Once burned, twice shy: Repeat fires result in black spruce regeneration failure

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Once burned, twice shy: Repeat fires reduce seed availability and alter substrate constraints on *Picea mariana* regeneration

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Disturbance characteristics exert a strong control over ecosystem structure and function

Serotinous regeneration strategy

- Allows for pulses of regeneration (via large releases of seed) following a “trigger”

strong → **weak**

P. halepensis; Wikipedia

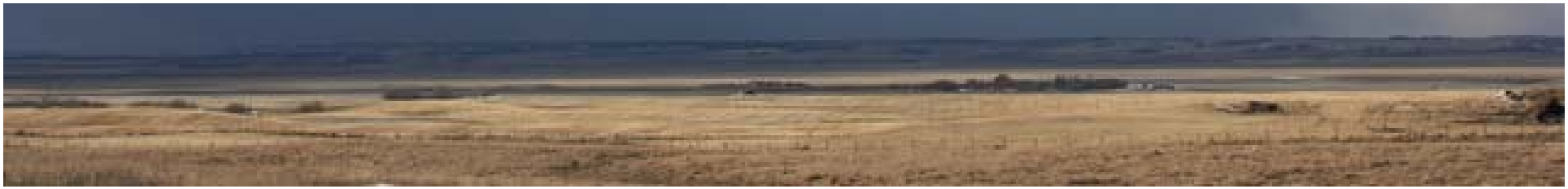
B. serrata; Wikipedia

Adaptations to disturbance

- Species' adaptations to disturbance generate resilience

- How? Historical legacies maintain vegetation through predictable disturbance cycles
  - Rhizomes, long-lived seed bank, serotiny

- Reinforced successional cycles

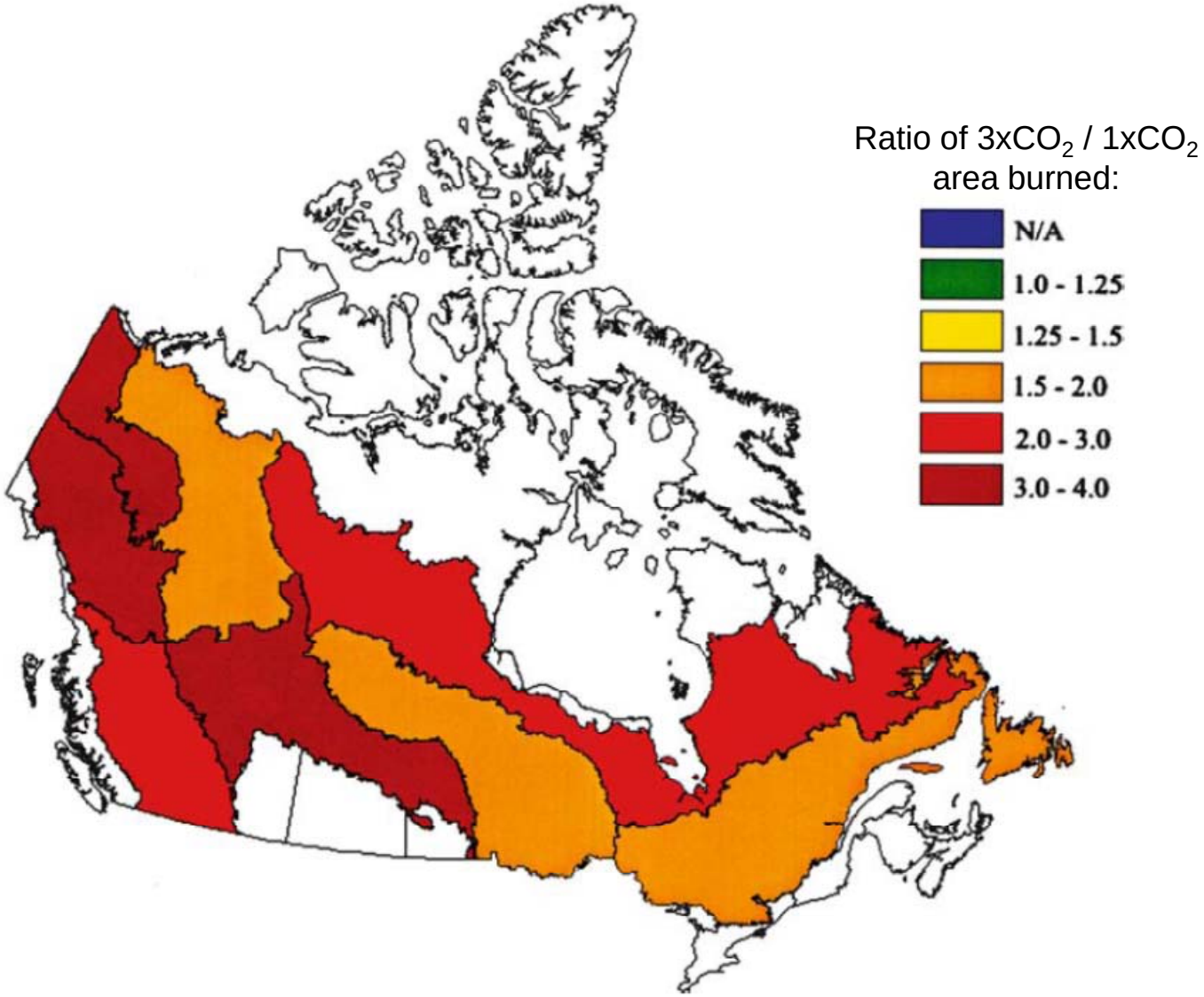


Climate change in sub-Arctic forest

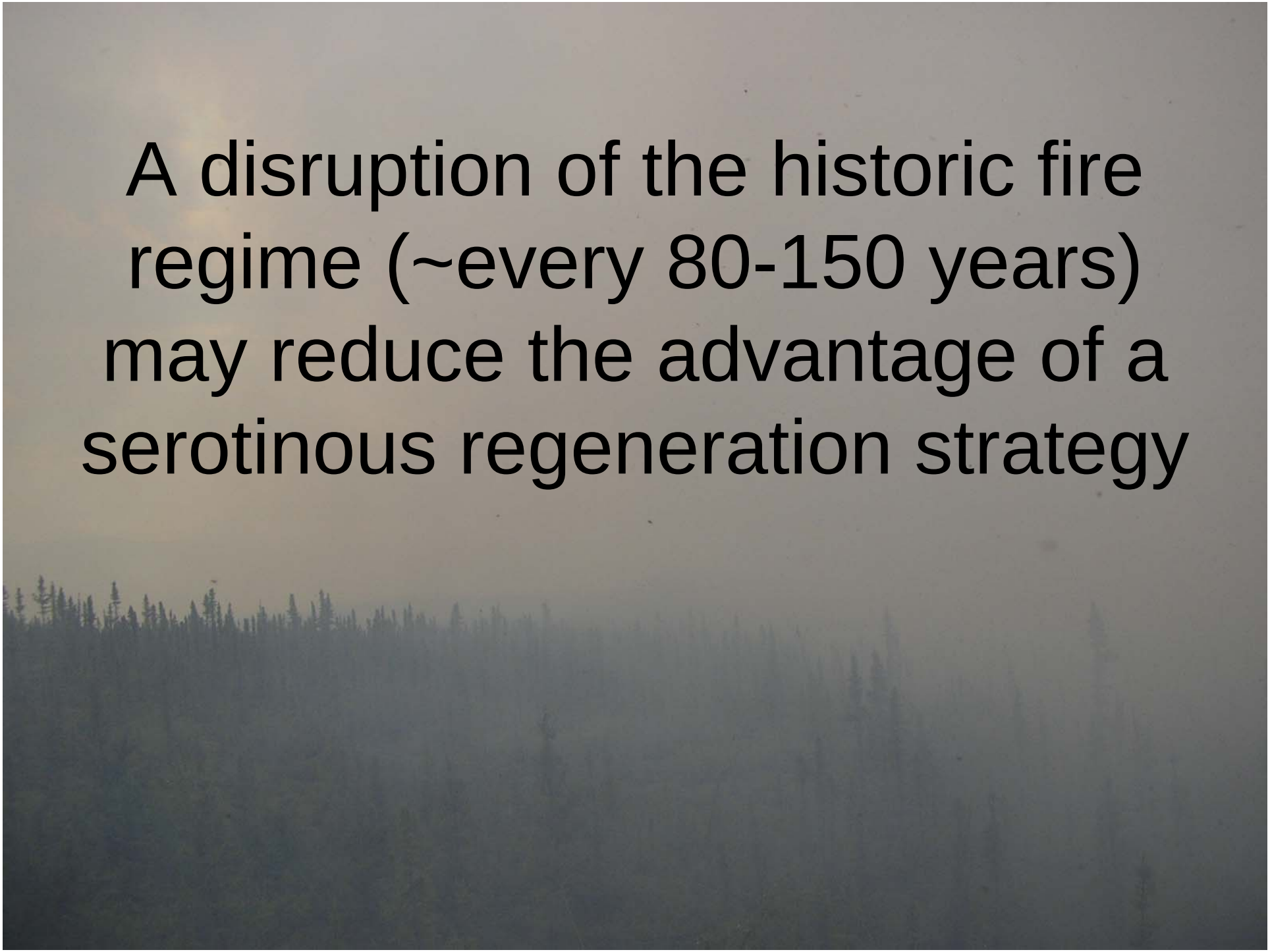
- We predict that species ranges will shift north as the climate warms
    - warmer T = warmer soils = happy trees
- We also predict that disturbance regimes will change as the climate warms

Species that have
adapted to regenerate with a
specific disturbance regime are
particularly sensitive to
disruptions to that regime

