Climate Responses and Adaptation in Heterogeneous Landscapes

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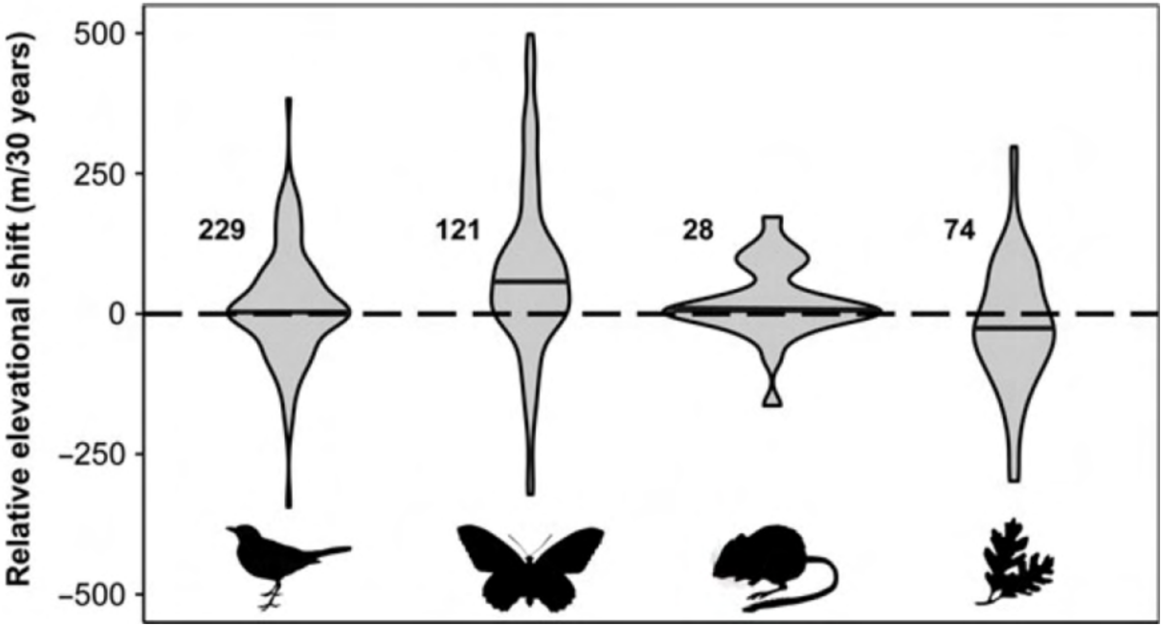
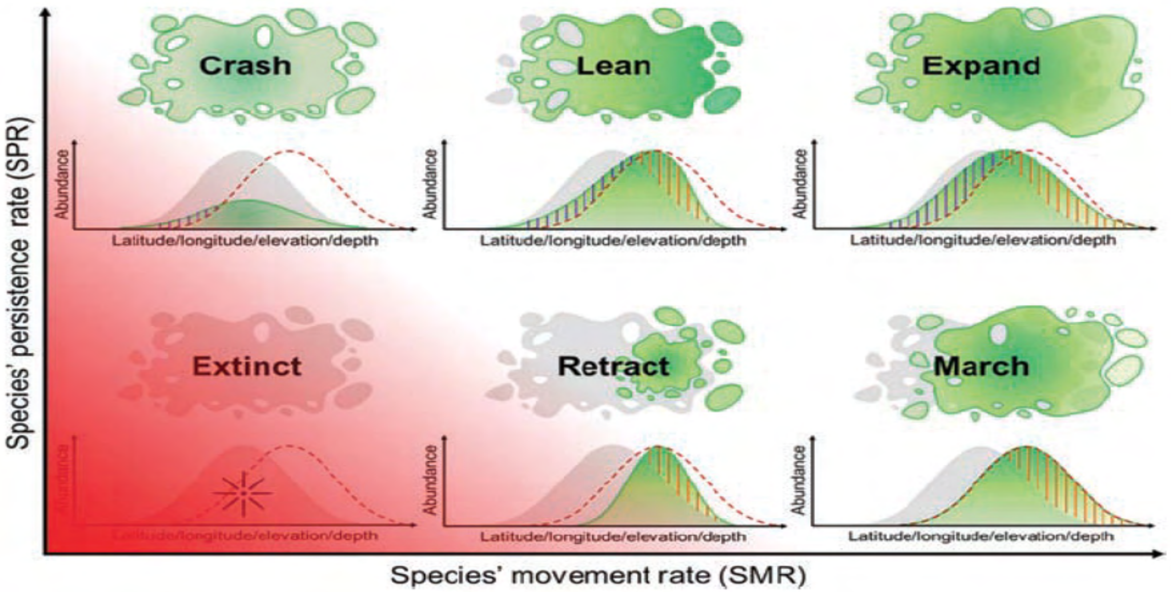
North Central Climate Adaptation Science Center

NC CASC Webinar

October 12th 2023

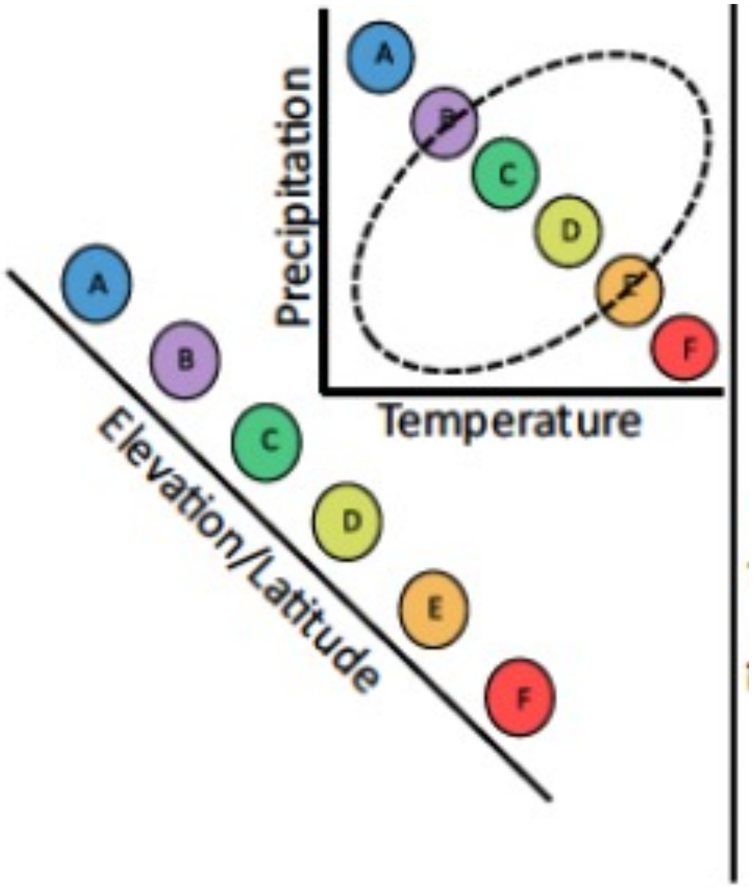
Range shifts with climate change





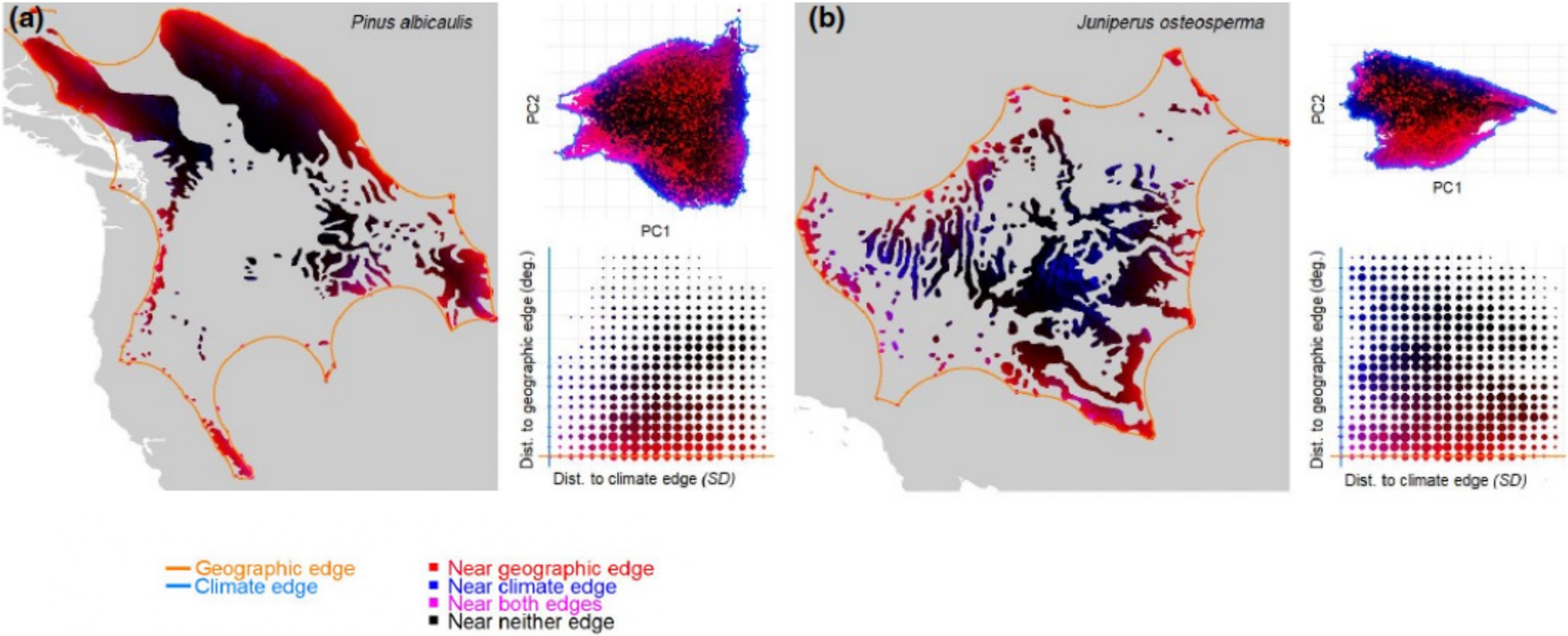
Rapacciuolo *et al.* 2014; Lenoir & Svenning 2014

