

Refugia from drought and mountain pine beetle in a whitebark and lodgepole pine ecosystem



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Photo by Tim Gage

Topographically complex terrain creates varied microclimates and increases the likelihood that current climates will continue to exist nearby.

Deep snow drifts provide insulation to the surface below and provide water later in the season.

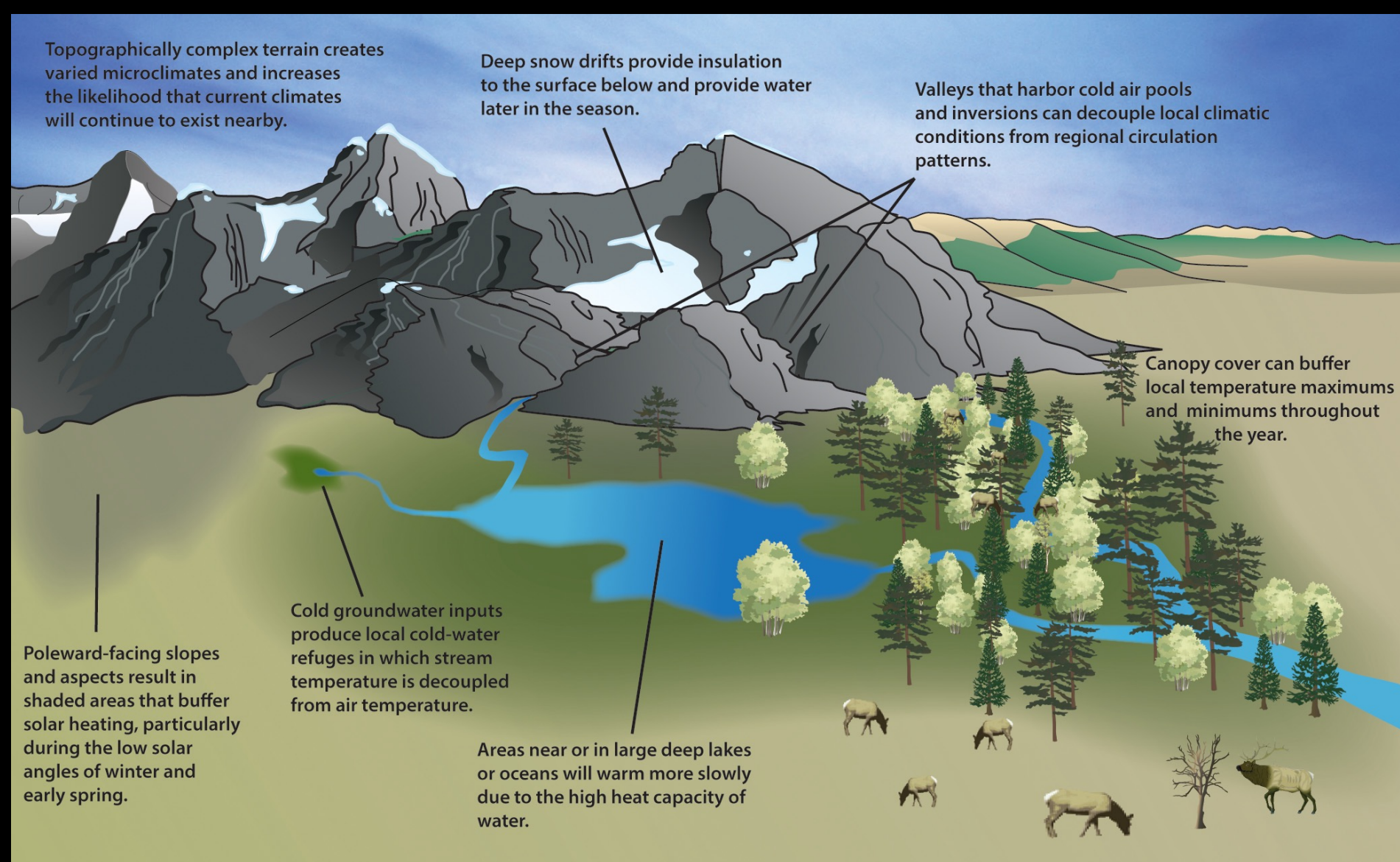
Valleys that harbor cold air pools and inversions can decouple local climatic conditions from regional circulation patterns.

Canopy cover can buffer local temperature maximums and minimums throughout the year.

Cold groundwater inputs produce local cold-water refuges in which stream temperature is decoupled from air temperature.

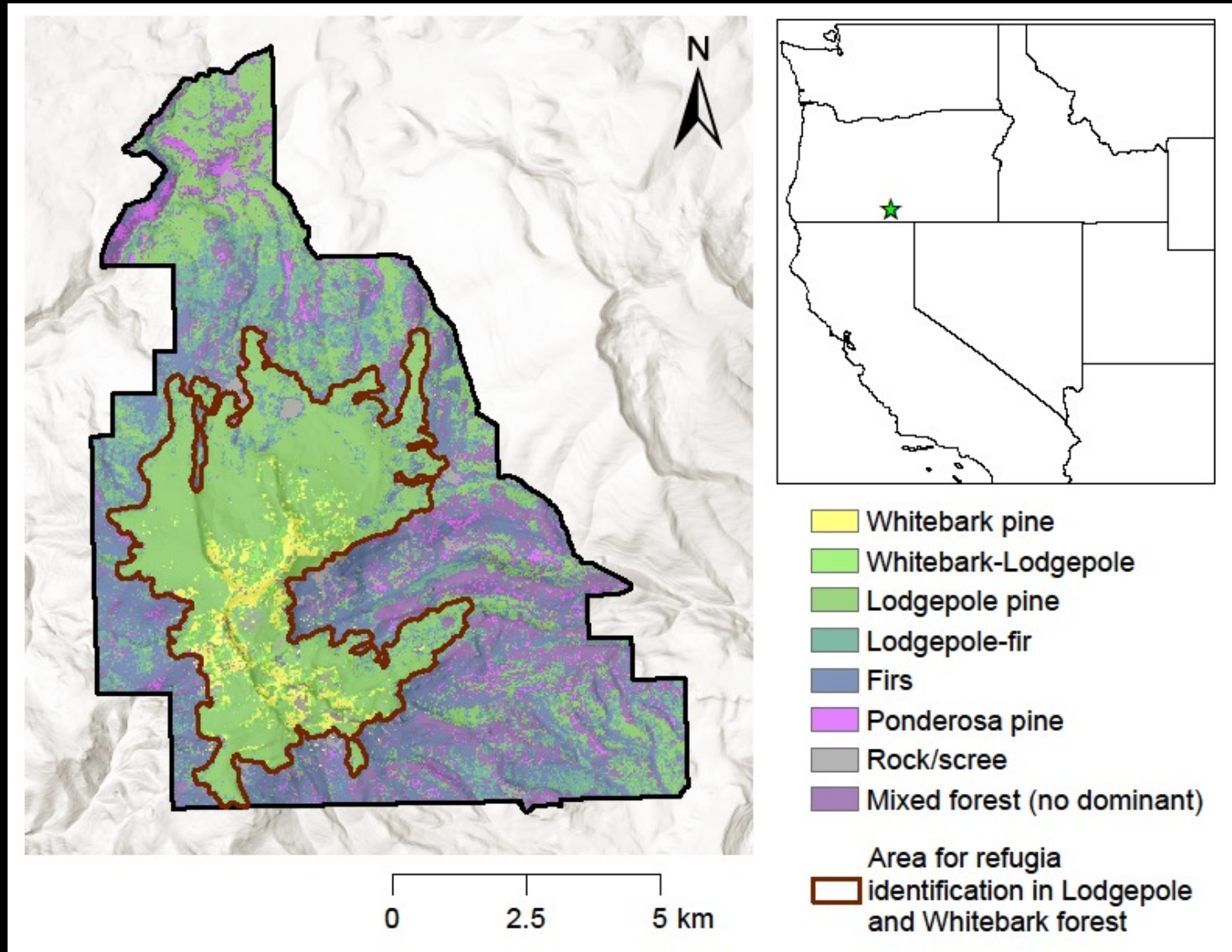
Poleward-facing slopes and aspects result in shaded areas that buffer solar heating, particularly during the low solar angles of winter and early spring.

