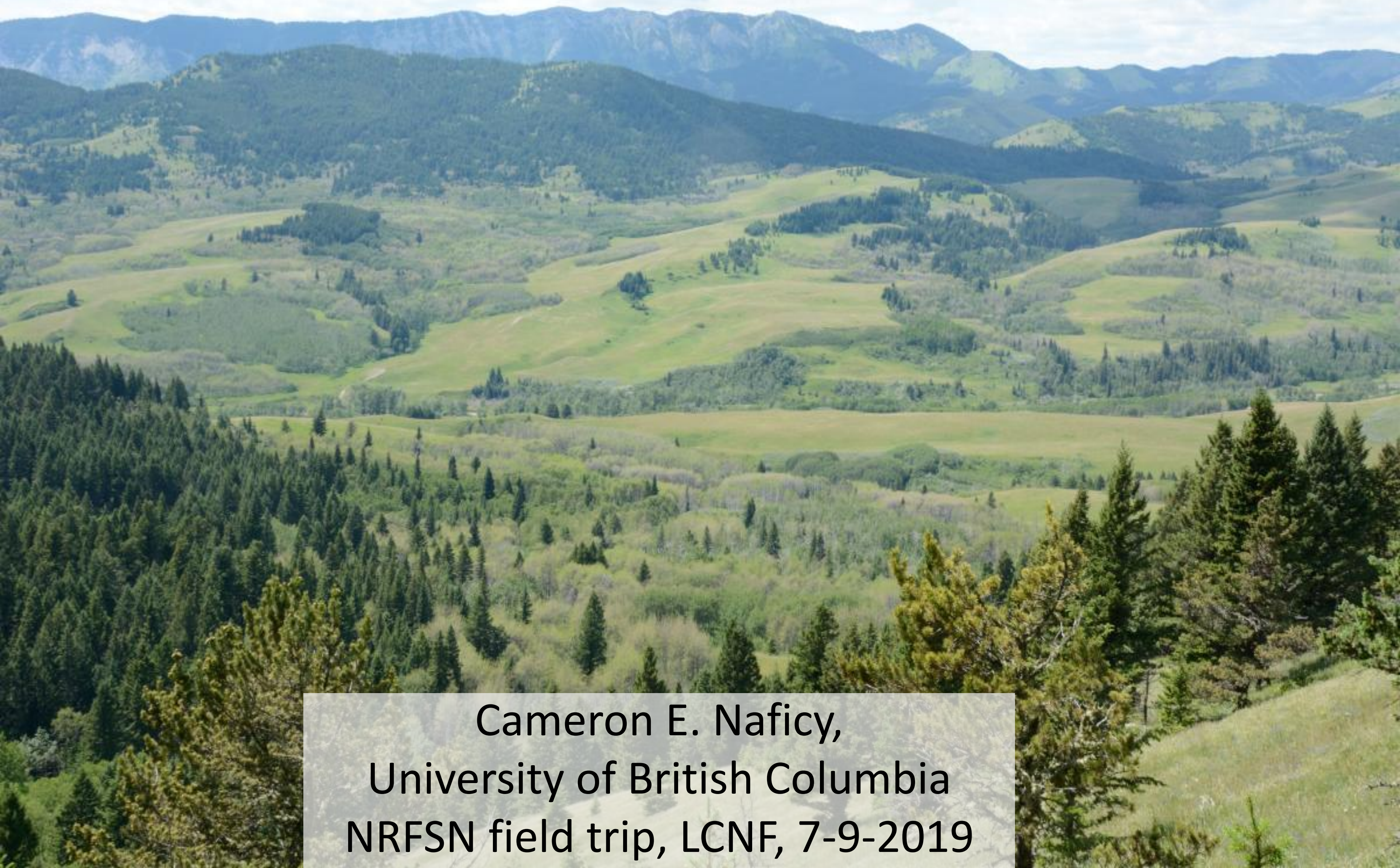
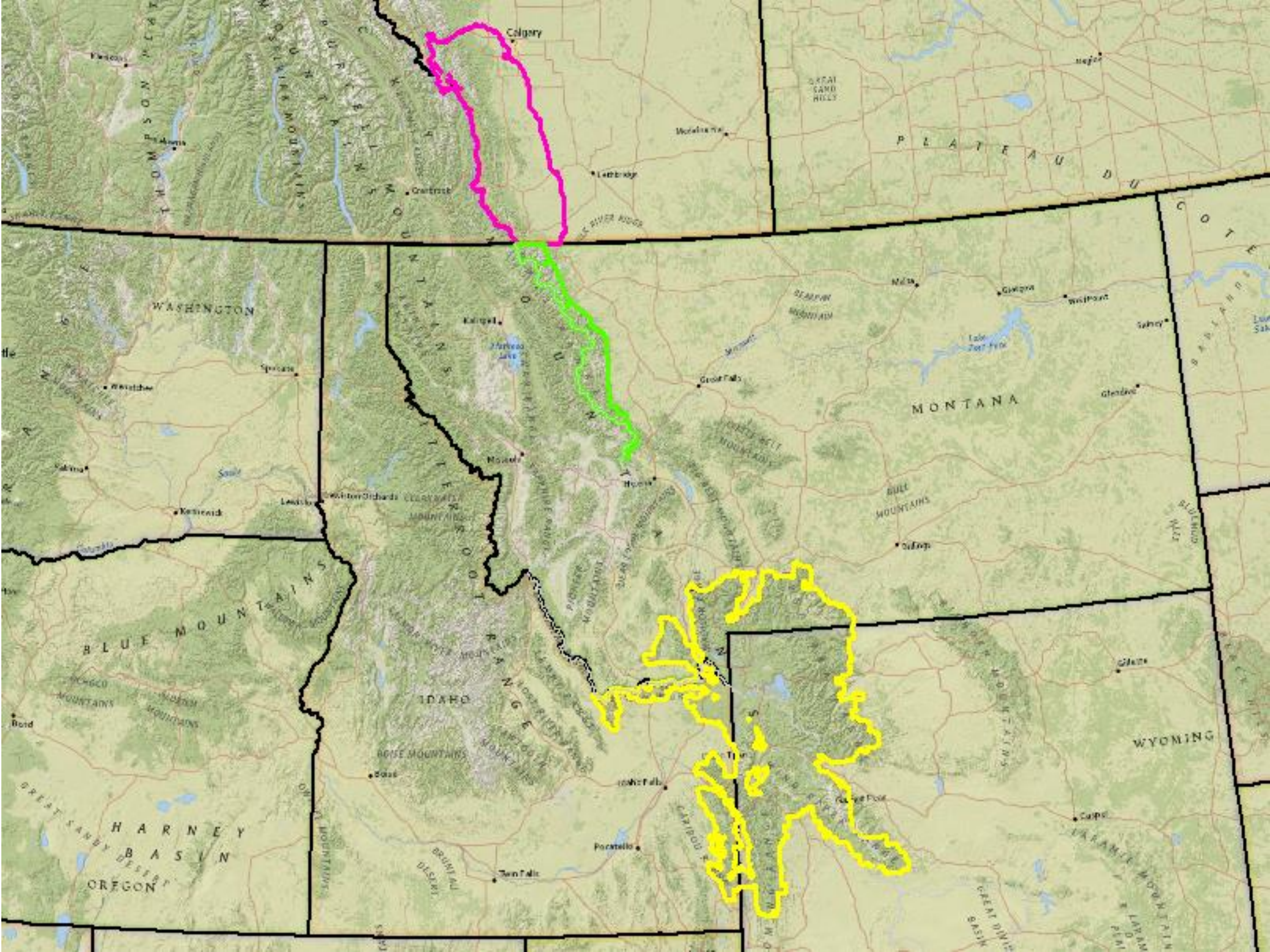
Resilience mechanisms and fire-driven tipping points in forests of the eastern Continental Divide

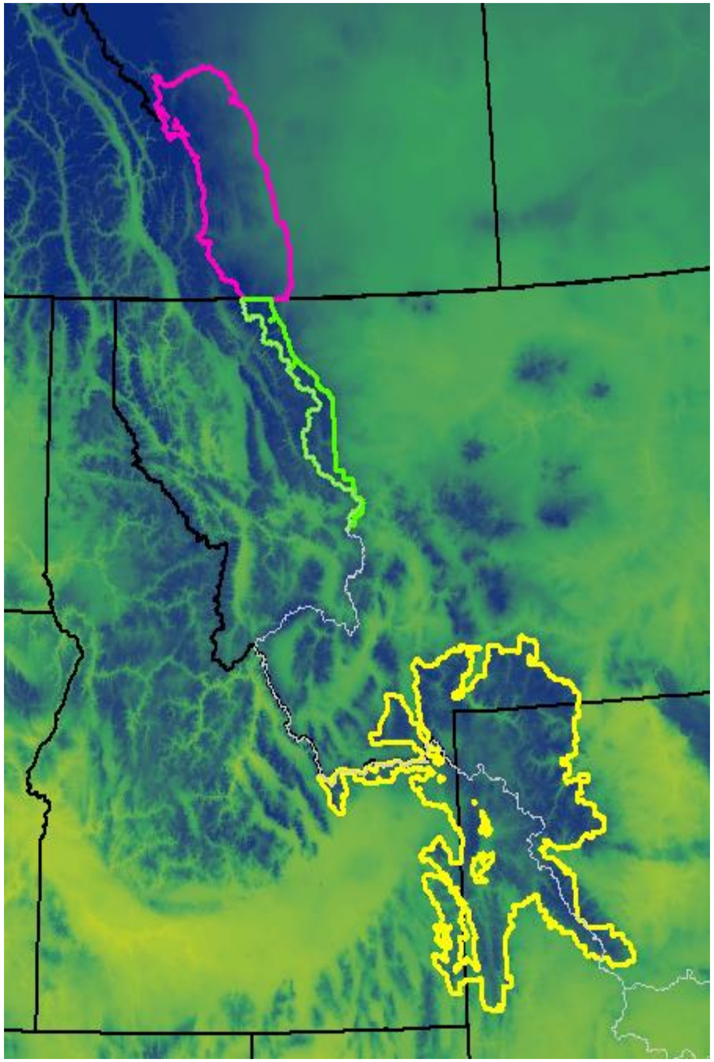


Cameron E. Naficy,
University of British Columbia
NRFSN field trip, LCNF, 7-9-2019

Research objectives

1. Understand ecological dynamics & resilience mechanisms in mixed-severity fire regime ecosystems
2. Characterize changes in fire regime & landscape vegetation condition along a gradient of fire frequencies
   - Detect & quantify fire frequency thresholds in fire regime properties & landscape conditions