Niches across landscapes



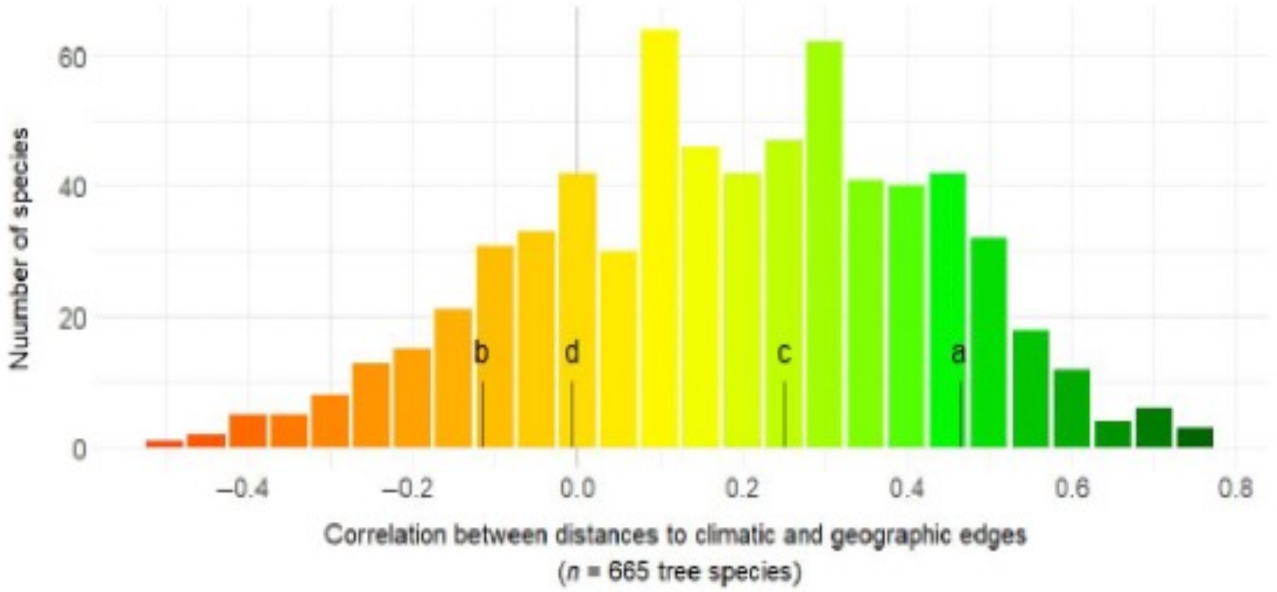
Oldfather et. al. 2020 Global Change Biology

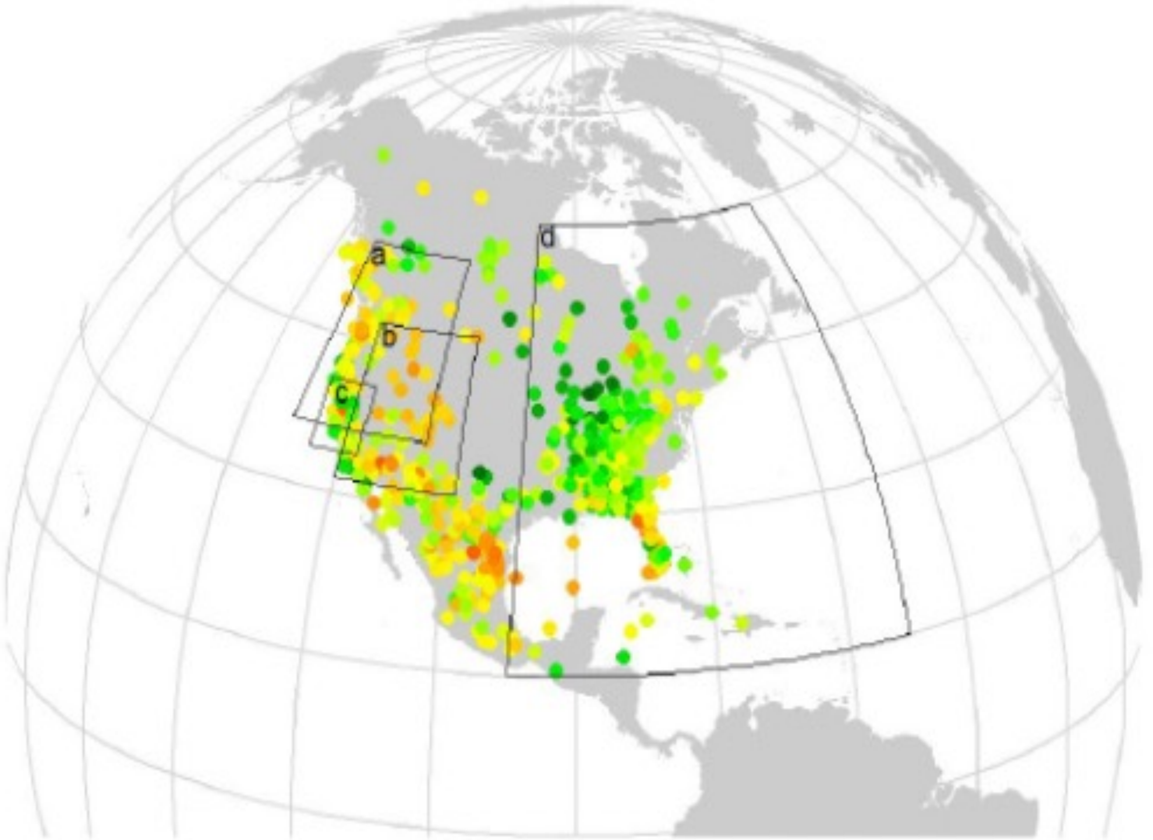
Niches across landscapes



Oldfather et. al. 2020 Global Change Biology

Geographic edges vs. climate edges





Oldfather et. al. 2020 Global Change Biology

Three important considerations

1. ***Climate heterogeneity*** the overall range of climate variables over a certain spatial domain (extent) and the likelihood of nearby patches having different climate conditions (patchiness)
2. ***Climate Collinearity*** dependence between pairs of climate variables across a landscape
3. ***Spatial scale*** geographic extent being considered (e.g., local, regional, global)

