Fire and Succession in Northern Black Spruce Forests

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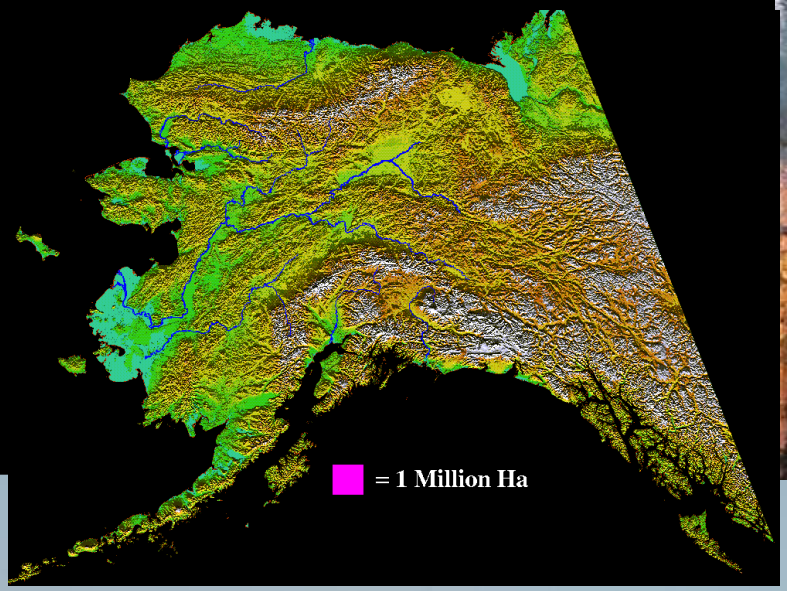
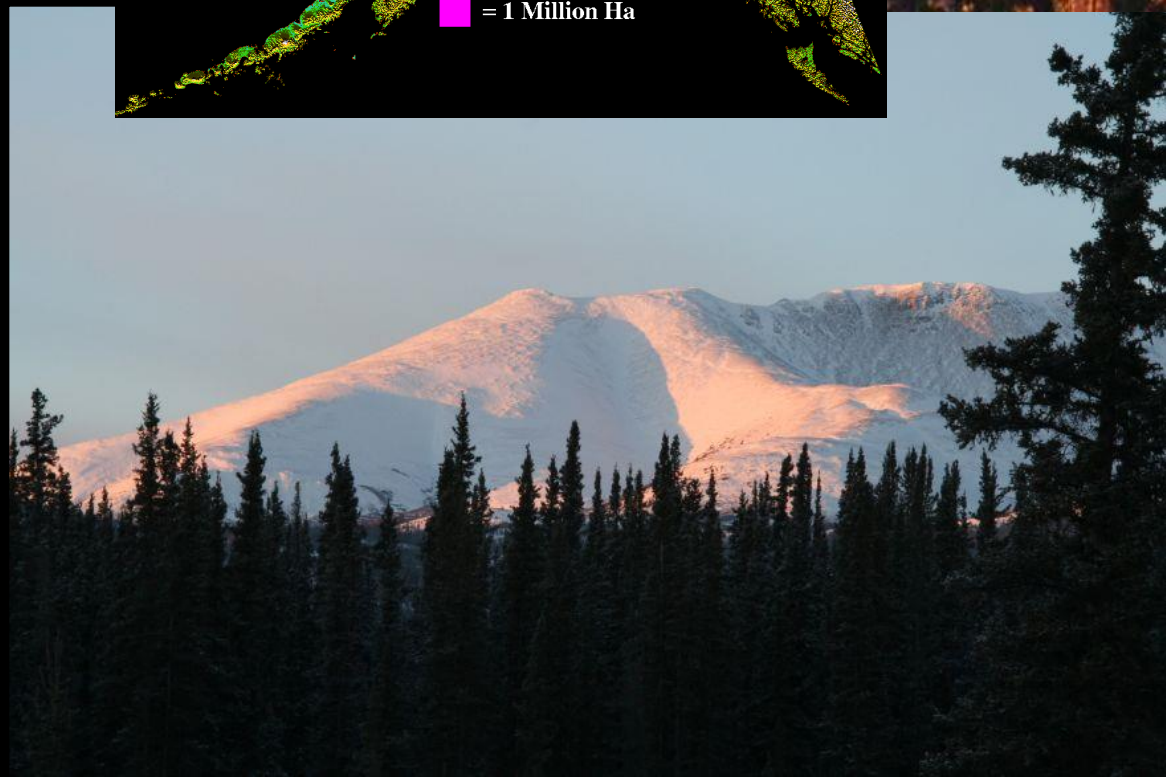
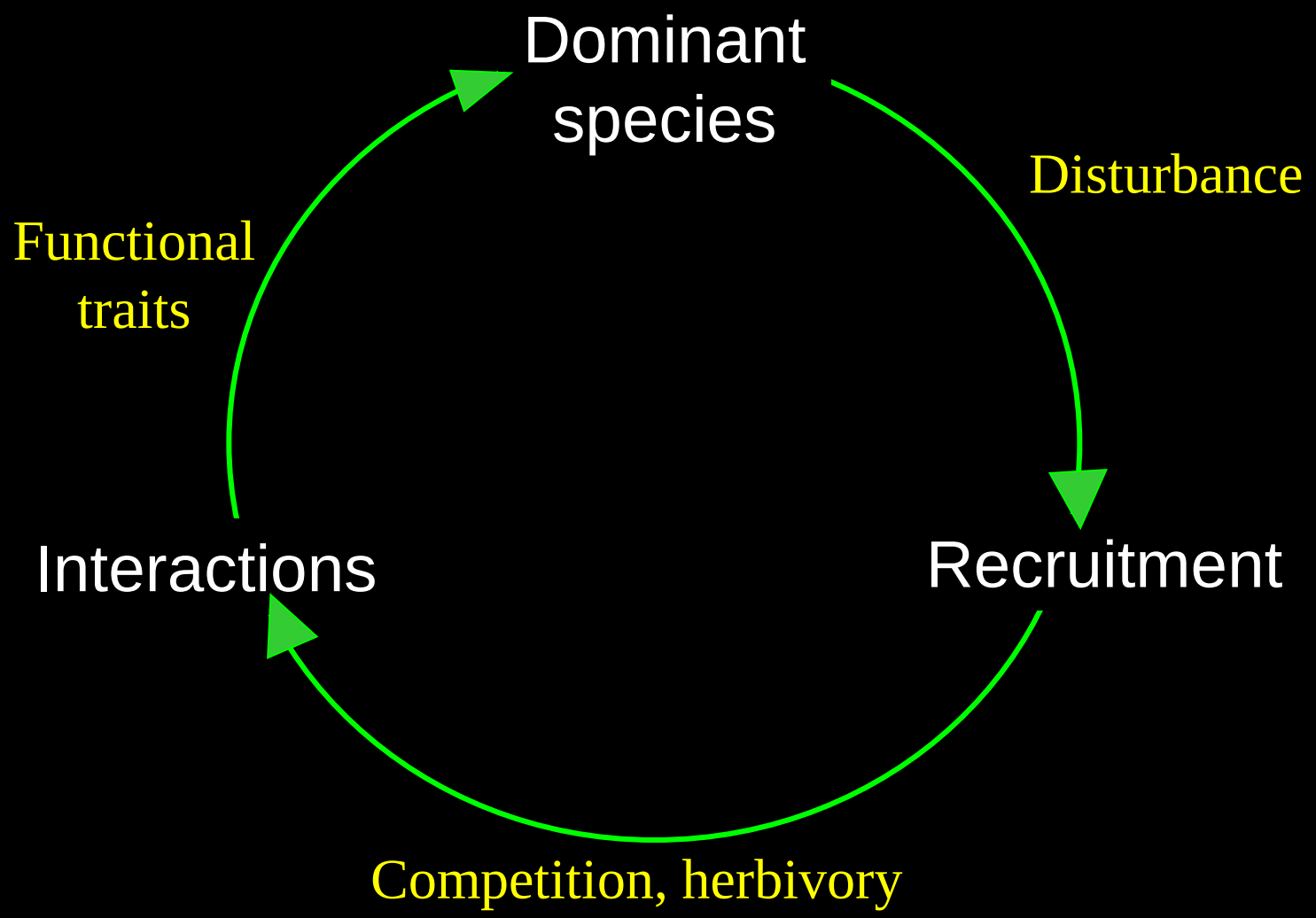
Northern boreal forest