Areas near or in large deep lakes or oceans will warm more slowly due to the high heat capacity of water.

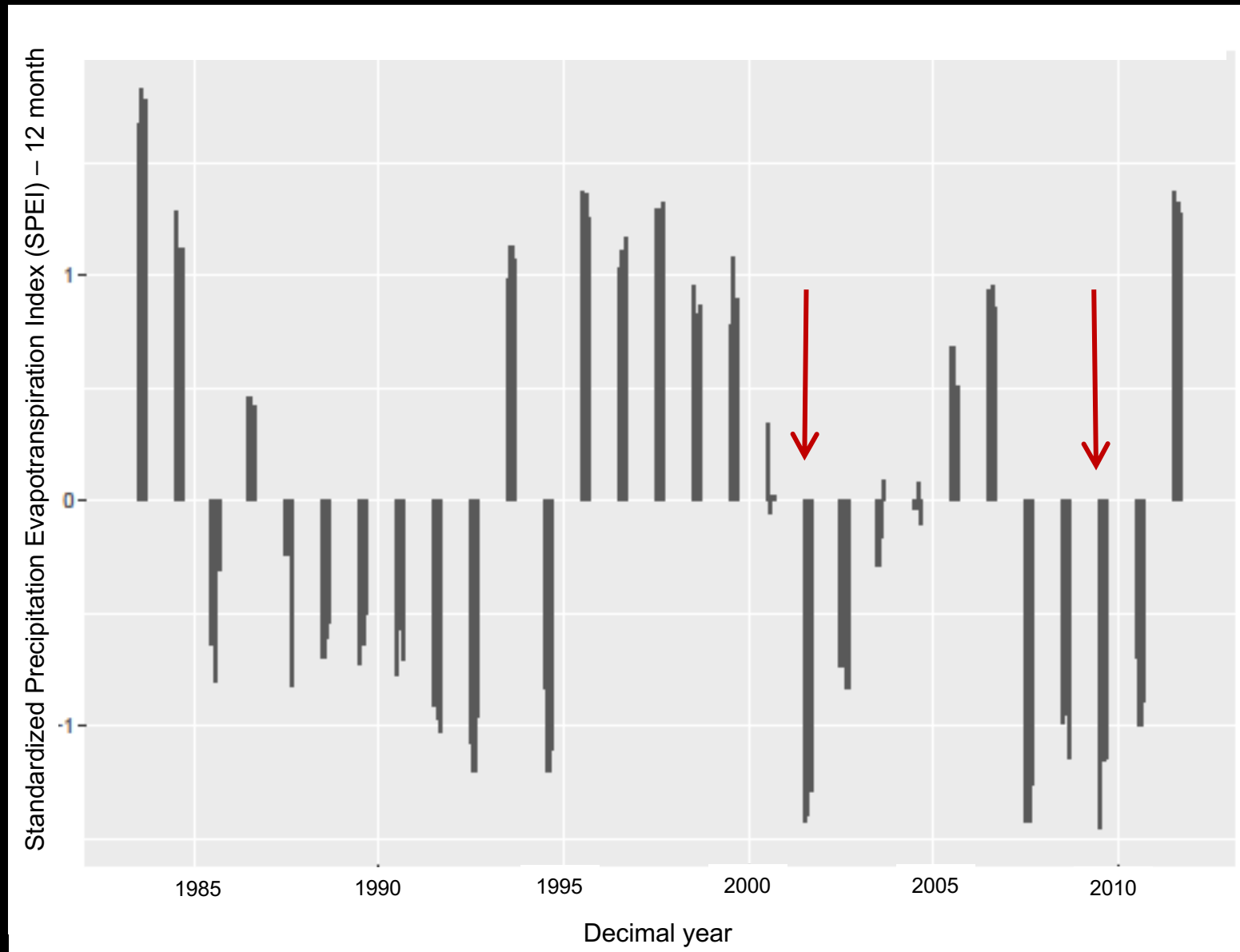


Morelli TL, Daly C, Dobrowski SZ, Dulen DM, Ebersole JL, Jackson ST, et al. (2016) Managing Climate Change Refugia for Climate Adaptation. PLoS ONE 11(8): e0159909.

