Functional Role of Whitebark Pine at Treeline Across its Rocky Mountain Range

Diana F. Tomback
University of Colorado Denver

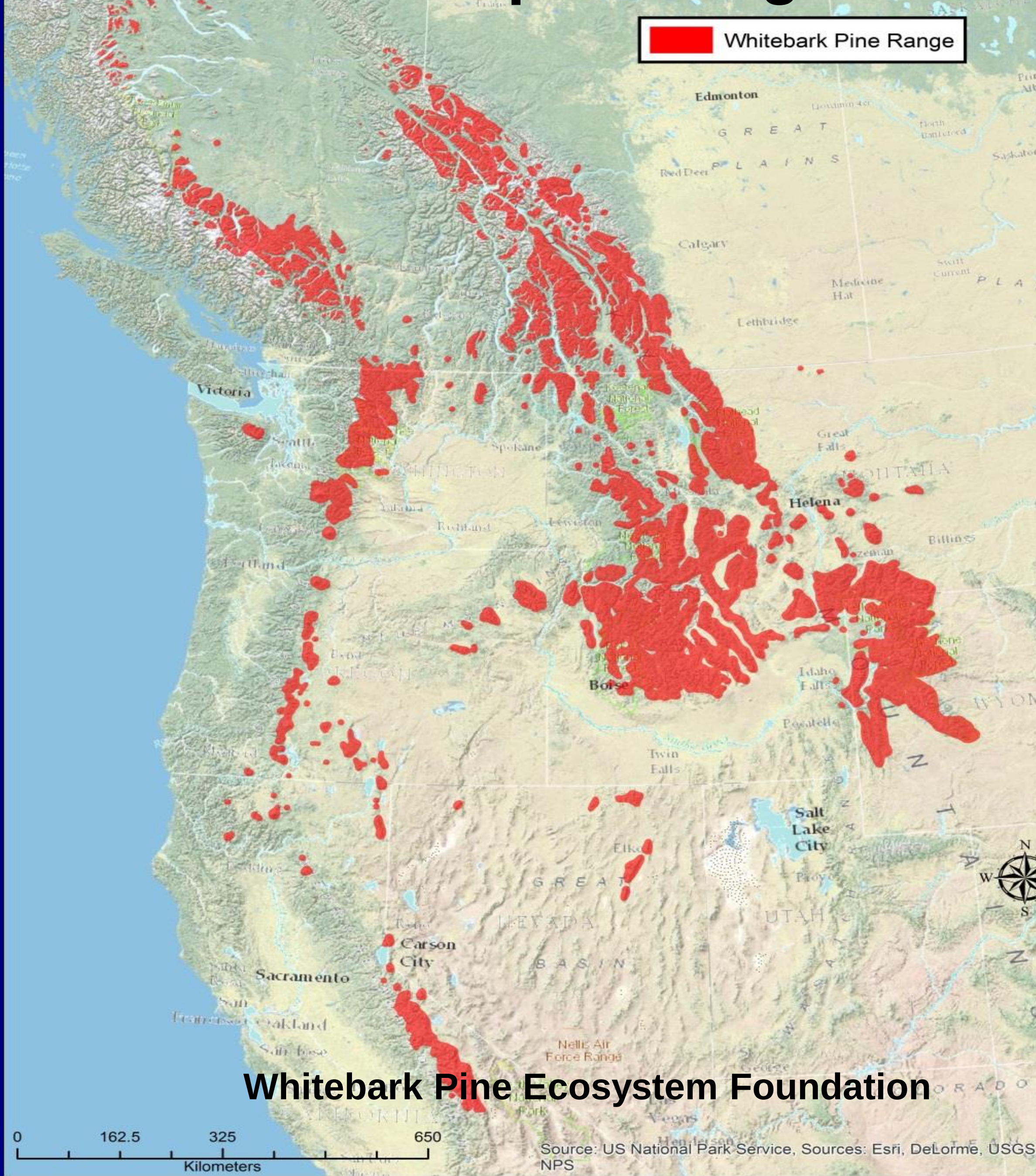
Lynn M. Resler
Virginia Tech

George P. Malanson
The University of Iowa

Whitebark Pine Ecosystem Foundation
Annual Science and Management Workshop
September 16-18, 2016, Whitefish, MT

Whitebark pine range

- Broadest latitudinal distribution of any five-needle white pine in North America.
- Narrow elevational range: subalpine and treeline.



Whitebark pine (*Pinus albicaulis*)

- Major component of high-elevation subalpine forest and treeline communities in the central and northern Rockies.
- Tolerates exposed, arid sites and poor soils.

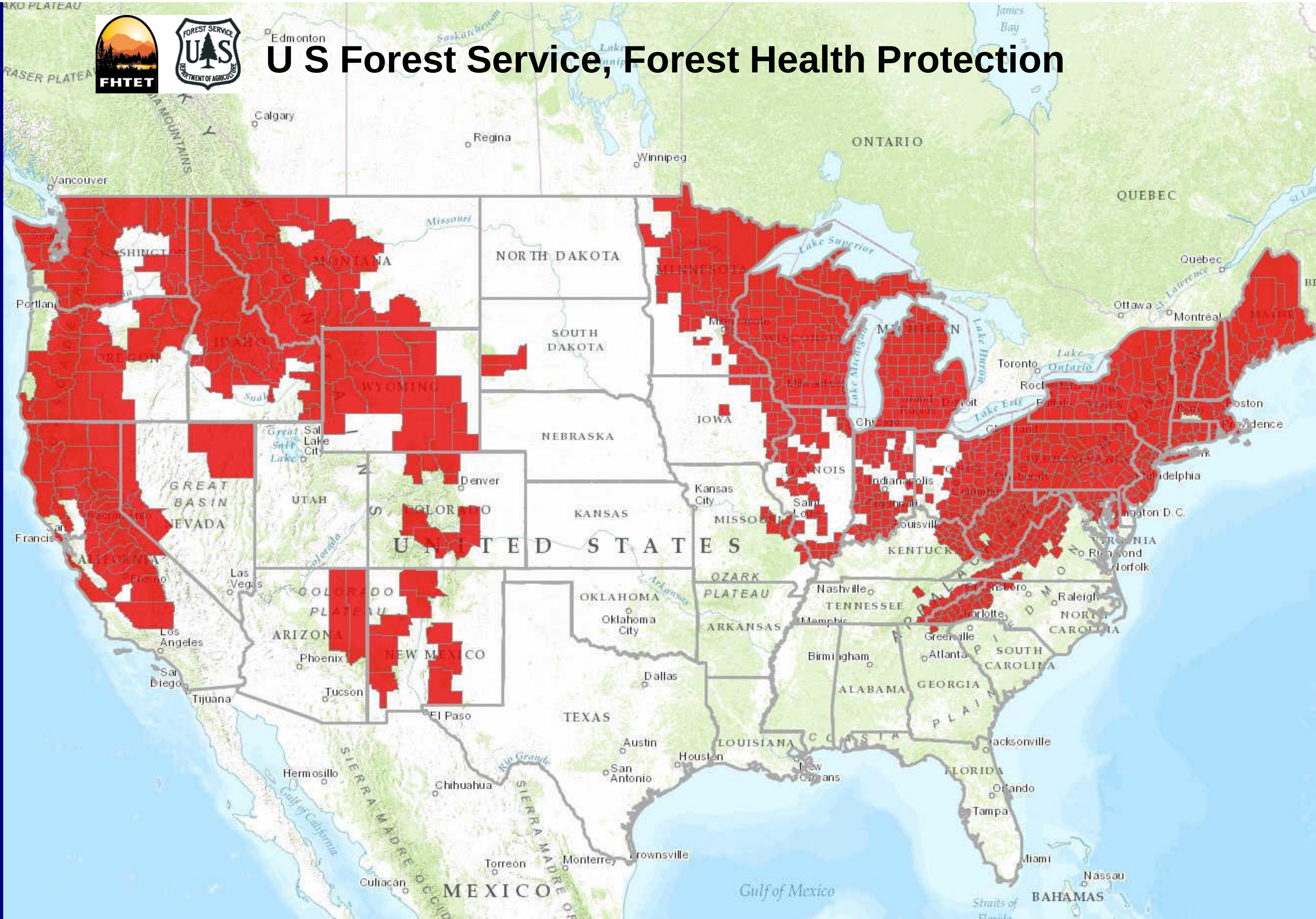
Treeline communities influence snow distribution, accumulation, and retention