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





Succession & Ecosystem Feedbacks

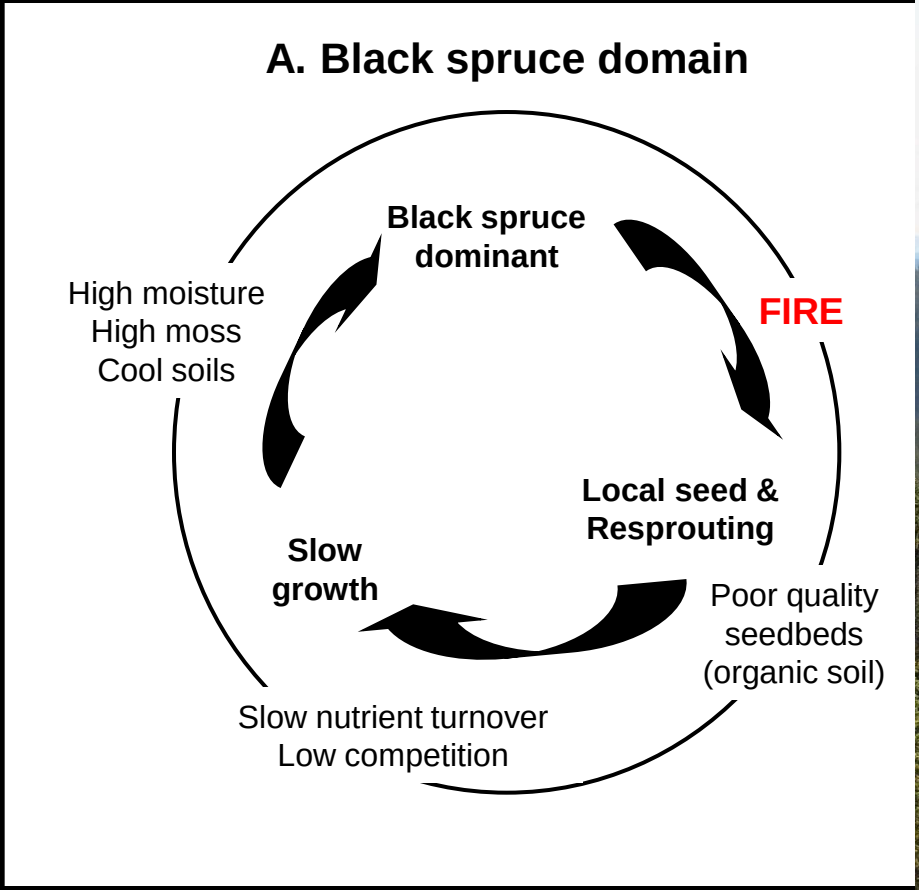


Black spruce ecology

Picea mariana forest

Serotinous cones - seed source for regeneration after fire

Black spruce succession cycle



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 serotinous conifers

High severity (mineral)