Range-limiting processes occur in both geographic and climate space





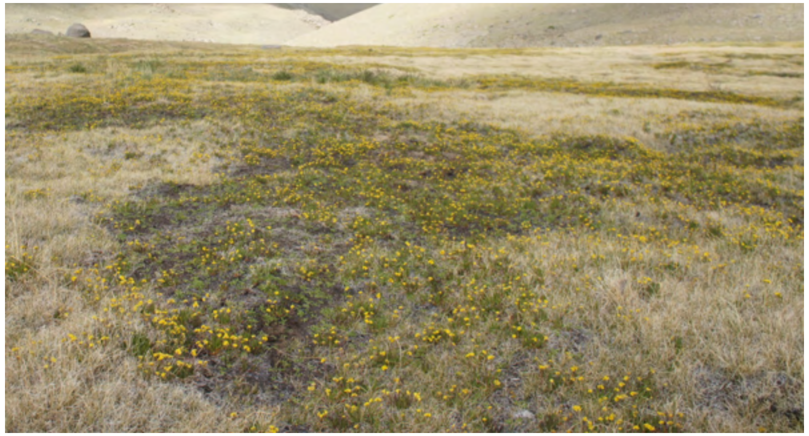
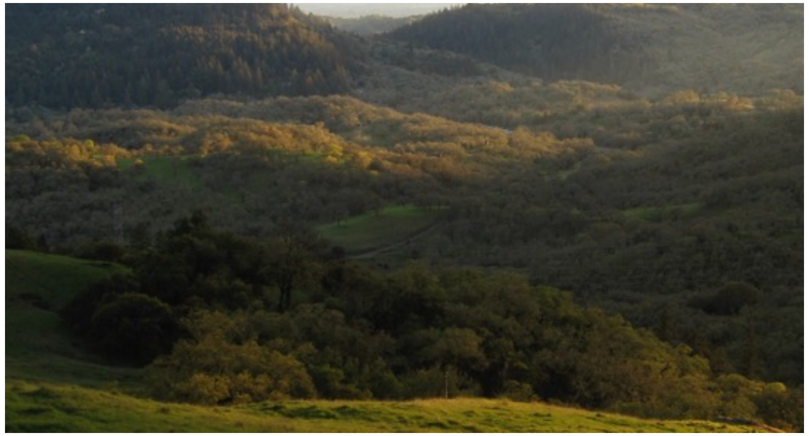
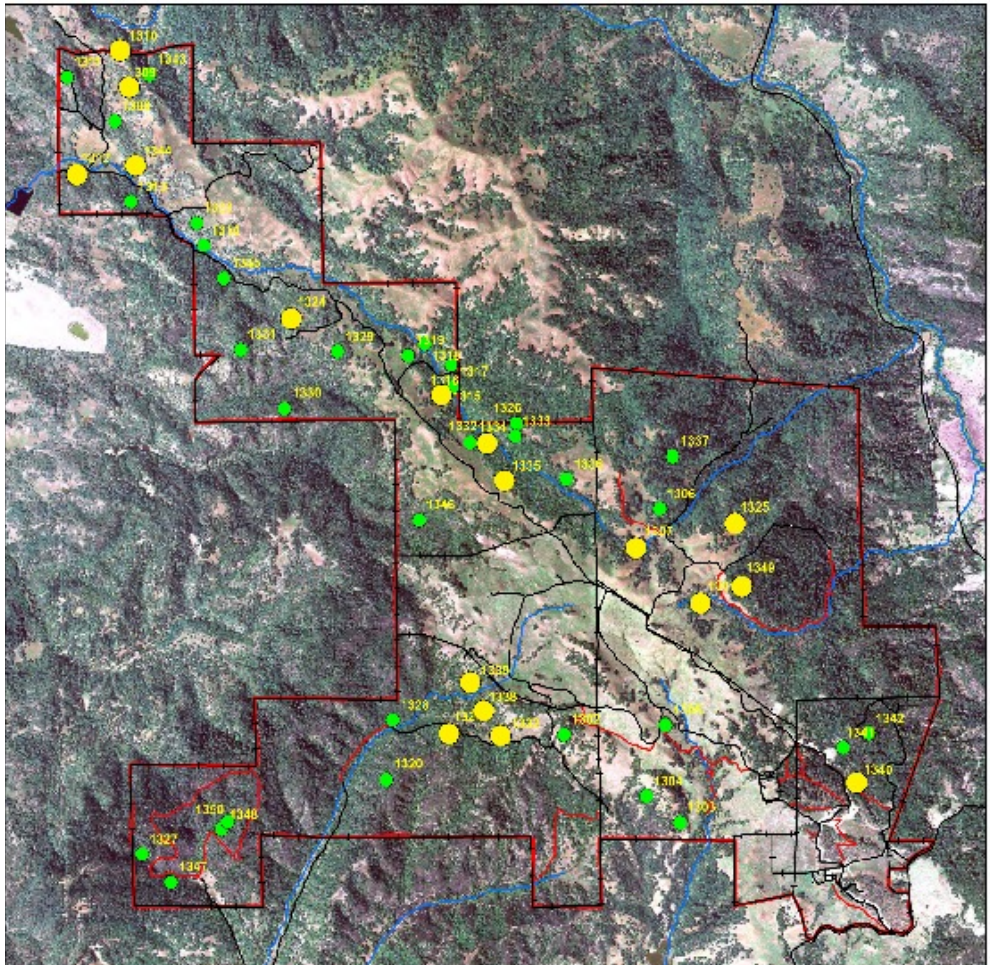



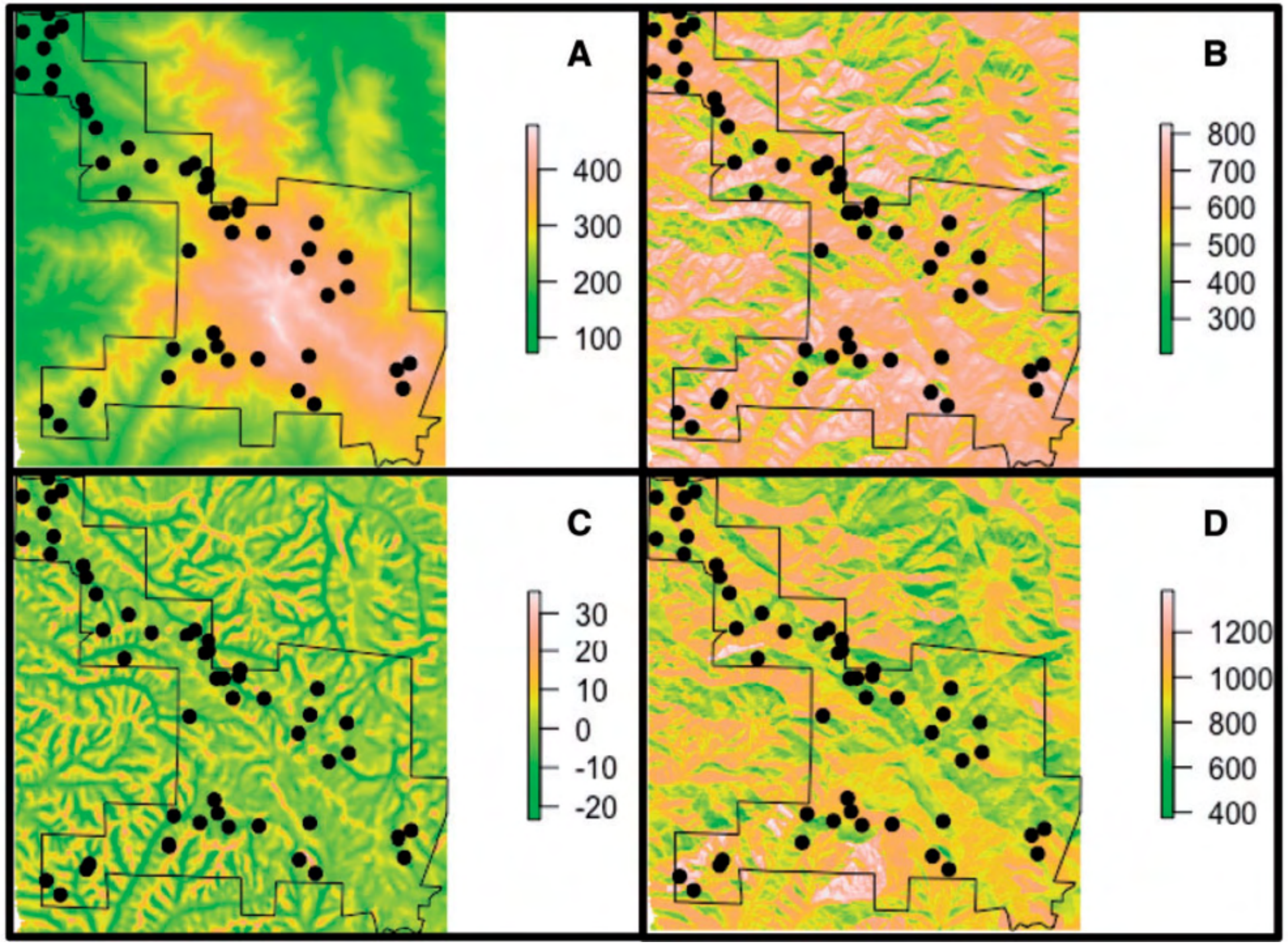
Photo Credits: W. Bowman, J. Smith

Mayacama Mountains (California)