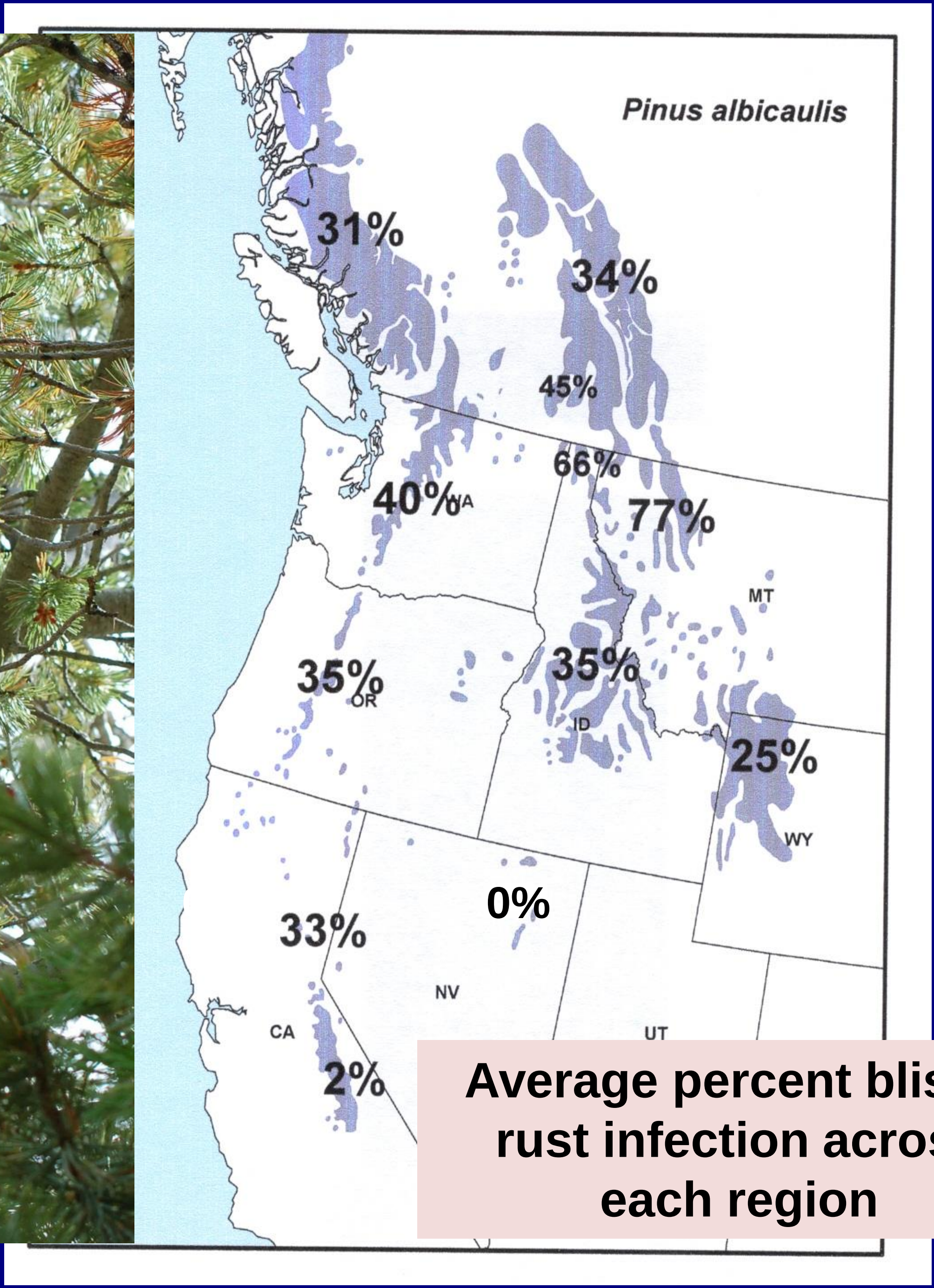
The top of the "water towers"

Threats

- The invasive pathogen *Cronartium ribicola*: white pine blister rust.
- Past and recent large-scale outbreaks of mountain pine beetles (*Dendroctonus ponderosae*).
- Altered fire regimes—advancing succession in seral white pine communities.
- Climate change: sustaining bark beetle outbreaks, producing drought stress and mortality, and altering pine distributions.