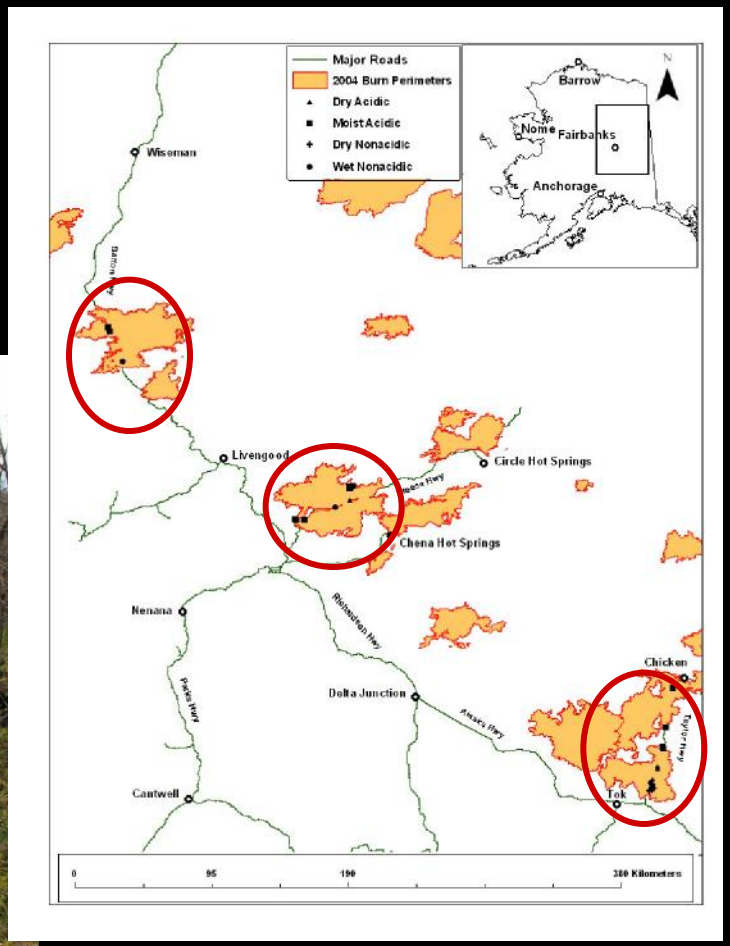
- Higher quality seedbeds
- Creates opportunities for deciduous establishment

Johnstone & Chapin 2006, *Ecosystems*


How does this influence forest recovery across heterogeneous landscapes?

Fire severity and post-fire recovery

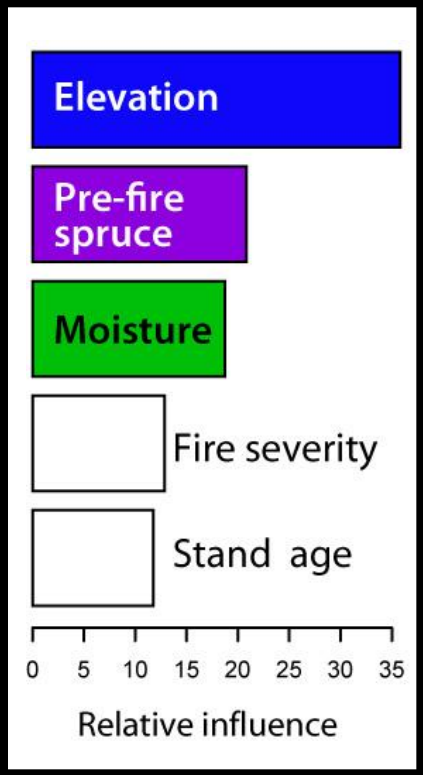
- Alaska 2004 fires
- 90 black spruce sites
- Initial stand recovery