fire and global change



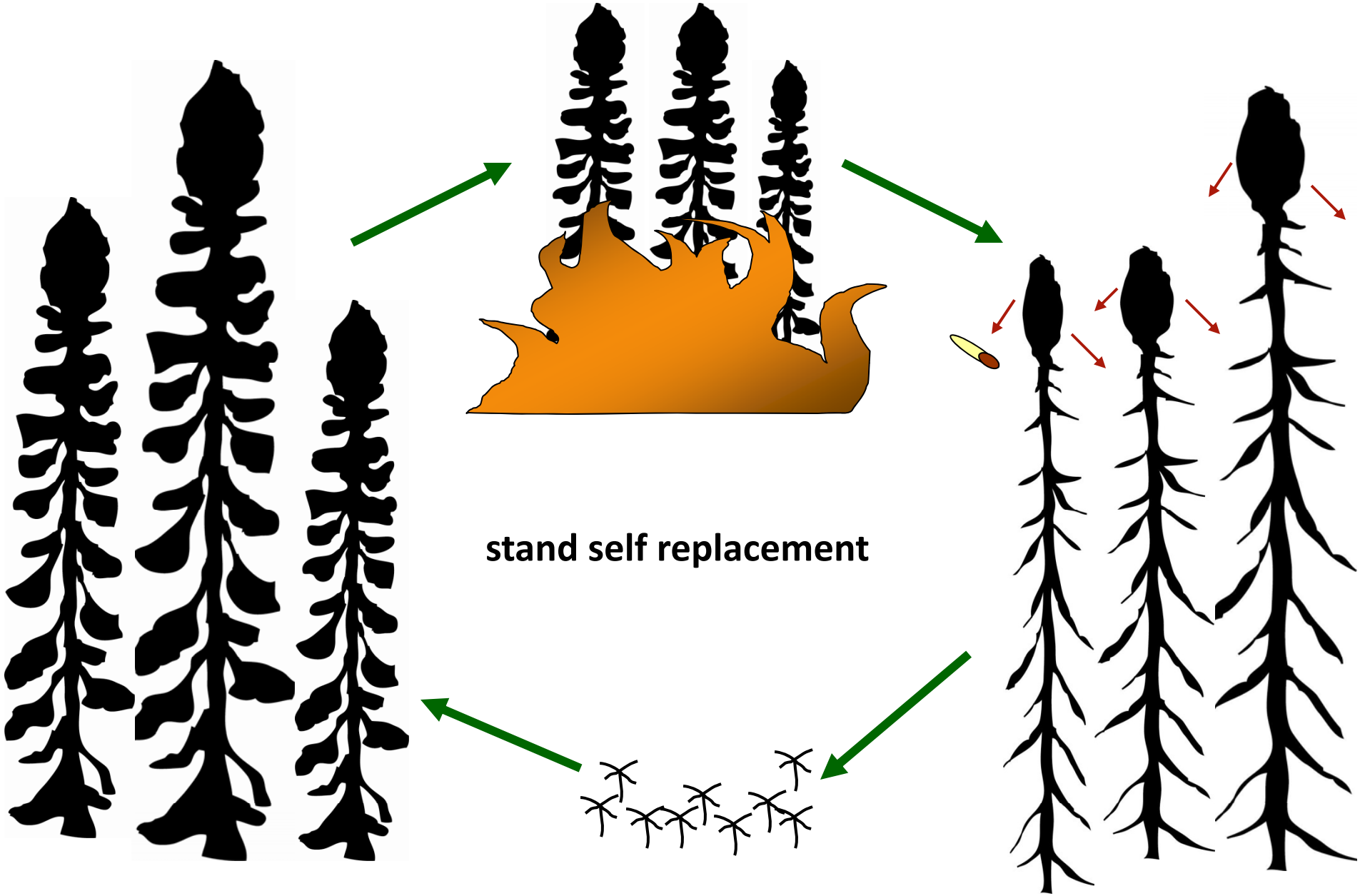
Flannigan *et al.* 2005

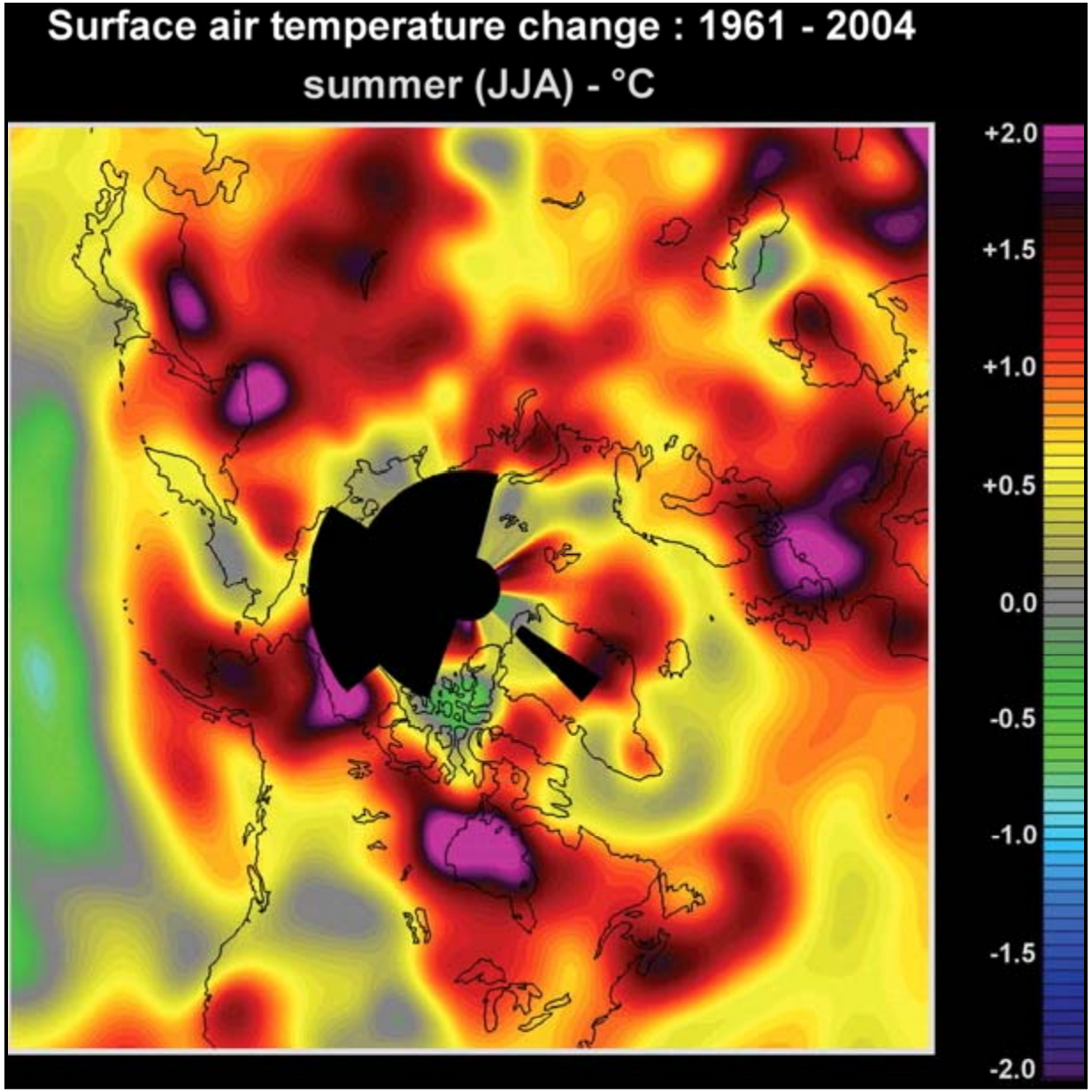

A disruption of the historic fire regime (~every 80-150 years) may reduce the advantage of a serotinous regeneration strategy

How can we predict ecosystem responses to historically unusual disturbances?

Case study: black spruce (*Picea mariana*)

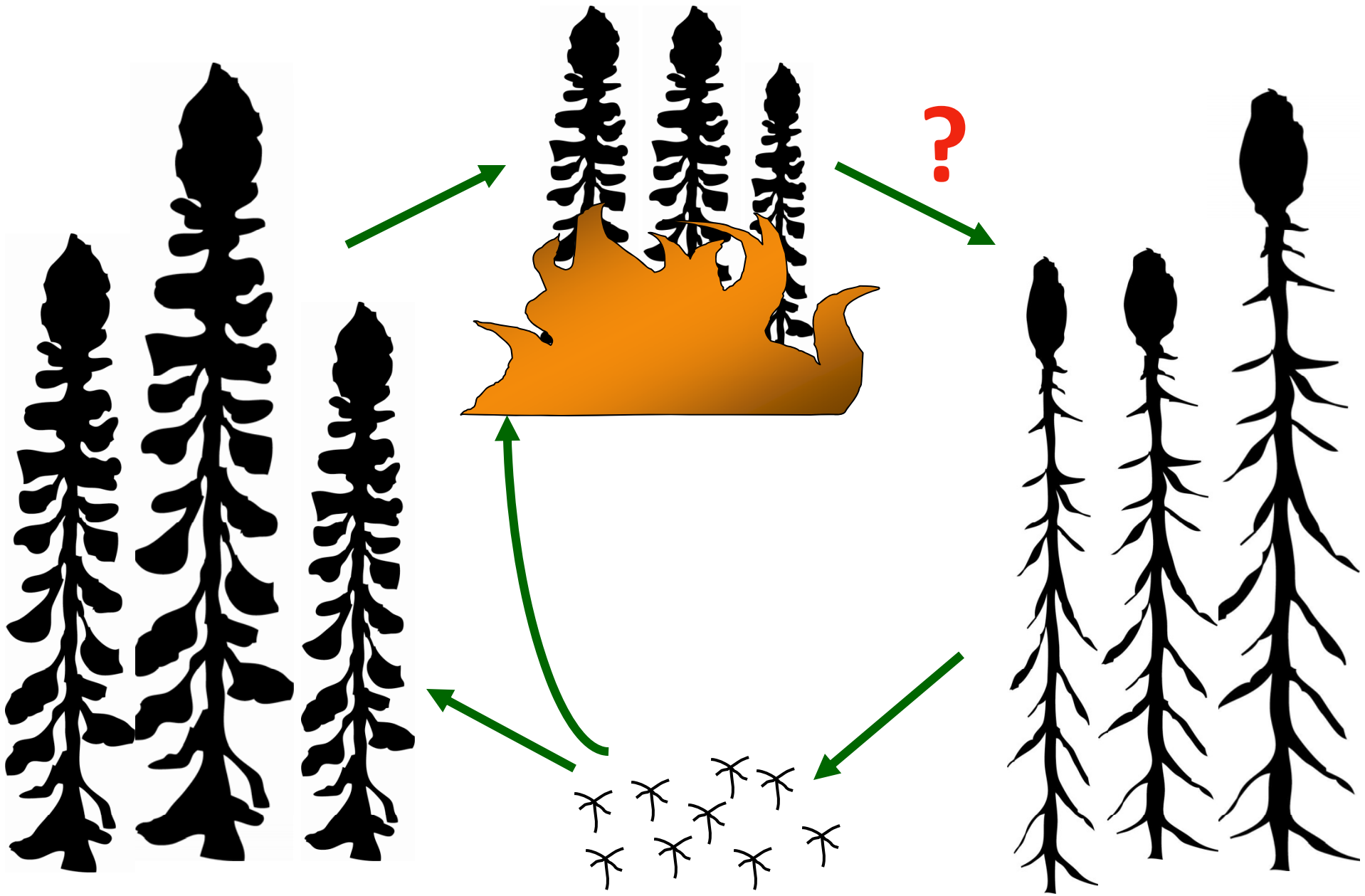
Fire initiates secondary succession in boreal forests of North America