Study area: Gearhart Mountain Wilderness in southern Oregon



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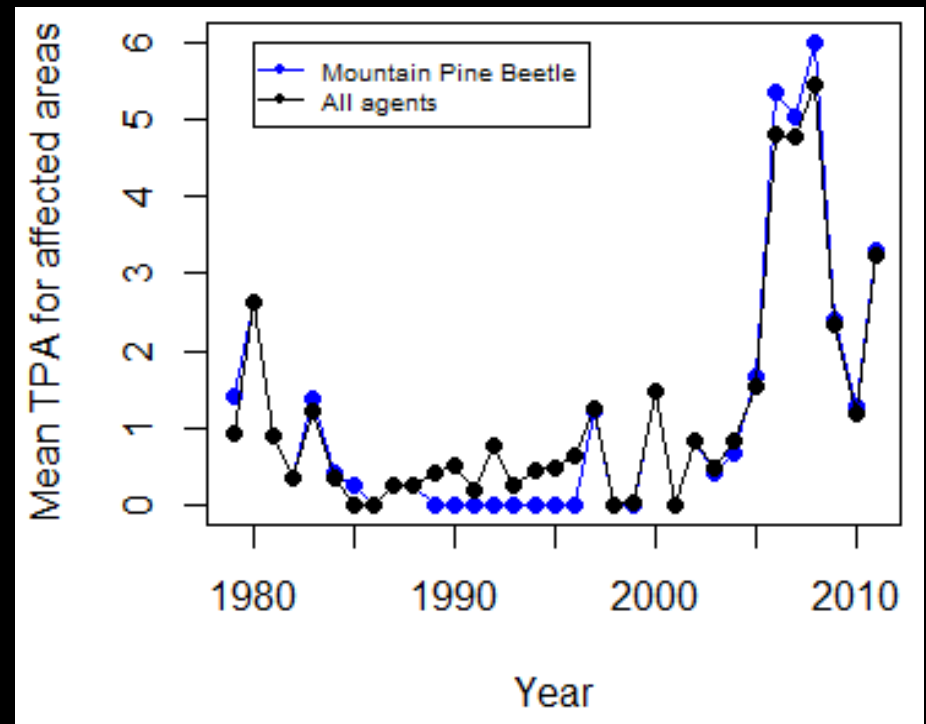
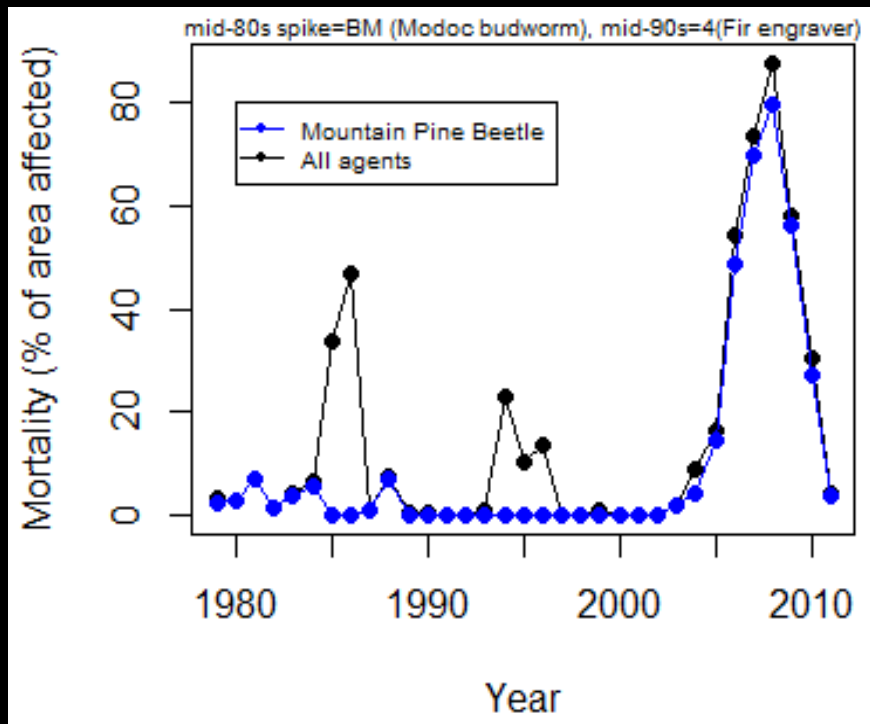
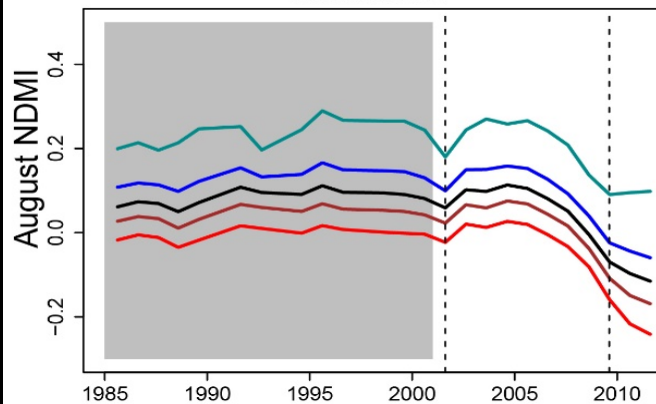
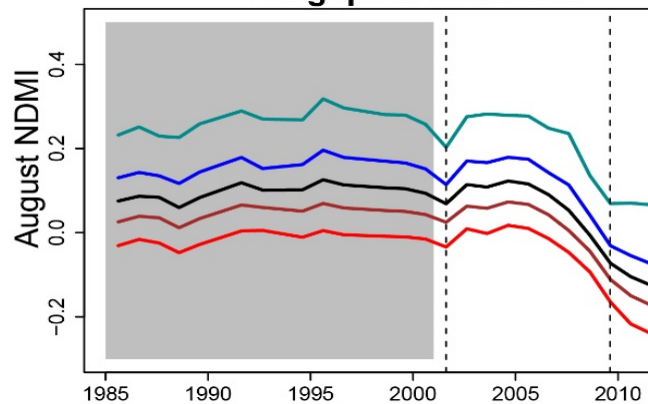
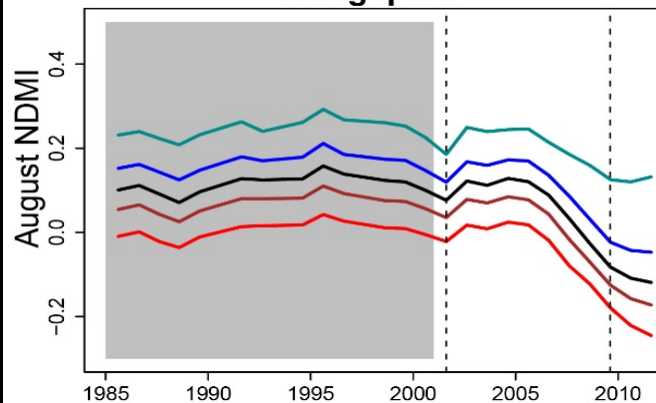
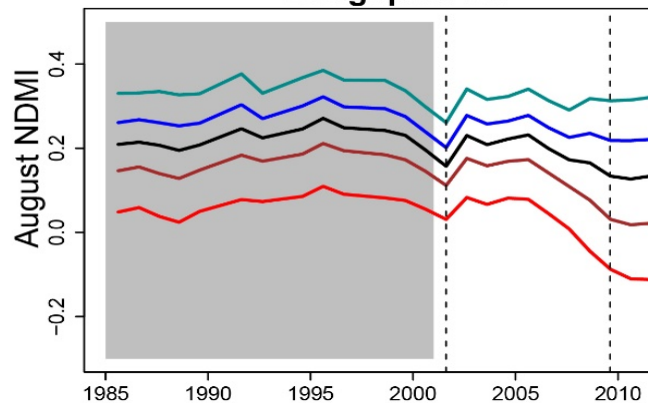
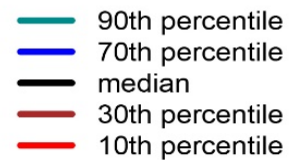
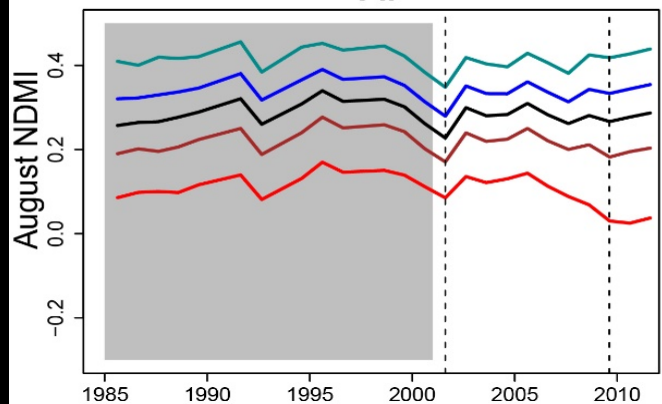
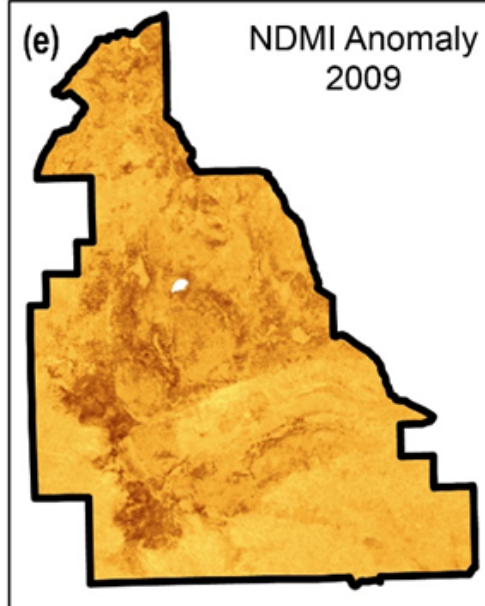
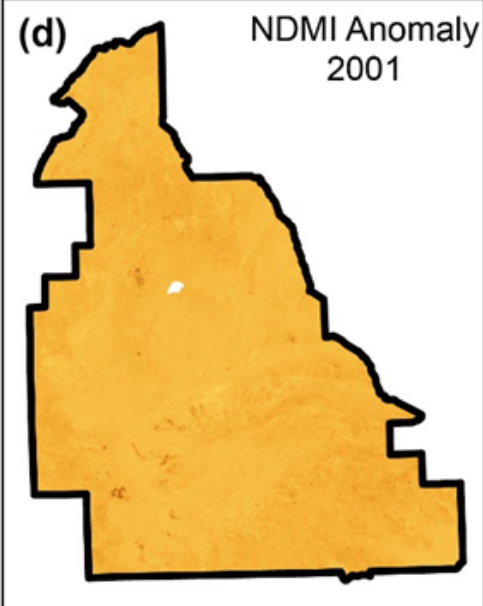
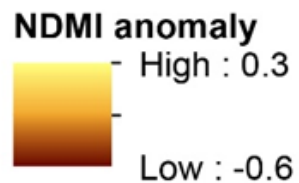
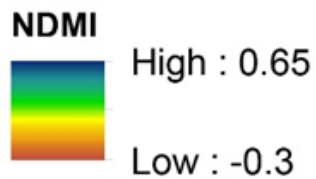
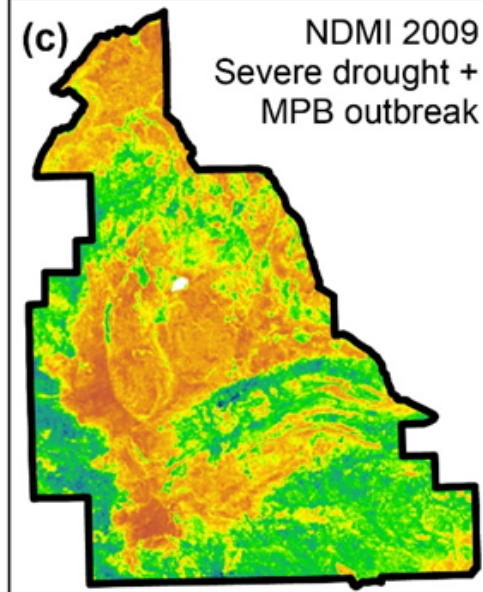
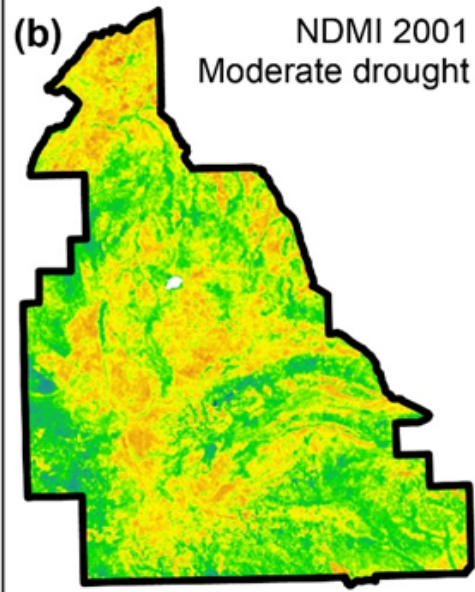
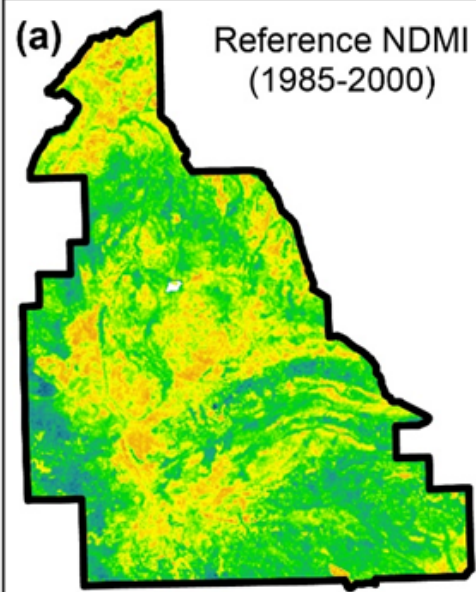