U.S. distribution of white pine blister rust





Average percent blister rust infection across each region

Mountain pine beetle

Mortality from MPB, through 2007, USA

Gibson et al. 2008

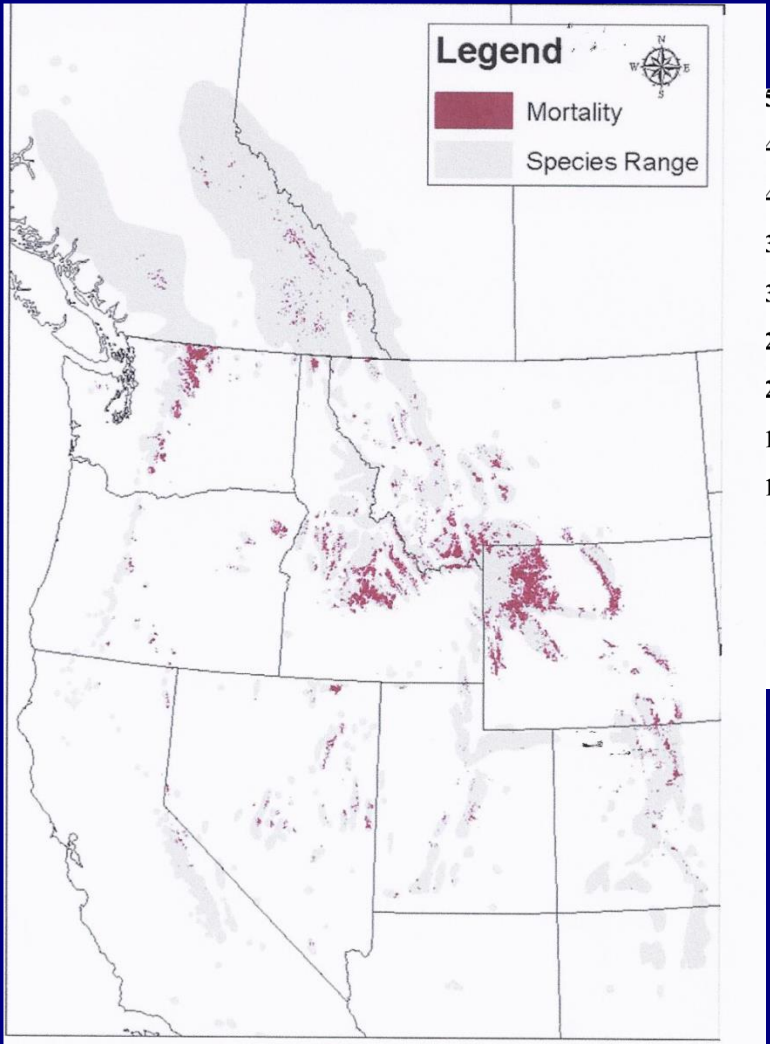
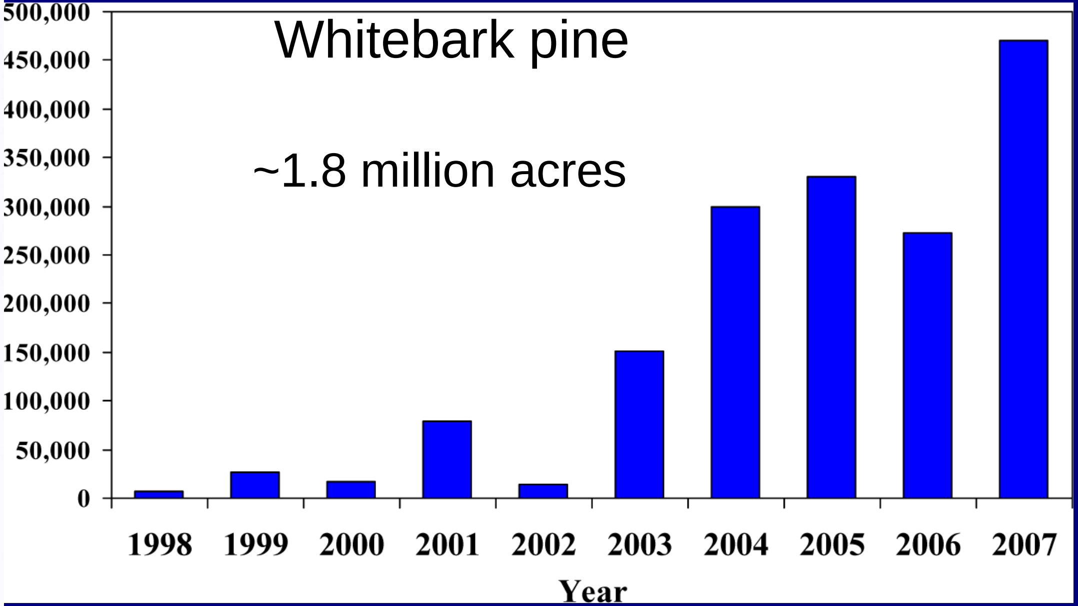
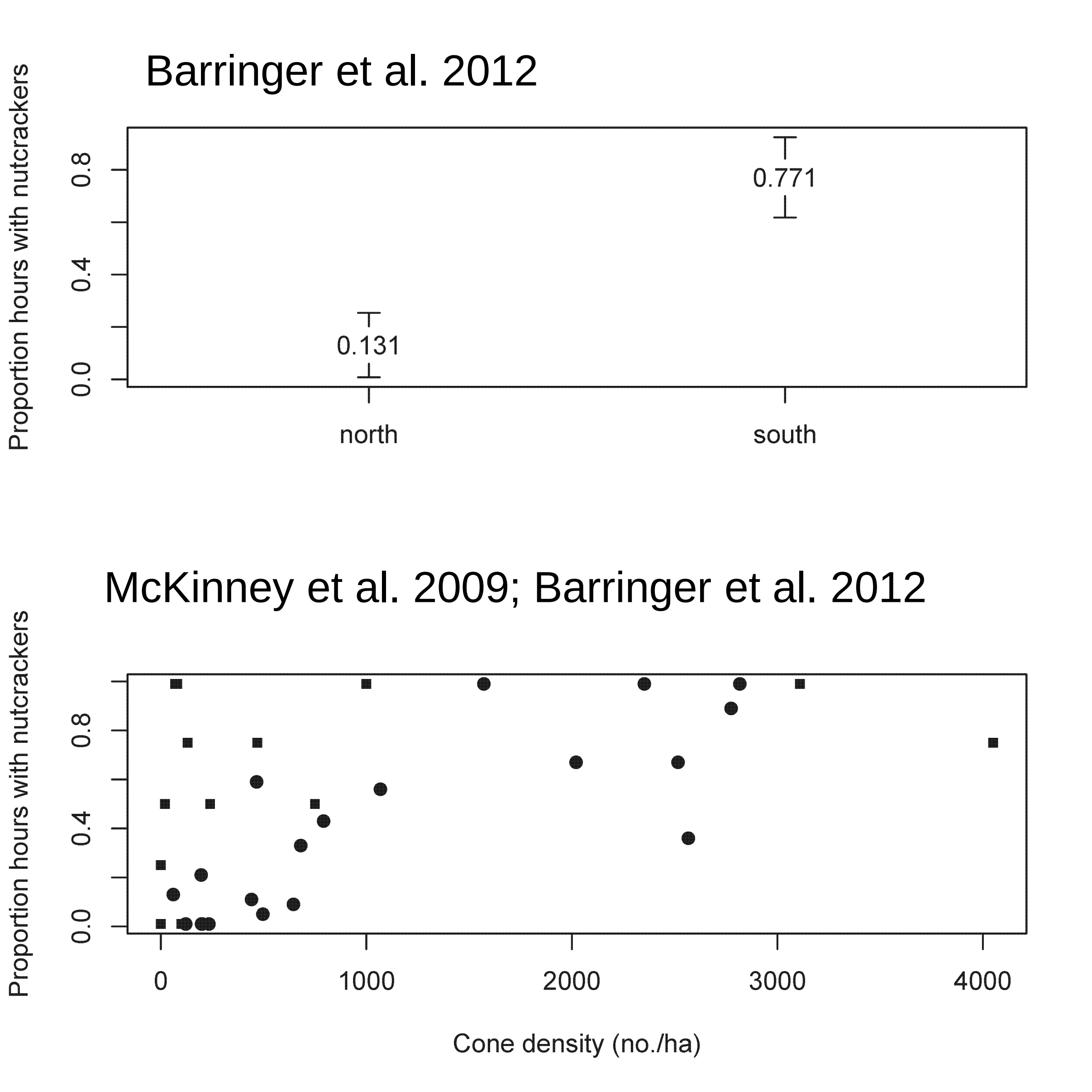


Figure 7. MPB-caused mortality of four pine species (whitebark, limber, Rocky Mountain bristlecone, and Great Basin bristlecone) in the western United States (1998-2007 ADS) and British Columbia (2006-2007) throughout the distributions of these tree species (United States Geological Survey).



Nutcracker response to reduced cone production



Whitebark pine at treeline

- What is the ecological role of whitebark pine in treeline communities?
- How will the spread of white pine blister rust and loss of seed production from mountain pine beetle impact treeline communities?

Whitebark pine depends on Clark's nutcracker for seed disperal

- Nutcrackers cache whitebark pine seeds within treeline communities.


At treeline, solitary trees often establish in protected locations leeward:

- Of nurse objects.
- Of nurse plants.
- In microtopography.

Nutcrackers also use these kinds of sites for seed caching.