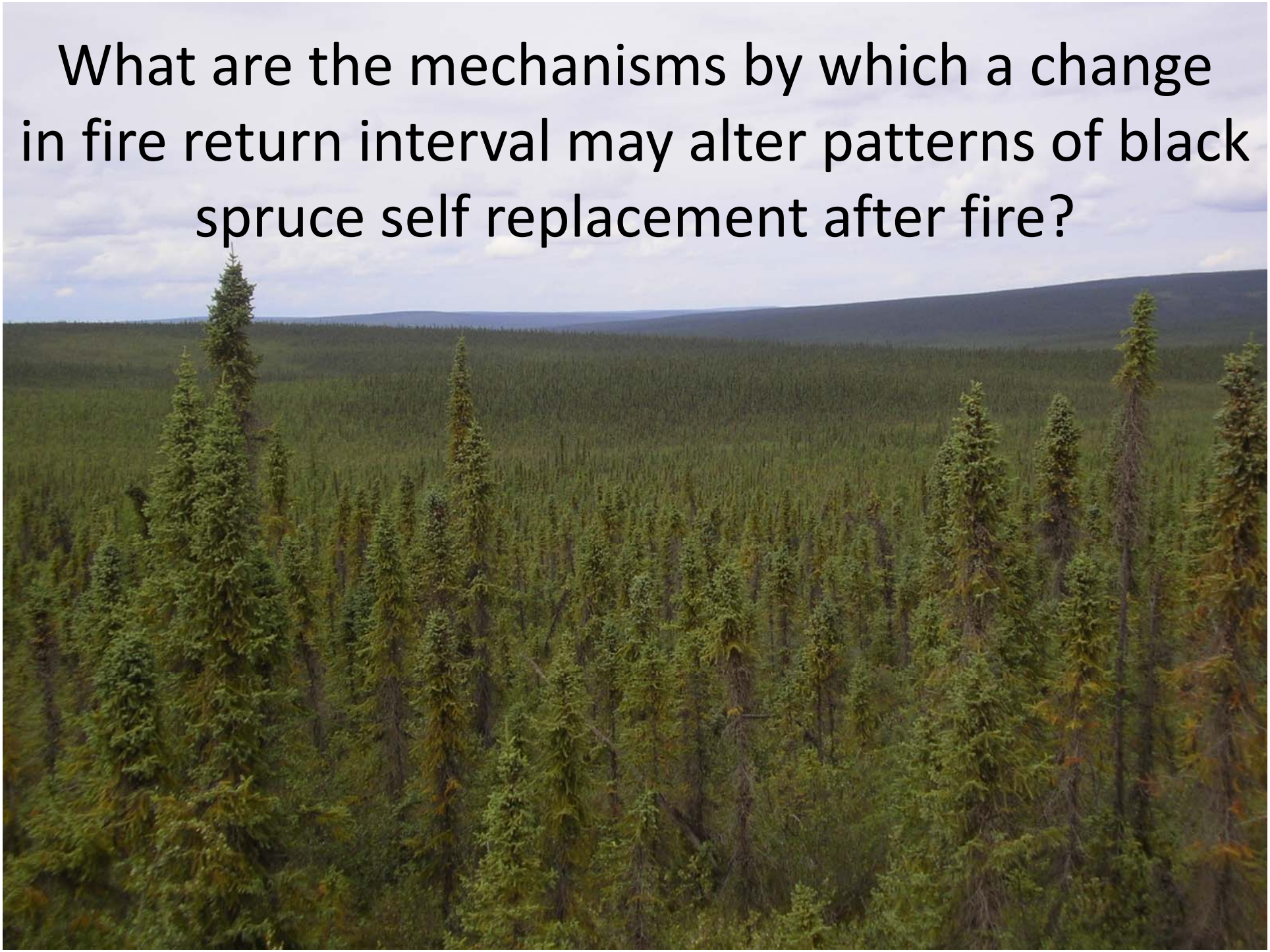


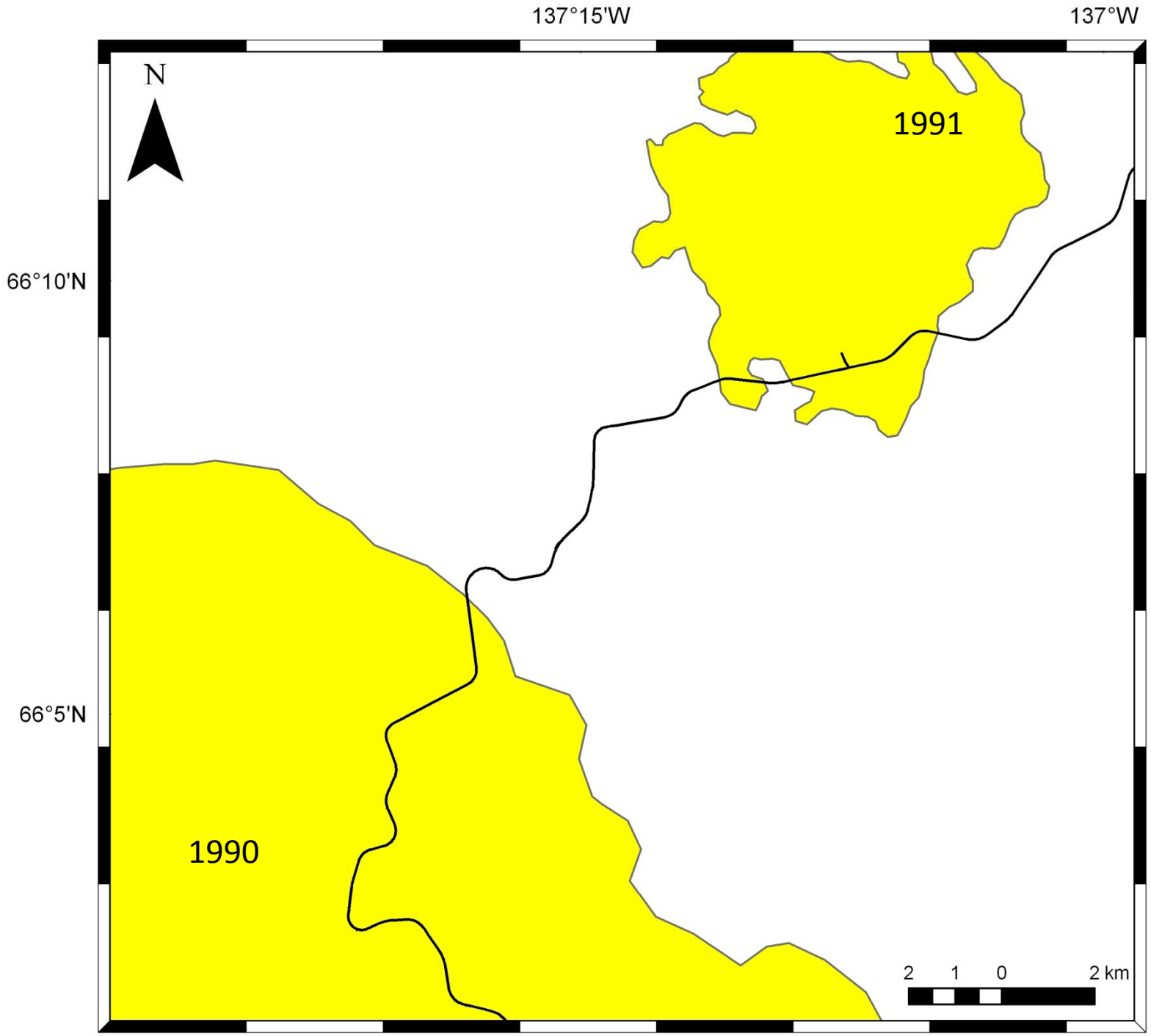
Chapin *et al.* 2005

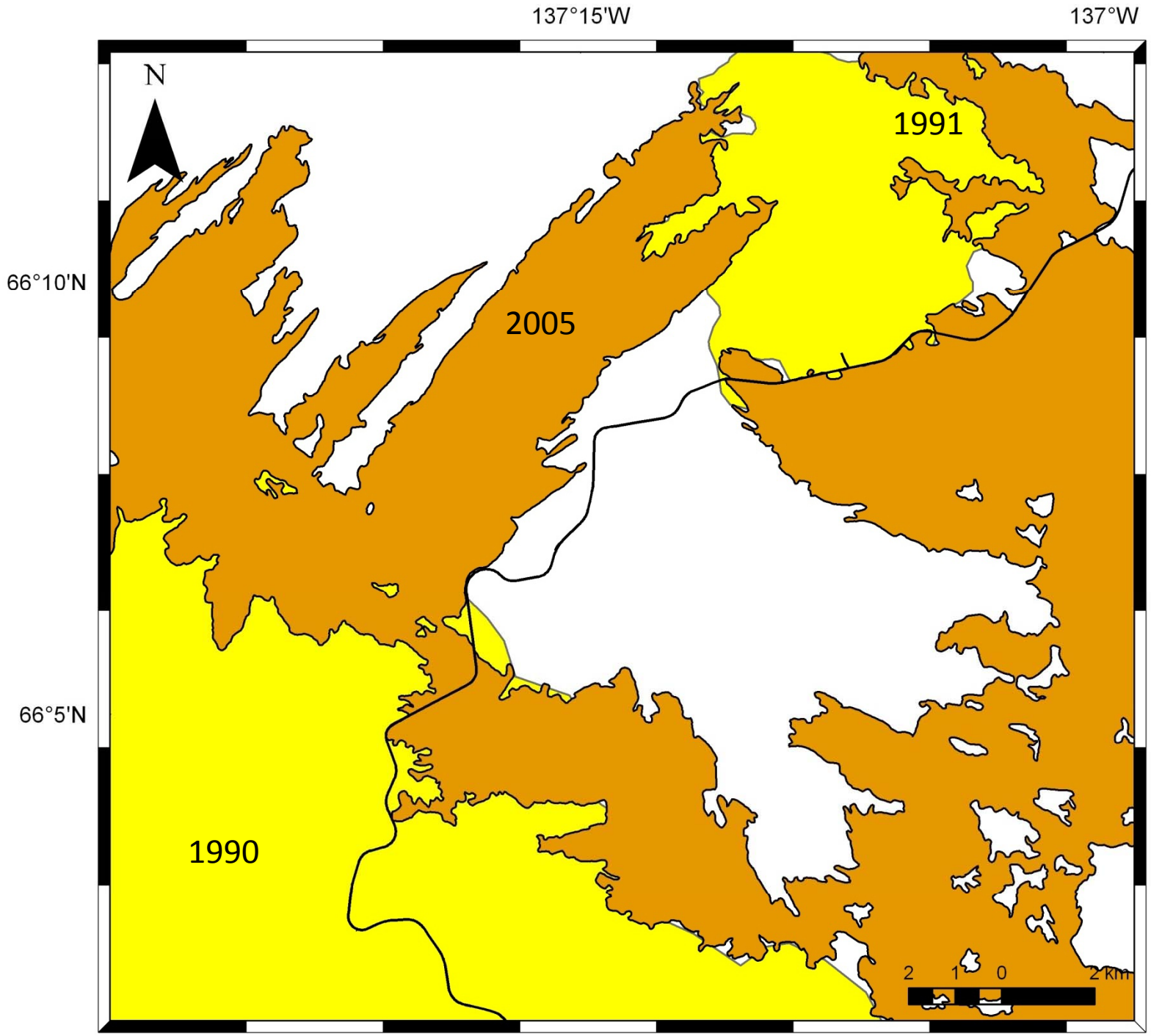
Photo credit: Yukon News

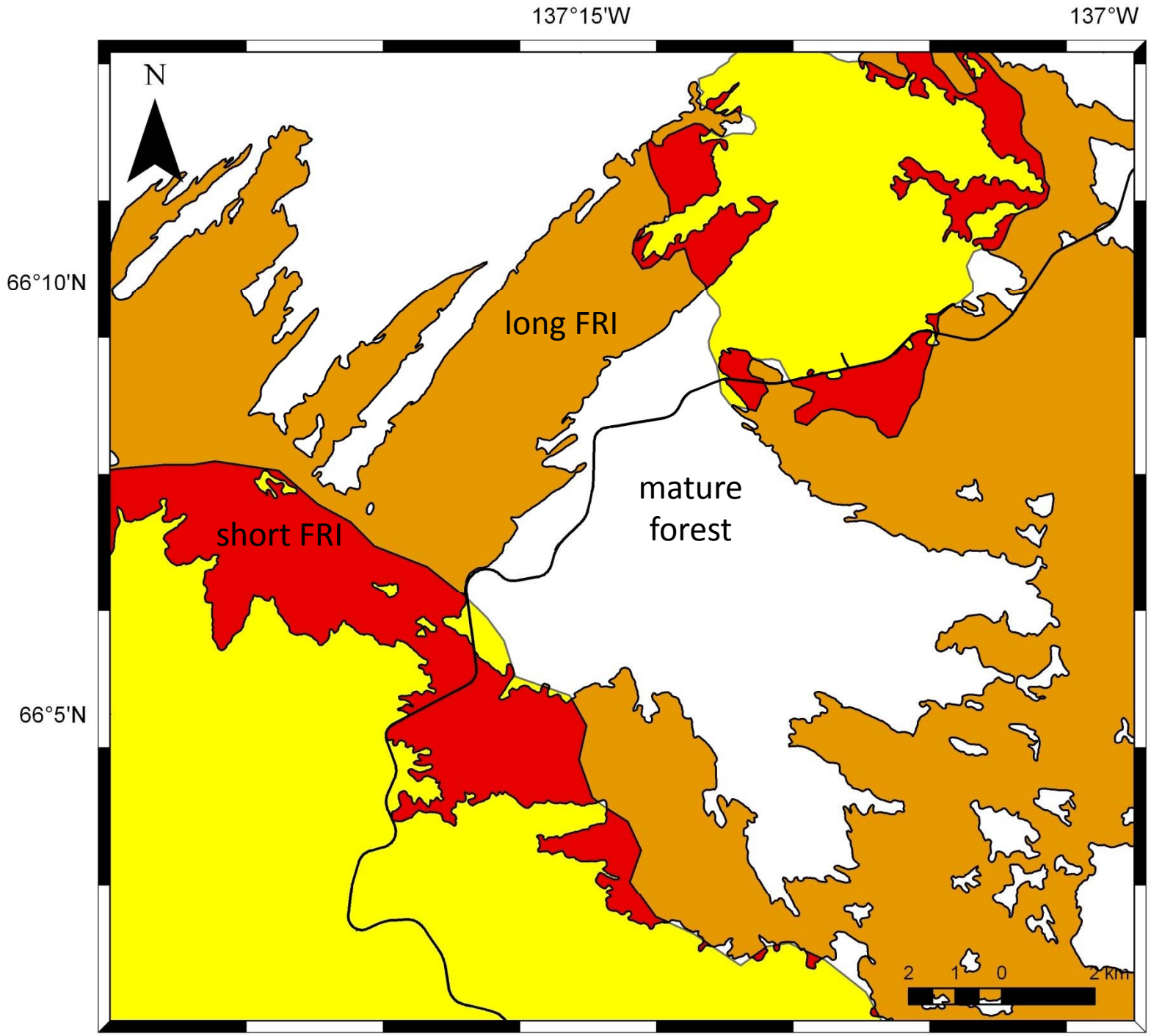


What are the mechanisms by which a change in fire return interval may alter patterns of black spruce self replacement after fire?




137°15'W
137°W
N
1991
66°10'N
66°5'N
1990
2 1 0 2 km


137°15'W
137°W
N
66°10'N
66°5'N
1991
2005
1990
2 1 0 2 km


137°15'W
137°W
N
66°10'N
66°5'N
long FRI
short FRI
mature
forest
2 1 0 2 km

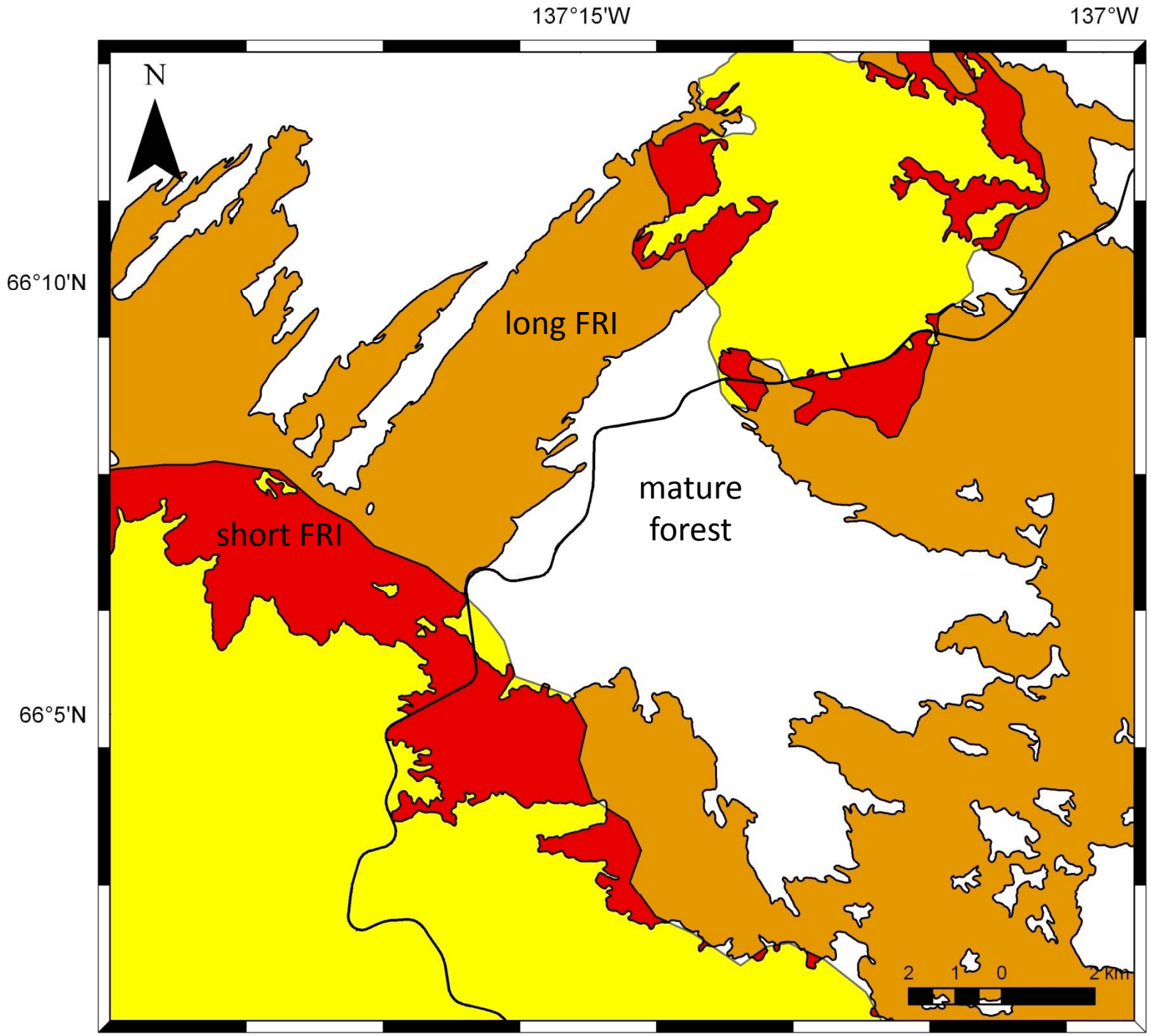
Fire characteristics

Table 1. Range of fire weather index and fire behaviour prediction component values for the study fires in the 2 weeks surrounding the date of ignition
(R Carr, P Englefield, unpubl. data)