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

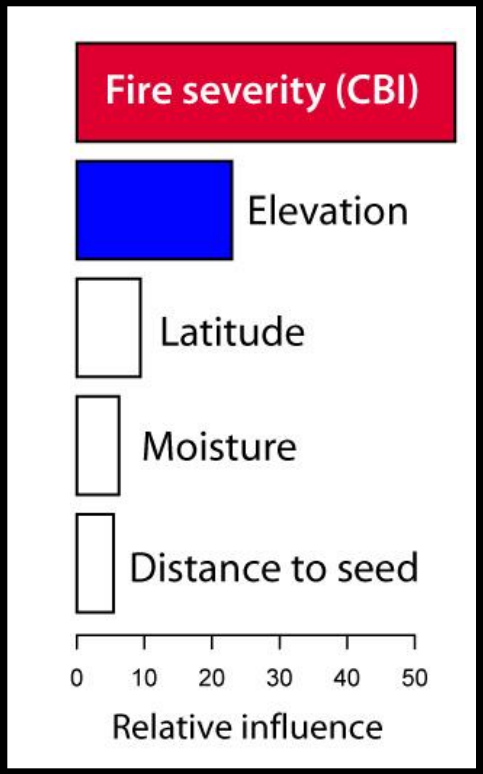
Spruce seedling density



Boosted regression tree, prediction error=0.54

Johnstone et al. 2010, *Global Change Biology*

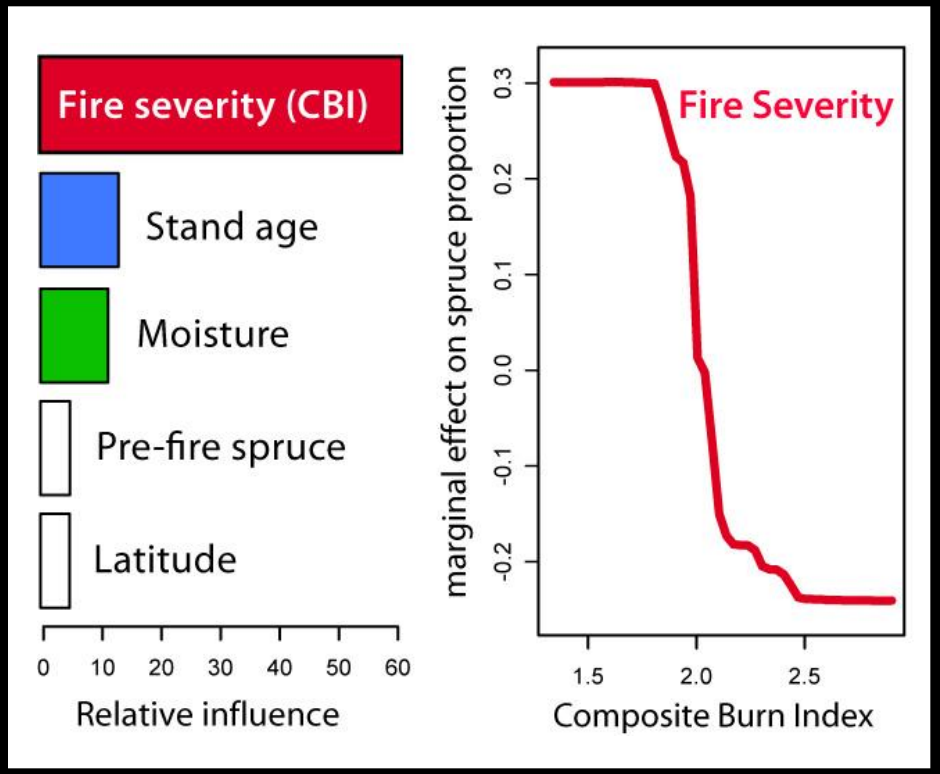
Deciduous seedling density



