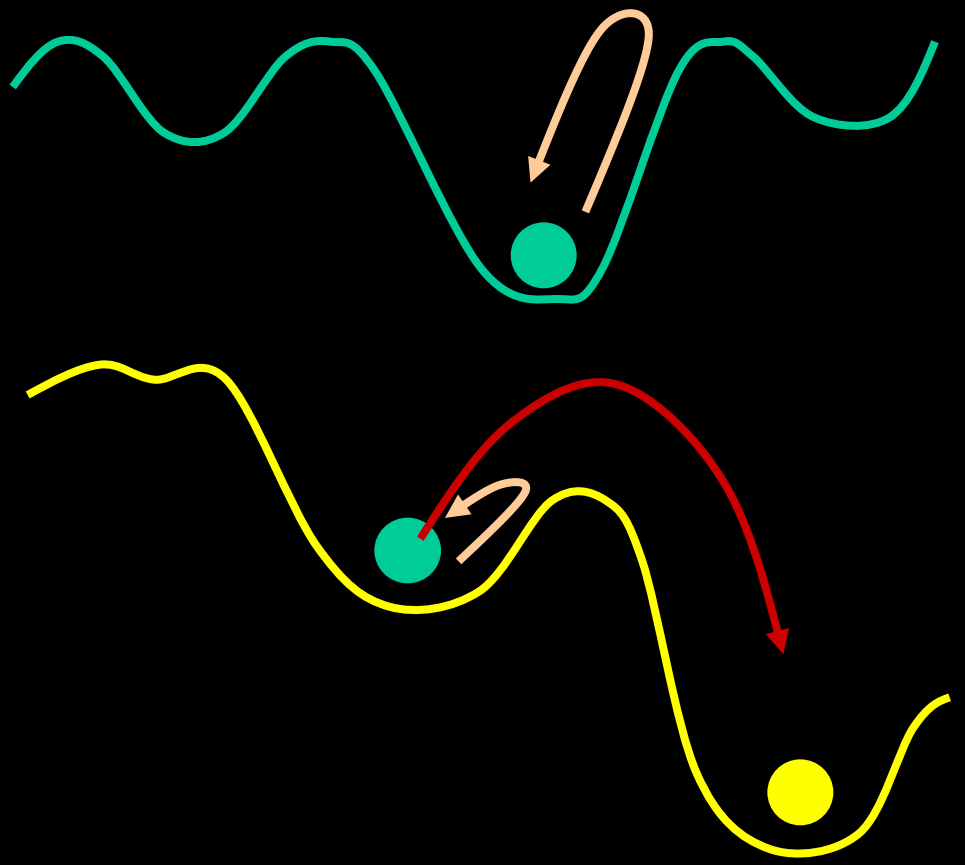



Johnstone, Rupp, et al., *in review*

# Disturbance & climate interact to alter black spruce resilience

dynamic equilibrium

directional change



tundra black spruce deciduous

# Future Research

- Mechanistic understanding of plant-soil-microbial feedbacks
- Quantifying thresholds and tipping points
- Landscape prediction of vulnerability to change

# Conclusions

- Fire is both catalyst and driver of change
  - Critical post-fire reorganization phase
  - Both frequency and severity shape future succession
- Landscape context => vulnerability to change
  - Understanding the drivers of resilience is key to predicting future change

# Acknowledgements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LTER

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