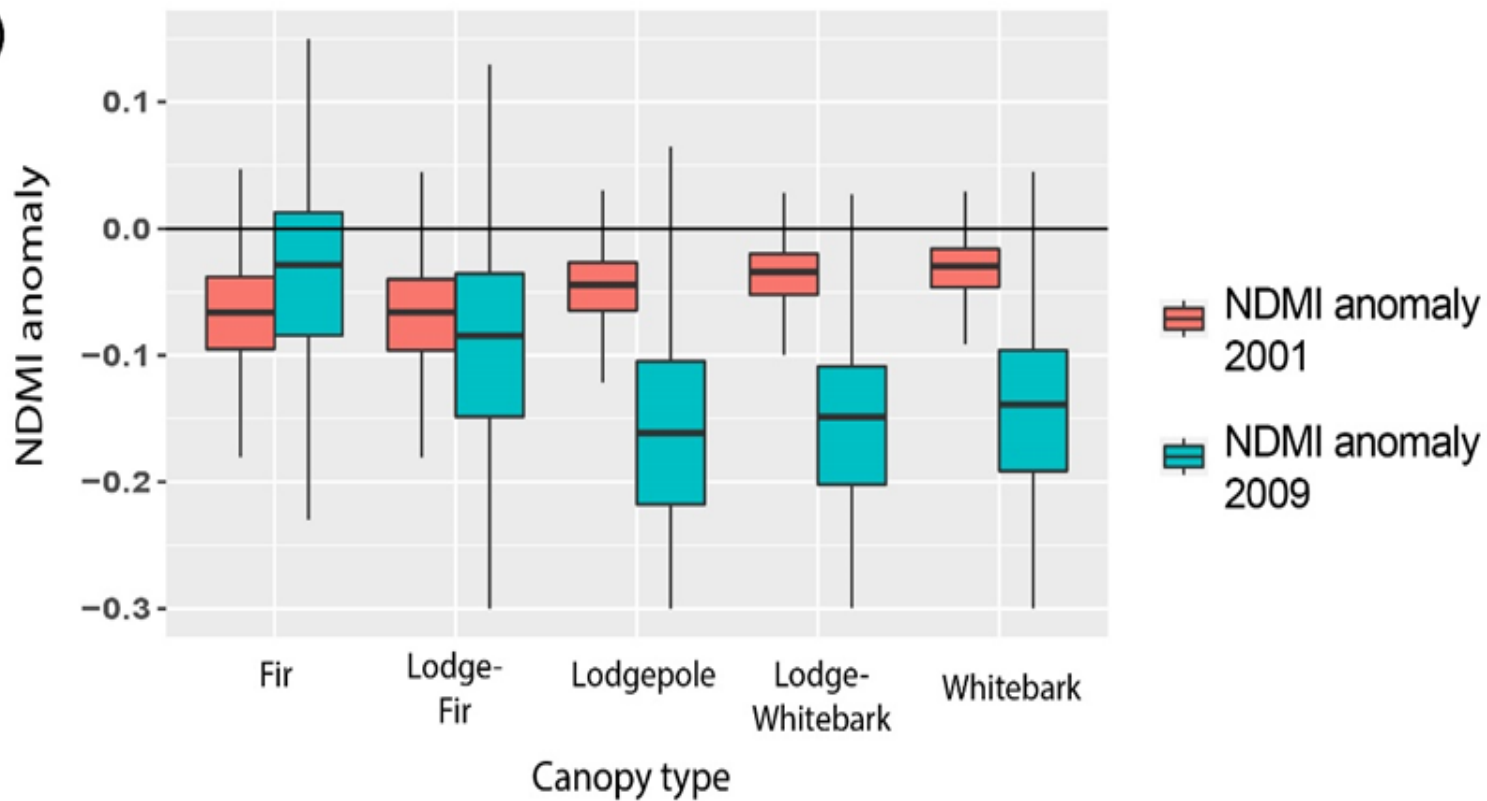


Photo by Michael McCullough

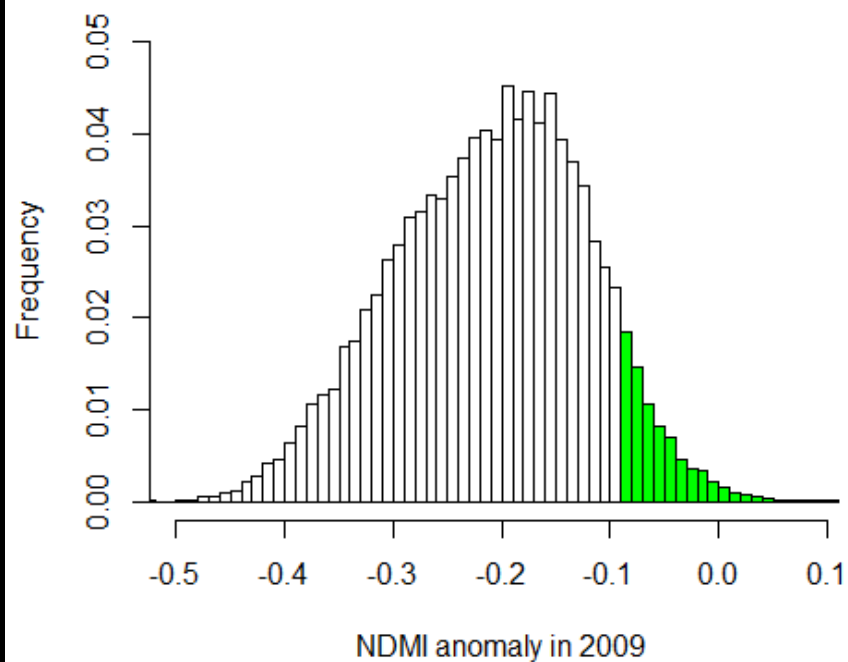
Whitebark**Lodgepole-Whitebark****Lodgepole****Lodgepole-Fir****Fir**