Calgary
Lethbridge
Medicine Hat
Cranbrook
GREAT SAND HILLS
P L A T E A U D U
C O T E
WASHINGTON
Spokane
Wenatchee
Yakima
Kennewick
Lewiston
Kalispell
Missoula
Helena
Great Falls
Malta
Glasgow
Wolf Point
Sidney
Glendive
Billings
MONTANA
BULL MOUNTAINS
BEARPAW MOUNTAIN
BLUE MOUNTAINS
IDAHO
BOISE MOUNTAINS
Boise
Idaho Falls
Pocatello
Twin Falls
Bend
H A R N E Y
B A S I N
OREGON
WYOMING
Gillette
Casper

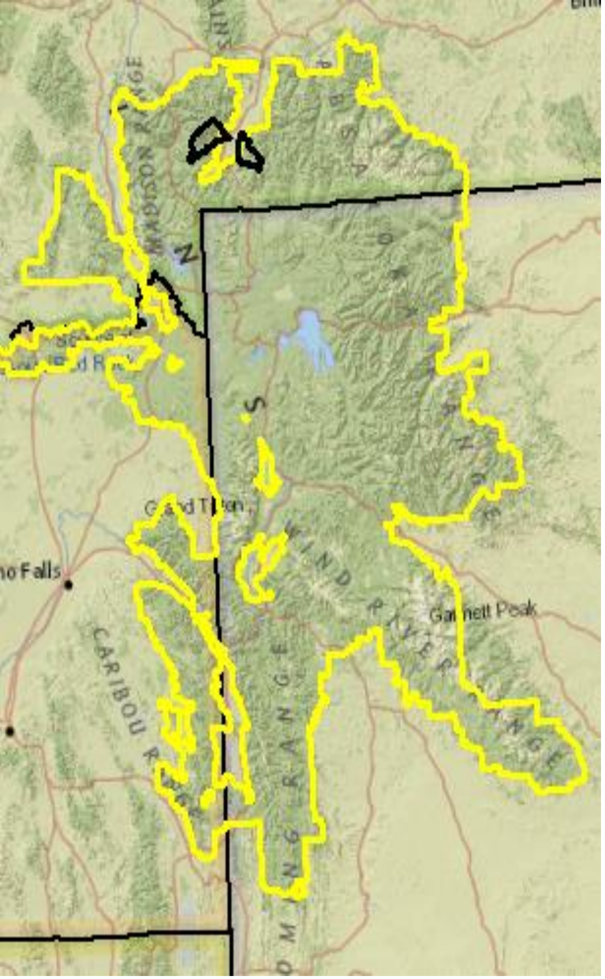


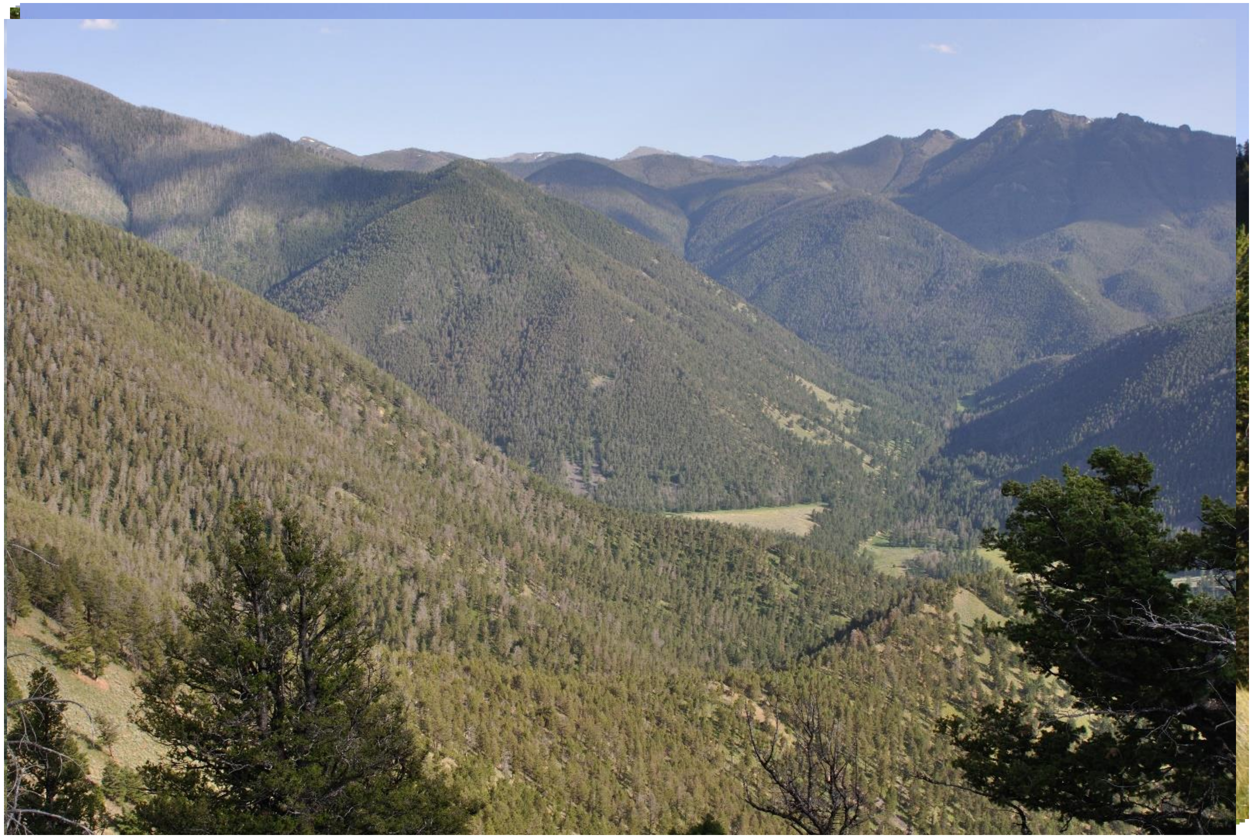
- Eastside forest types:
  - Douglas-fir at low elevations
  - abundant trembling aspen
  - widespread lodgepole pine
  - spruce-fir at high elevations
- Variable climatic & topographic setting
- Varying disturbance regimes

	Mean Climatic Water Deficit				
	All	PSME	POTR	PICO	PIEN-ABLA
SW Alberta	165	159	151	99	84
GYE	244	285	322	285	203