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*

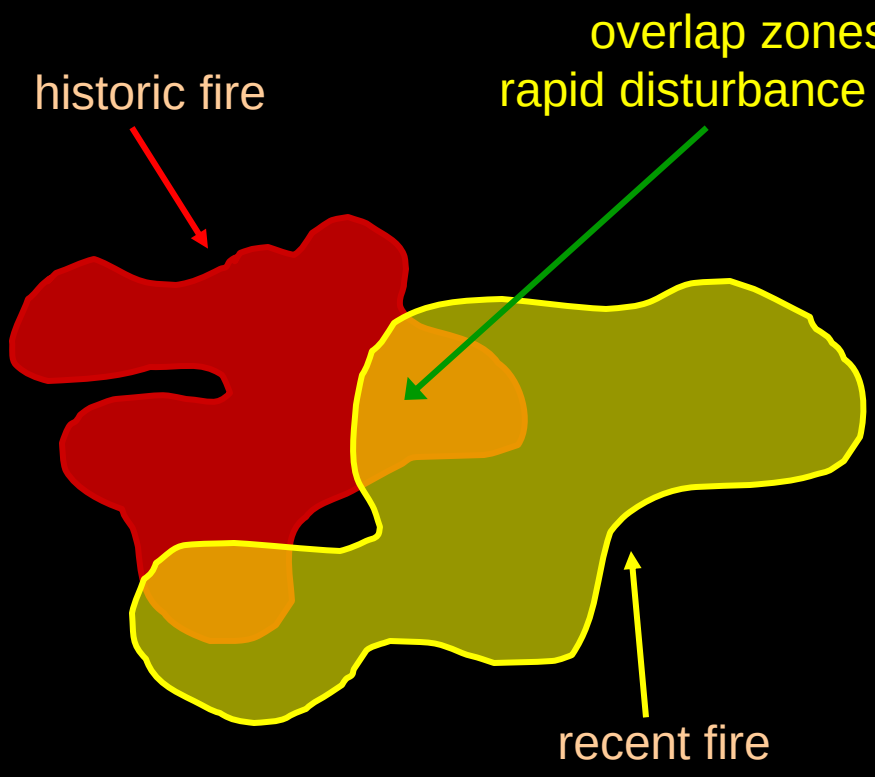
Controls on spruce forest recovery

- 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



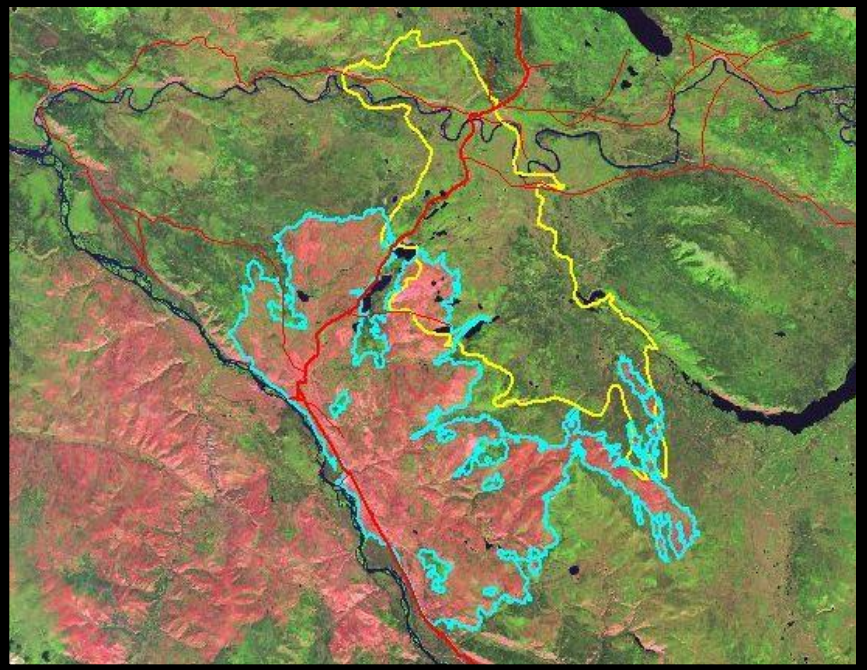
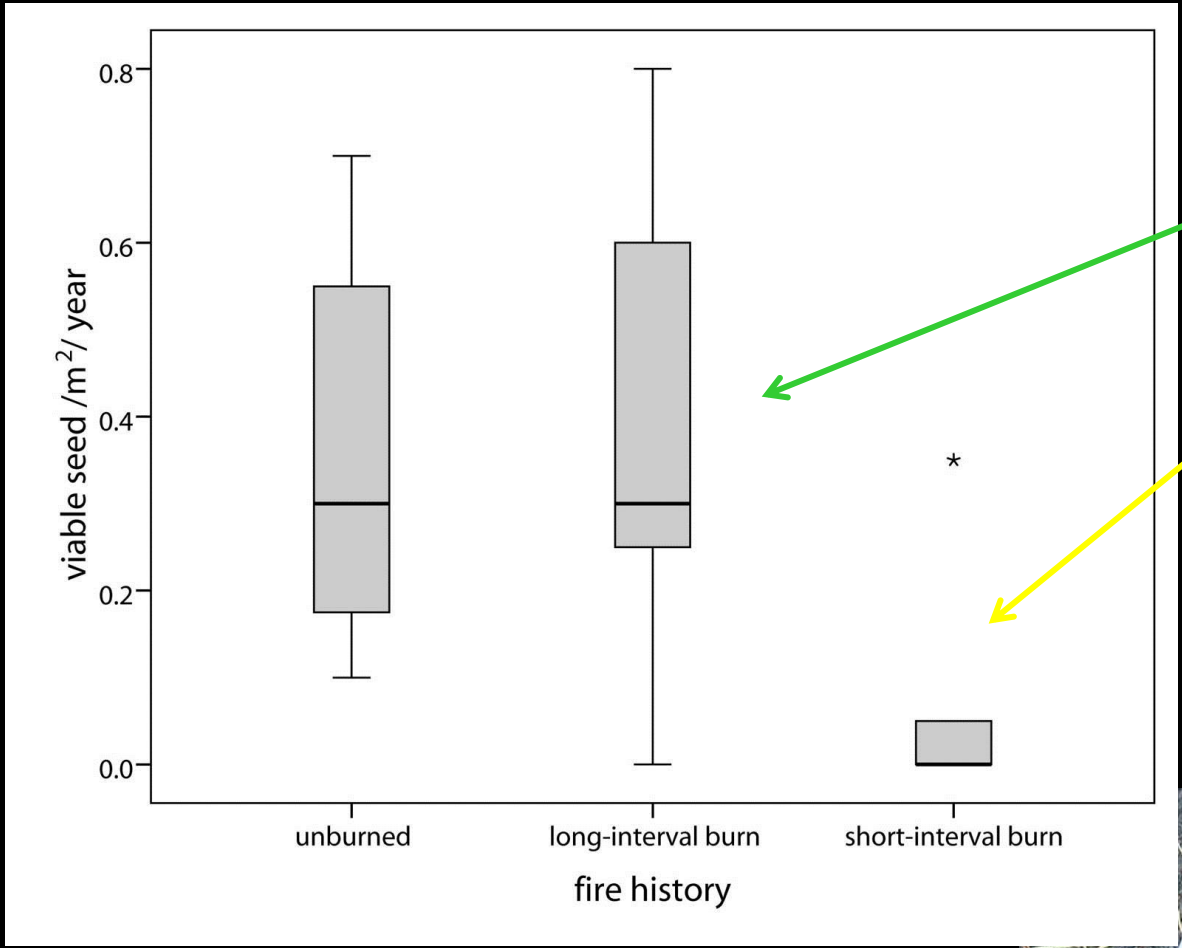


image courtesy of David Milne, Yukon Gov.