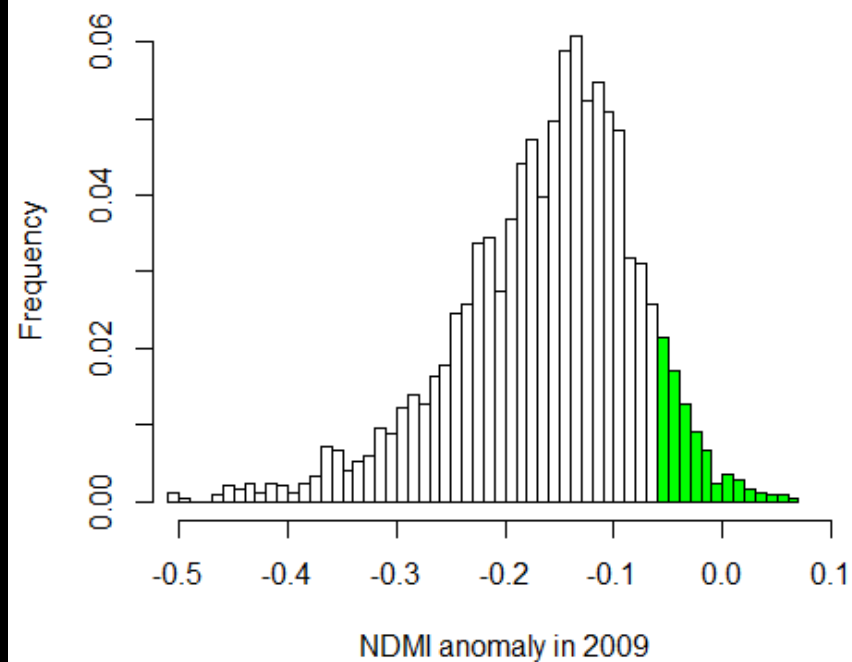
(f)



Lodgepole pine

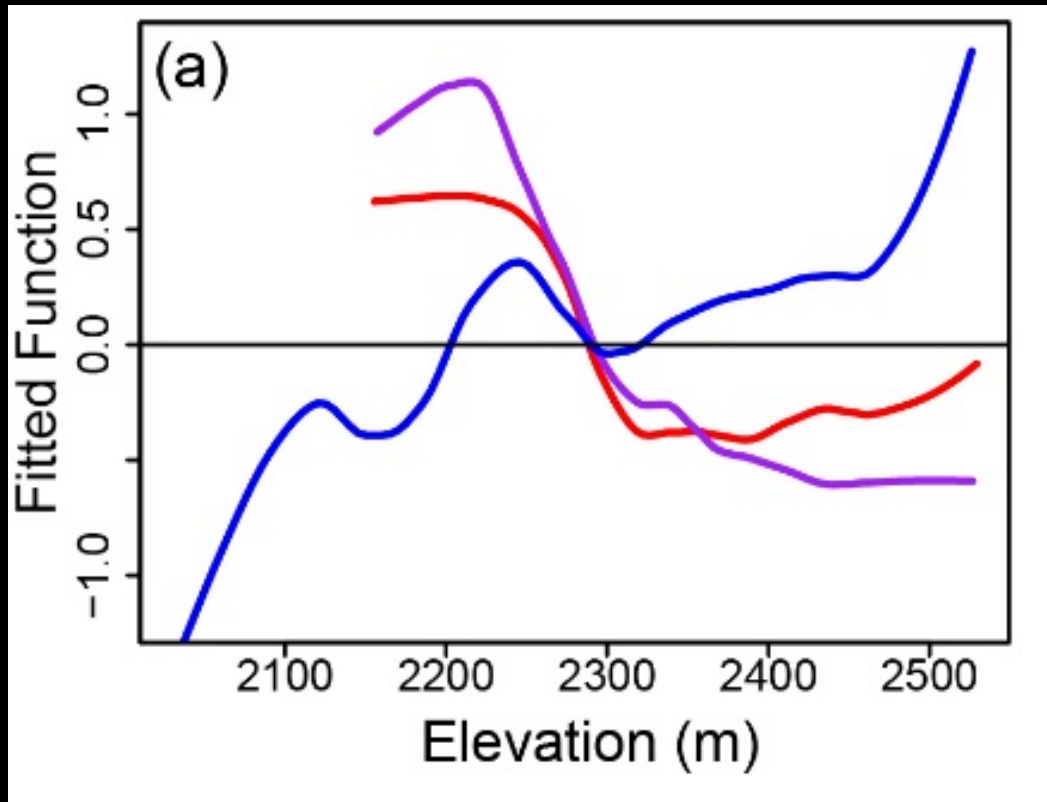


Whitebark pine



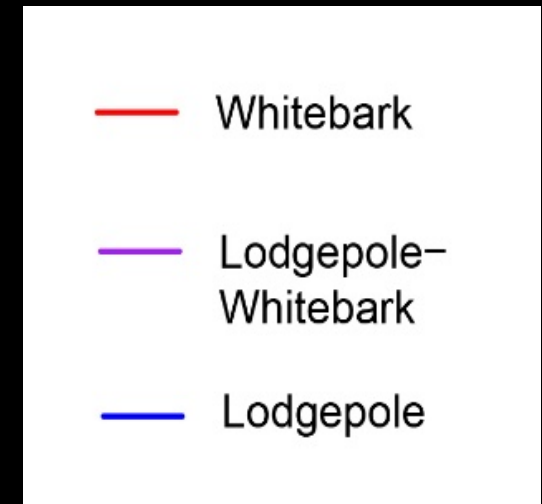
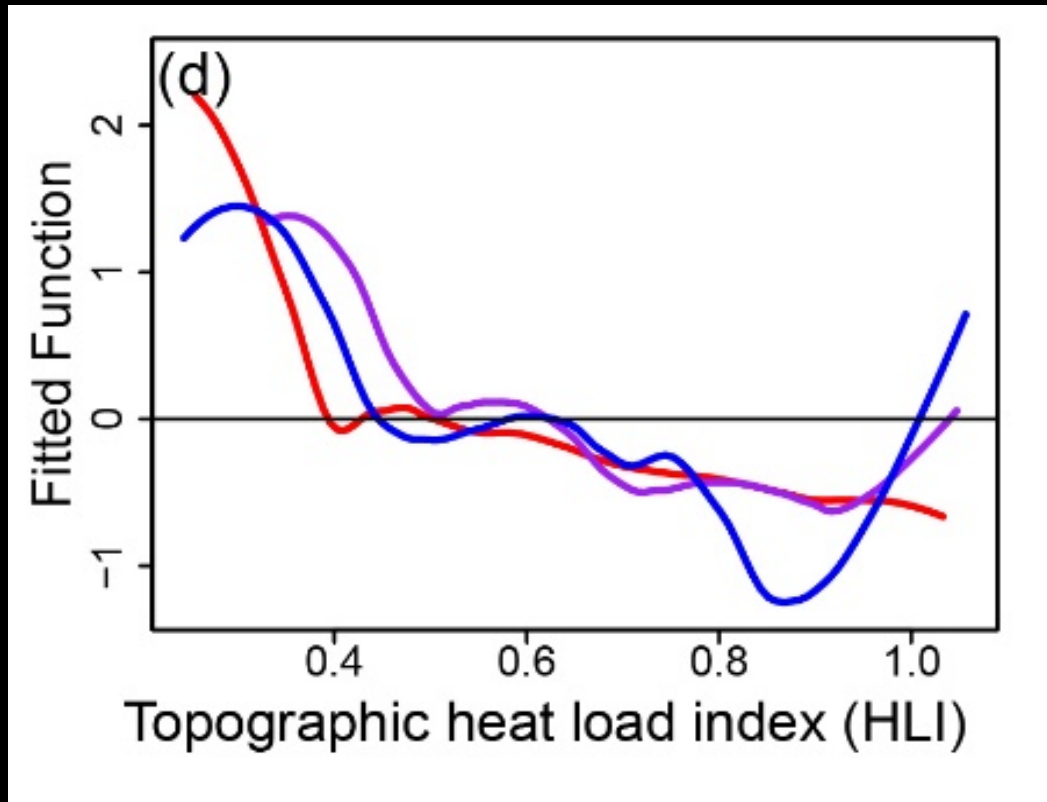
Elevation