Year of fire	Area burned (ha)	Fine fuel moisture code	Duff moisture code	Drought code	Initial spread index	Build up index	Fire weather index	Rate of spread (m min^{-1})	Surface fuel consumption (kg m^{-2})	Total fuel consumption (kg m^{-2})
1990	33 500	54.7–89.2	13.7–33.3	327–398	0.3–7.3	25–55	0–16	0.02–2.7	0.8–1.2	0.8–1.4
1991	4800	52.1–84.2	20.2–29.7	277–360	0.3–3.0	34–49	0–9	0.03–0.9	1.0–1.3	1.0–1.2
2005	69 000	49.4–88.2	19.6–40.5	328–384	0.4–8.2	35–64	1–21	0.09–10.1	1.7–2.6	1.8–3.2

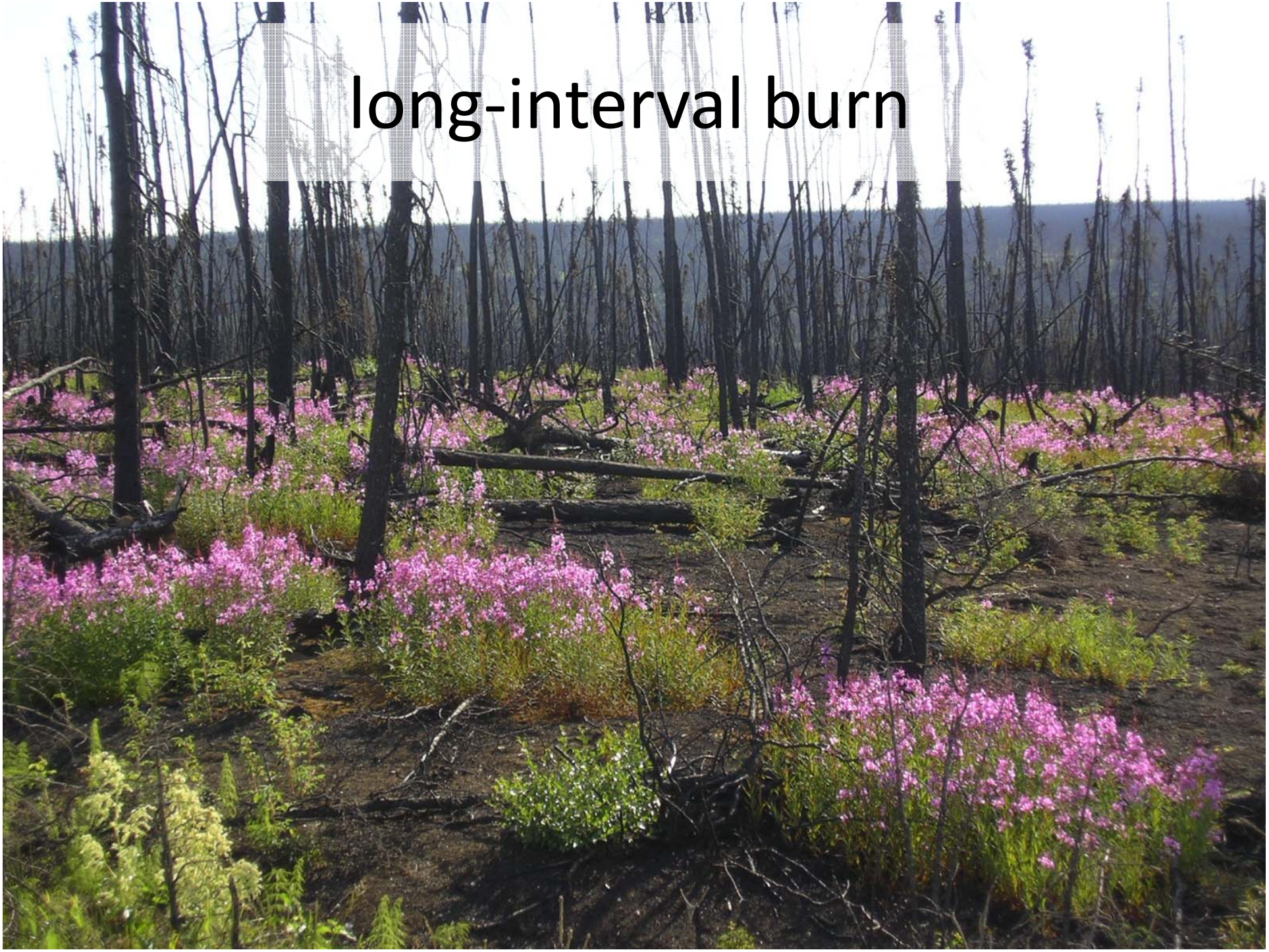
More volatile conditions, but...

Brown and Johnstone 2011 IJWF


137°15'W
137°W
N
66°10'N
66°5'N
long FRI
short FRI
mature
forest
2 1 0 2 km

mature forest

long-interval burn



short-interval burn

- continuous permafrost
- hummock-hollow

- soil moisture
- thick organic horizon

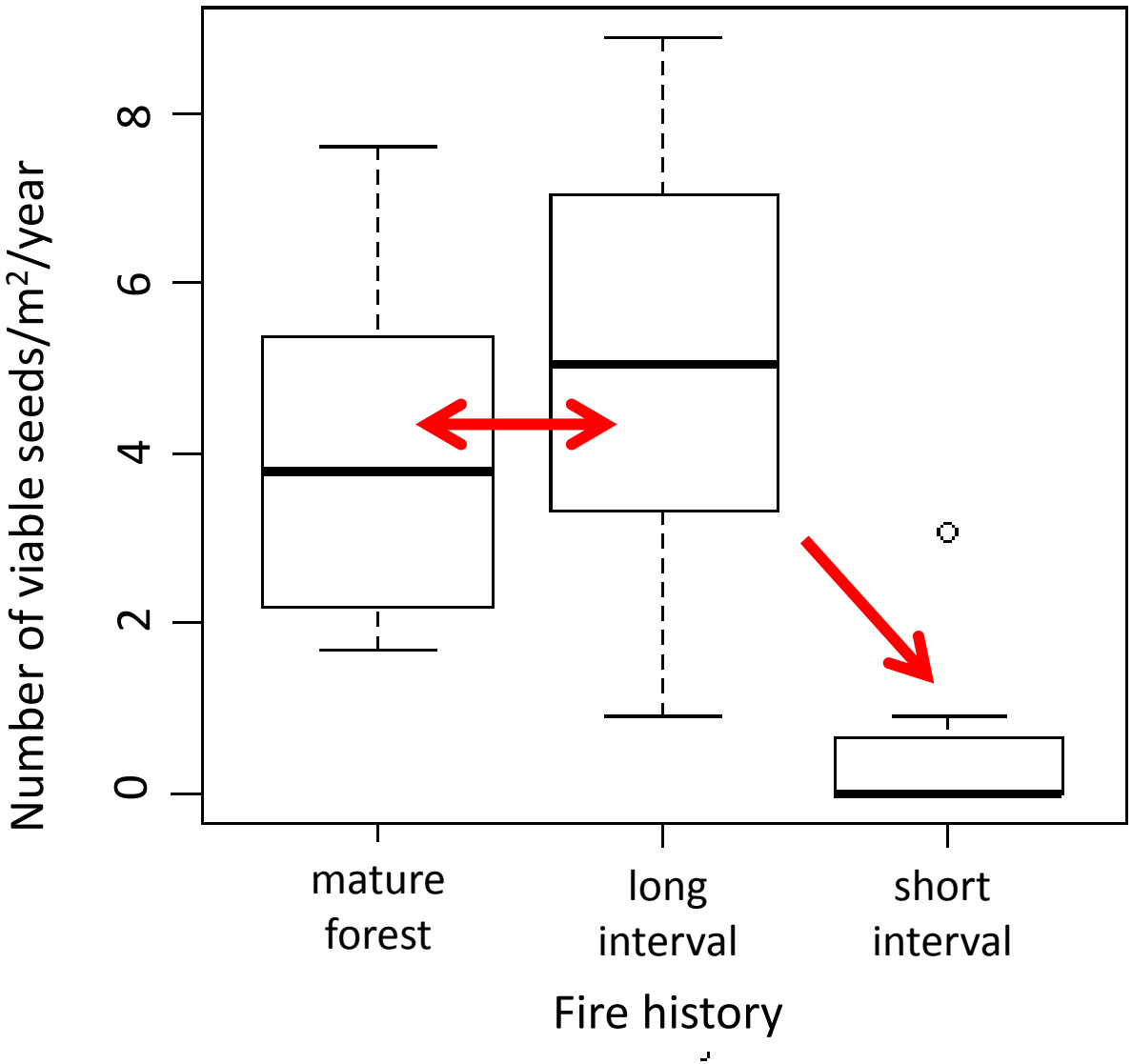
Post-fire colonization: is seed available?