Woodland communities across topographic gradients

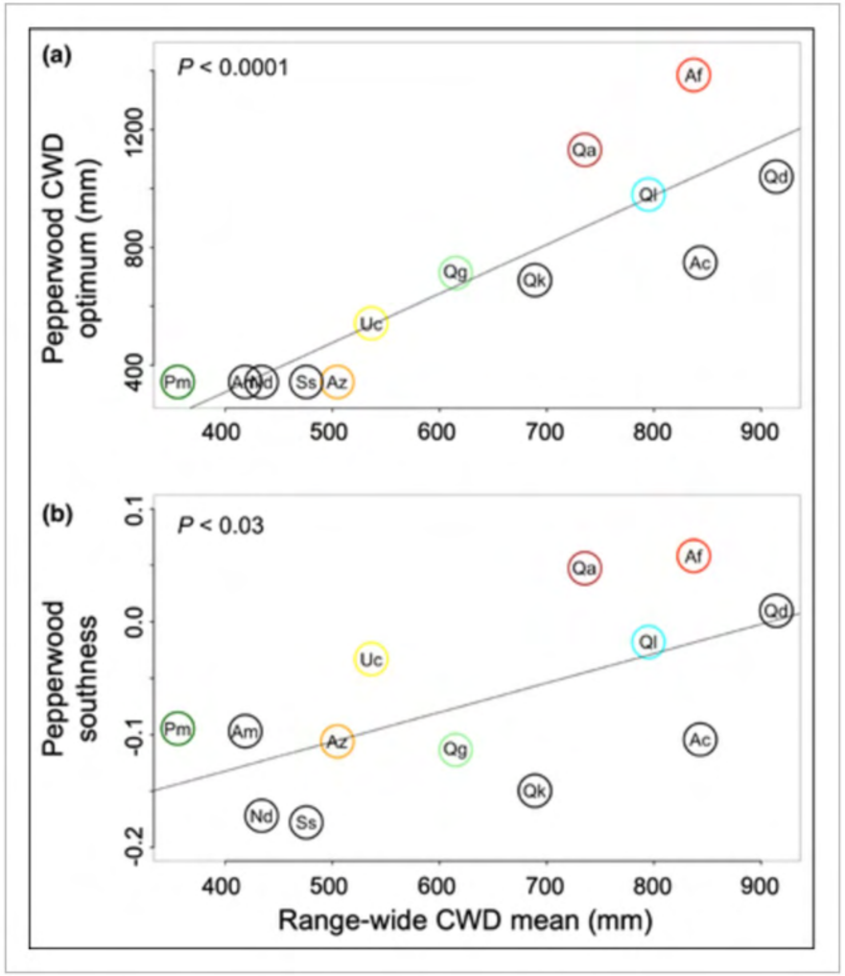
Fifty woody demography plots





Oldfather et. al. 2016 AoB Plants

Weak Community topoclimate signal and strong inertia

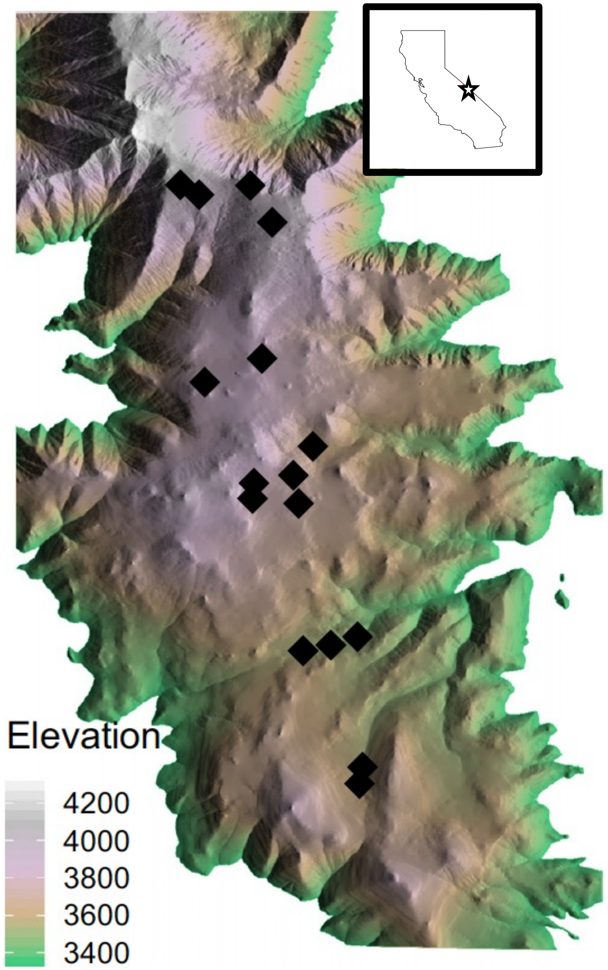


Oldfather et. al. 2016 AoB Plants; Ackerly et al. 2020

White Mountains (California)

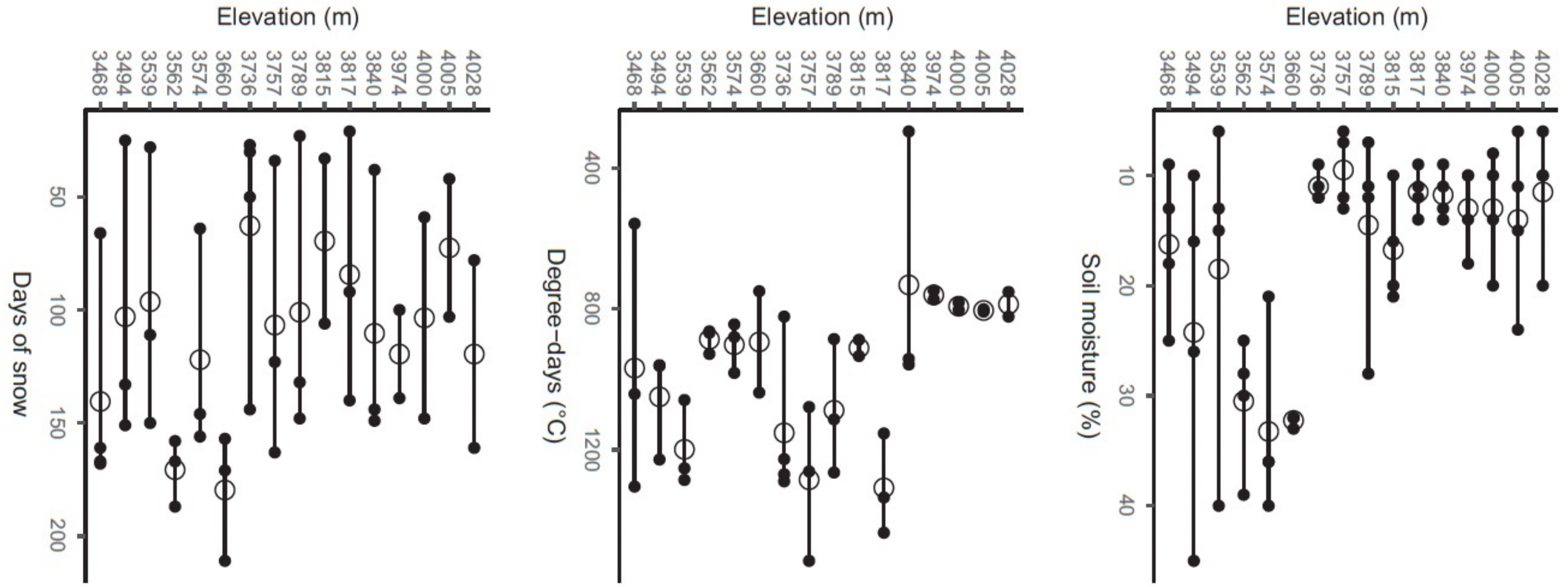
Population dynamics across an alpine species range