Hypothesis: more refugia at higher elevations



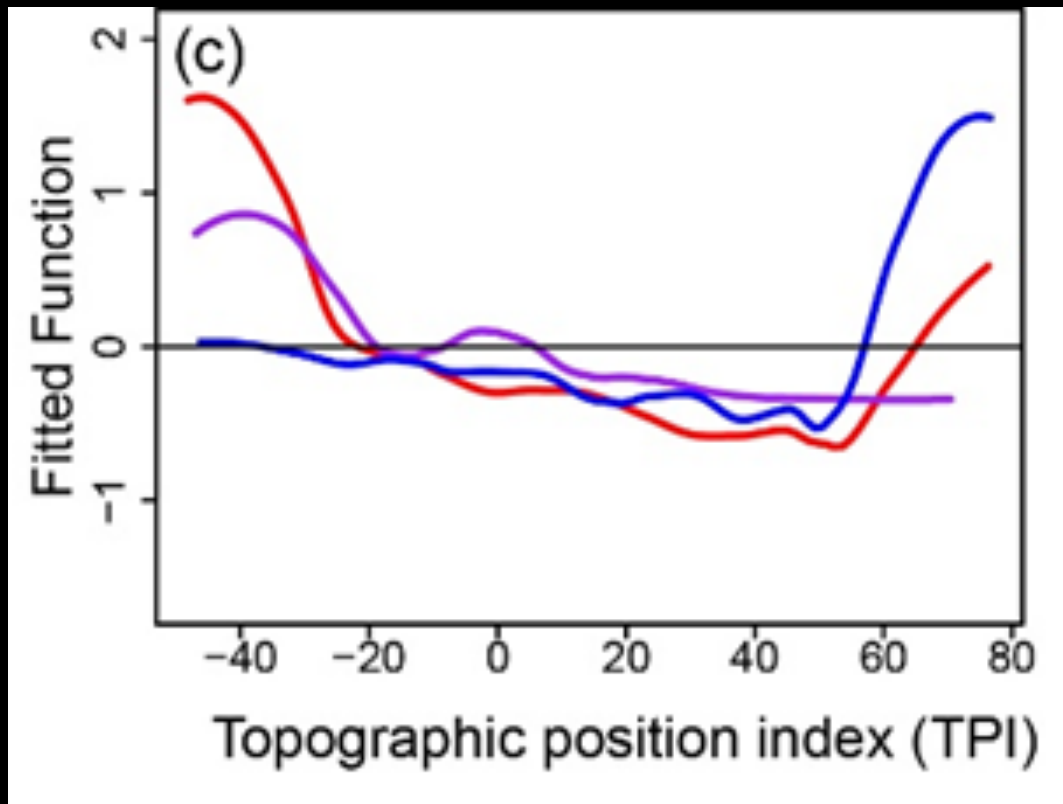
Topographic heat load

Hypothesis: more refugia on shaded slopes



Topographic position index

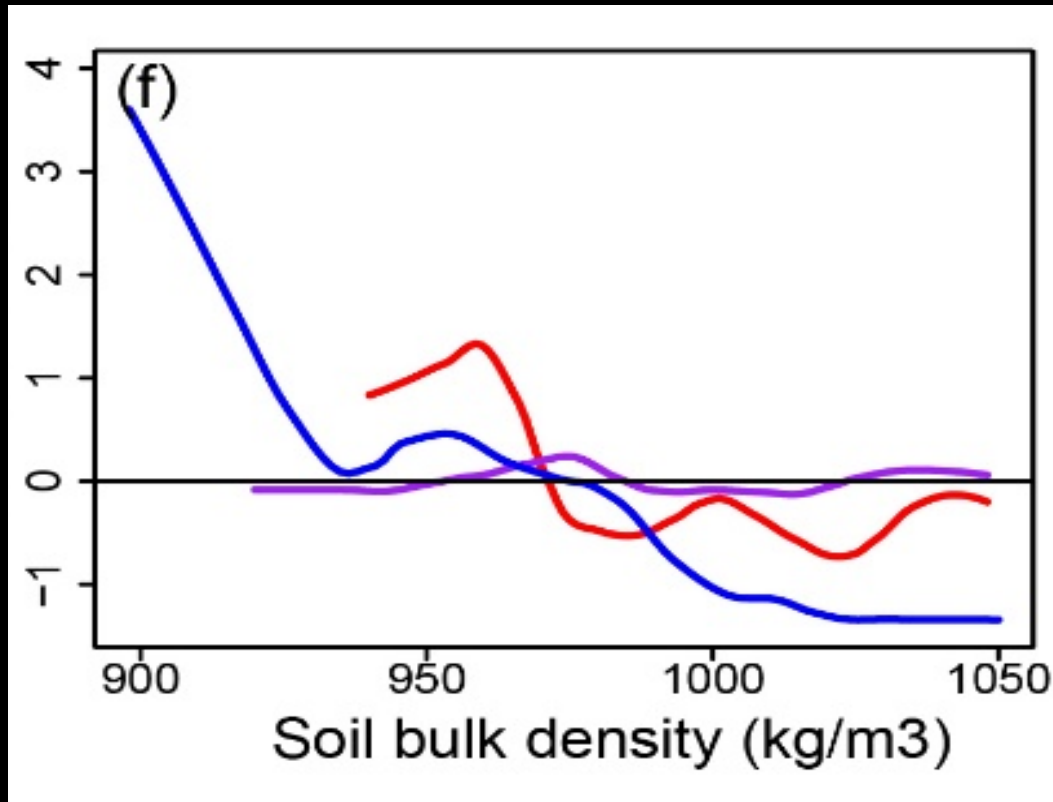
Hypothesis: more refugia at low TPI (valleys)