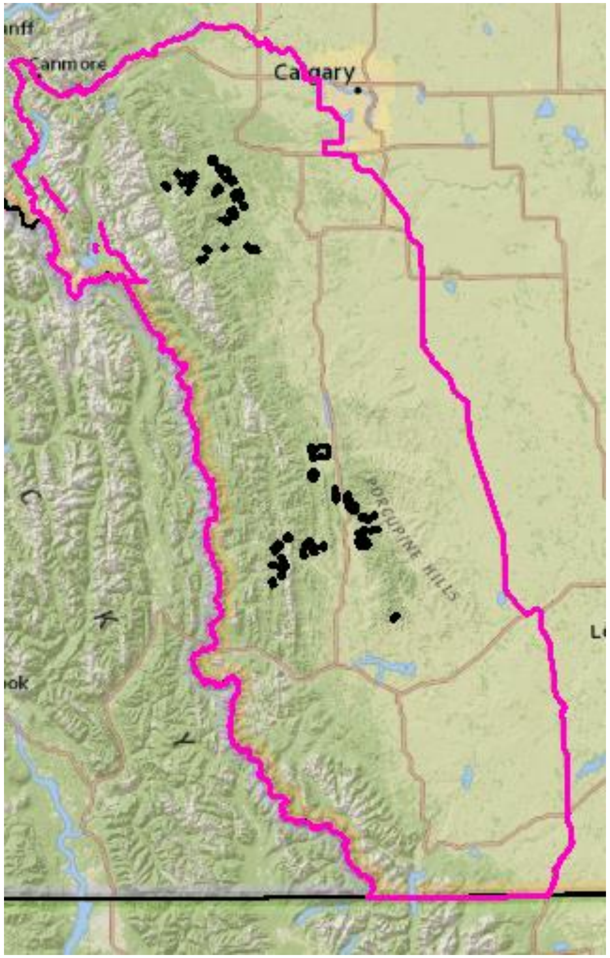



Greater Yellowstone Ecosystem





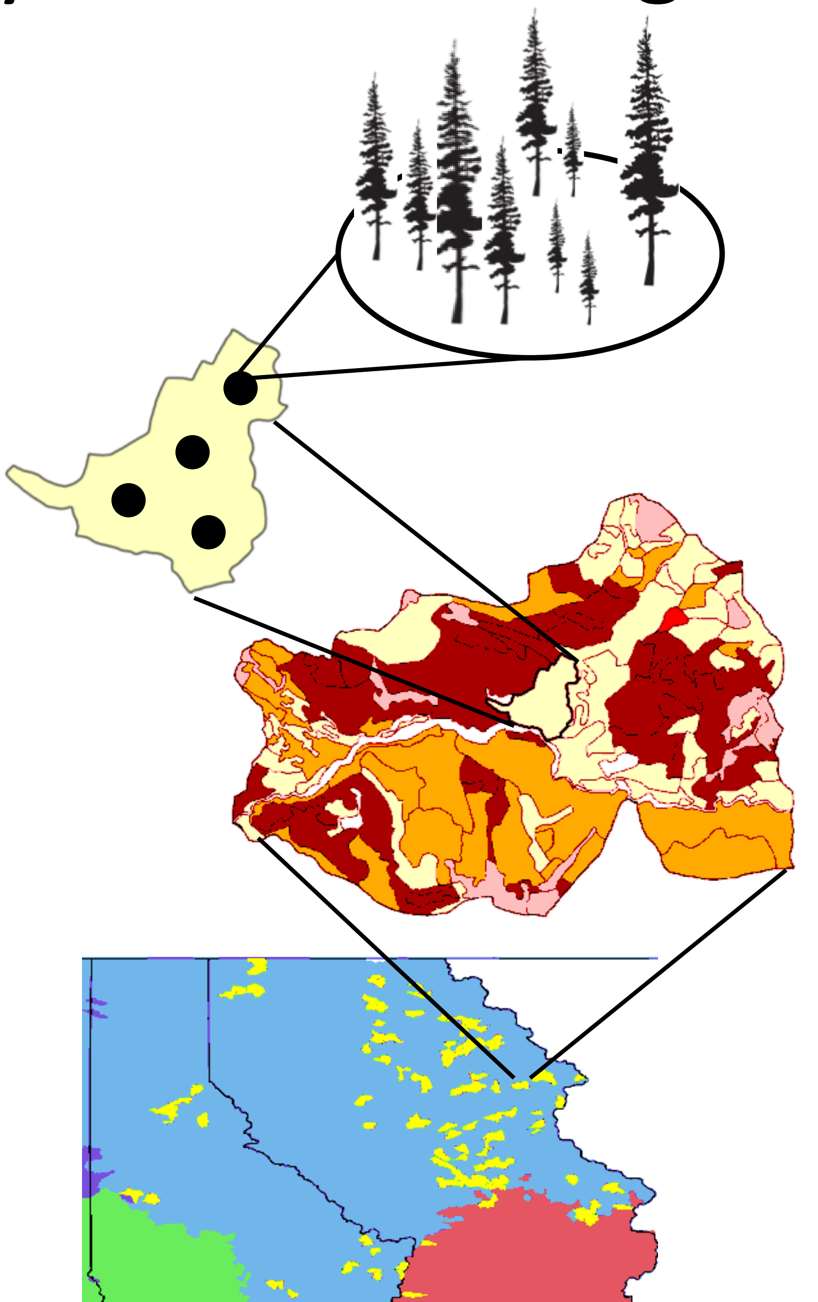
Alberta Foothills

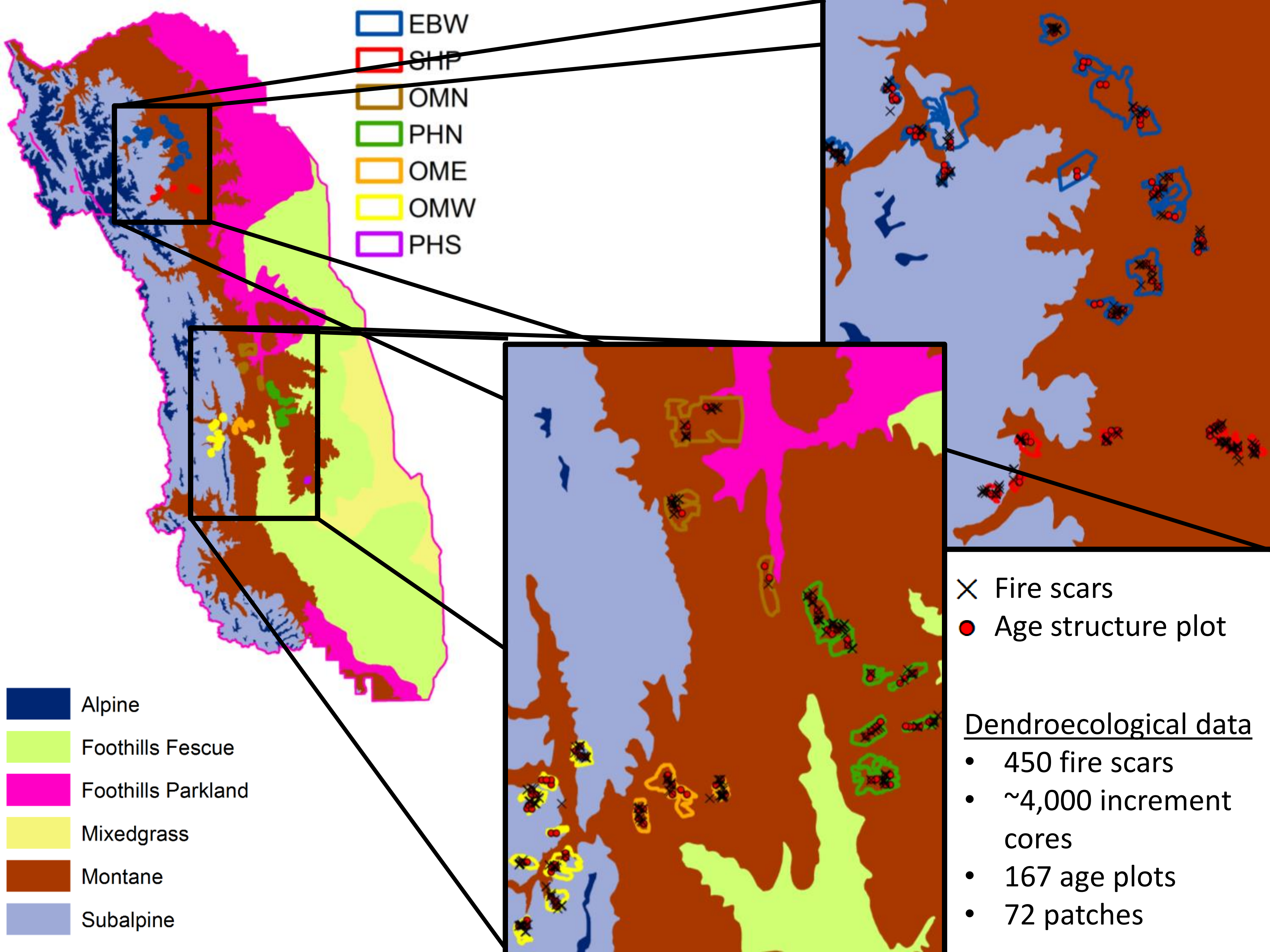


Methods

Hierarchical, multi-proxy research design

- Plots
  - dendroecological samples
  - fire-mediated dynamics
    → age structure
    → fire frequency & severity
- Patches
  - historical aerial photography
  - spatial & structural properties
    → patch boundaries & vegetation attributes
- Watersheds
  - dendroecological sample stratification
  - meso-scale biophysical gradients
  - develop statistical models
- Landscapes
  - broad–scale biogeographic gradients
  - apply statistical models





EBW
SHP
OMN
PHN
OME
OMW
PHS
Alpine
Foothills Fescue
Foothills Parkland
Mixedgrass
Montane
Subalpine
Fire scars
Age structure plot
Dendroecological data
• 450 fire scars
• ~4,000 increment cores
• 167 age plots
• 72 patches

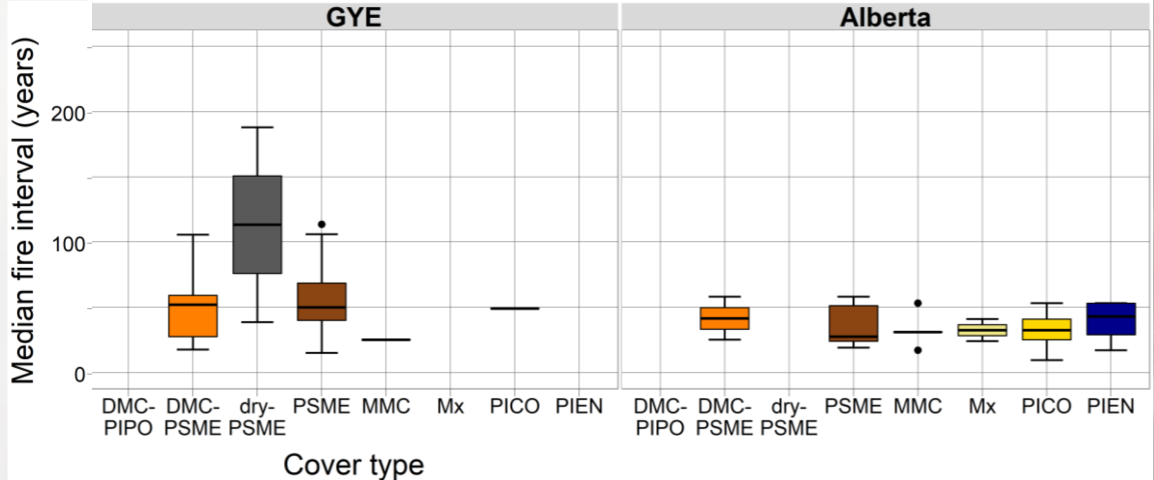
Results

GYE:

- intermediate frequency
- high variability

Alberta:

- high frequency
- low variability
- intermixed forest types, similar fire history

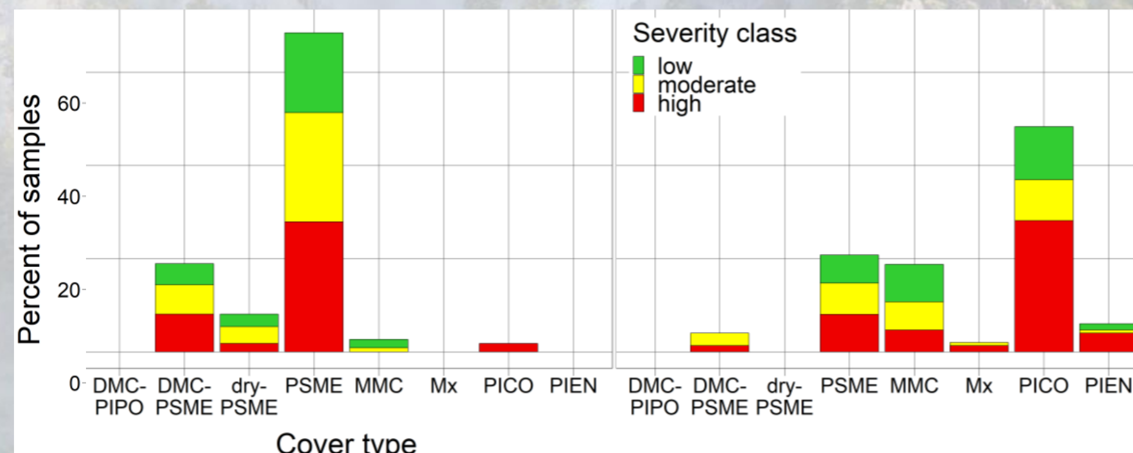


GYE:

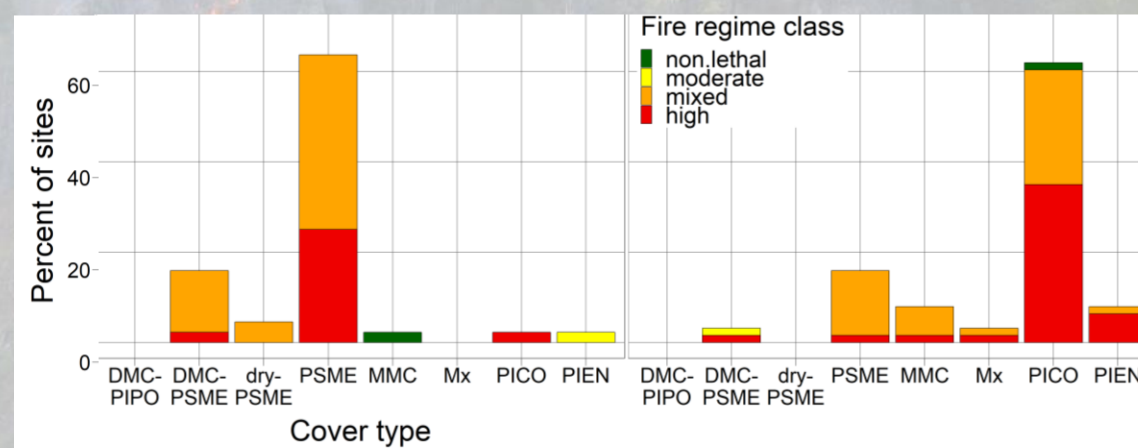
- high severity fire in 40-60%

Alberta:

- PSME similar to GYE
- high severity dominates PICO
- ~30% of samples low-moderate

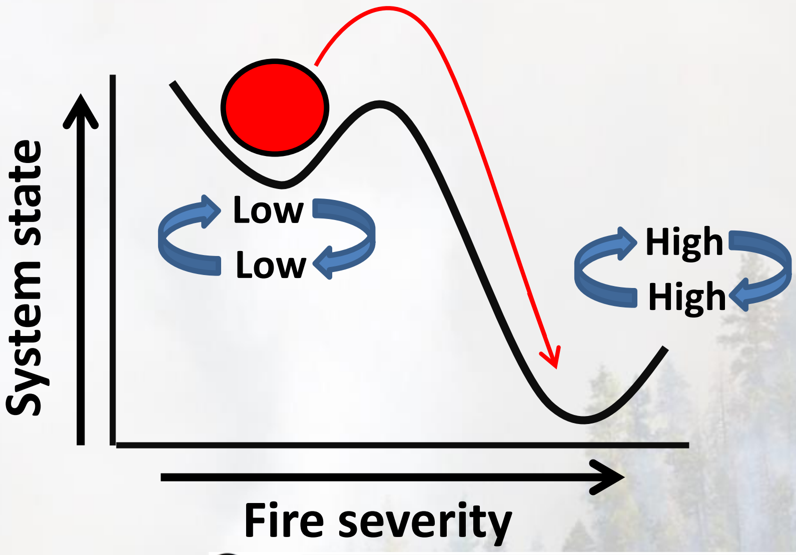


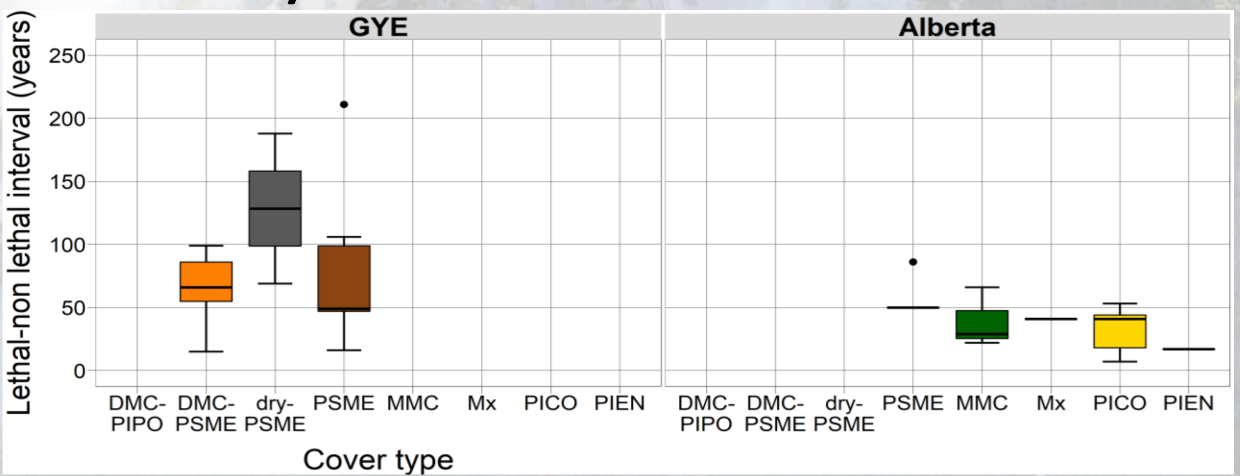
- mixed severity dominates →high-severity fire affected > 80% of sampled sites
- non-equilibrium patch-level dynamics




Resilience mechanisms in MSFRs

Resilience mechanisms in MSFRs





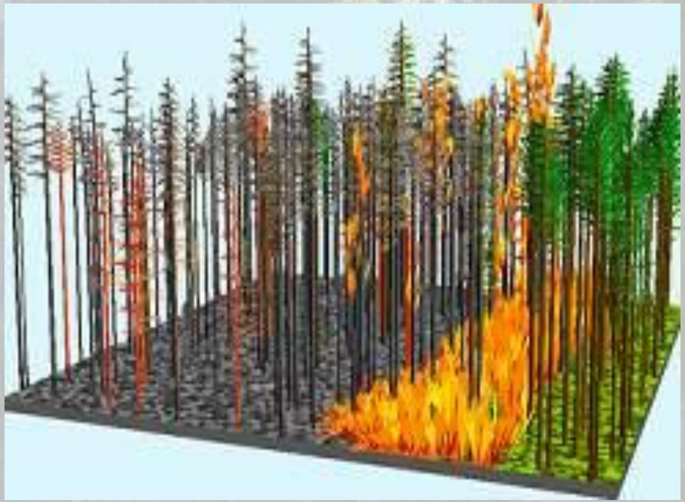
- > 60% of sites affected by high severity fire escaped the feedback loop
- Lethal-non lethal interval = time between high severity fire & first subsequent low-moderate fire = 30-70 years

  → suggests pathway for escape from high-severity feedback loop

  → dynamics of fuel complexes & fire behavior in post-high severity burn areas

1987 high-severity burn in dry mixed-conifer forest, Lolo NF, Montana, 29 years post-fire

- fire behavior in post high-severity forest
  - fire-sensitive trees (thin bark, low crown base height)
  - abundant fine fuels
  - high elemental (sun, wind) exposure



- most fire behavior modeling in mature forest
  - → are models from mature forests transferable?

- fire behavior & effects in young post-high severity landscapes not well understood

2013 Red Shale Fire reburn through 25 year old Gates Park Fire of 1988, Bob Marshall, Montana

Rocky Mountain Ranger District, LCNF

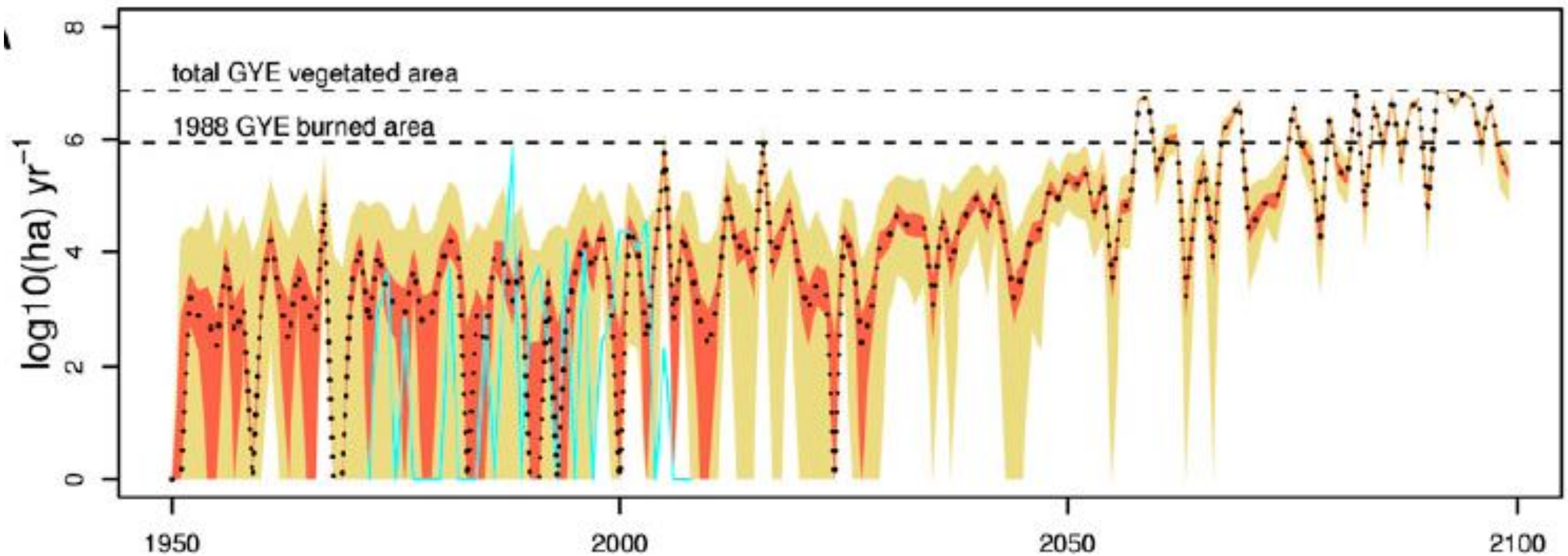

Fire-driven tipping points

Continued warming could transform Greater Yellowstone fire regimes by mid-21st century