16 populations
116 alpine demography & community plots



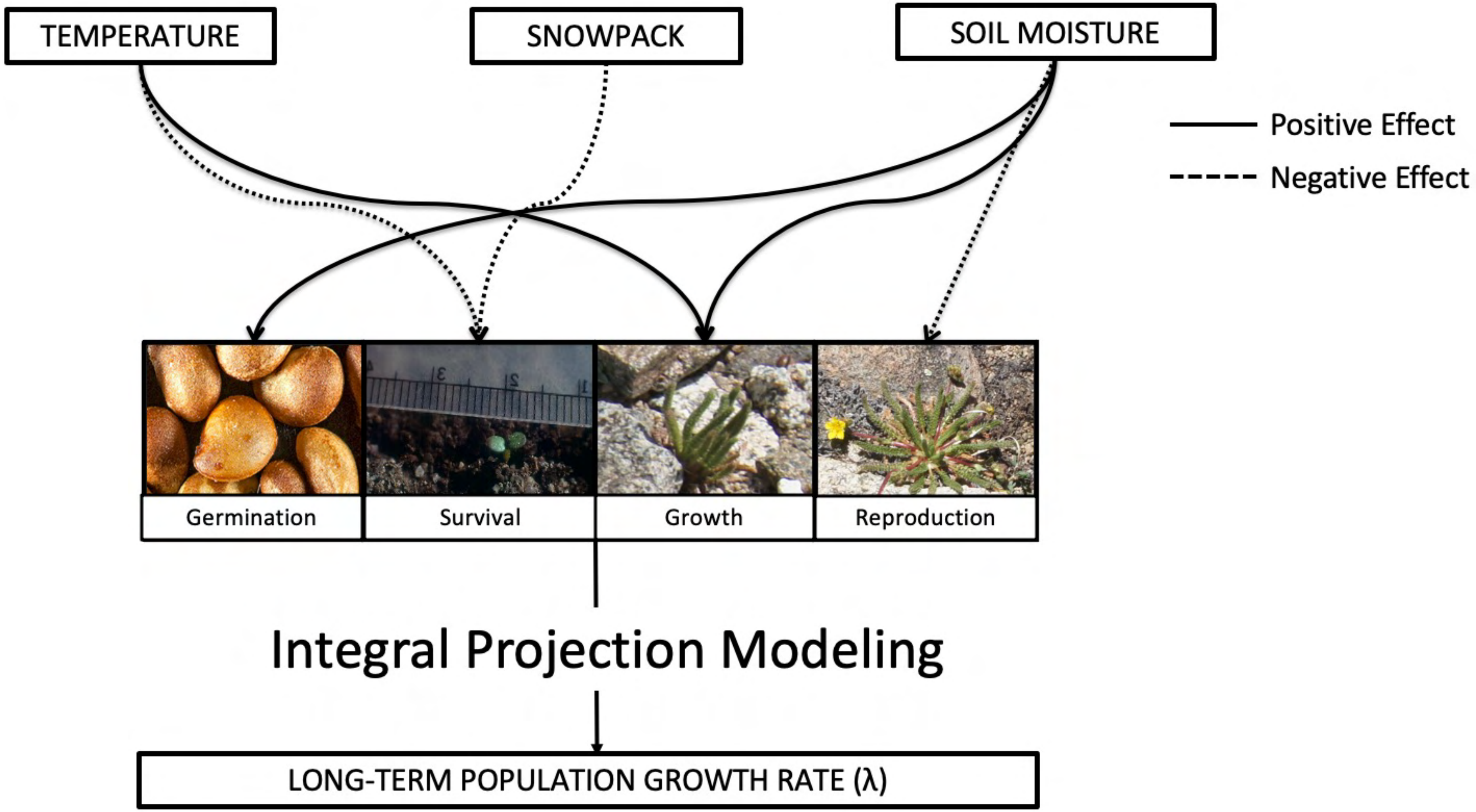
Ivesia lycopodioides

Microclimate decoupled from elevation



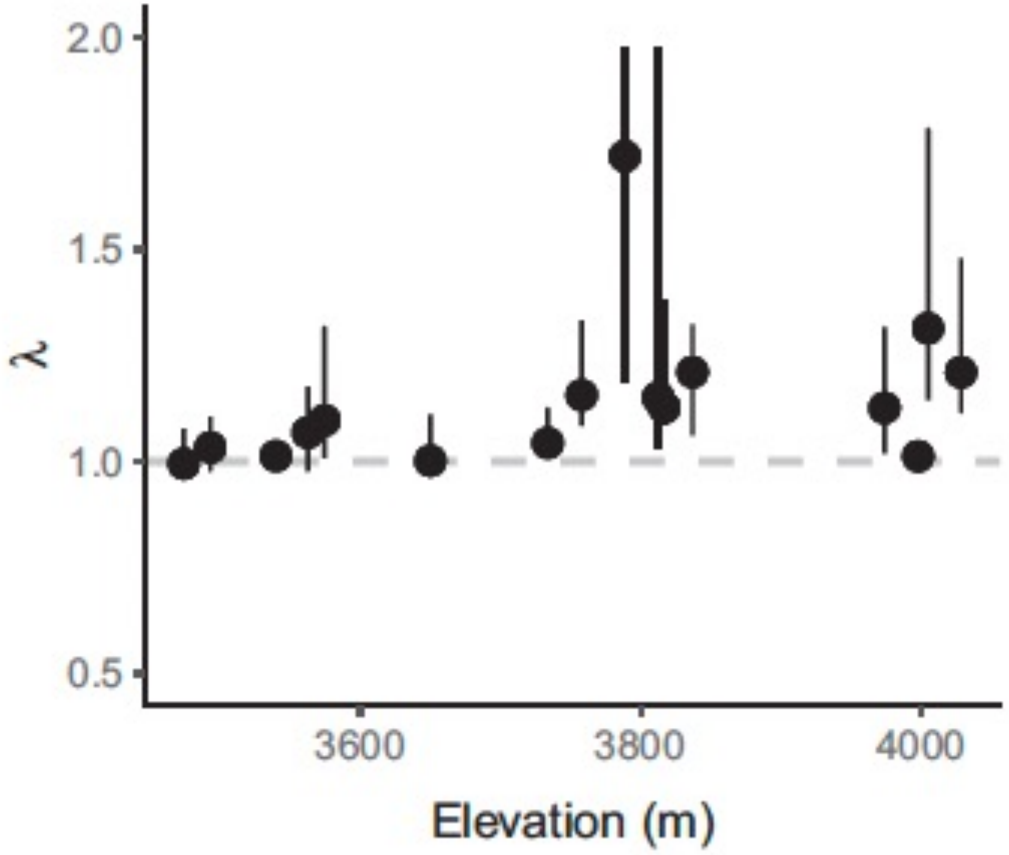
Oldfather & Ackerly 2019 New Phytologist

Demography decoupled from elevation



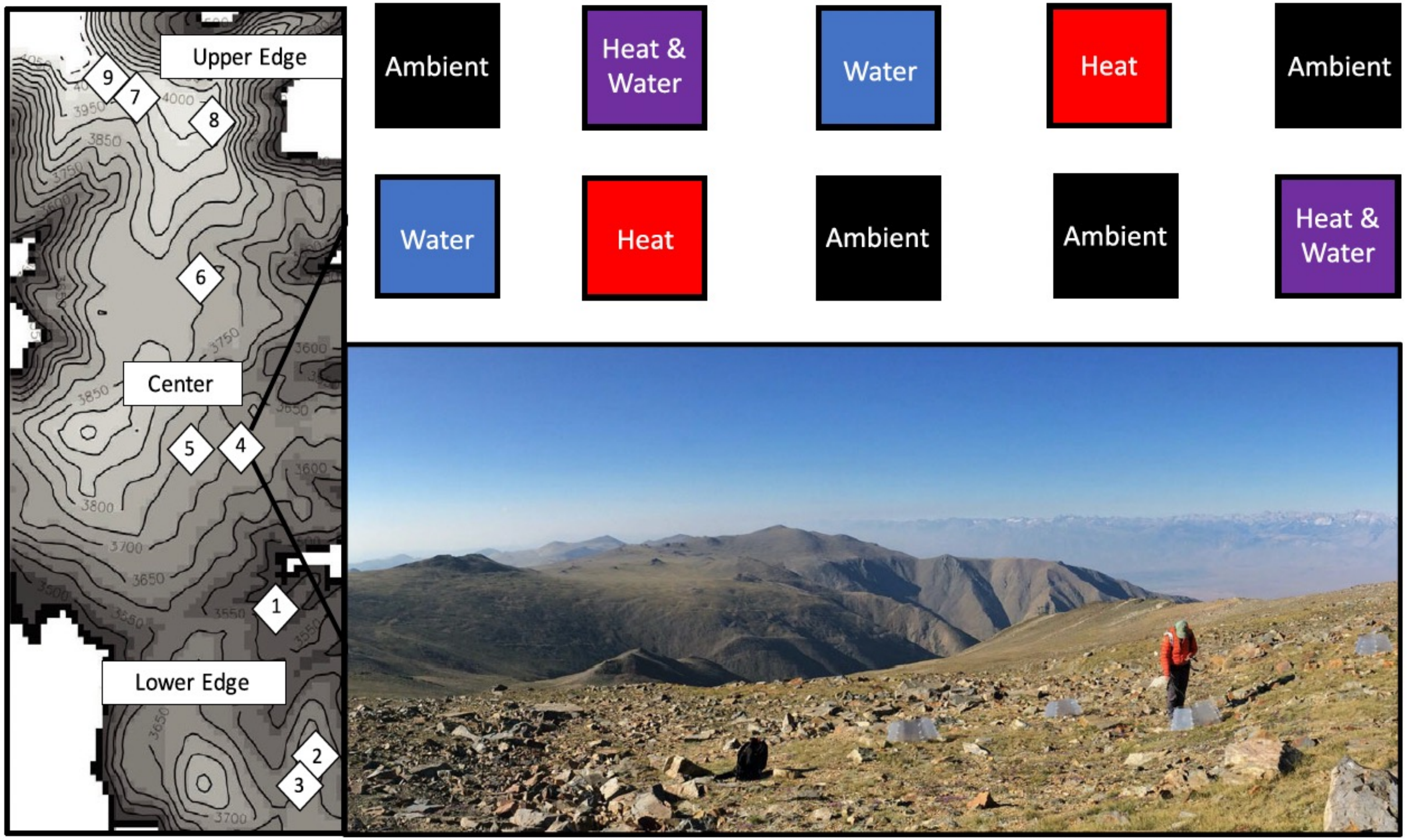
Oldfather & Ackerly 2019 New Phytologist