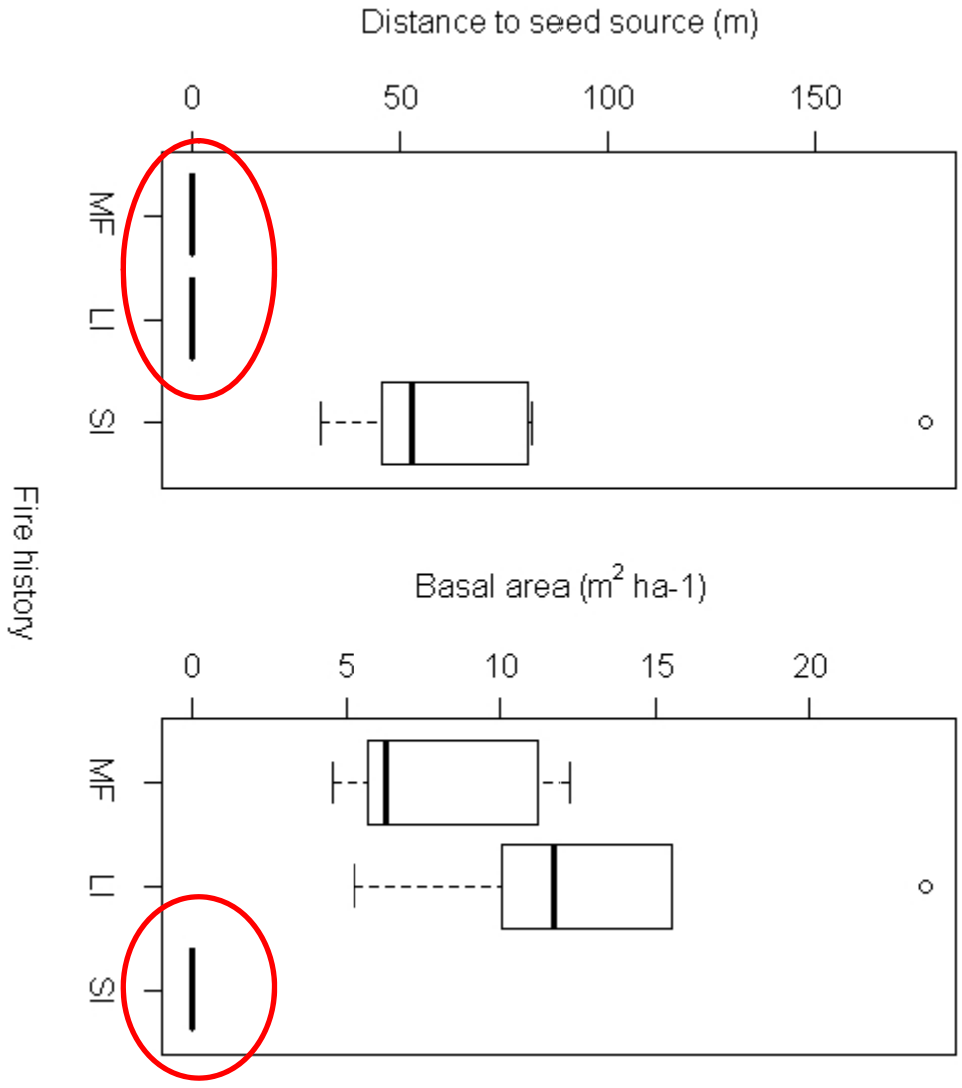
mature forest

long-interval burn

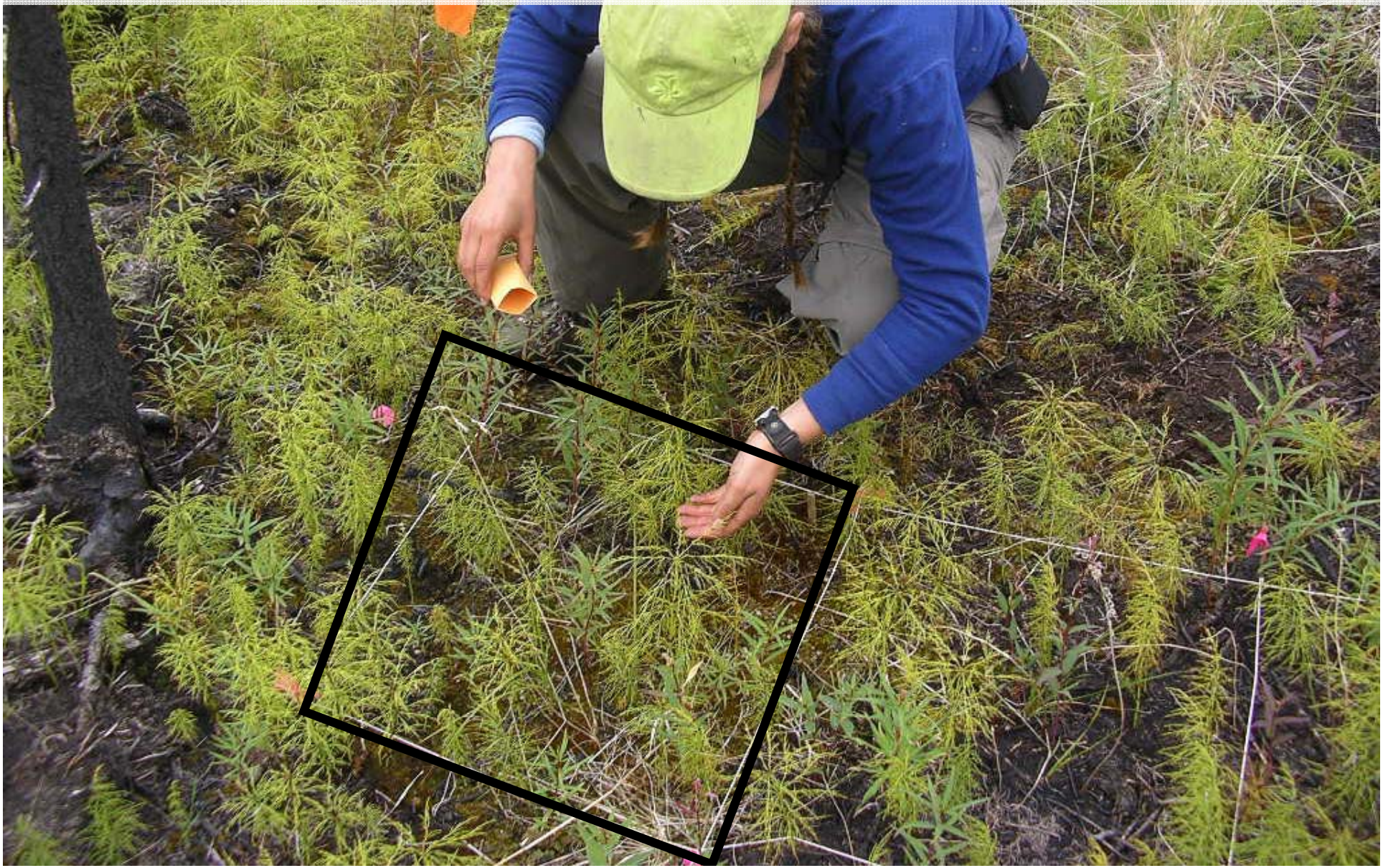
short-interval burn

Seed availability

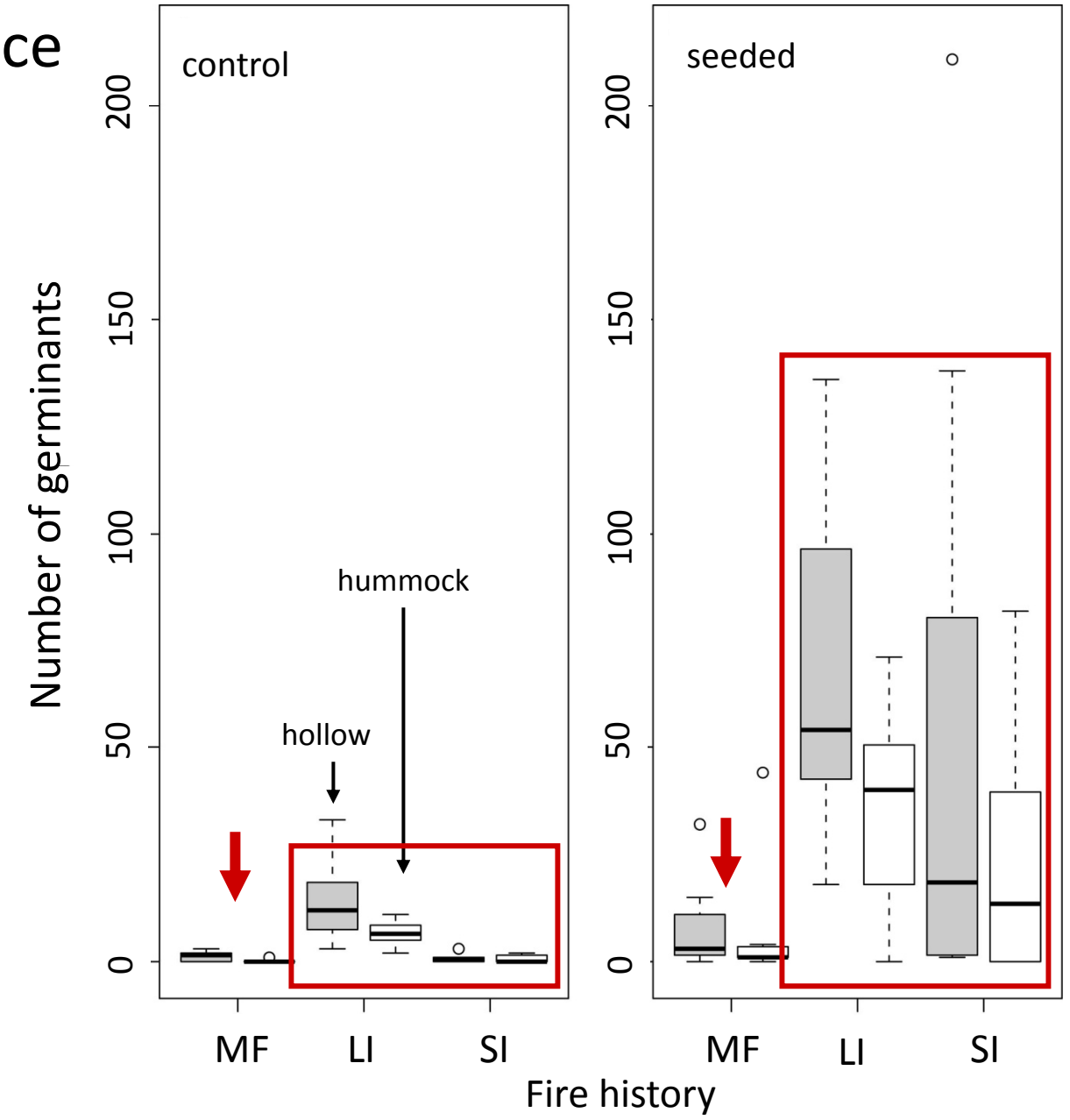


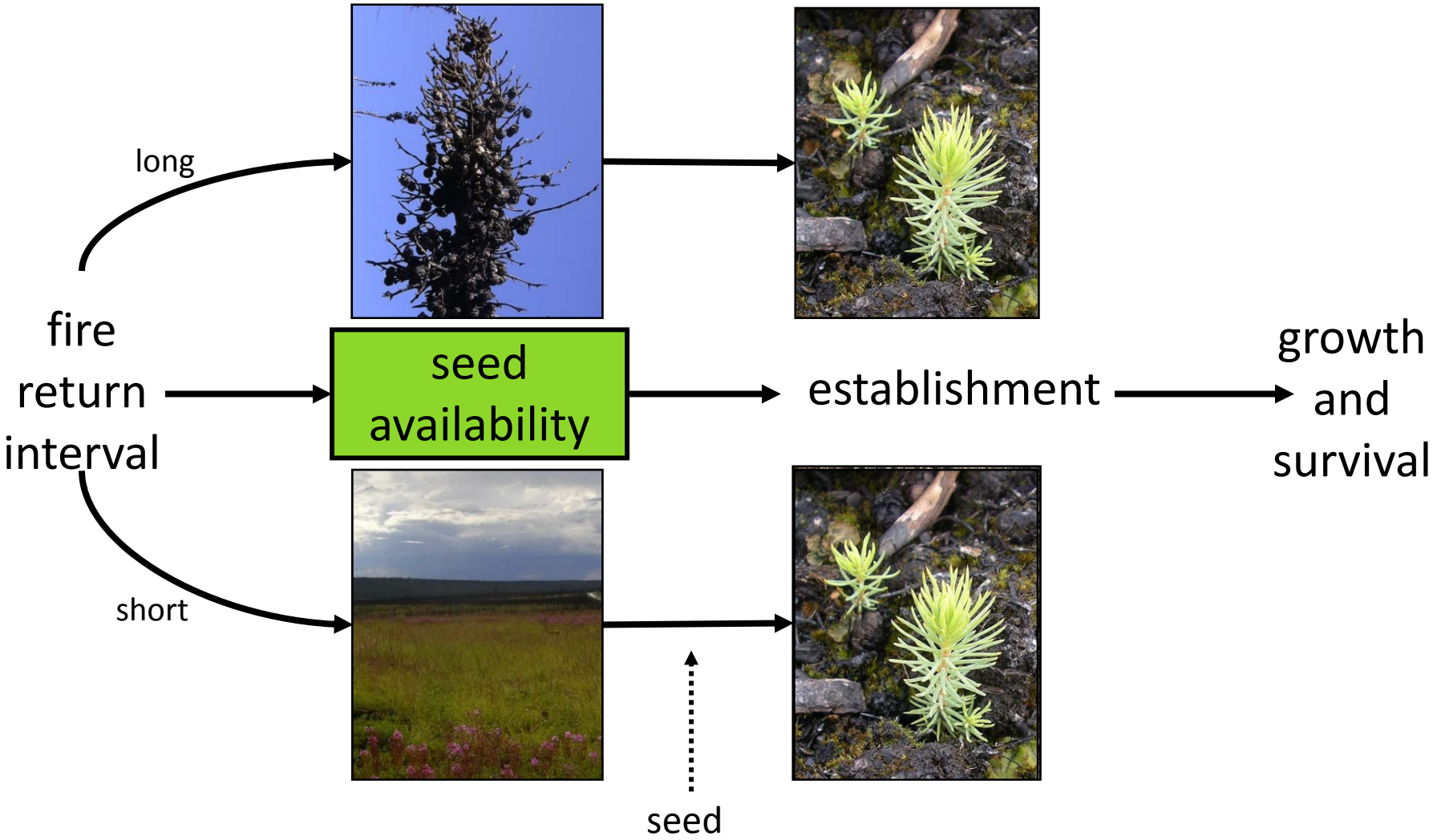

Distance to seed source (m)
0
50
100
150
MF
LI
SI
Fire history
Basal area (m2 ha-1)
0
5
10
15
20
MF
LI
SI