- Whitebark
- Lodgepole-Whitebark
- Lodgepole

Soil bulk density

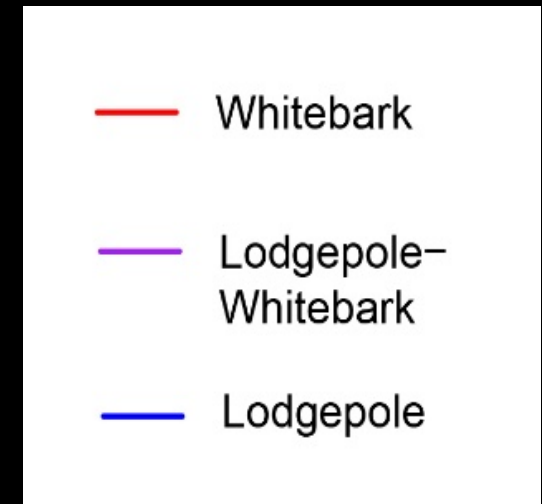
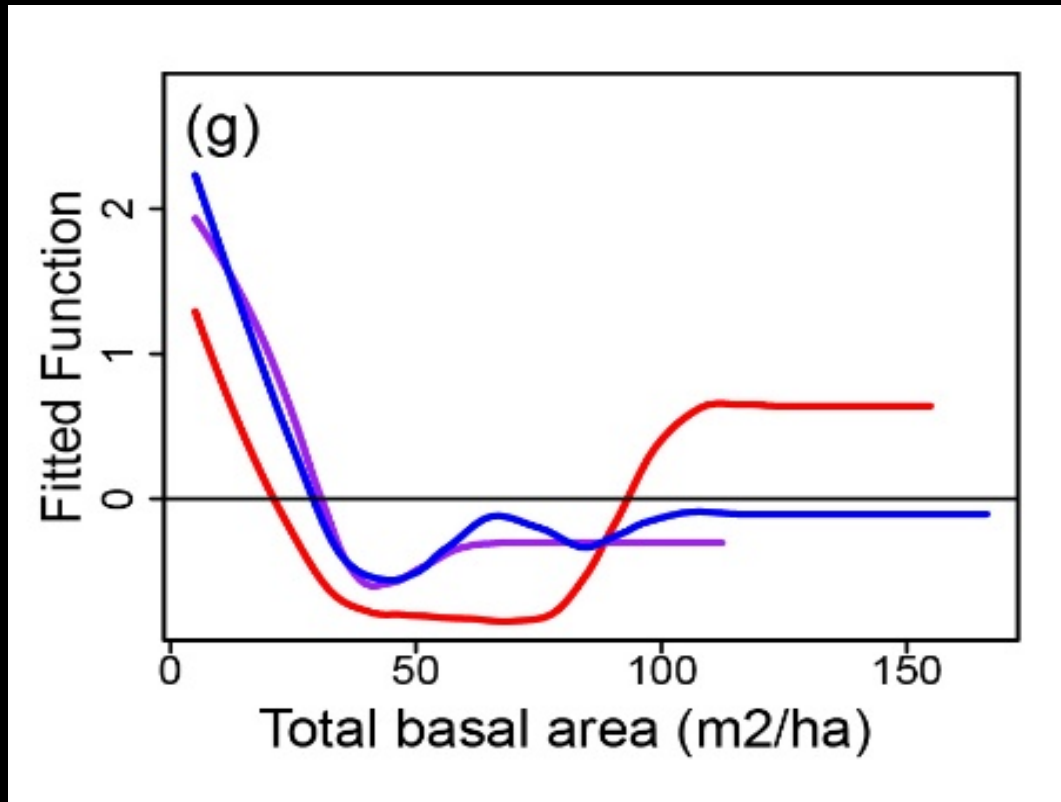
Hypothesis: more refugia in less dense soil



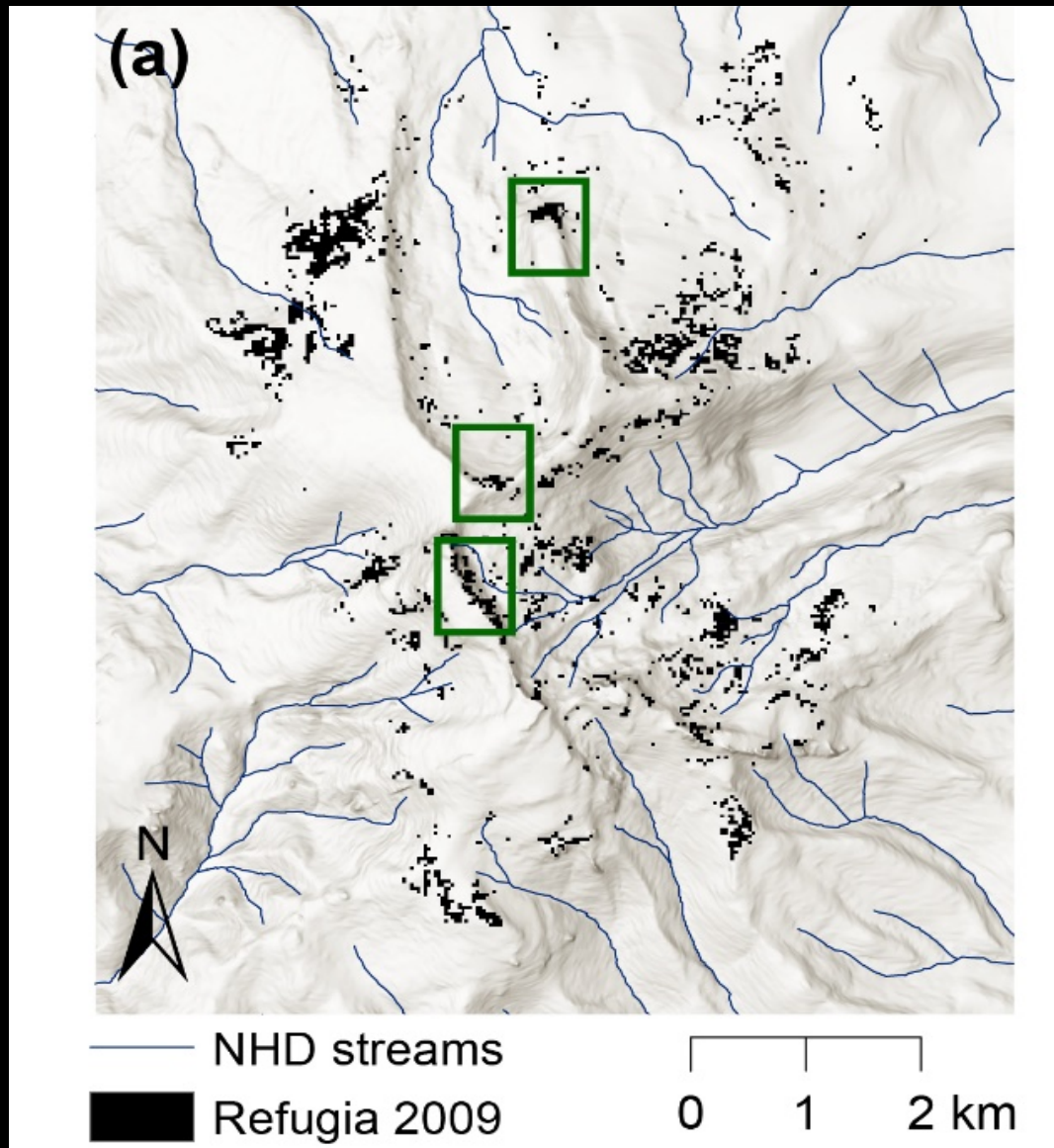
- Whitebark
- Lodgepole-Whitebark
- Lodgepole

Forest density

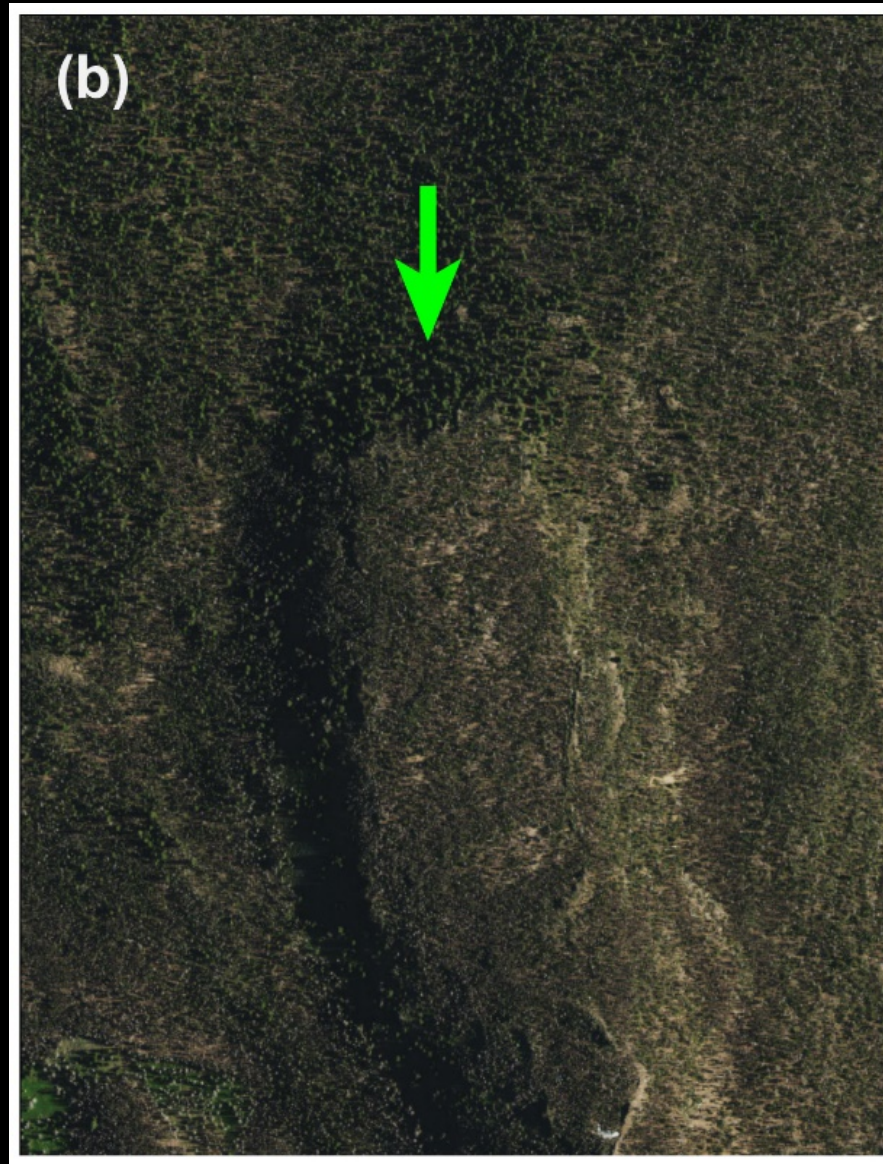
Hypothesis: more refugia in thinner forest stands