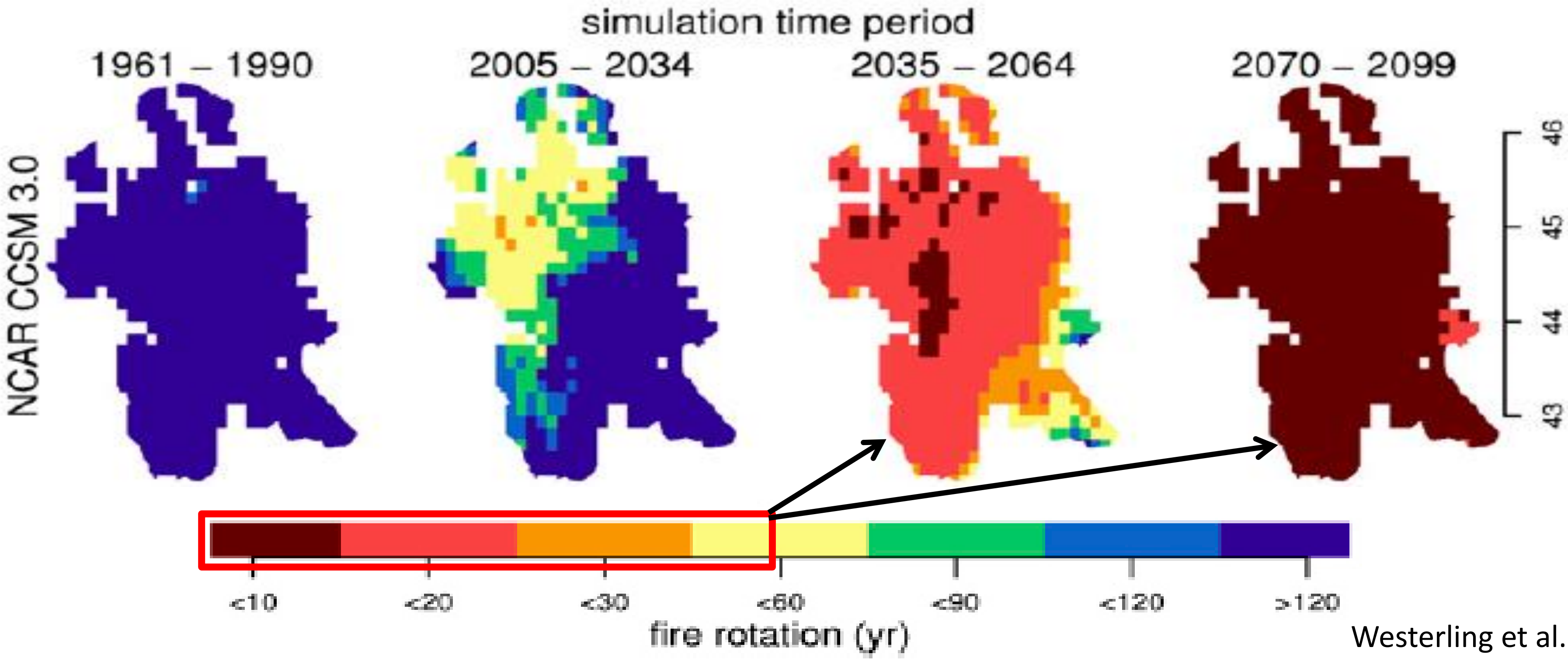
Anthony L. Westerling[a,1], Monica G. Turner[b,1], Erica A. H. Smithwick[c], William H. Romme[d], and Michael G. Ryan[e]

[a]Sierra Nevada Research Institute, University of California, Merced, CA 95343; [b]Department of Zoology, University of Wisconsin, Madison, WI 53706; [c]Department of Geography and Intercollege Graduate Degree Program in Ecology, Pennsylvania State University, University Park, PA 16802; [d]Warner College of Natural Resources, Colorado State University, Fort Collins, CO 80523; and [e]US Department of Agriculture Forest Service, Rocky Mountain Research Station, Fort Collins, CO 80526

Contributed by Monica G. Turner, June 24, 2011 (sent for review May 28, 2011)



*"**Our findings suggest a shift to novel fire–climate–vegetation relationships in Greater Yellowstone by midcentury because fire frequency and extent would be inconsistent with persistence of the current suite of conifer species**. The predicted new fire regime would transform the flora, fauna, and ecosystem processes in this landscape and may indicate similar changes for other subalpine forests."*



Westerling et al. 2011

- GCMs predict shortened FRIs
- By 2035, FRIs exceed resilience thresholds in GYE

<u>What's missing?</u>

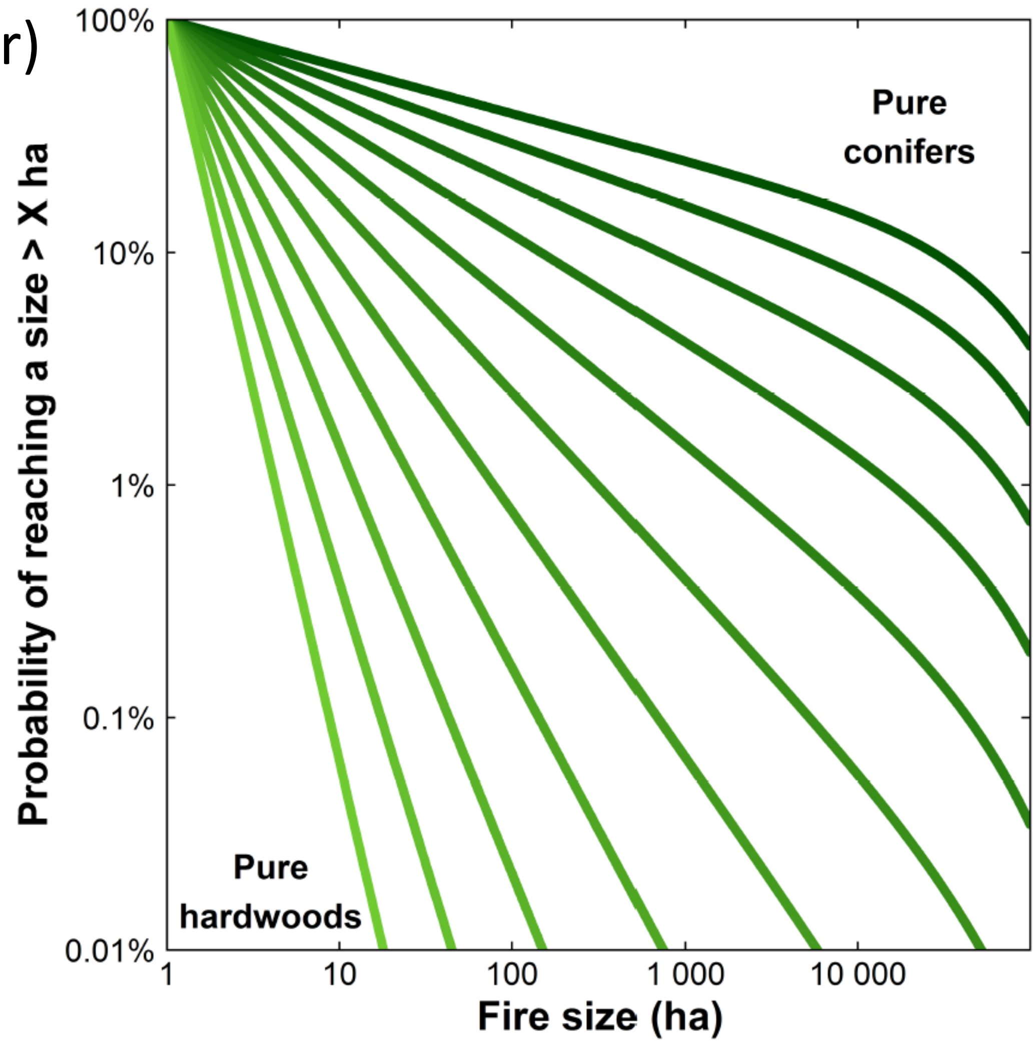
- Fire regime and vegetation response to ↑ fire frequency
- Fire-vegetation-climate feedbacks will dictate ecosystem response

Vegetation feedbacks on fire-climate relationships

Marchal et al. 2017 PLoS ONE

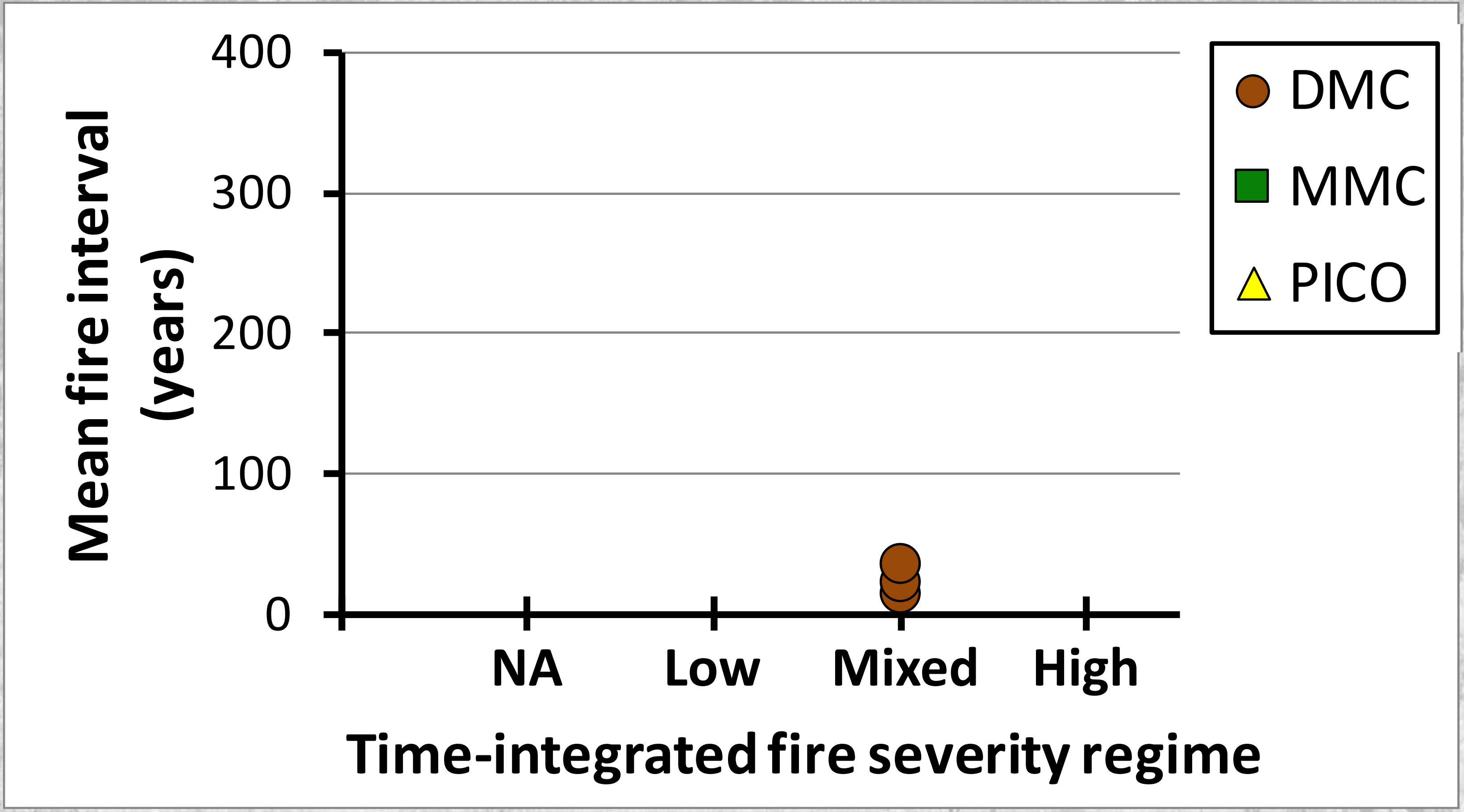
Burn area = f(weather, land cover)

Model variables	**AIC**
Weather, Land cover	1215
Land cover	1237
Weather	1303
Null model	1318



Feedbacks are critical to system behavior!