Fire frequency in N Yukon

Seed rain

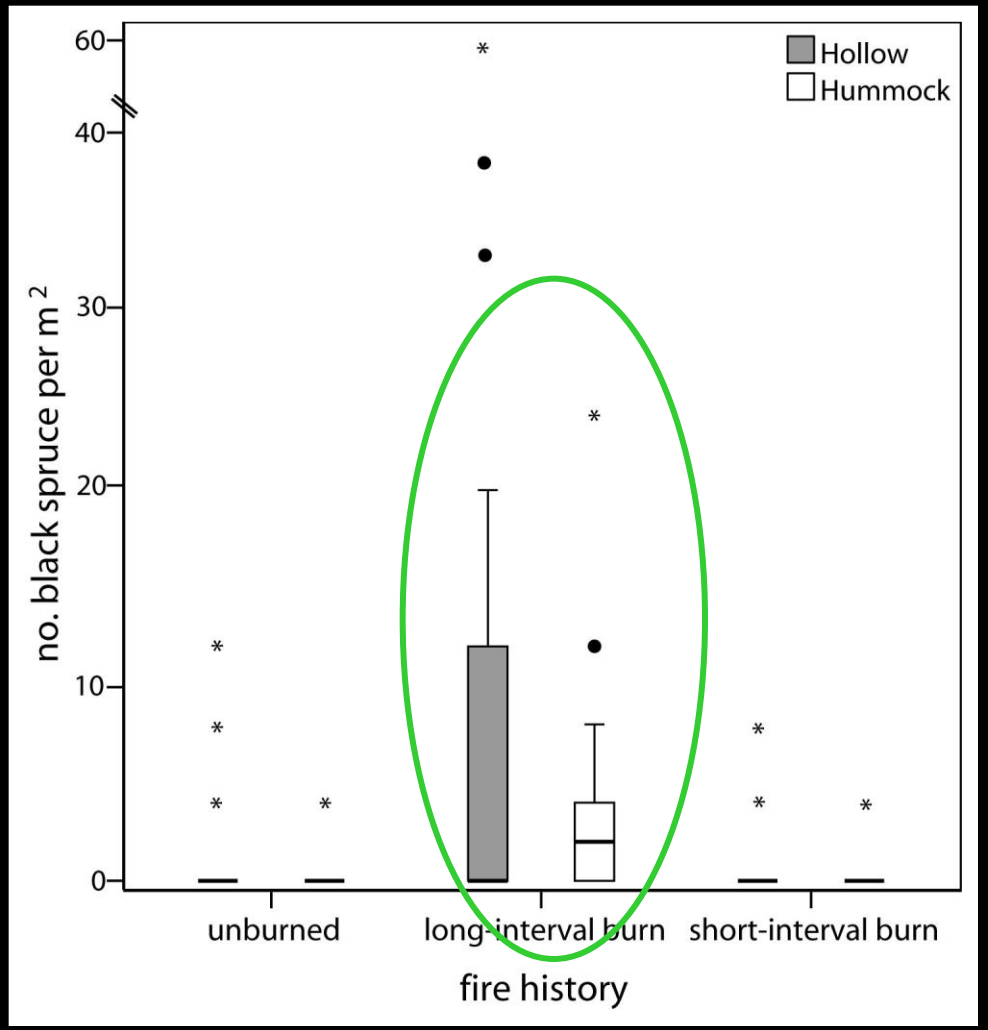


~80 years between fires

15 years between fires

Brown & Johnstone 2012, *Forest Ecology and Management*

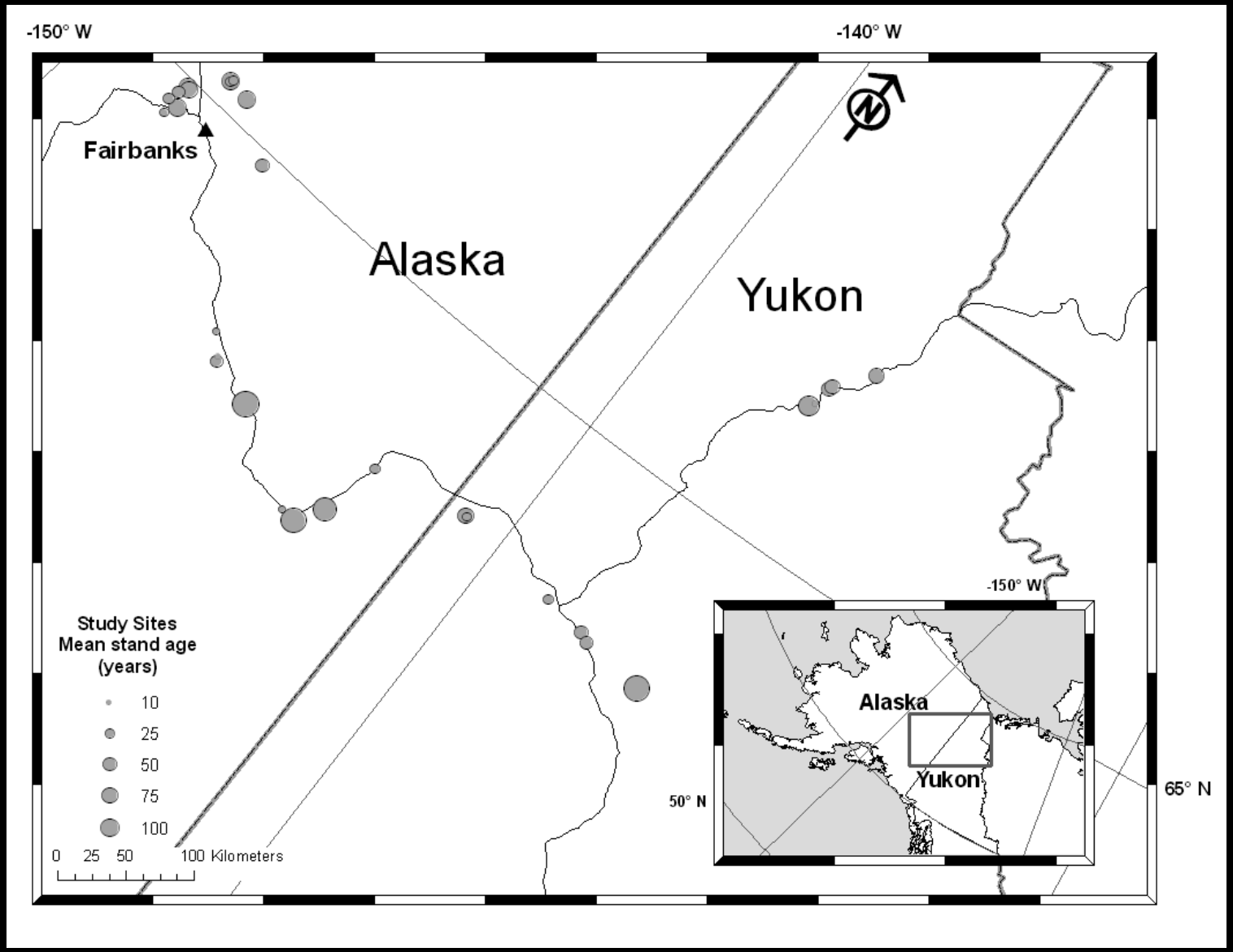
Seedling establishment



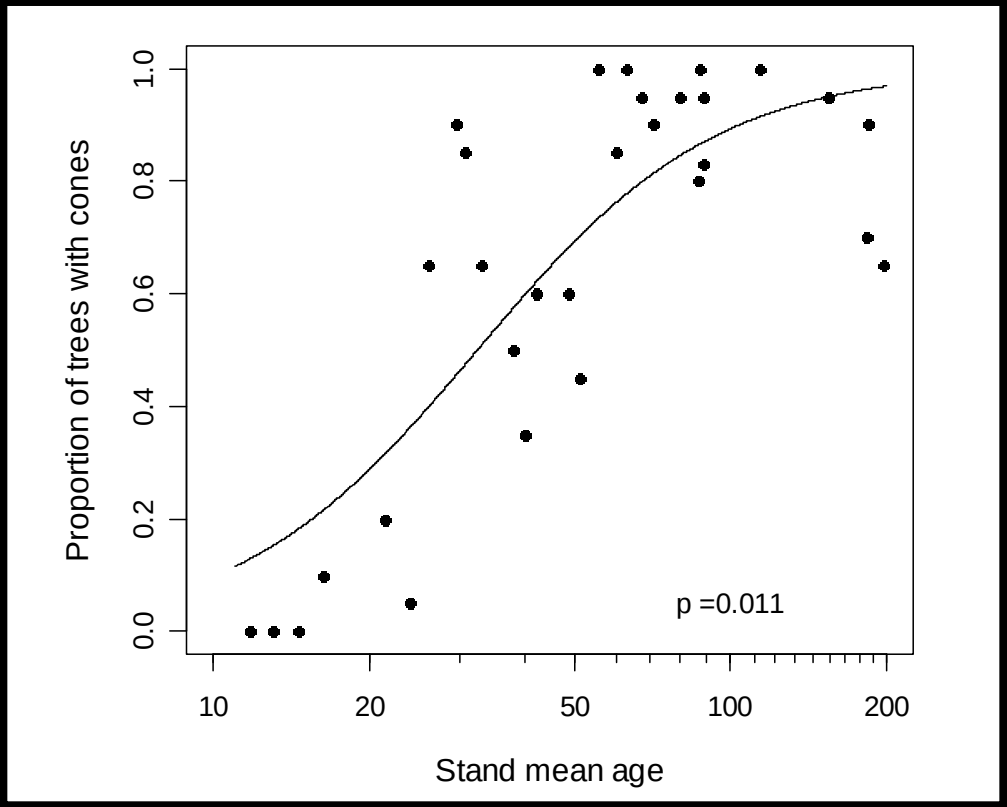
Brown & Johnstone 2012, *Forest Ecology and Management*