Whitebark Pine at Treeline

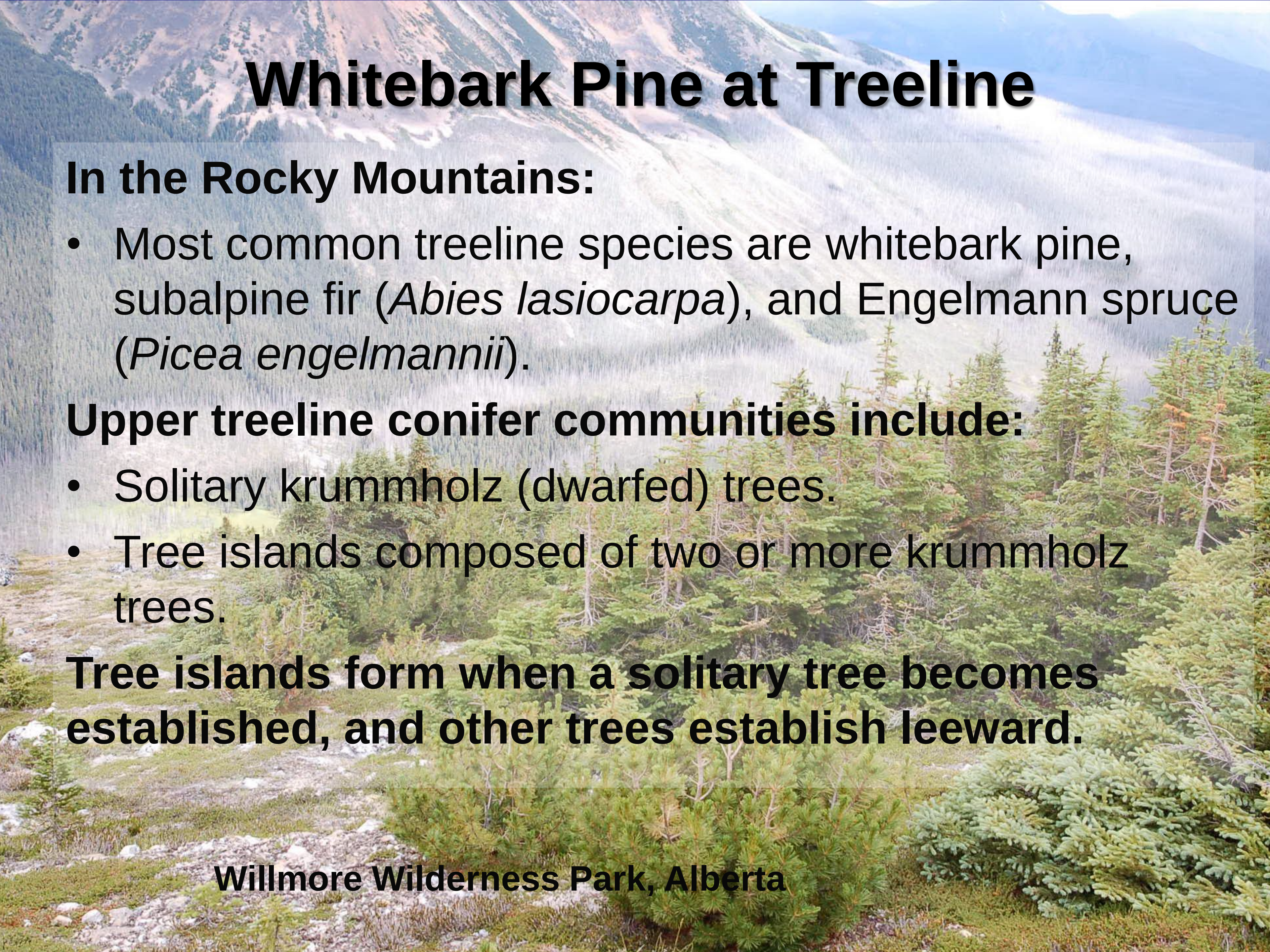
In the Rocky Mountains:

- Most common treeline species are whitebark pine, subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*).

Upper treeline conifer communities include:

- Solitary krummholz (dwarfed) trees.
- Tree islands composed of two or more krummholz trees.

Tree islands form when a solitary tree becomes established, and other trees establish leeward.

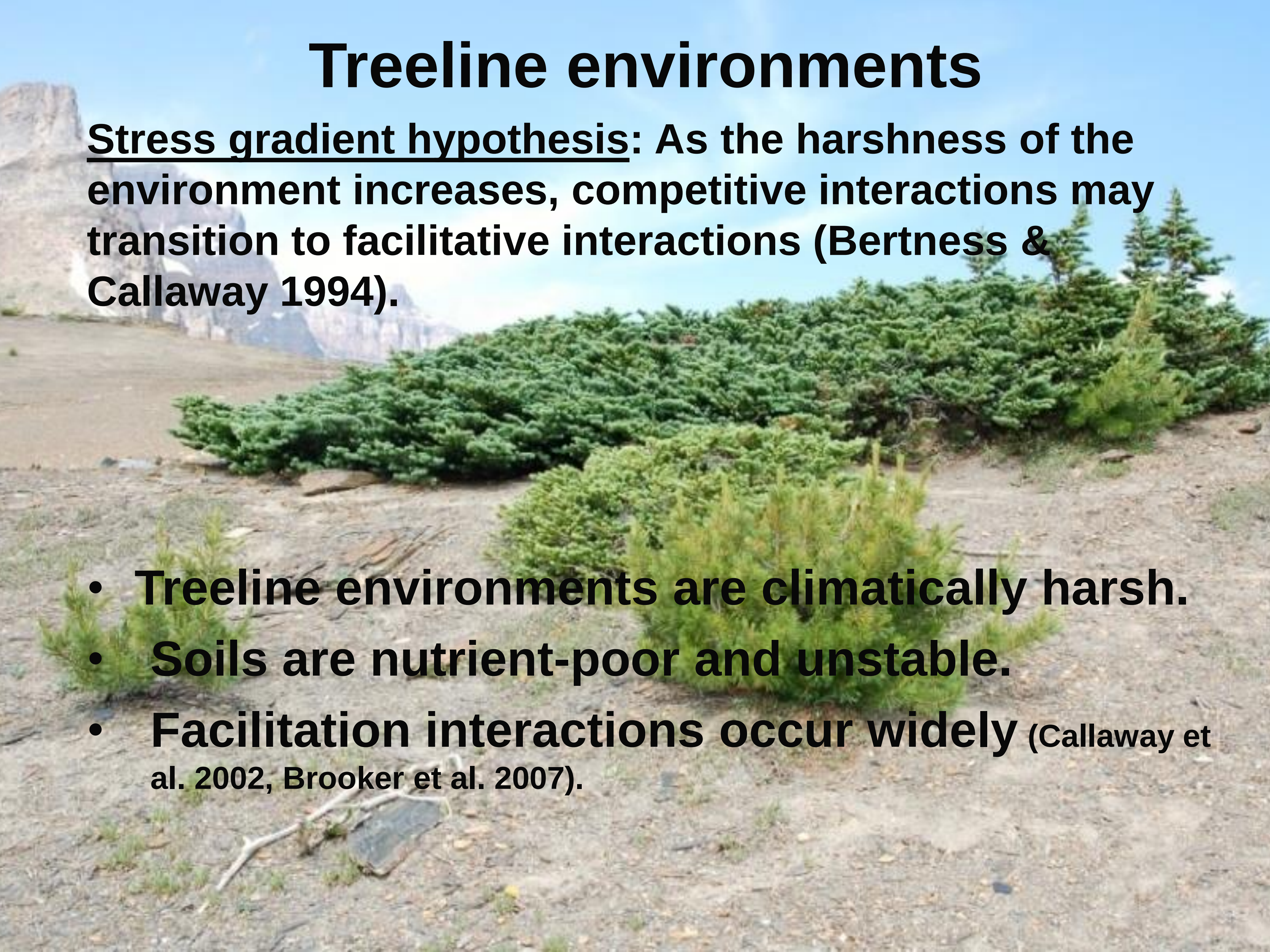


Willmore Wilderness Park, Alberta

Facilitation

- Facilitation is a positive interaction between two plants.
- The presence of one plant ("nurse plant") increases the probability of survival of the second.
- Facilitation leads to community development.

Facilitative interactions are important to plant survival and regeneration in stressful environments. (Bertness and Callaway 1994, Lortie *et al*. 2004, Brooker *et al.* 2008).