Southern Foothills fire regime, lodgepole pine in context (n=32)



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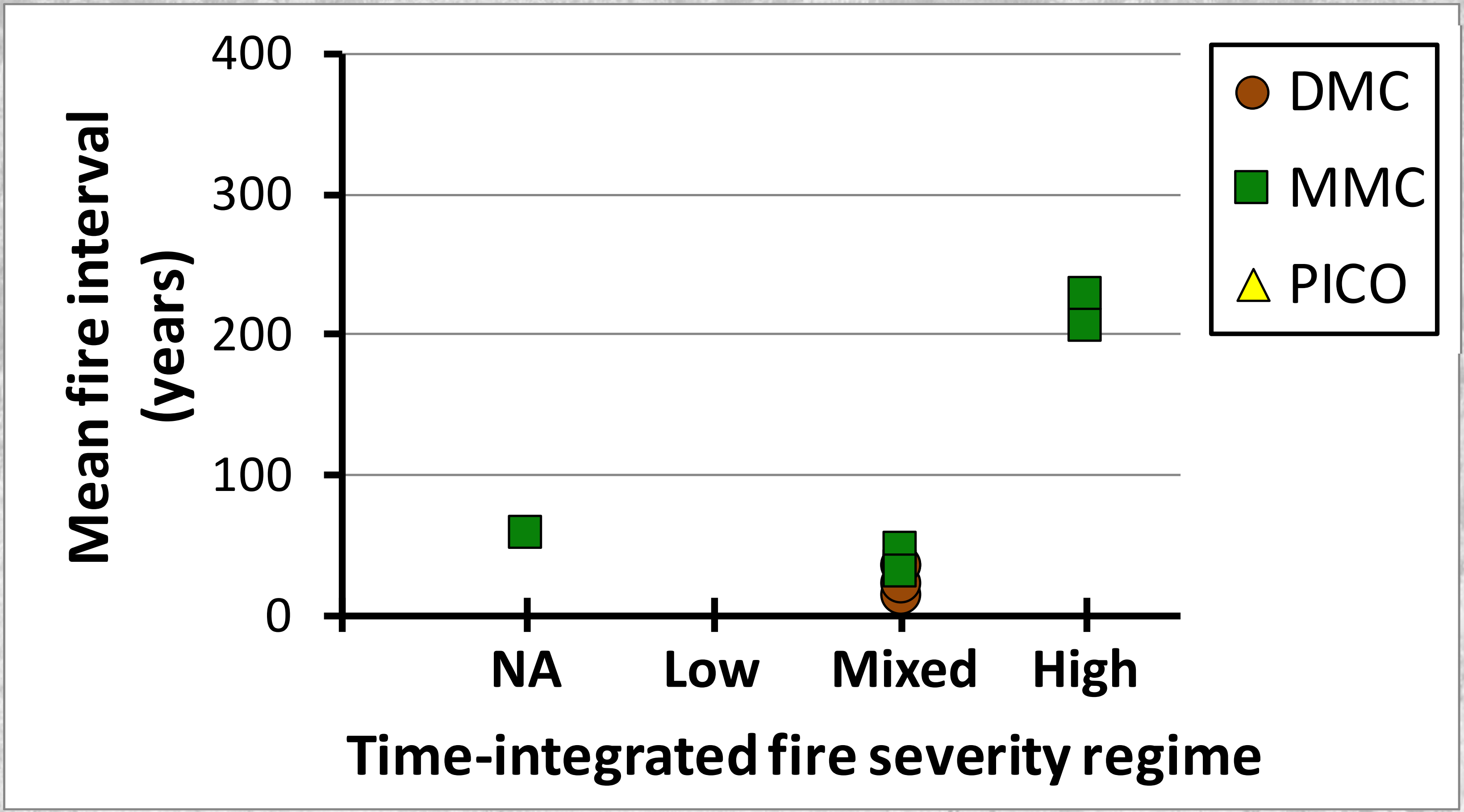

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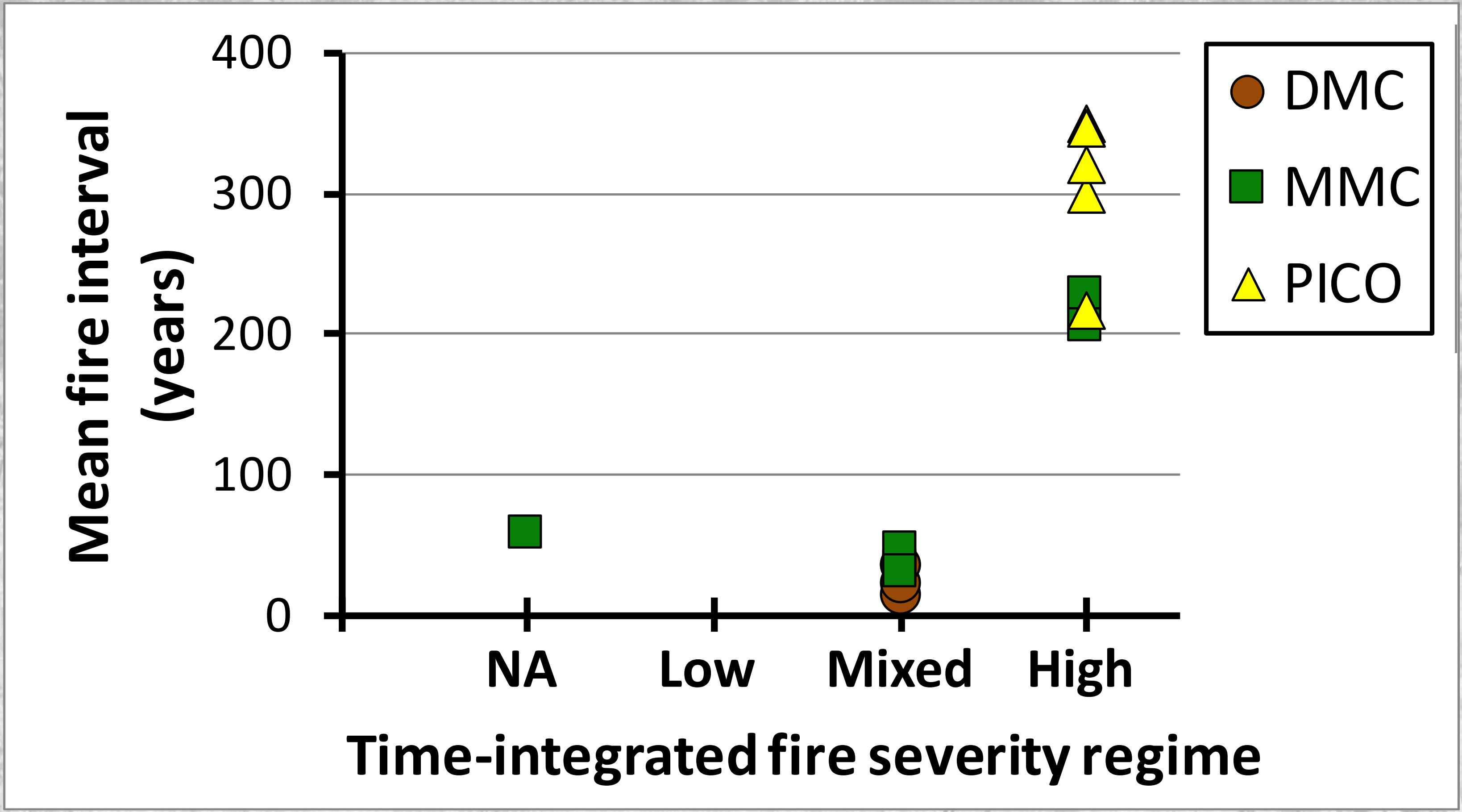
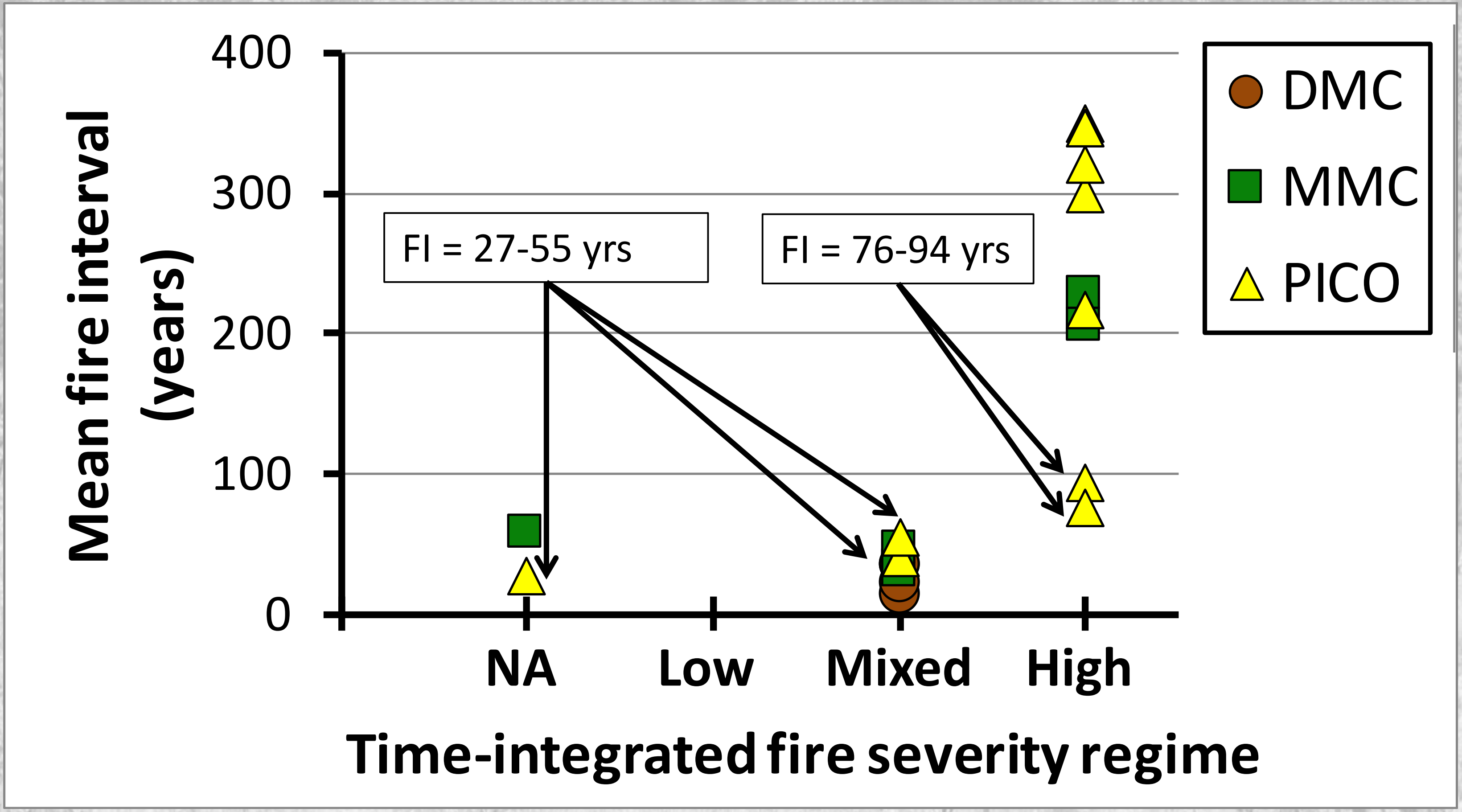