Range-wide stable population growth

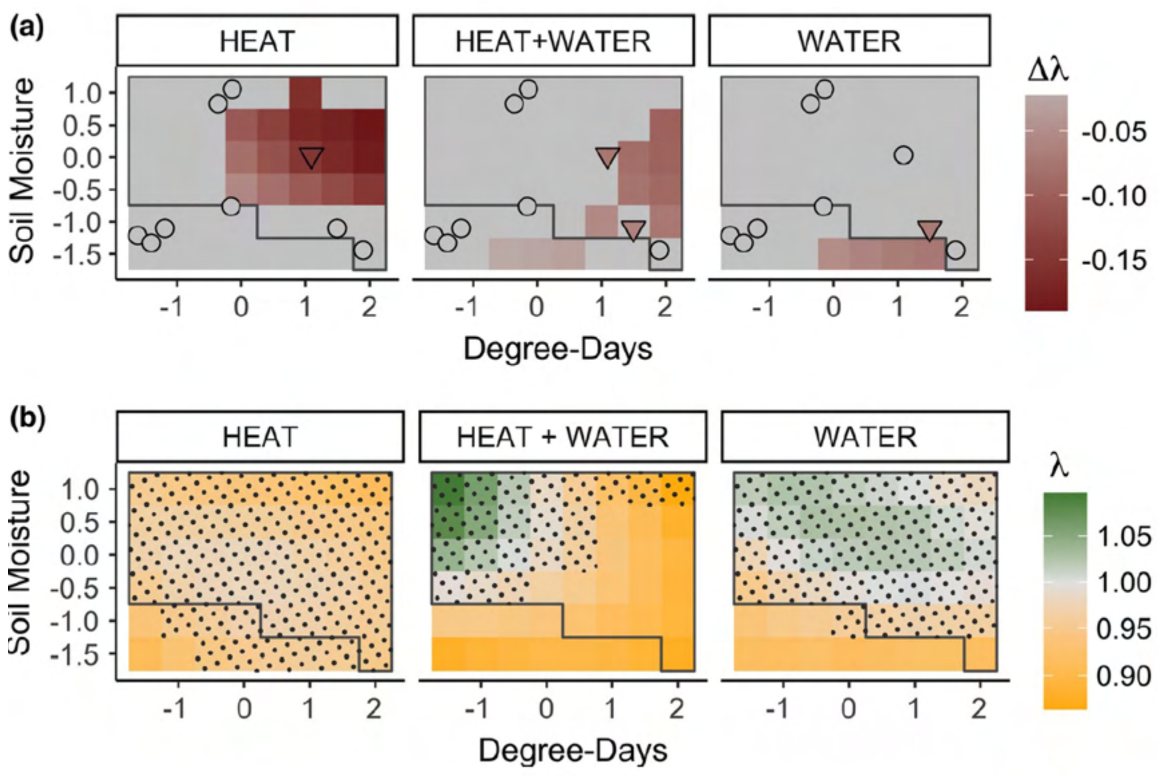


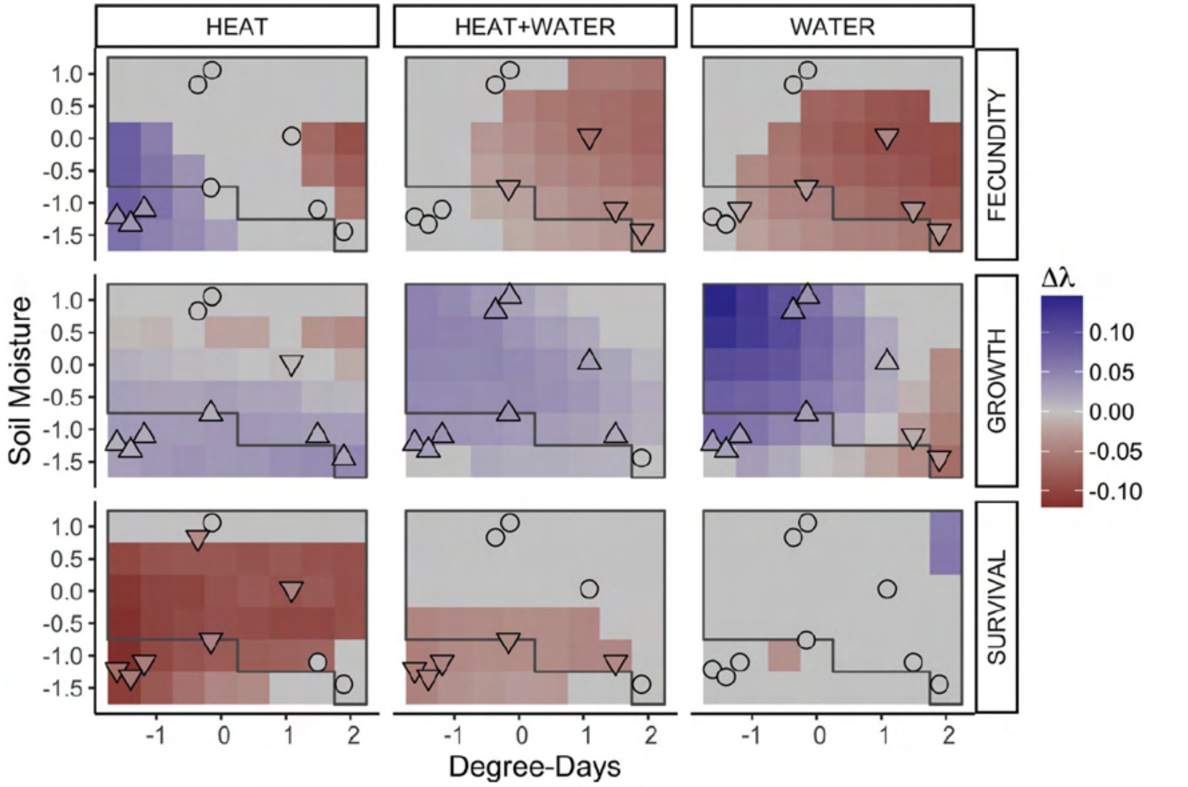
Oldfather & Ackerly 2019 New Phytologist

Range-wide experimental manipulations



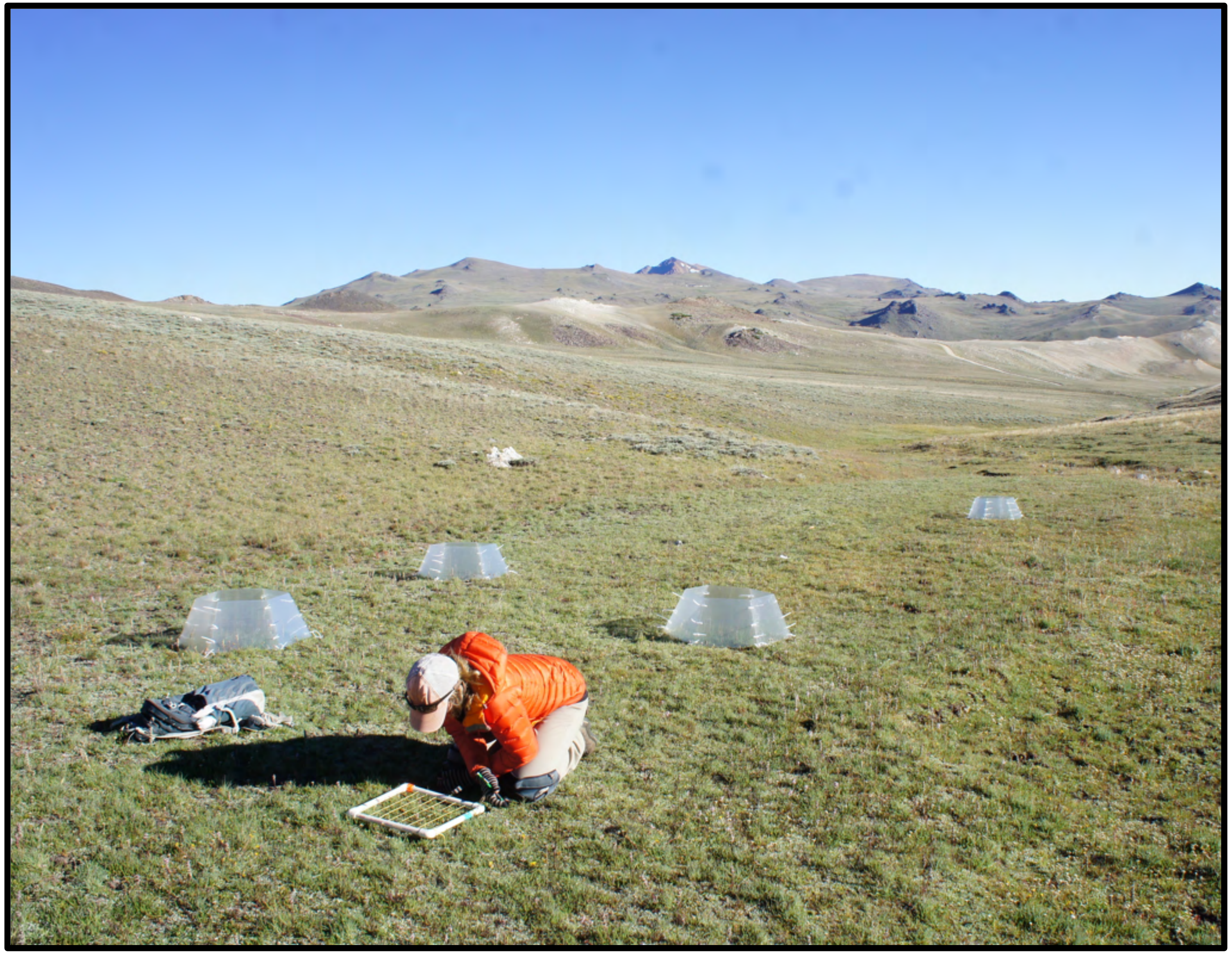
Inverse demographic reponses to manipulations leads to population decline