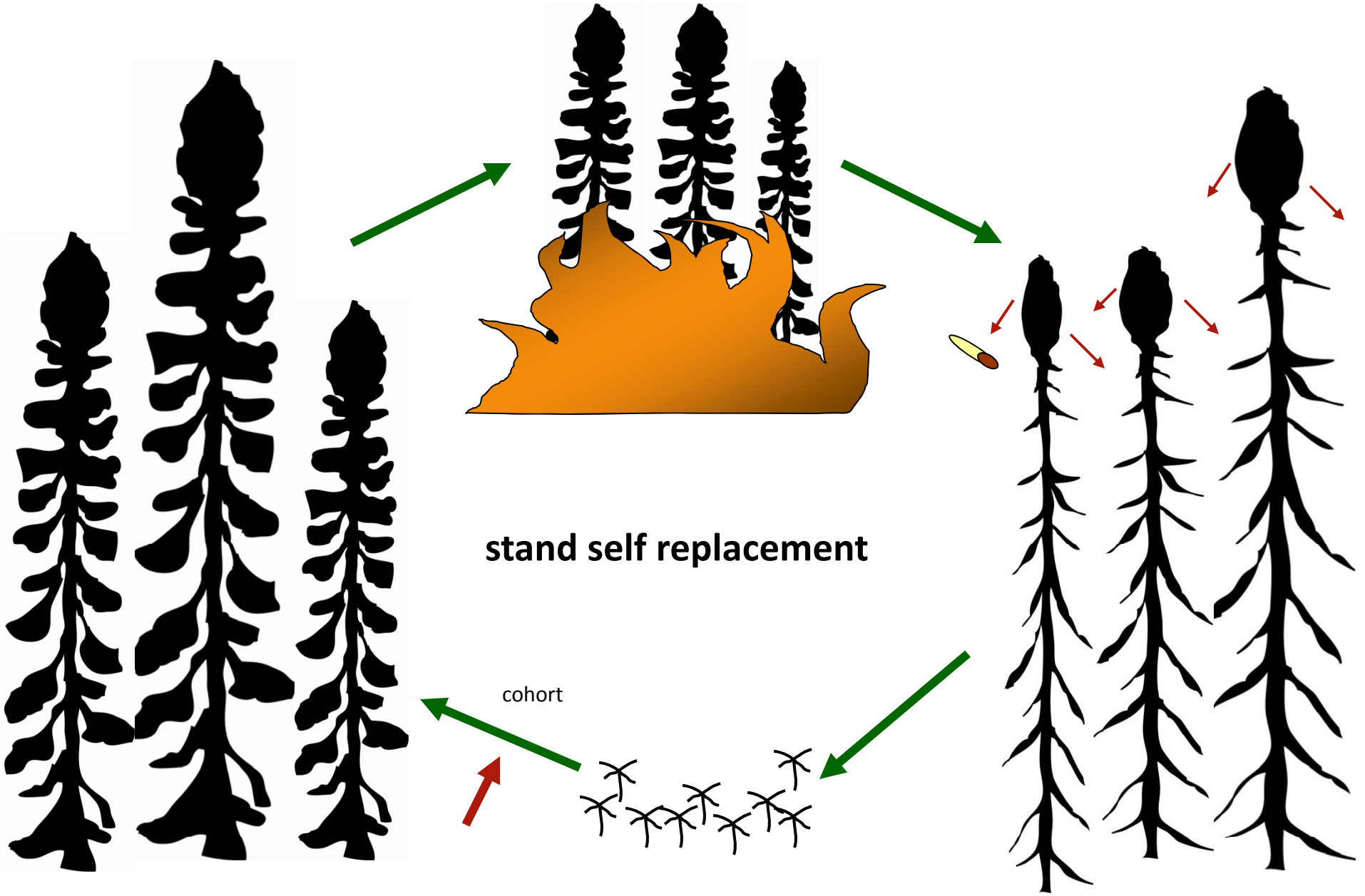
Establishment: if seed is available, will it germinate and survive?



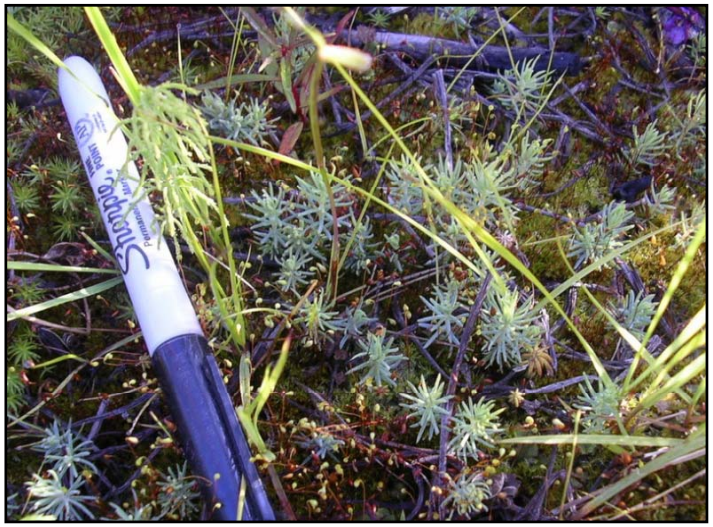
Seedling emergence




long
fire
return
interval
short
seed
availability
establishment
growth
and
survival
seed


stand self replacement
cohort

FINE



observed

expected

Number of seedlings

50
45
40
35
30
25
20
15
10
5
0

hum hol hum hol hum hol hum hol hum hol hum hol hum hol

charred moss

colonizer moss

litter

Polytricum

Marchantia

mineral soil

lichen

Substrate class

A failure in two parts

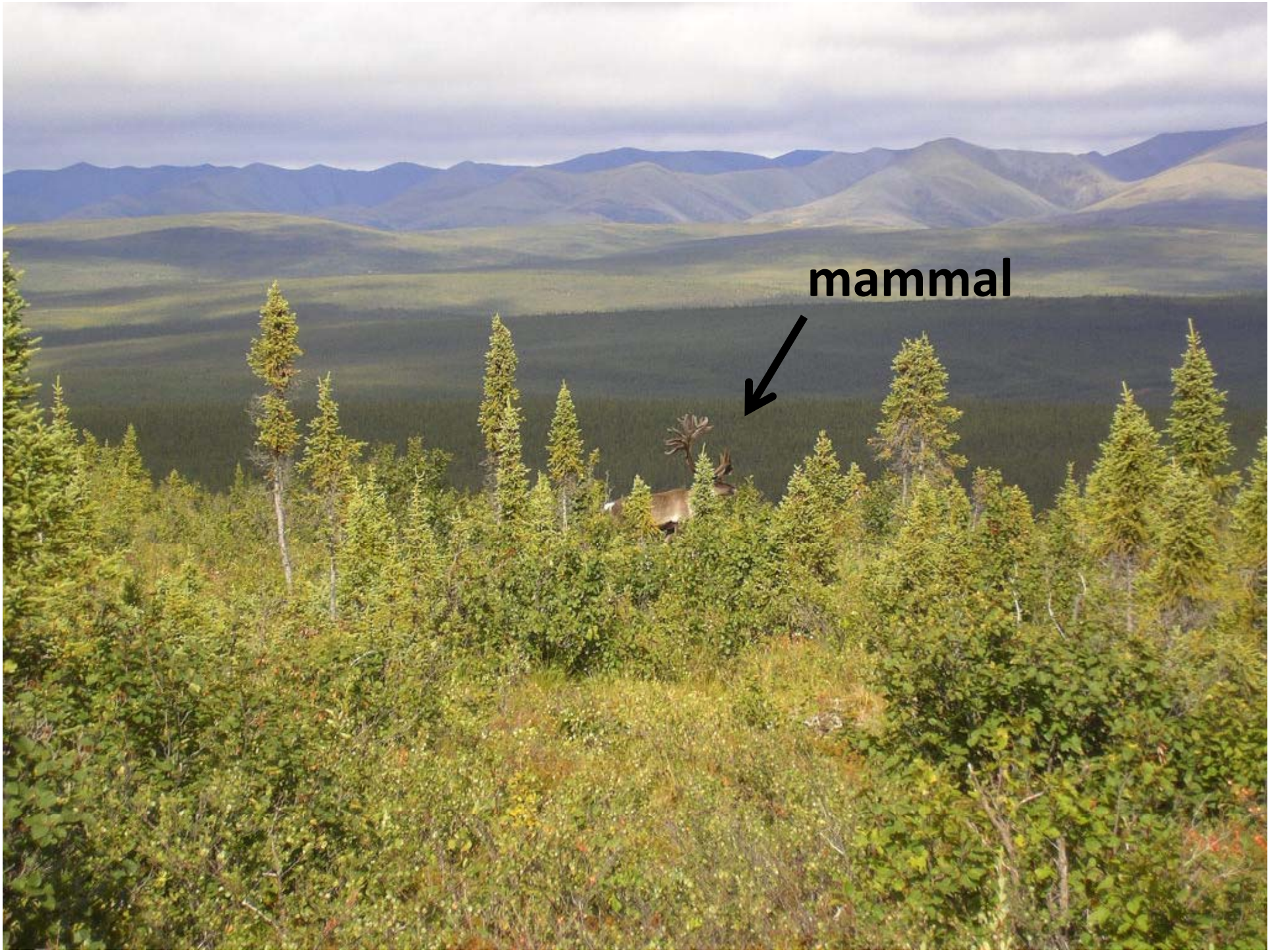
These constraints on seedling recruitment are key ecological mechanisms driving fire and vegetation interactions in these forests

1. constraints on seed germination in unburned stands means that cycles of seedling recruitment and stand renewal are primarily restricted to short periods of establishment on seed beds exposed after fire

2. historical factors that reduce seed stores and post-fire seed availability can dramatically alter patterns of post-fire stand recruitment and dominance

→ long-term disruption

Implications


mammal

biomass = carbon storage

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International Journal of Wildland Fire **2011**, *20*, 829–837 www.publish.csiro.au/journals

How does increased fire frequency affect carbon loss from fire? A case study in the northern boreal forest

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[B]Corresponding author. Email: carissa.brown@usask.ca

Abstract. Fire frequency is expected to increase due to climate warming in many areas, particularly the boreal forests. An increase in fire frequency may have important effects on the global carbon cycle by decreasing the size of boreal carbon stores. Our objective was to quantify and compare the amount of carbon consumed during and the amount of carbon remaining following fire in black spruce (*Picea mariana* (Mill.) BSP) forests burned after long *v.* short intervals. We hypothesised that stands with a shortened fire return interval would have a higher carbon consumption than those experiencing a historically typical fire return interval. Using field measurements of forest canopy, soil organic horizons and adventitious roots, we reconstructed pre-fire stand conditions to estimate the biomass lost in each fire and the effects on post-fire residual carbon stores. We found evidence of a higher loss of carbon following two fire events that recurred after a short interval, resulting in a much greater total reduction in carbon relative to pre-fire or mature stand conditions. Consequently, carbon storage across disturbance intervals was dramatically reduced following short-interval burns. Recovery of these stores would require a subsequent lengthening of the fire cycle, which appears unlikely under future climate scenarios.

Additional keywords: adventitious root method, biomass, fire return interval, soil organic layer, Yukon.

Variation in postfire organic layer thickness in a black spruce forest complex in interior Alaska and its effects on soil temperature and moisture[1]

Eric S. Kasischke and Jill F. Johnstone

Can. J. For. Res. **35**: 2164–2177 (2005)

Topographic influences on wildfire consumption of soil organic carbon in interior Alaska: Implications for black carbon accumulation

E. S. Kane,[1] E. S. Kasischke,[2] D. W. Valentine,[3] M. R. Turetsky,[1] and A. D. McGuire[4]

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, G03017

Quantifying fire severity, carbon, and nitrogen emissions in Alaska's boreal forest

Leslie A. Boby,[1,2] Edward A. G. Schuur,[2,5] Michelle C. Mack,[2] David Verbyla,[3] and Jill F. Johnstone