Treeline environments

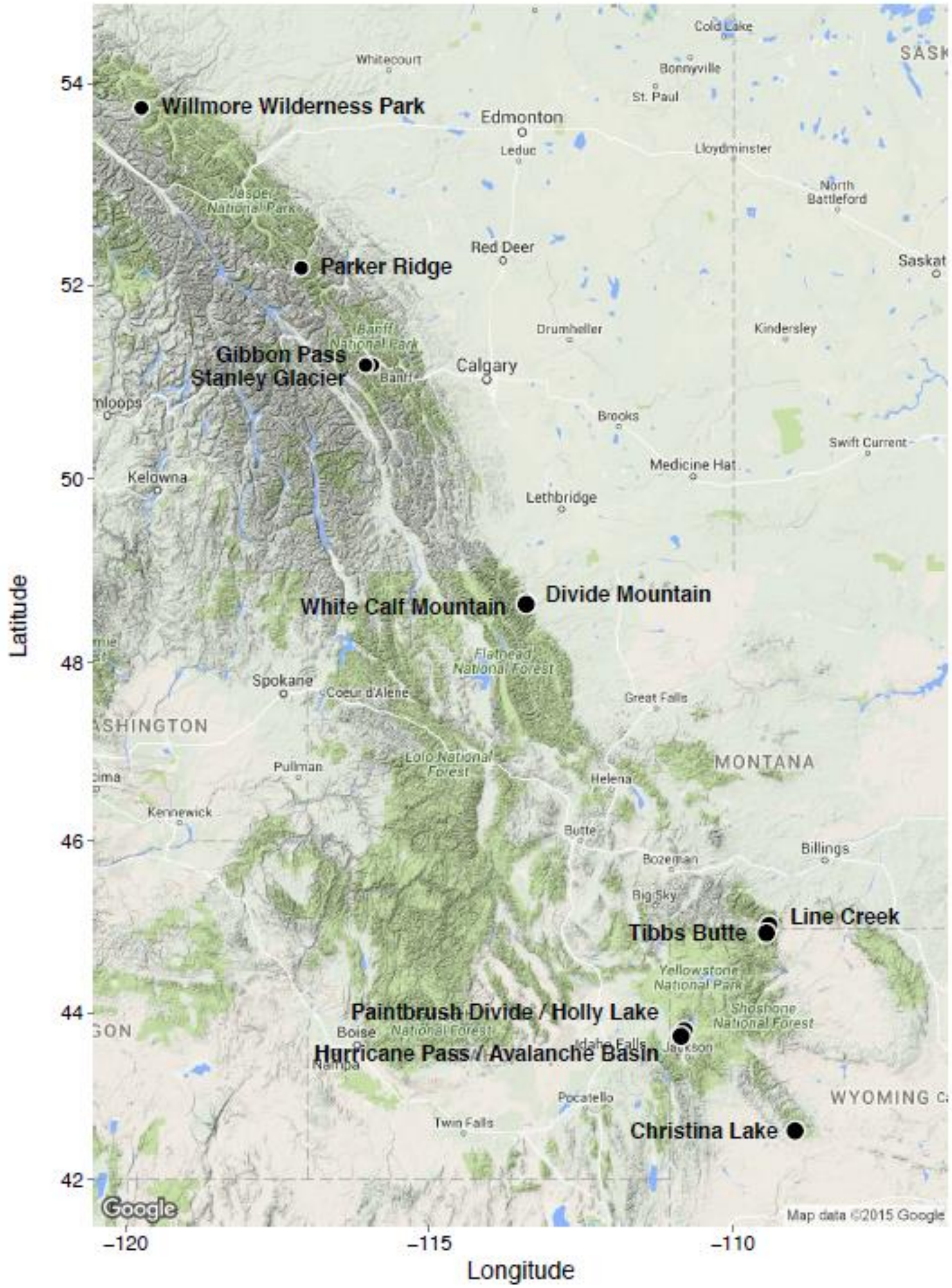
<u>Stress gradient hypothesis</u>: As the harshness of the environment increases, competitive interactions may transition to facilitative interactions (Bertness & Callaway 1994).

- **Treeline environments are climatically harsh.**
- **Soils are nutrient-poor and unstable.**
- **Facilitation interactions occur widely (Callaway et al. 2002, Brooker et al. 2007).**

In 2006, Lynn Resler and I discovered that whitebark pine functioned as a major “tree island initiator” or facilitator in treeline communities on the harsh, wind-swept eastern front of the Crown of the Continent, northern Rocky Mountains, U.S. (Resler and Tomback 2008)

- Confirmed with a more robust random sampling scheme. (Smith-McKenna et al. 2013)
- How common is whitebark pine function as initiator?

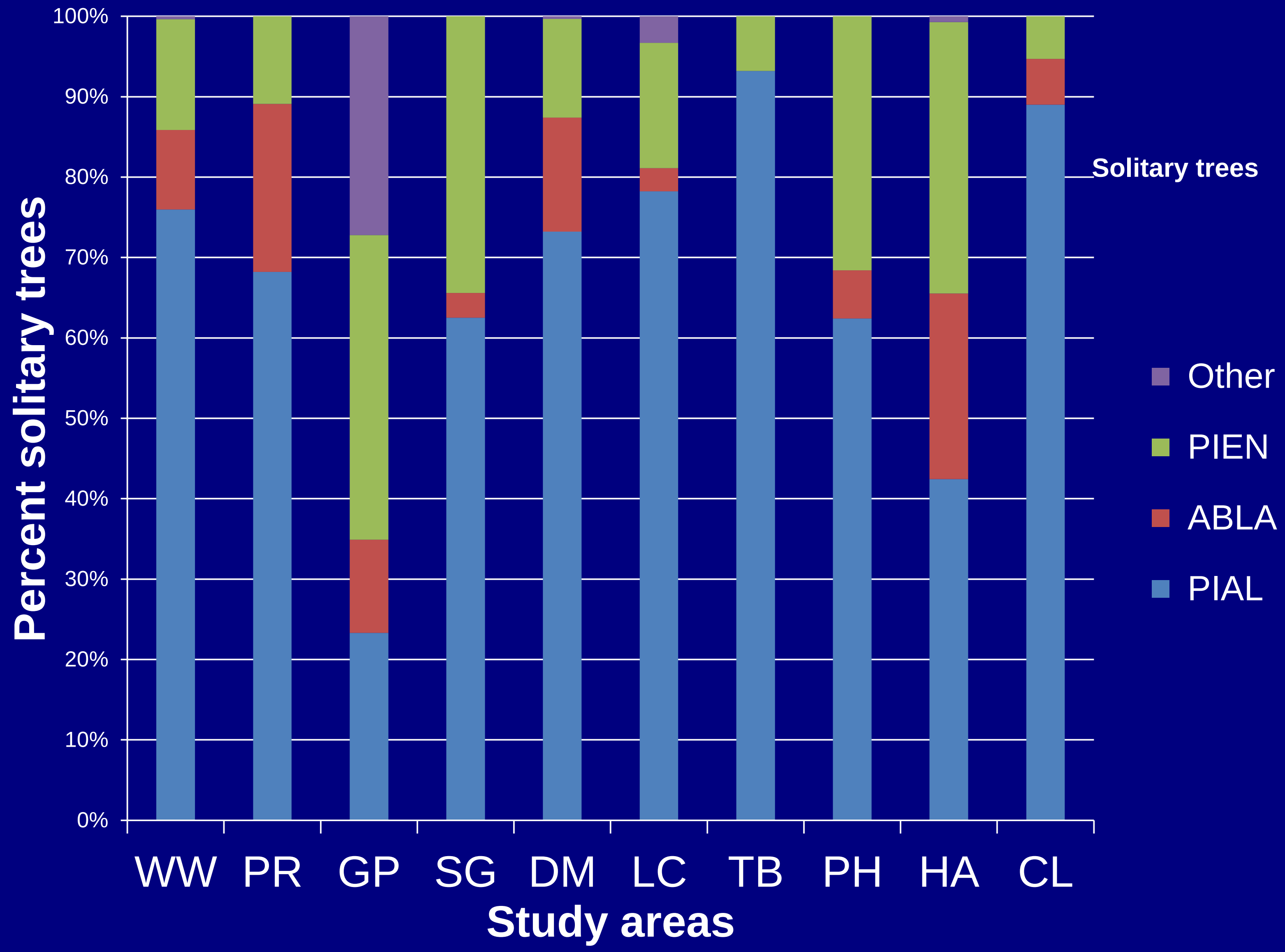
Divide Mountain, Blackfoot Indian Reservation, Montana



