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

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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

U.S. Forest Service, Forest Health Protection
Whitebark pine

Average percent blister rust infection across each region
Mountain pine beetle
Mortality from MPB, through 2007, USA

Gibson et al. 2008

Whitebark pine
~1.8 million acres

Legend
- Mortality
- Species Range

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

Barringer et al. 2012


Proportion hours with nutcrackers

Cone density (no./ha)
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 dispersal

- 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

Stress gradient hypothesis: 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?
## Study areas

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

Study areas

PIAL  ABLA  PIEN  Other
Percent tree island initiators

Study area

WW  PR  GP  SG  DM  LC  TB  PH  HA  CL
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

<table>
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<th>Location</th>
<th>Infection Incidence</th>
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<tbody>
<tr>
<td><strong>Glacier National Park: Divide Mountain and Lee Ridge</strong></td>
<td>33.7% multiple symptoms; 24.3% confirmed cankered; (Resler and Tomback 2008)</td>
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<tr>
<td><strong>Willmore Wilderness Park</strong></td>
<td>1.1% (confirmed cankers) (Tomback et al., in prep)</td>
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<tr>
<td><strong>Glacier National Park, 6 study areas</strong></td>
<td>47% (0%–100% per plot) (Smith et al. 2011)</td>
</tr>
<tr>
<td><strong>Divide Mountain; Line Creek</strong></td>
<td>23.6% (confirmed cankers); 19.2% (confirmed cankers) (Smith-McKenna et al. 2013)</td>
</tr>
<tr>
<td><strong>Gibbon Pass; Stanley Glacier; Tibbs Butte</strong></td>
<td>16.2% (multiple symptoms); 10.8% (confirmed cankers); 0% (on transects; presence off transects) (Tomback et al. 2016)</td>
</tr>
<tr>
<td><strong>Paintbrush Divide/Holly Lake; Hurricane Pass/Avalanche</strong></td>
<td>17.2%; 14.9% (Tomback et al. 2016)</td>
</tr>
<tr>
<td><strong>Christina Lake</strong></td>
<td>&lt;10% (Tomback et al. 2016)</td>
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Will declines in whitebark pine alter treeline response to climate warming?

- Fewer seeds dispersed to treeline by nutcrackers: blister rust & mpb in subalpine whitebark pine
- Blister rust damages and kills whitebark pine at treeline
- Decline in treeline whitebark pine
- Fewer tree islands initiated by whitebark pine (less facilitation)
- Whitebark pine shows little or no response to global warming in upper treeline boundary
- Reduced ability of treeline to respond (or lag in response time) to global warming at the upper boundary
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 1m².
- **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.)
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.
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