Southern Foothills fire regime, lodgepole pine in context (n=32)




Parlee survey, 1940

Bridgland survey, 1913

Parlee survey, 1940


Parlee survey, 1940

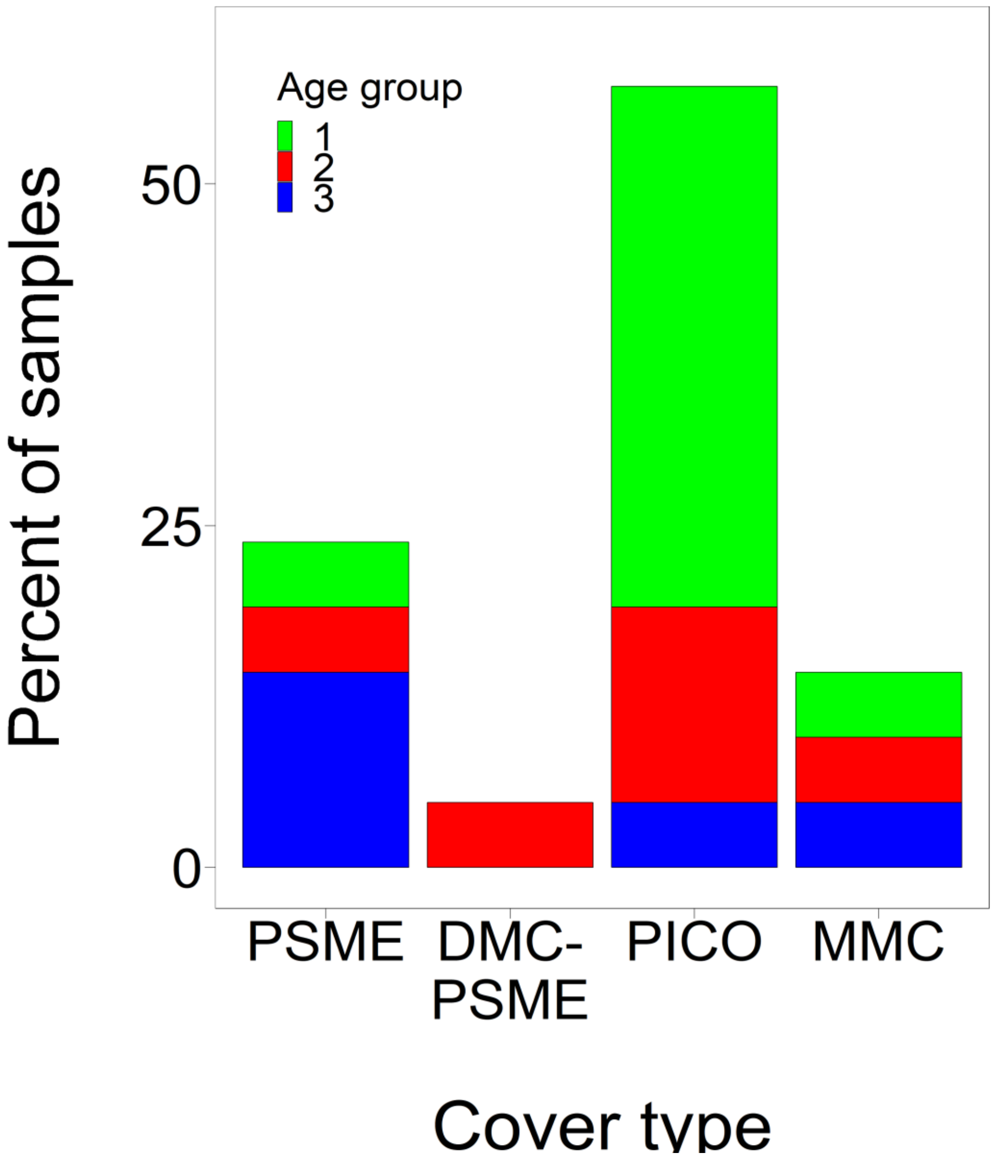

fires in 1839, 1863
Wheeler Survey, 1895

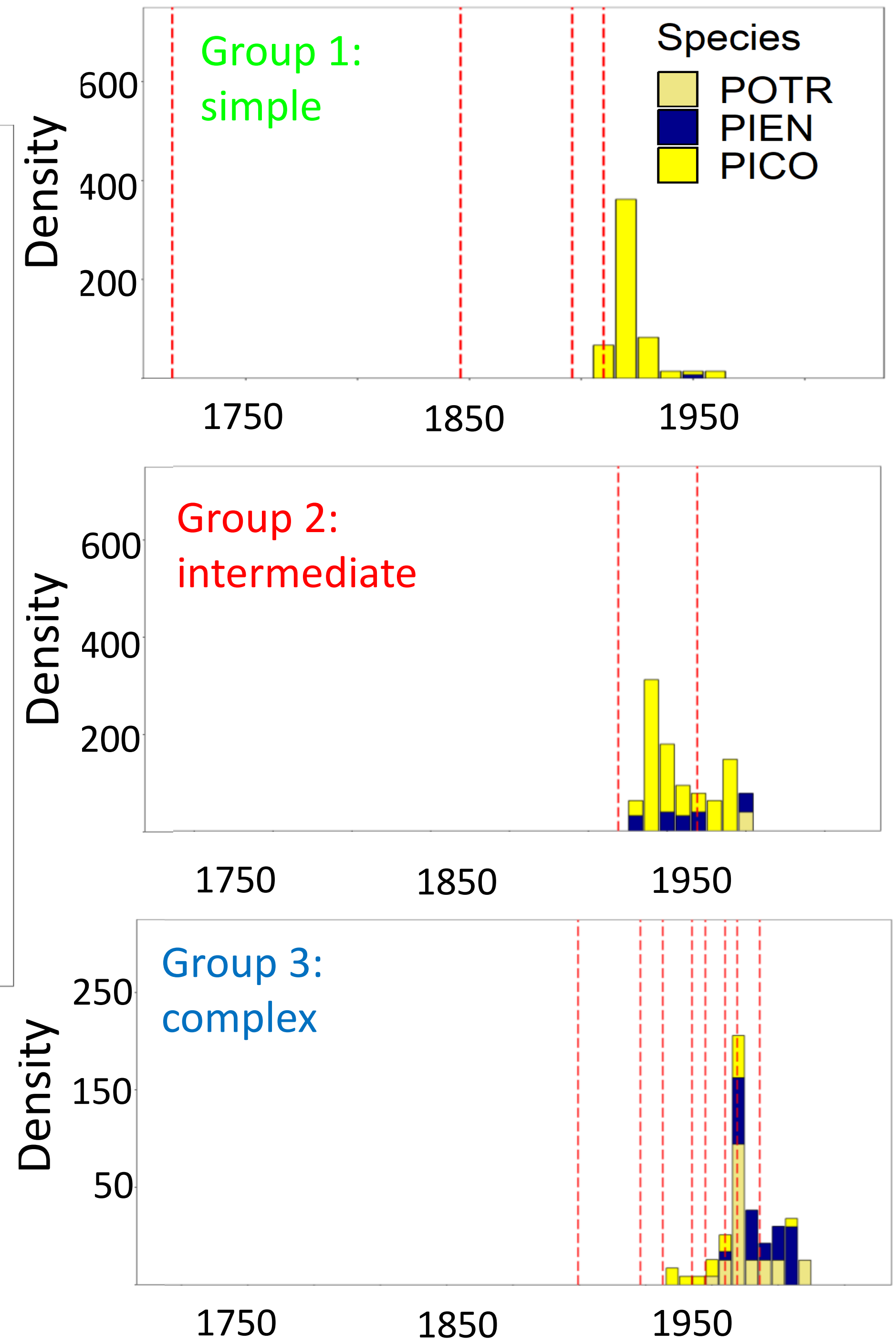

fires in 1896, 1910, 1919, 1929, 1936
Parlee survey, 1940

Ecosystem response to fire frequency

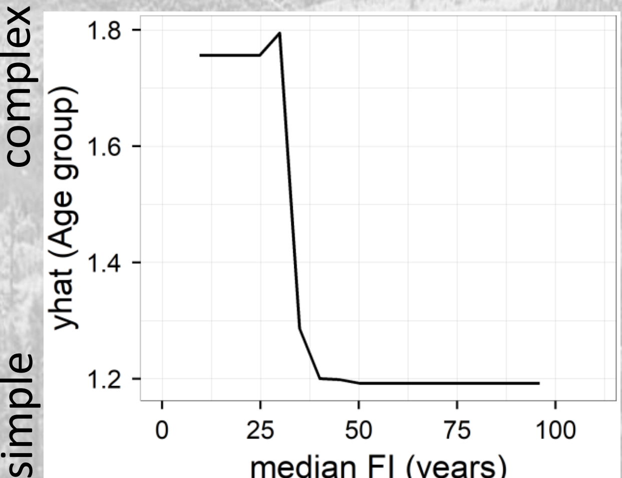
- Boosted regression/classification trees
- 4 response variables
  - Age groups (simple, intermediate, complex)
  - Fire severity (continuous index)
  - Fire regime (non lethal, mixed, high)
  - Landscape metrics (patch sizes, spatial arrangement)
- Predictors
  - Median, mean, SD of fire return interval distribution
  - Censored & uncensored interval data
- Threshold responses & locations