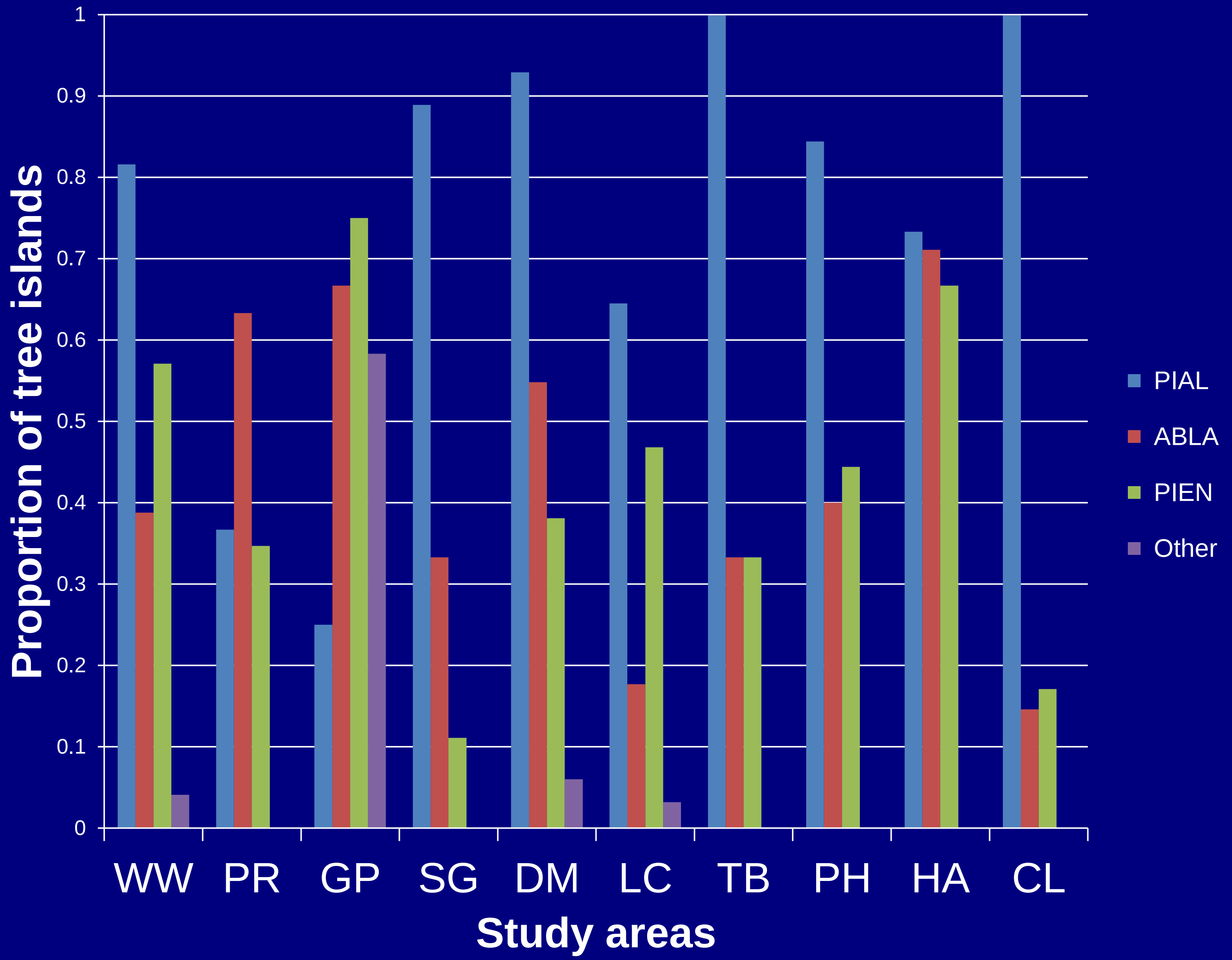
Willmore Wilderness Park
Parker Ridge
Gibbon Pass
Stanley Glacier
White Calf Mountain
Divide Mountain
Line Creek
Tibbs Butte
Paintbrush Divide / Holly Lake
Hurricane Pass / Avalanche Basin
Christina Lake
Edmonton
Calgary
Red Deer
Lethbridge
Medicine Hat
Spokane
Great Falls
Helena
Billings
Bozeman
Boise
Pocatello
Twin Falls
MONTANA
WYOMING
Latitude
Longitude
54
52
50
48
46
44
42
−120
−115
−110
Map data ©2015 Google