Oldfather et. al. 2021 Ecology Letters

Take-aways



- Multiple life history transitions impact how populations across a species' range may respond to current and future climate variation
- Multiple pathways of demographic stability may lead to multiple pathways of vulnerability

Niwot Ridge LTER (Colorado)

Alpine community trajectories across a snow gradient

Photo Credits: W.Bowman

How does a fine-scale snow depth gradient mediate alpine plant community change over the last 30 years?

88 Alpine Vegetation Plots
1990 – 2020

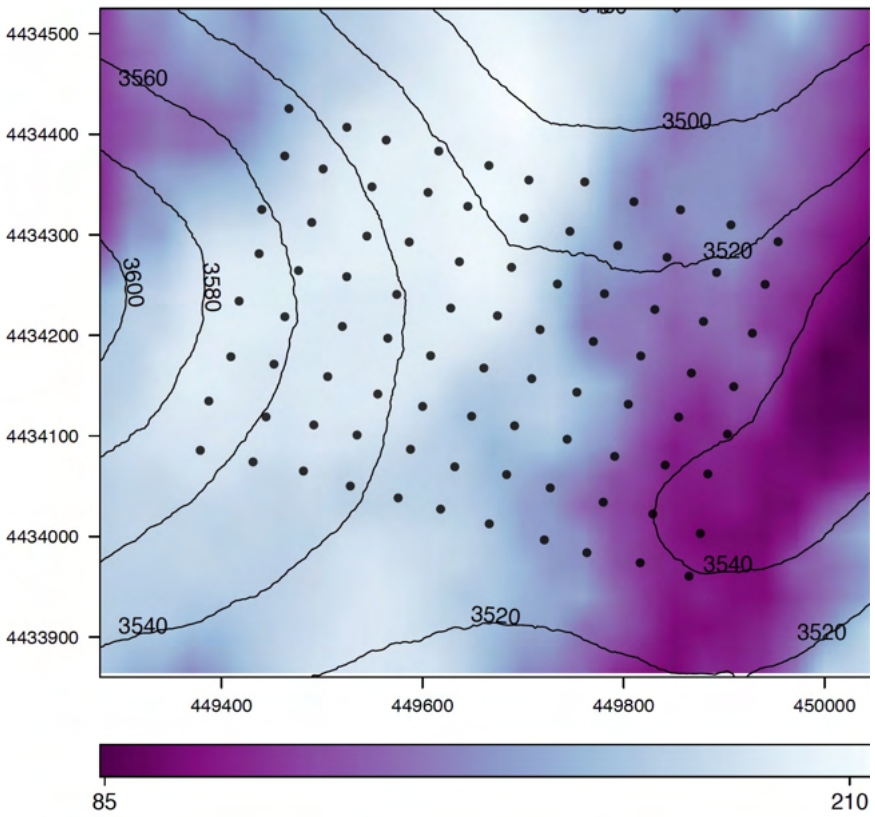
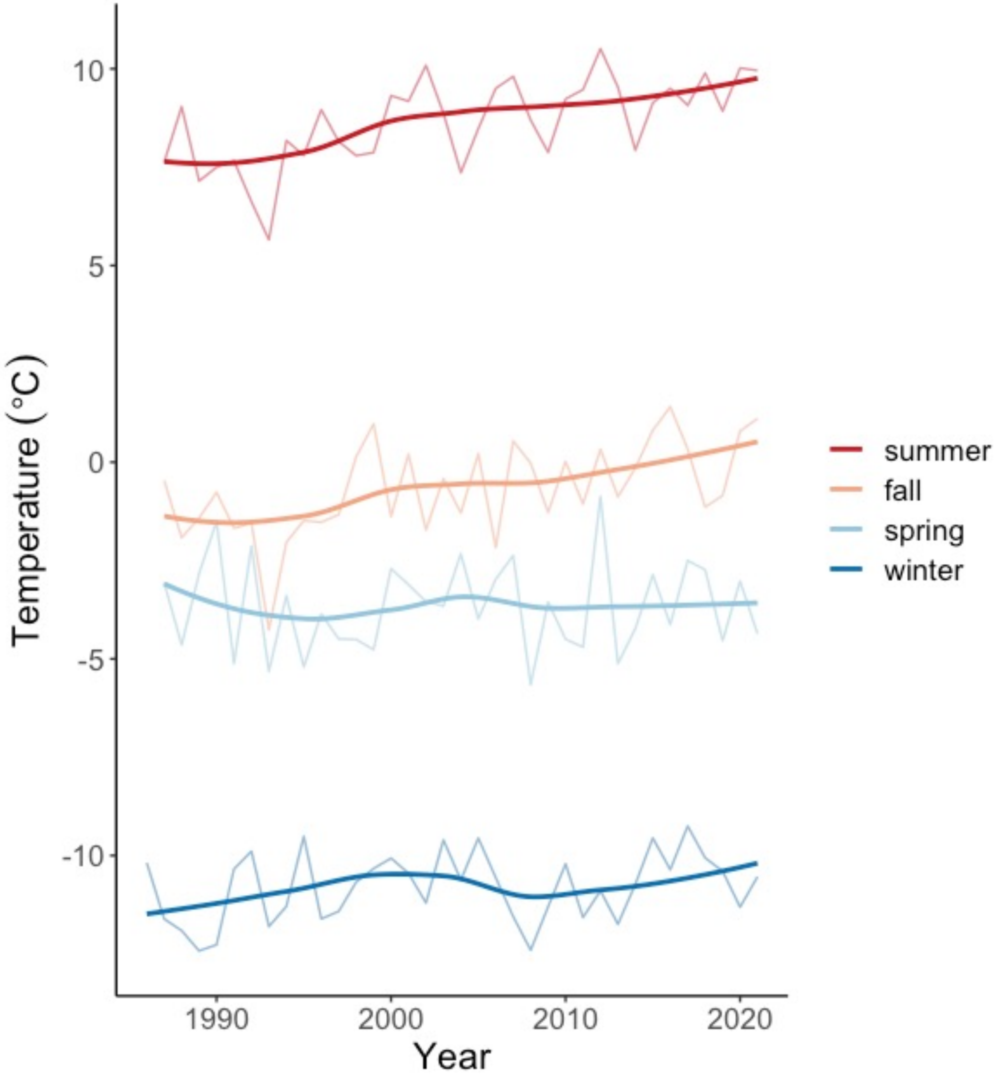
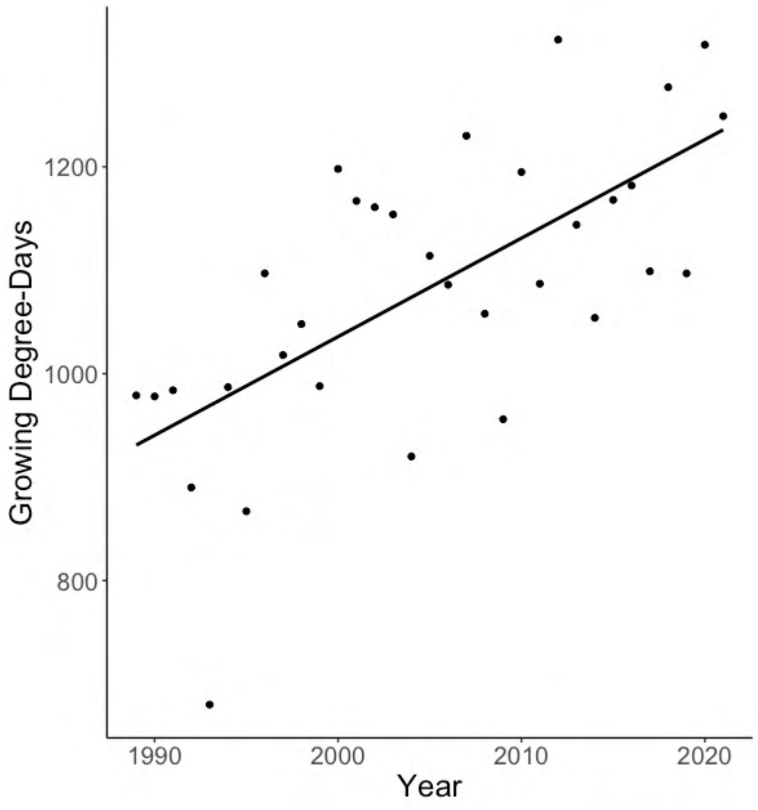