Ecological Applications, 20(6), 2010, pp. 1633–1647

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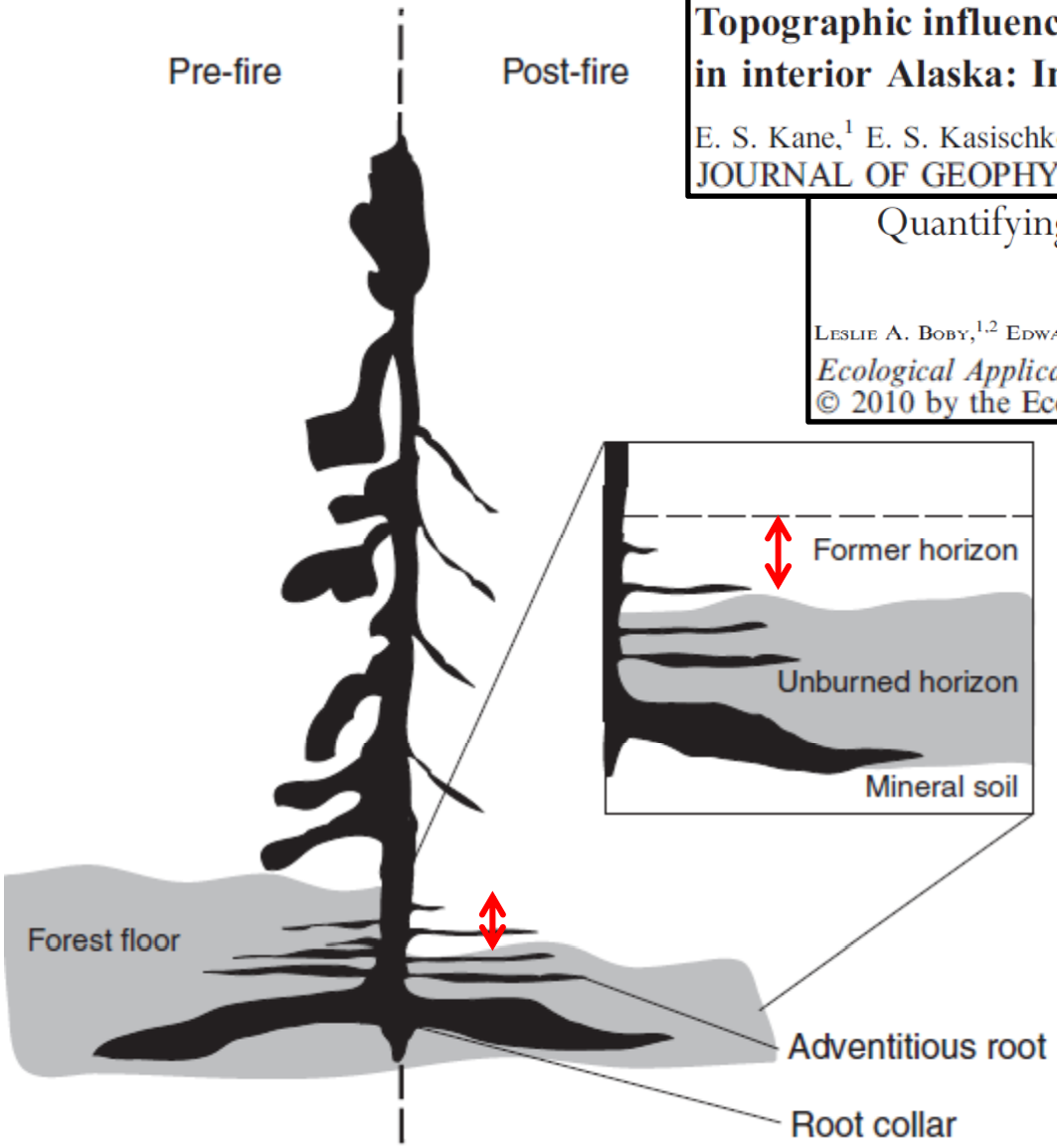
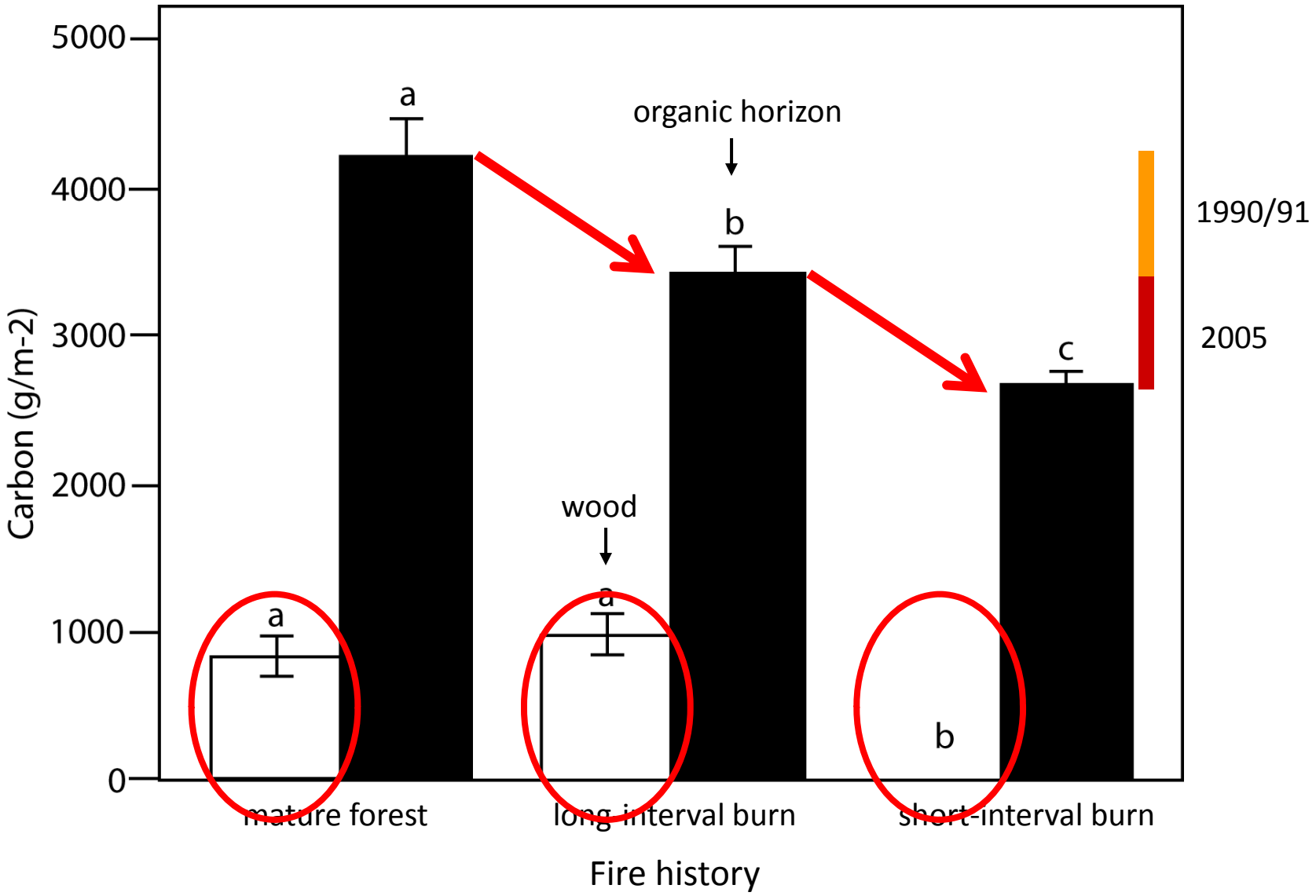
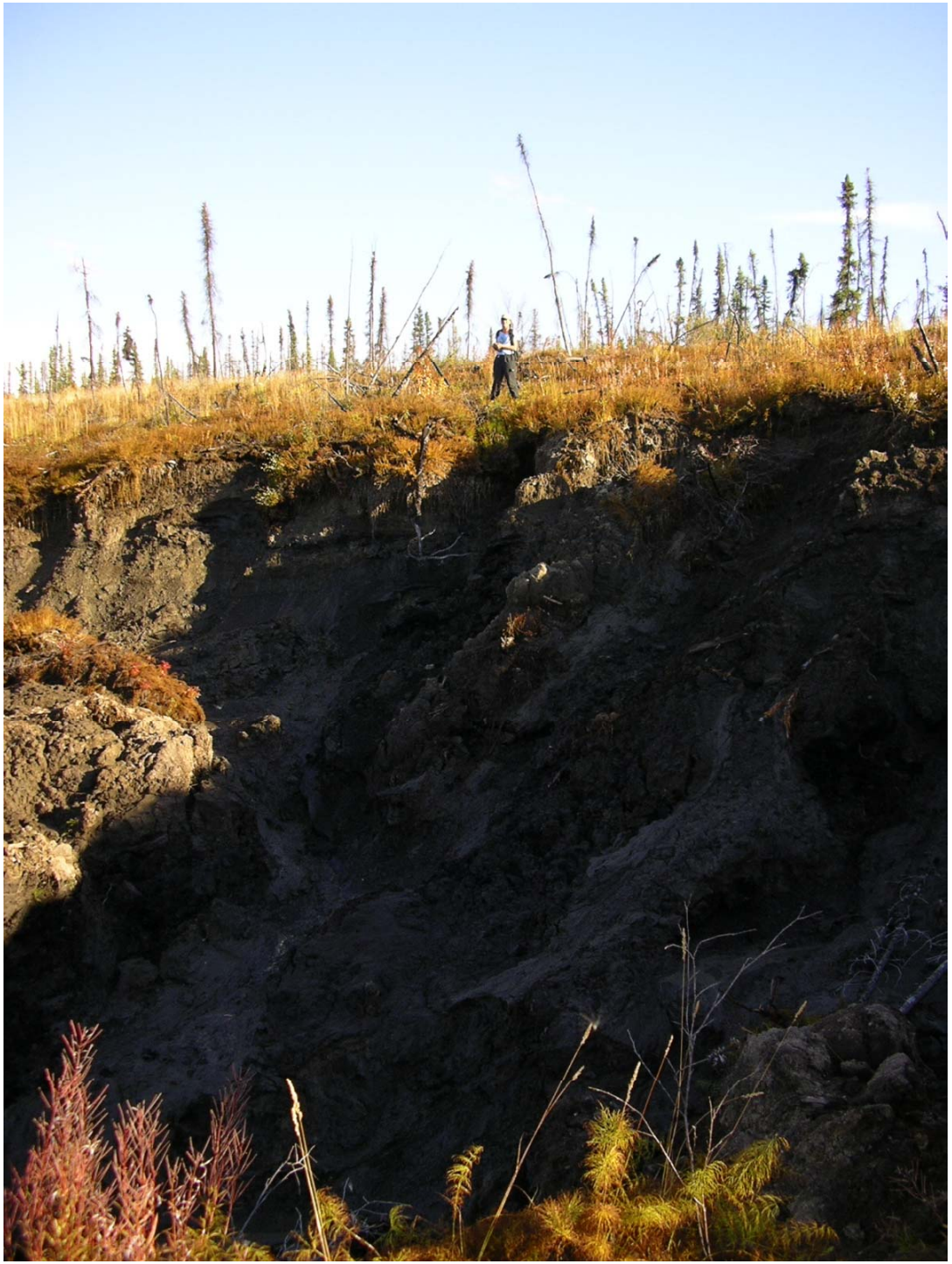



5000
4000
3000
2000
1000
0
Carbon (g/m-2)
a
organic horizon
b
wood
a
a
c
b
1990/91
2005
mature forest
long-interval burn
short-interval burn
Fire history