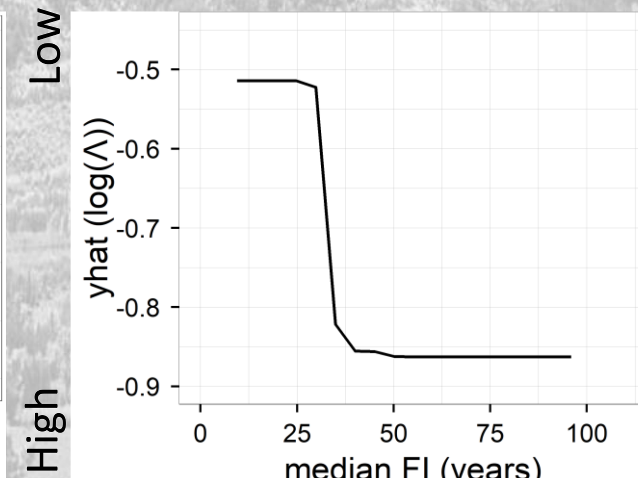
Forest age structure

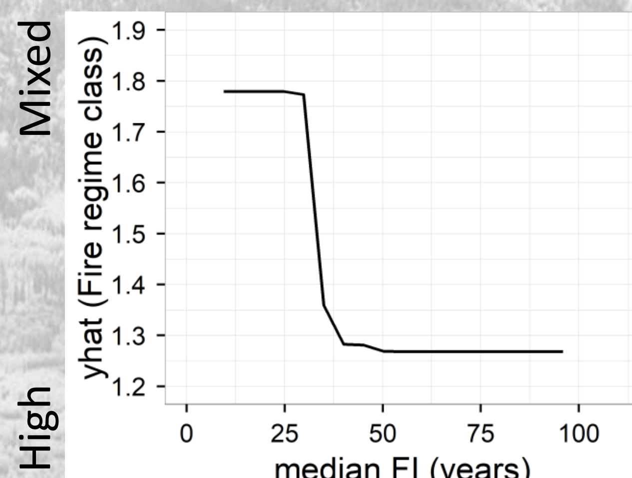


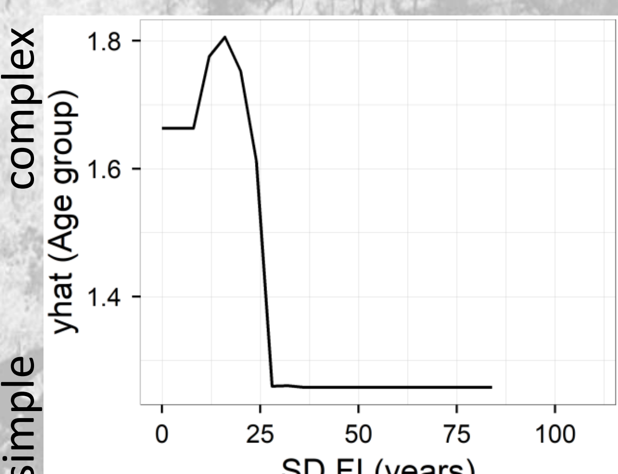


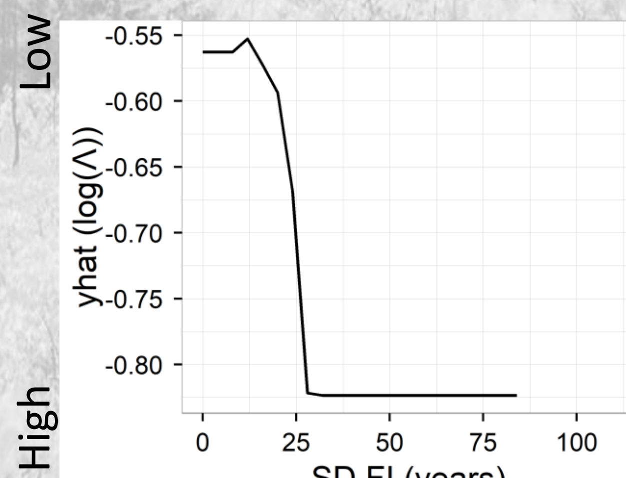
Age group | Fire severity | Fire regime

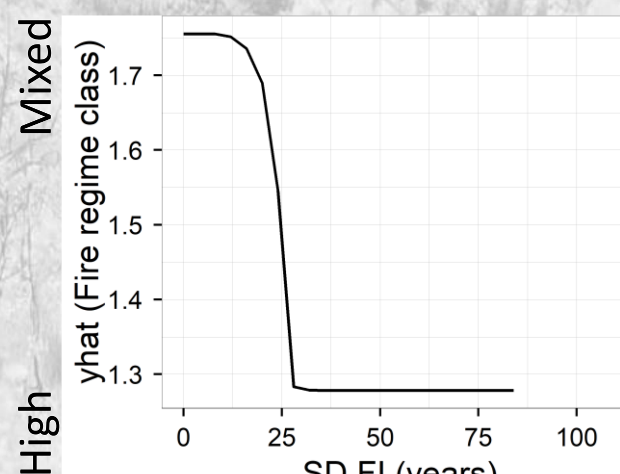




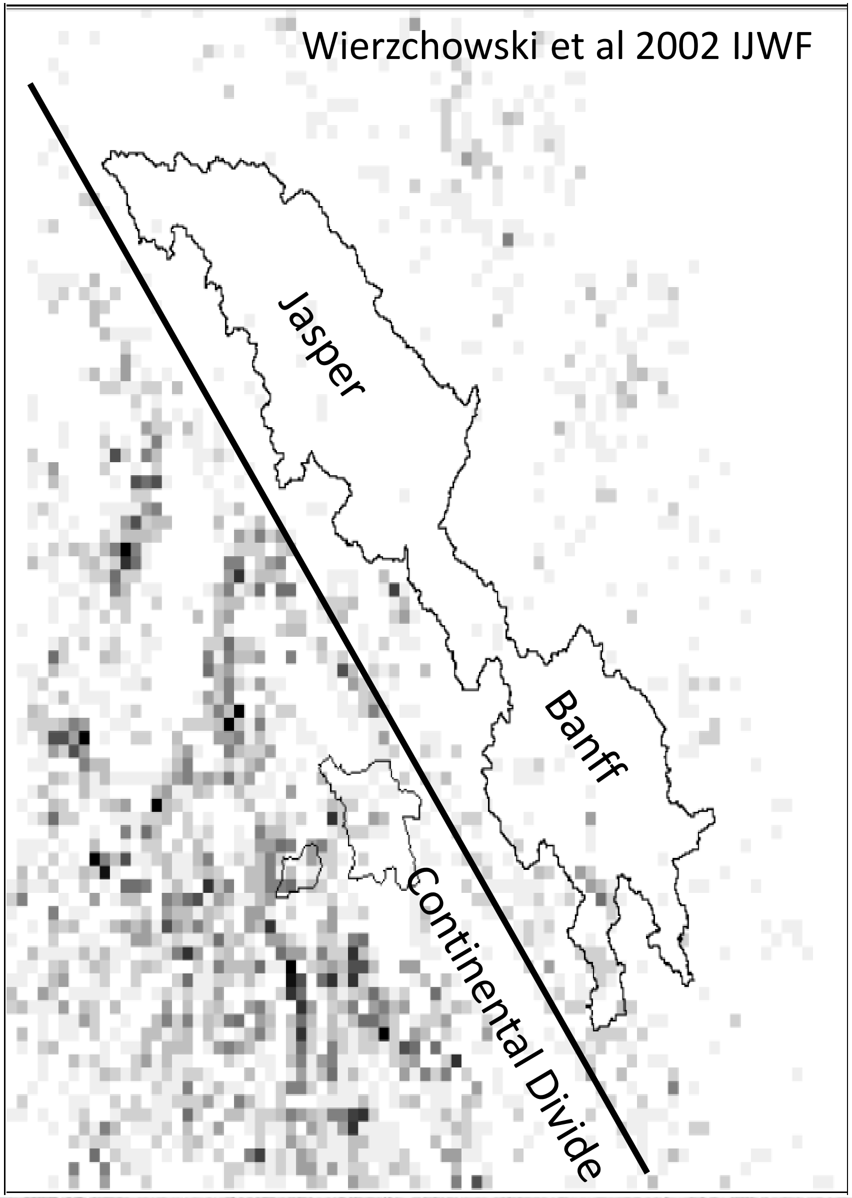




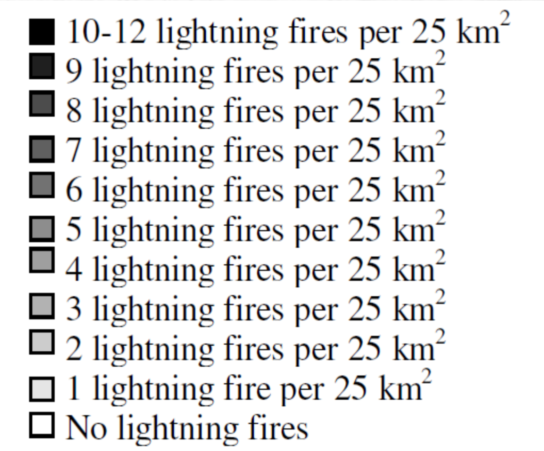




Anthropogenic influence on fire regimes of the SW Alberta Foothills



- Infrequent lightning fires
- ~40% of fire scars intra-ring → many spring-early summer fires
- Suggests anthropogenic forcing of historical fire frequency



Indigenous influence on fire regimes

	Ponderosa pine forest, western North America	Lodgepole pine forest, Alberta Foothills
		
	Ignition-saturated, fire-resistant forest	**Ignition-limited, fire-sensitive forest**
Fire frequency	Marginal increase	Large increase
Fire severity	Marginal decrease	Significant decrease
Fire regime	Reinforced	Divergent
Change in landscape condition	Marginal change	Increased fragmentation & complexity
Forest-non forest conversion	Minimal	Significant

Conclusions

- Novel resilience mechanisms in MSFRs
  - Escape from high severity feedbacks
- Recurrent fire (25-45 year FRIs) does not lead to system collapse
  - although some forest-non forest conversion does occur
- Fire frequency drives changes in fire severity, fire regime and landscape conditions
- Strong threshold behaviors around 30 year median FRI
- Below threshold:
  - high severity fire still important & non equilibrium dynamics persist
  - key feedbacks emerge:
    1. more mixed-severity fire & complex forest structures
    2. β-diversity of landscape mosaic increases
- Divergent landscape conditions and resilience revealed by indigenous burning

Questions?

Collaborators

- Lori D. Daniels (UBC)
- Thomas T. Veblen (CU Boulder)
- Paul F. Hessburg (PNW RS)
- Alan Tepley, Smithsonian Institute
- Dave Andison, fRI Research
- Ceres Barros, Canadian Forestry Service

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- John Stadt, Alberta Environment & Parks
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