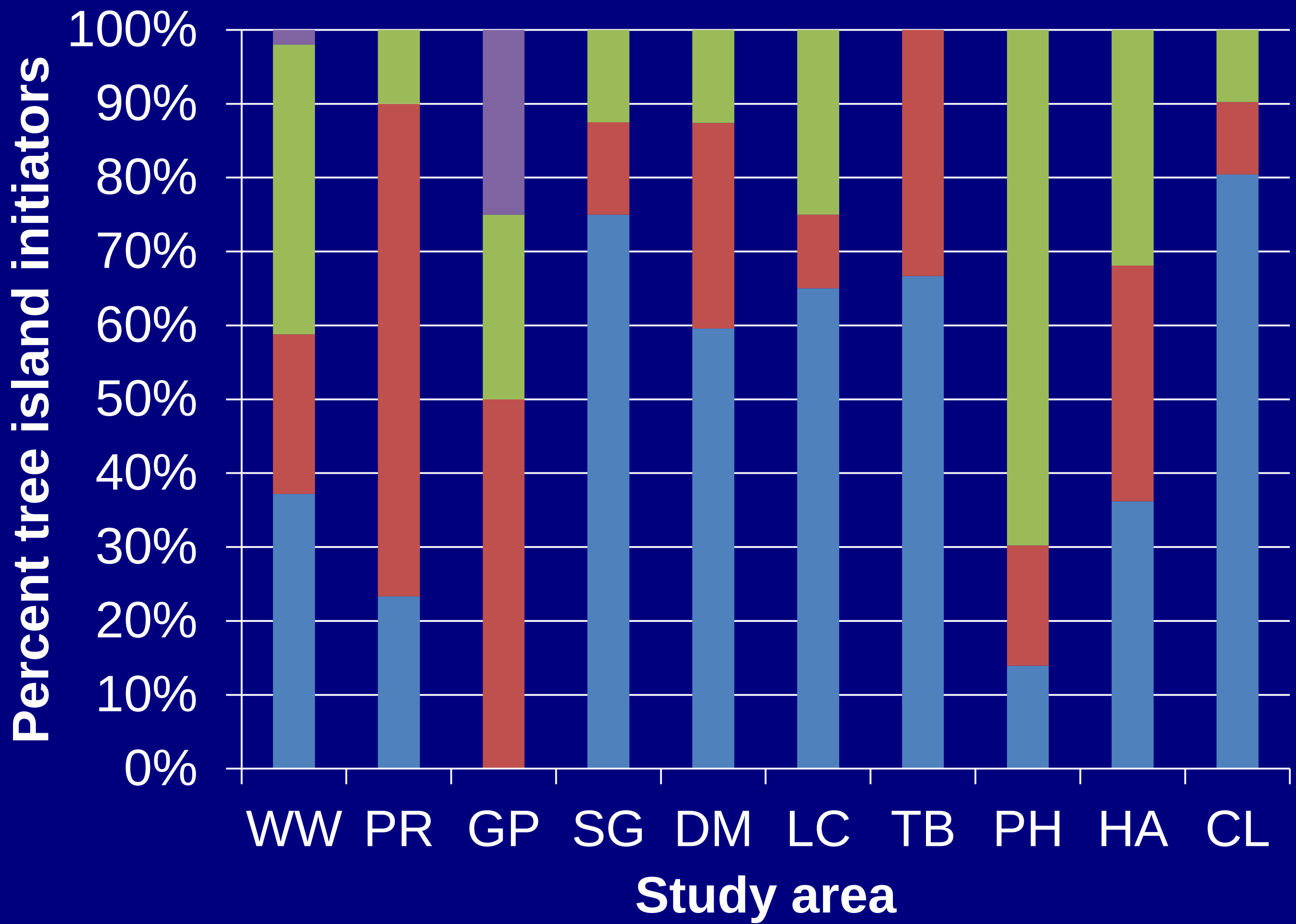
Study areas

Study Area	Latitude and Longitude	Elevation m	Aspect
Willmore Wilderness Park; **Alberta, Canada**	53°46′0″N; 19°44′22″W	1964–2175	SW, SE, E, NE
Parker Ridge Banff National Park; **Alberta, Canada**	52°10′44″N; 117°06′24″W	2100	NE, NW, S, SE, SW
Gibbon Pass; **Banff National Park, Alberta, Canada**	51°11′15″N; 115°56′12″W	2389–2430	SE, NE
Stanley Glacier; **Banff National Park, Alberta, Canada**	51°11′13″N; 116°02′51″W	1969–1997	SW, NW
Divide Mountain/White Calf Mountain; **Glacier National Park, Blackfeet Indian Reservation, MT**	48°39′25″N 113°23′45″W; 48°38′20″N; 113°24′08″W	1920–2272	NE, NW, W, SW
Line Creek; **Custer National Forest, MT**	45°01′47″N; 109°24′09″W	2950	NE
Tibbs Butte; **Shoshone National Forest, WY**	44°56′28″N; 109°26′39.69″W	2983–3238	E, NE
Paintbrush Divide/Holly Lake; **Grand Teton National Park, WY**	43°47′34″N; 110°47′54″W	3055–3289	NW, SW, NE
Hurricane Pass/Avalanche Basin; **Grand Teton National Park, WY**	43°43′41″N; 110°51′02″W	3045–3204	NW, SW, NE
Christina Lake; **Shoshone National Forest, WY**	42°35′35″N; 108°58′24″W	3200–3400	SW, SE, NE



Solitary trees
Percent solitary trees
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
WW
PR
GP
SG
DM
LC
TB
PH
HA
CL
Study areas
Other
PIEN
ABLA
PIAL


Proportion of tree islands
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
WW
PR
GP
SG
DM
LC
TB
PH
HA
CL
Study areas
PIAL
ABLA
PIEN
Other



Percent tree island initiators
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
WW
PR
GP
SG
DM
LC
TB
PH
HA
CL
Study area

Solitary tree occurrence and tree island initiation

- The proportional abundance of whitebark pine among solitary trees predicted its proportional occurrence as a tree island initiator:

F = 8.724, r = 0.722, R^2 =0.533, df = 8, P = 0.018.

- The relationship was *not* as strong for subalpine fir:

F = 5.192, r = 0.627, R^2 = 0.3936, df = 8, P = 0.0522

- Or Engelmann spruce

F = 2.645, r = 0.498, R^2 = 0.2485, df = 8, P = 0.143

Ecological functions

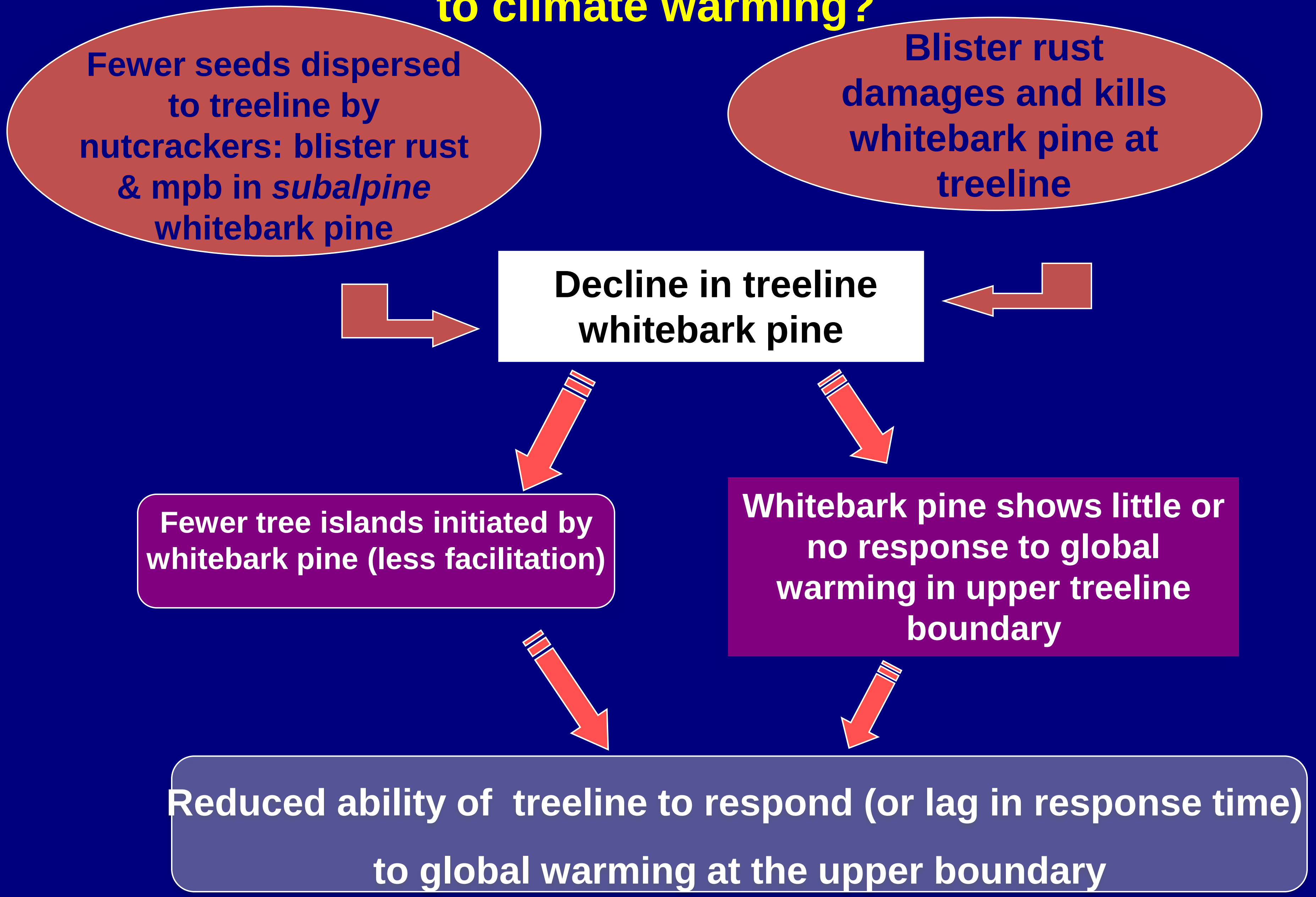
Our studies indicated that whitebark pine:

- Was the majority solitary tree in most treeline communities.
- Had the highest proportional occurrence among tree islands in most study areas.
- Was the majority tree island initiator in half the communities examined.