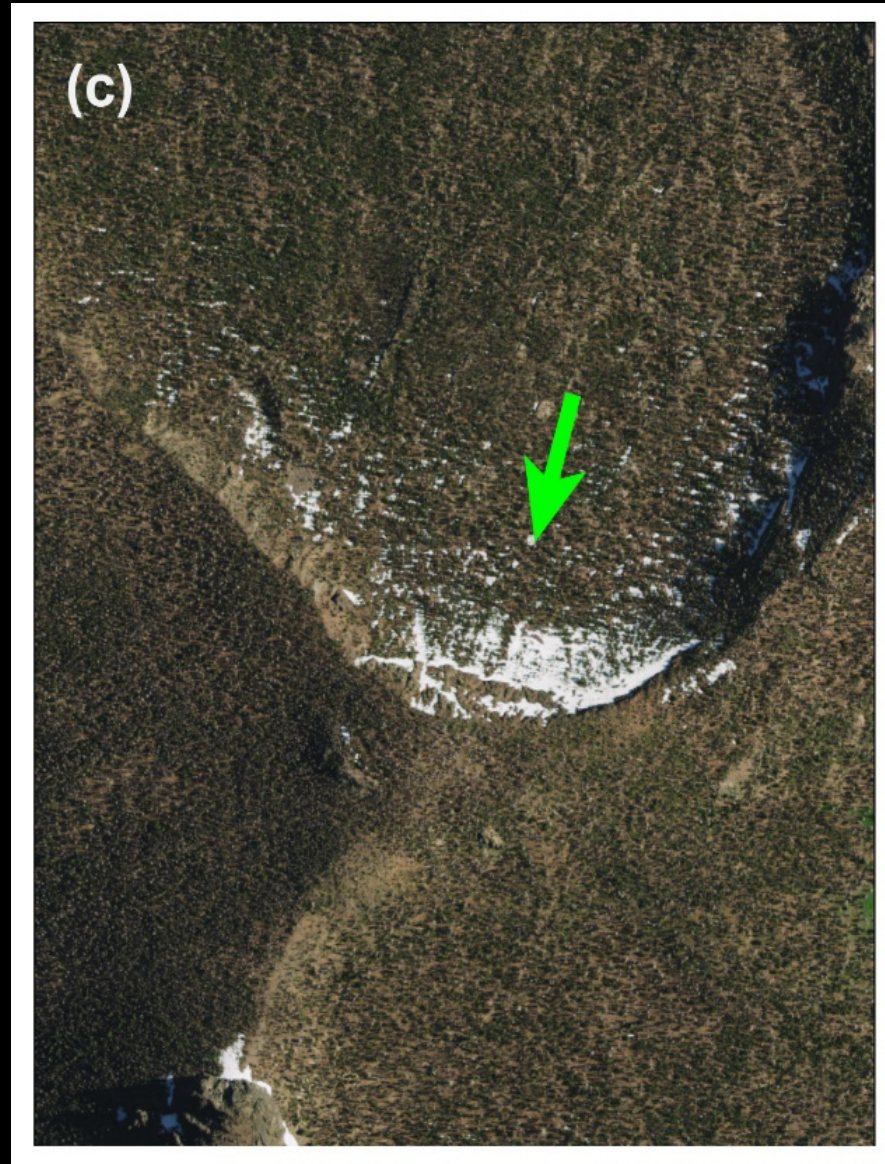
Refugia and landforms



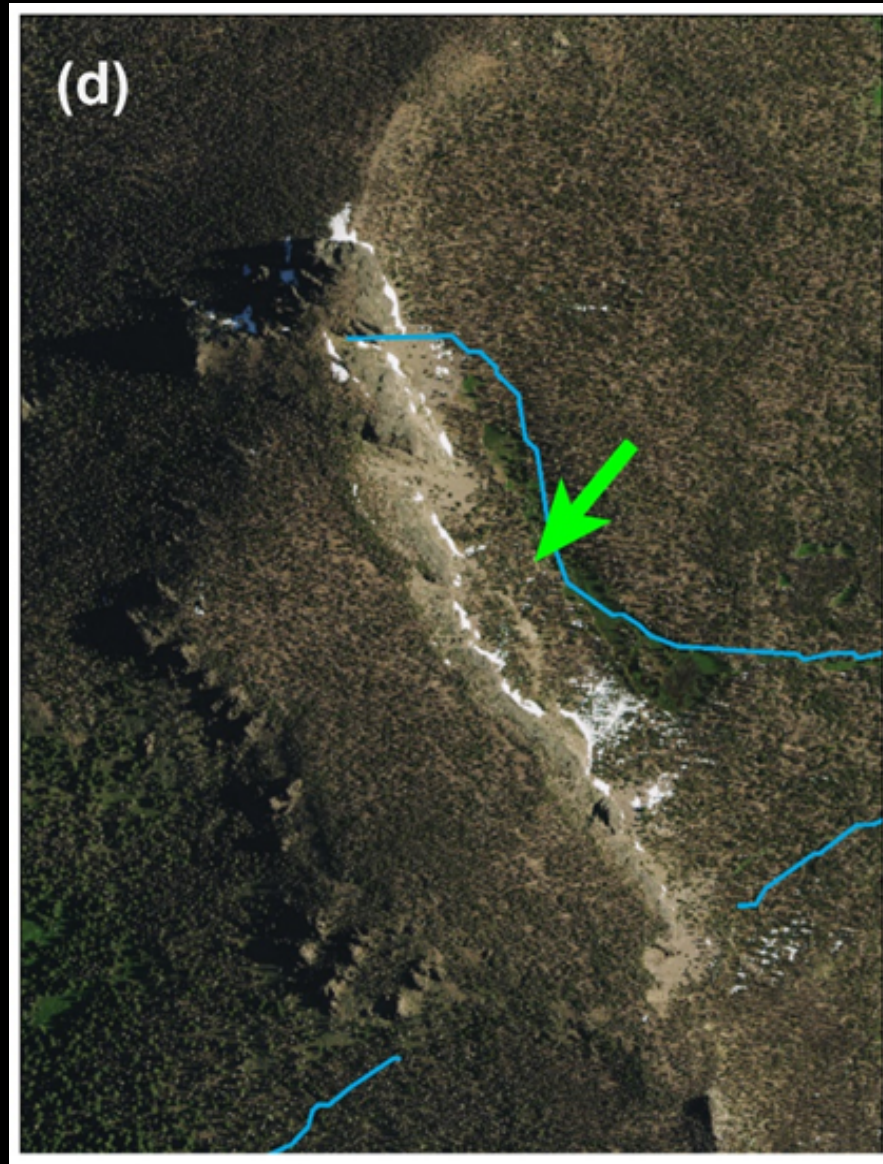
Refugia and landforms



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