How old does a stand need to be to support post-fire regeneration?

Surveys of black spruce stands

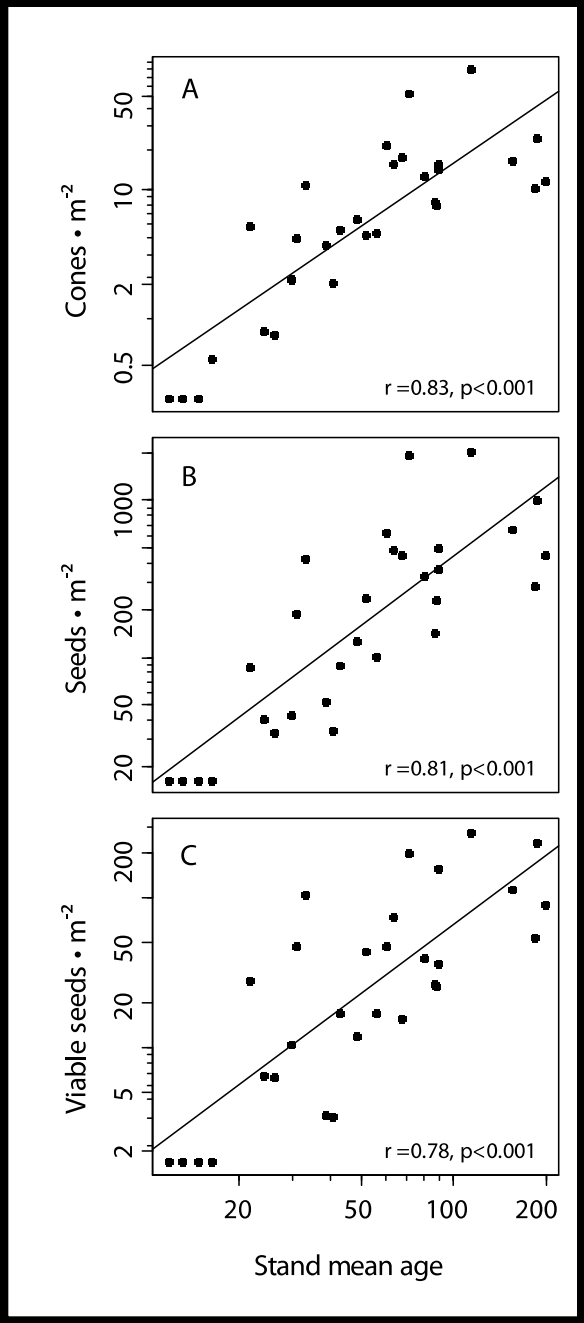


Cone Production



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

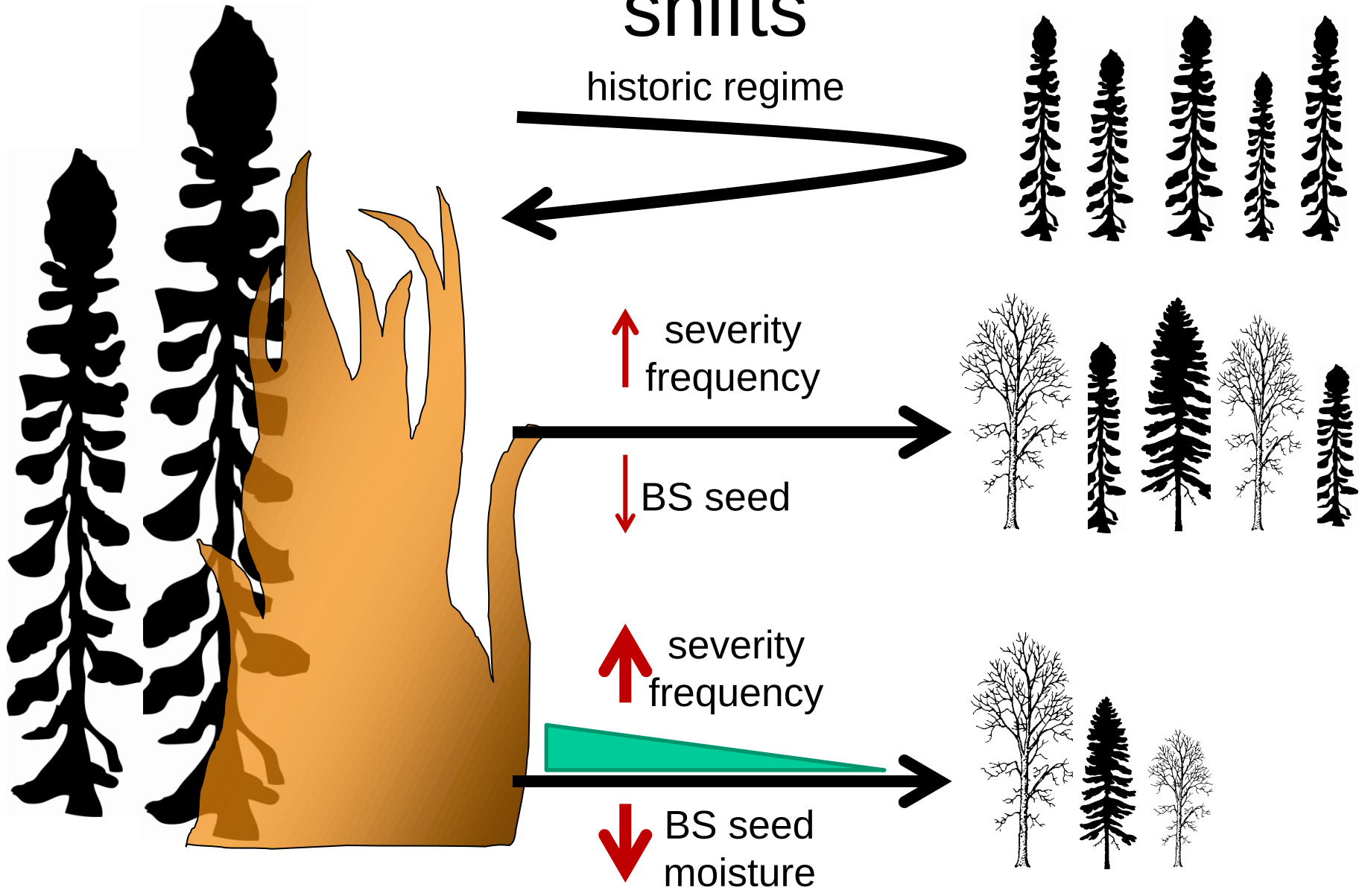