Blister rust at treeline

Location	Infection Incidence
Glacier National Park: Divide Mountain and Lee Ridge	33.7% multiple symptoms; 24.3% confirmed cankered; (Resler and Tomback 2008)
Willmore Wilderness Park	1.1% (confirmed cankers) (Tomback et al., in prep)
Glacier National Park, 6 study areas	47% (0%–100% per plot) (Smith et al. 2011)
Divide Mountain; Line Creek	23.6% (confirmed cankers); 19.2% (confirmed cankers) (Smith-McKenna et al. 2013)
Gibbon Pass; Stanley Glacier; Tibbs Butte	16.2% (multiple symptoms); 10.8% (confirmed cankers); 0% (on transects; presence off transects) (Tomback et al. 2016)
Paintbrush Divide/Holly Lake; Hurricane Pass/Avalanche	17.2%; 14.9% (Tomback et al. 2016)
Christina Lake	<10% (Tomback et al. 2016)

Will declines in whitebark pine alter treeline response to climate warming?



ABM, assumptions

Basic model (Smith-McKenna et al. 2014, *Environmental Modelling & Software*), Netlogo (v. 5.3.1) software

- **Agents**: stems and branches, whitebark (green) and spruce/fir (blue), dead stems and branches (black).
- **BR infected pine**: whitebark (red)
- **Spatially explicit grid**: 101 x 101 cells, each cell is $1m^2$.
- **Simulated Divide Mountain landscape**.
- **Non-conifer cells**: tundra.
- **Site quality**: decreases non-linearly with Y axis.
- **Facilitation:** Positive from rocks initially for seedling establishment and adjacent tree agents (4 cells+).
- **Time step**: one growing year, run for 300 years to achieve baseline, then 301 to 500 years.

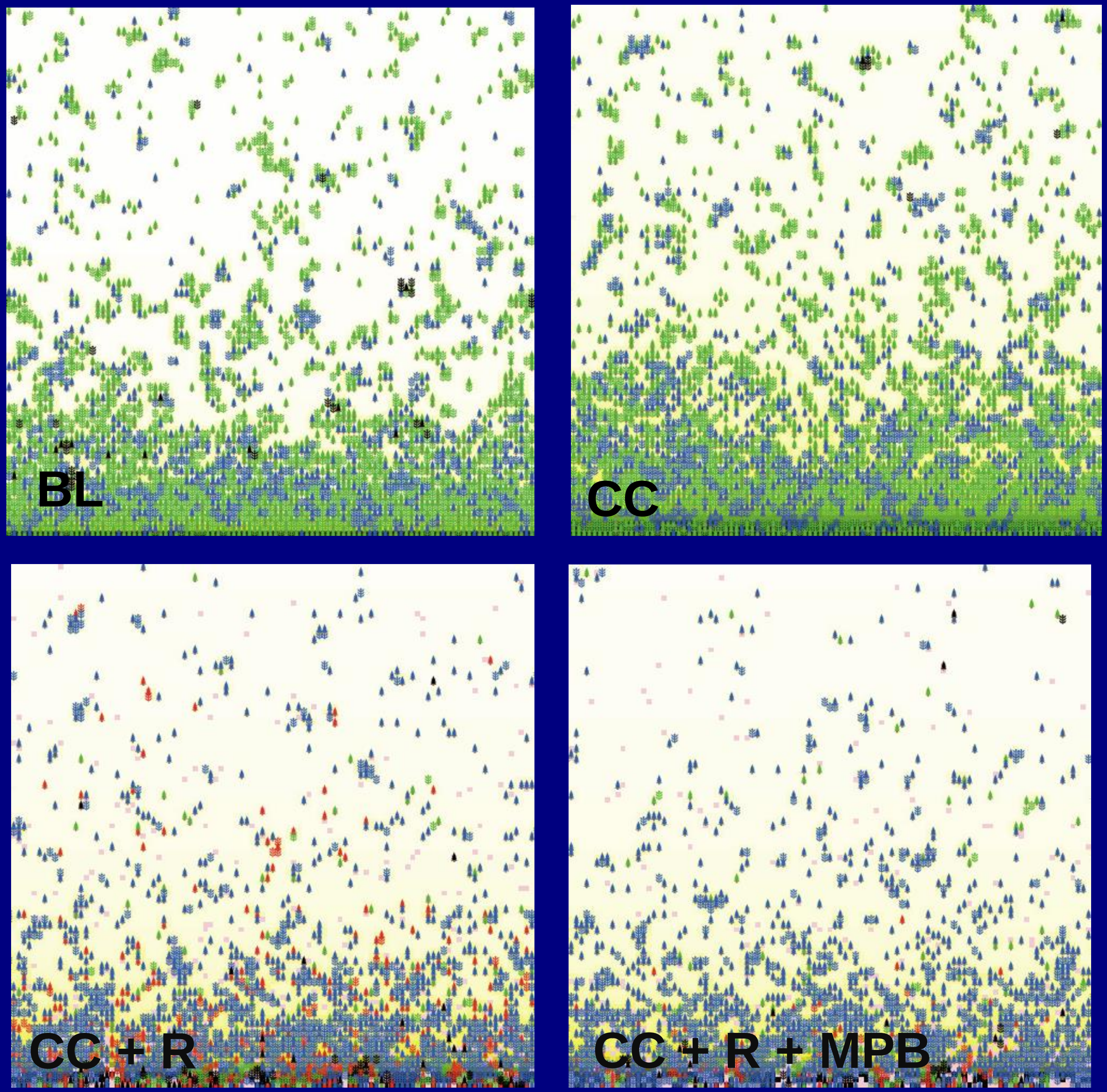
Environment and population dynamics computed stochastically.

Scenarios

Whitebark pine seed production in highest quality environment, at bottom of grid.

1. **Baseline BL** generates treeline community structure calibrated by field sampling.
2. **Climate change CC**, the environmental quality of each cell is increased by 1.005 in years 301-500.
3. **Rust R (+ CC),** infection rate increases with climate change. Multiplied by 1.005 every year in years 301-500. Kills branches and trees.
4. **MPB (+ R +CC)** doubles the mortality rate of whitebark pine seed source.

(Malanson et al., in prep.)


BL
CC
CC + R
CC + R + MPB

Conclusions

- Treeline communities provide ecosystem services related to snow retention, regulation of downstream flows, and water quality.
- Whitebark pine is an important component of Rocky Mountain treeline communities.
- In some communities, whitebark pine functions as majority tree island initiator.
- White pine blister rust (WPBR) is present in all treeline communities.
- WPBR has the potential to alter community development, ecosystem services, and also response to climate change.
- Loss of seed production to WPBR and mountain pine beetle further exacerbate these effects.
- **The potential benefits of restoration plantings of WPBR-resistant seedlings at treeline should be evaluated.**

ACKNOWLEDGMENTS

Logistics:

Glacier National Park (thanks to Tara Carolin)
Blackfeet Nation (thanks to Mark Magee)
Shoshone and Custer National Forests (thanks to Ken Houston)
Rocky Mountain Research Station, Ft. Collins
Banff National Park (Parks Canada)
Alberta Provincial Parks (thanks to Joyce Gould)
University of Alberta (thanks to Ellen Macdonald)

We thank:

Emily Smith-McKenna
Jill Pyatt
Sarah Blakeslee
Aaron Wagner

Financial Support:

National Science Foundation:
NSF BCS-0850548