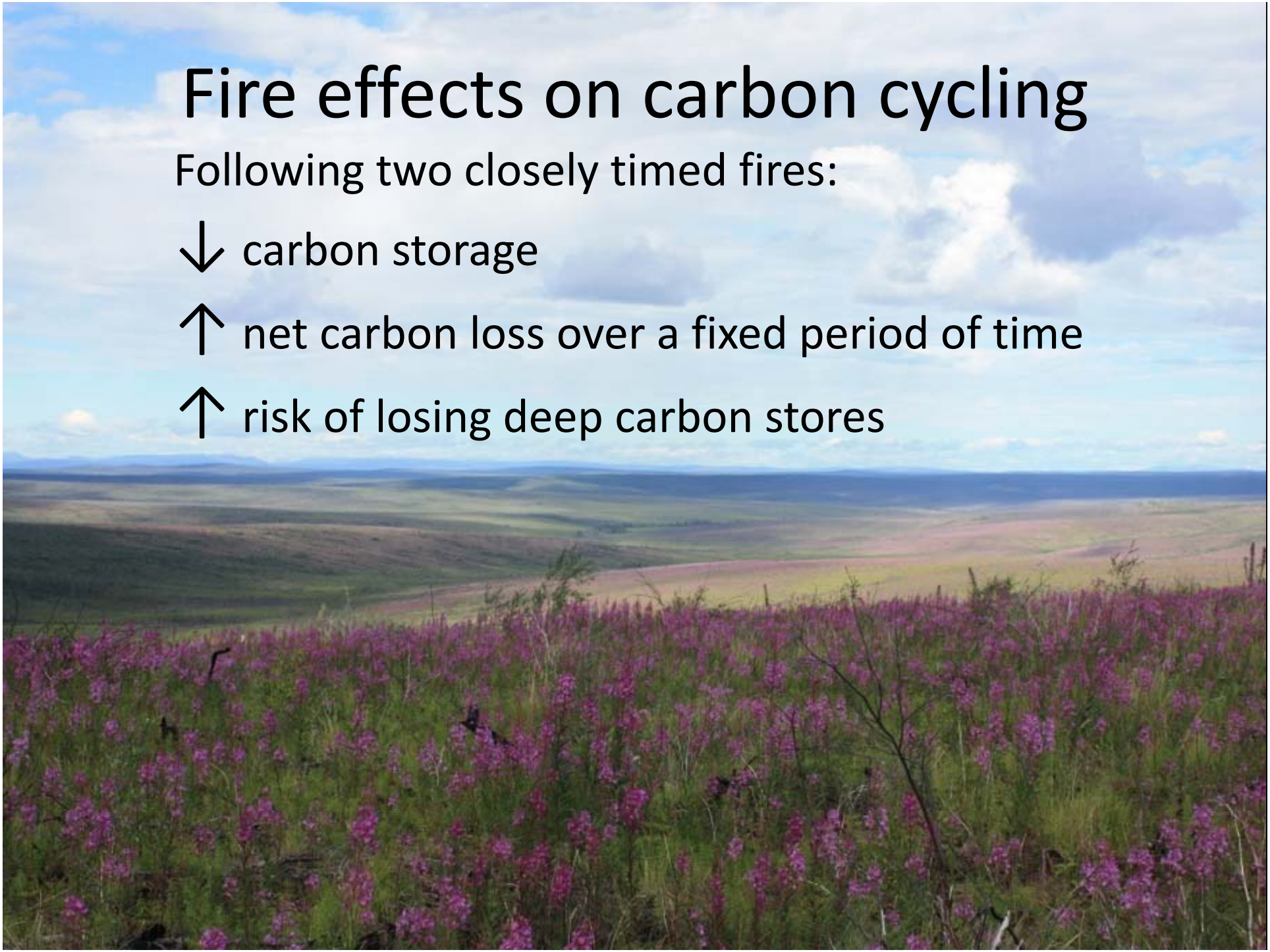
forest floor insulates permafrost



permafrost zone is estimated to store 1672 petagrams of carbon

1 petagram = 1 billion tonnes

~double the amount of carbon stored in the atmosphere



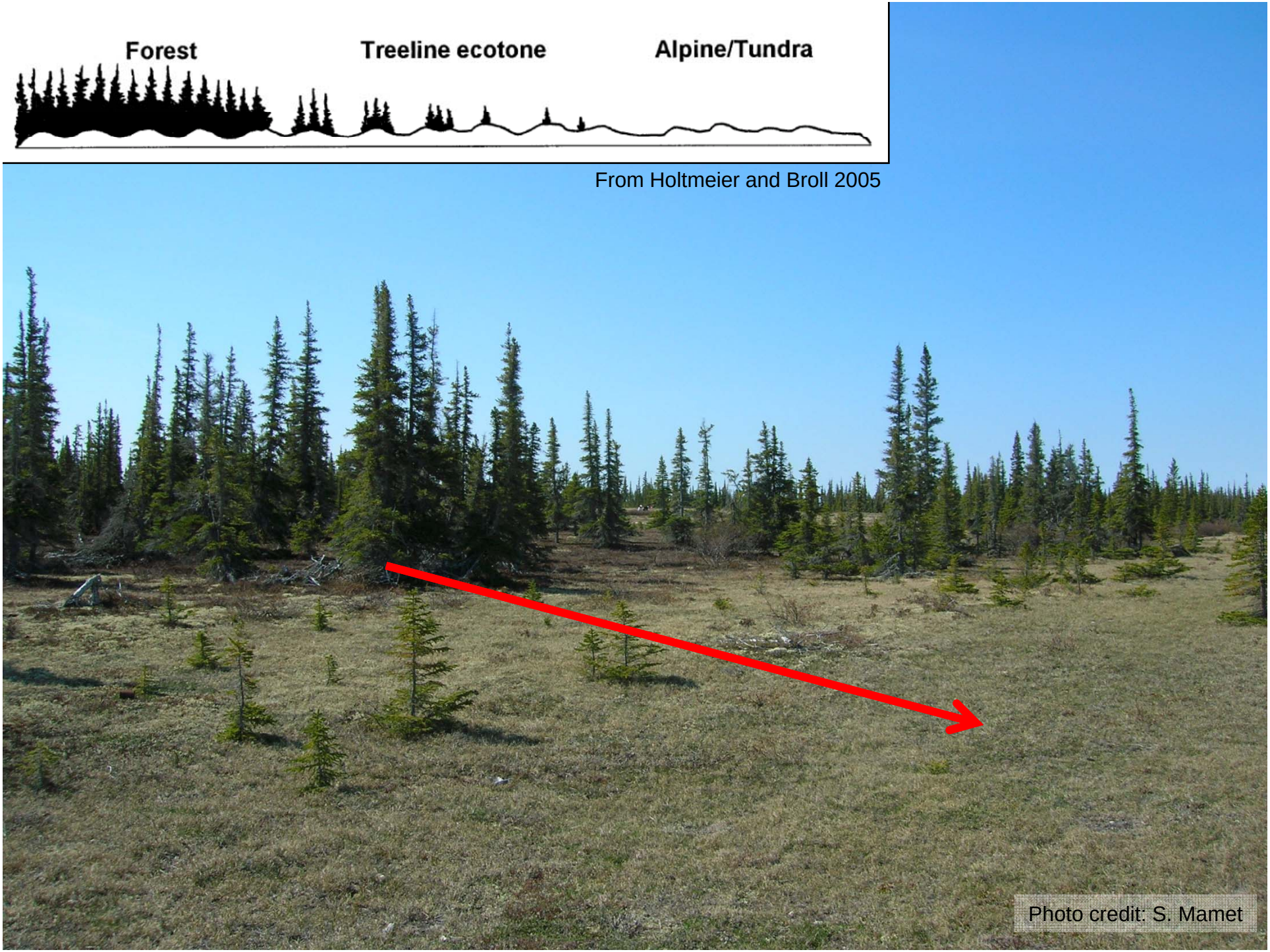
Fire effects on carbon cycling

Following two closely timed fires:

↓ carbon storage

↑ net carbon loss over a fixed period of time

↑ risk of losing deep carbon stores


Forest
Treeline ecotone
Alpine/Tundra
From Holtmeier and Broll 2005
Photo credit: S. Mamet

The dynamics of adjacent northern forests may act as important controls over the potential for expansion or retraction of the local treeline.

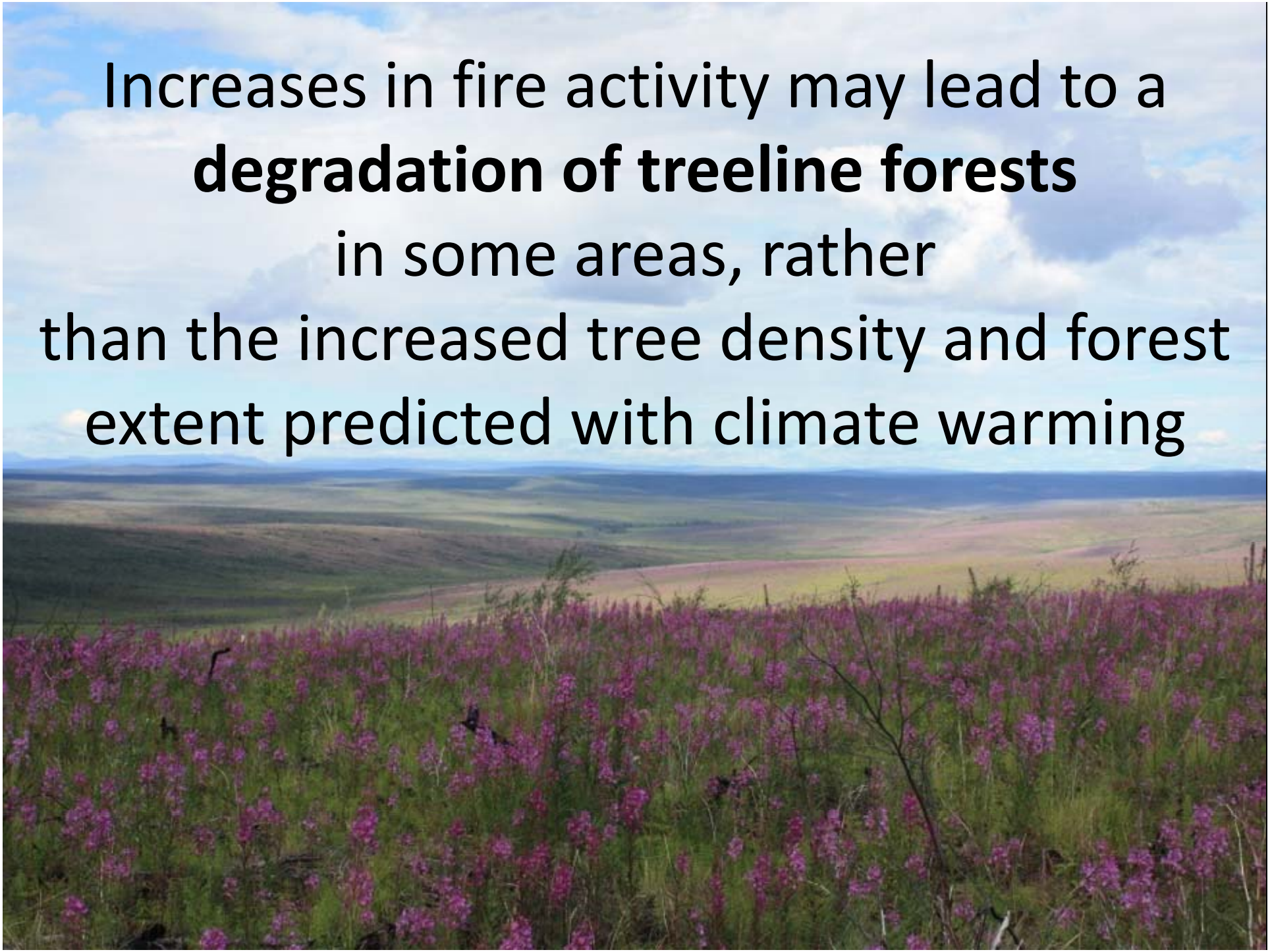
Climate change in sub-Arctic forest

- We predict that species ranges will shift north as the climate warms
    - warmer T = warmer soils = happy trees
- We also predict that disturbance regimes will change as the climate warms

Climate change in sub-Arctic forest

Empirical evidence of rapid vegetation change at the northern margin of the boreal forest due to a shortened fire return interval

This may have long-term consequences for tree range expansion into tundra ecosystems


Increases in fire activity may lead to a
degradation of treeline forests
in some areas, rather
than the increased tree density and forest
extent predicted with climate warming

Northern Plant Ecology Lab
University of Saskatchewan

PPS Arctic

International Polar Year 2007-2008

NSERC
CRSNG

Arctic Institute of North America 1945

The W. Garfield Weston Foundation

University of Saskatchewan

Friends of Dempster Country

Int. Assoc. of Wildland Fire

Association of Canadian Universities for Northern Studies
Association universitaire canadienne d'études nordiques

Yukon

PRTA
Altogether a better approach

Northern Research Institute

Northern Scientific Training Program

Vuntut Gwitchin Government

Affaires indiennes et du Nord Canada
Indian and Northern Affairs Canada

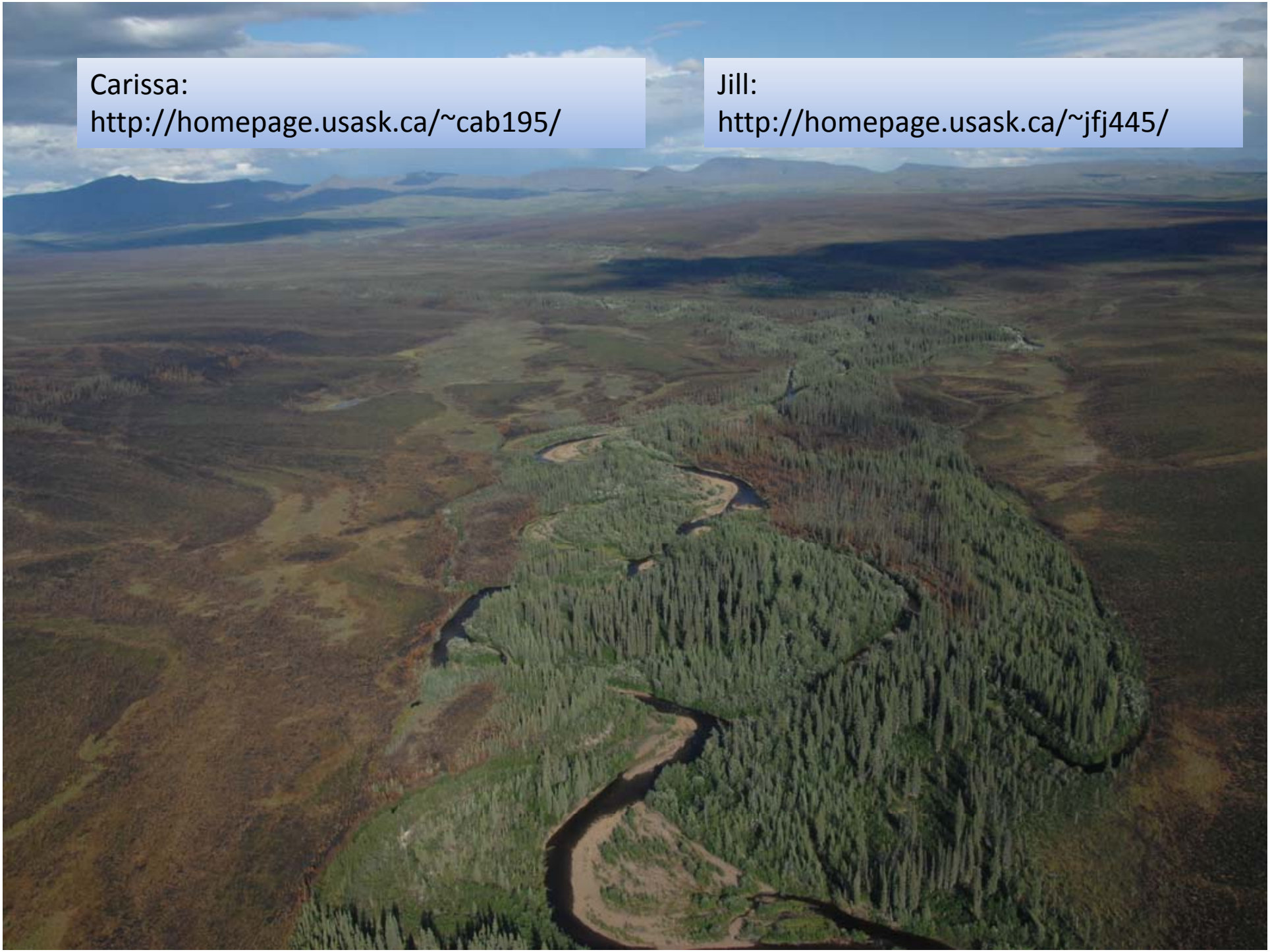
• **Jill Johnstone**

• Dorothy Cooley and the Yukon Territorial Government, Tombstone Territorial Park, and Friends of Dempster Country
• Grant Harrison and PRT Nurseries in Prince Albert, SK
• Richard Carr and Peter Englefield of Canadian Forest Service, Edmonton, Alberta
• Permission to use lands for field research was granted by the Yukon Heritage Branch and the Vuntut Gwitchin First Nation
• Eric Vander Wal, Andrew Trant, Brian Starzomski, Jonathan Henkelman, and François Messier

Field work: Jayme Viglas (2007, 2009, 2010); Jodi Crewe (2007); Jamie Leathem, Eric Pedersen, Sara Pieper, Katrina Wohlfarth, and Nicole Wunderlich (2008); Mac Brown, Sylvia Frisch, Berwyn Larson, Jenalee Mischkolz, and Marcus Phillips (2009).

Lab work: Matt Frey, Eric Pedersen, Janet Pritchard, Emily Tissier, Katherine Trembath, Jayme Viglas, and Xanthe Walker.

Northern Plant Ecology lab: Sara Pieper, Nicole Wunderlich, Aditi Shenoy, Jayme Viglas, Emily Tissier, Kirsten Allen, Matt Frey, and Xanthe Walker.


Carissa:
http://homepage.usask.ca/~cab195/
Jill:
http://homepage.usask.ca/~jfj445/