Seed Production



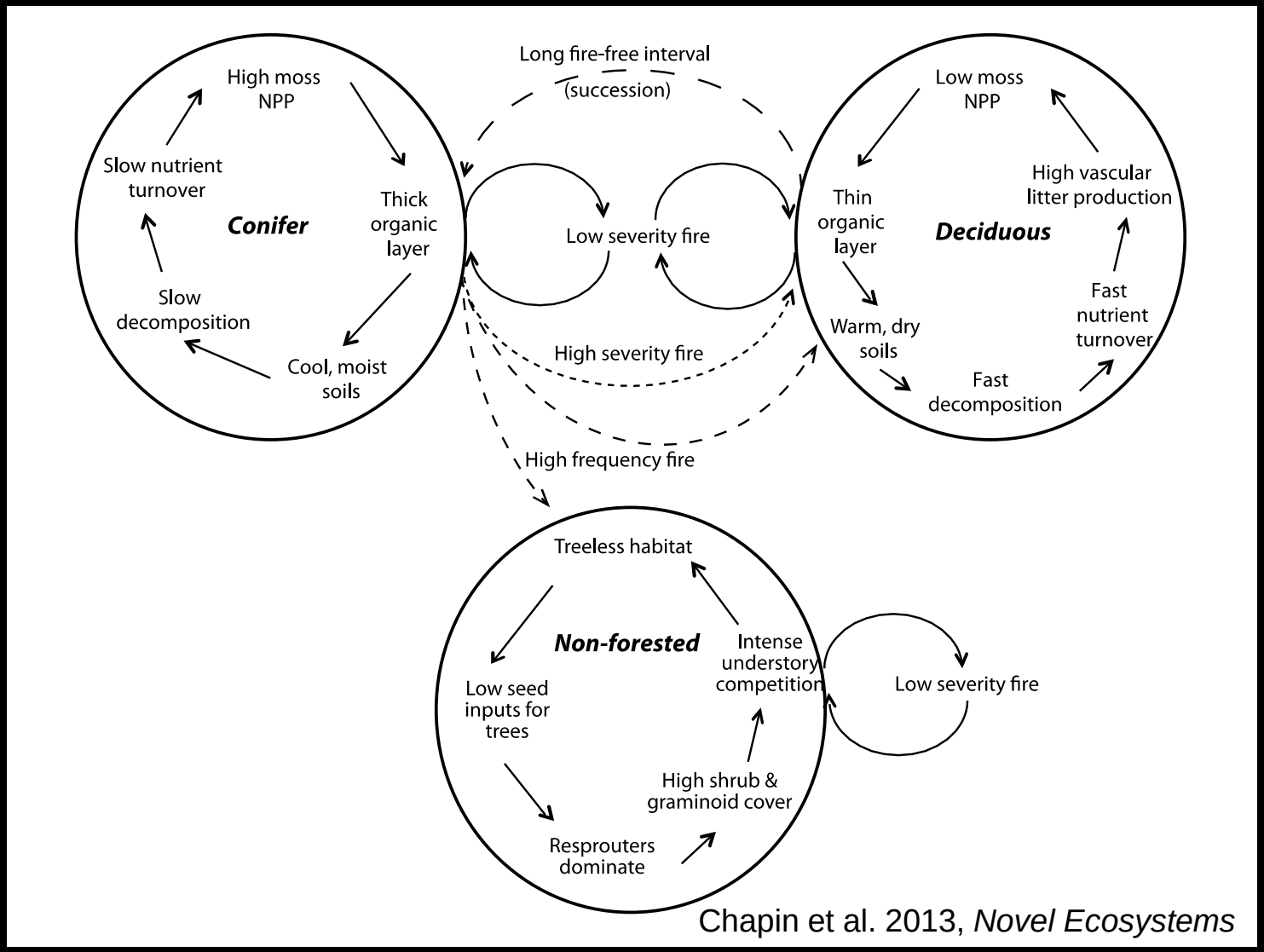
Fire interval effects

- 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



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

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