Photo Credits: J. Smith

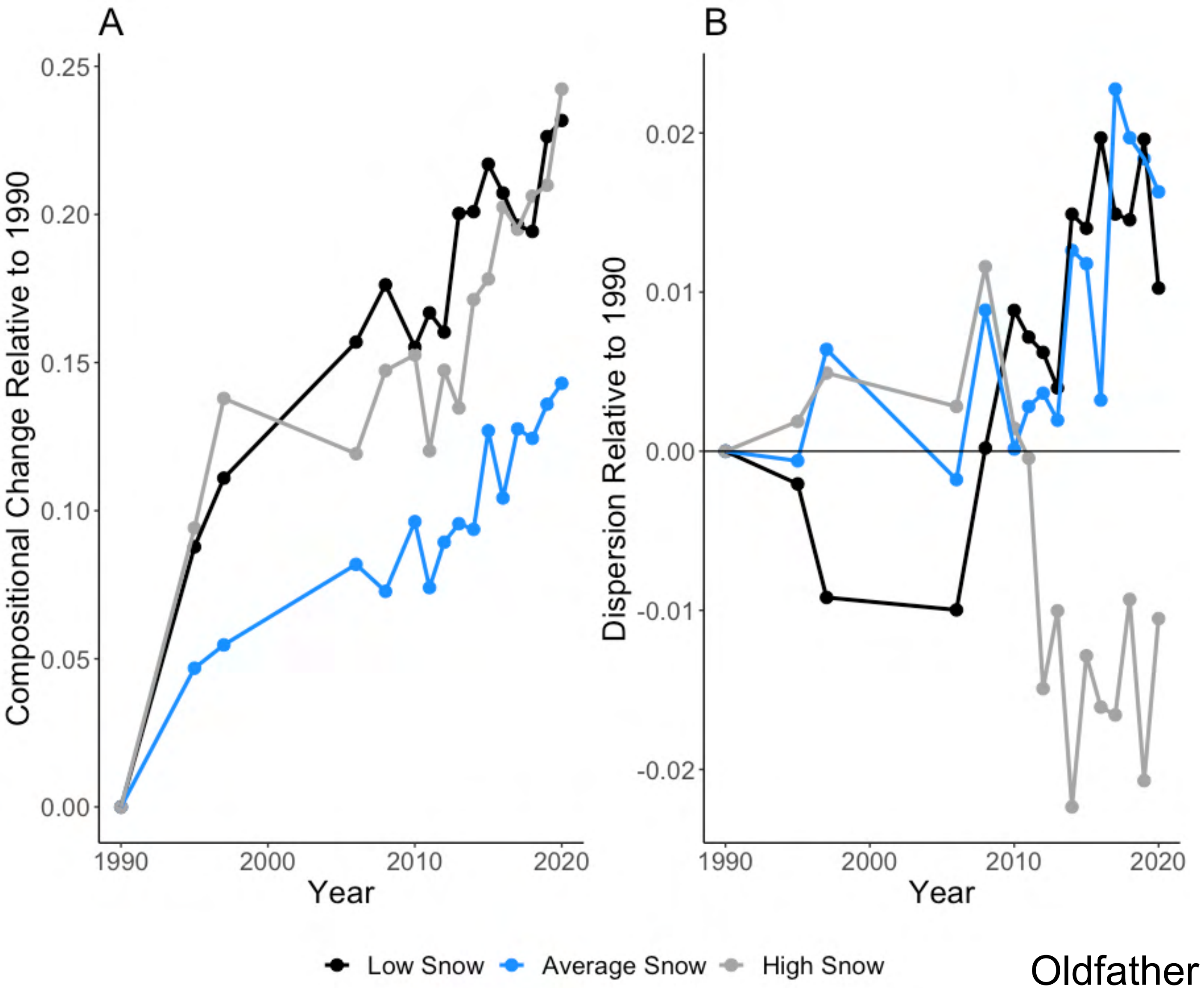
Changing Climate at Niwot Ridge





Oldfather et al. 2023 Journal of Ecology

Extreme location have changed the most



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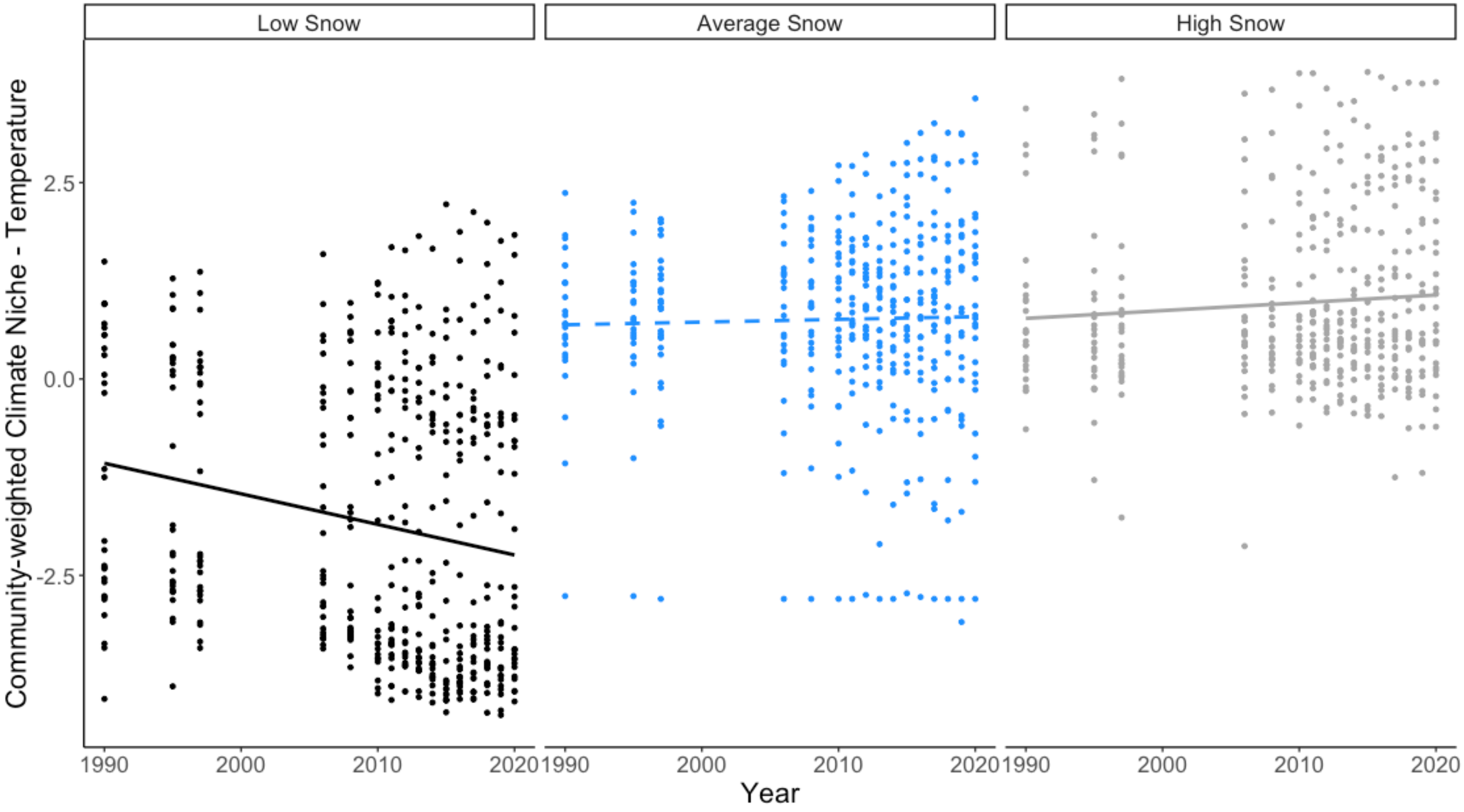
Thermophilization in high snow sites and ‘reverse thermophilization’ in low snow sites



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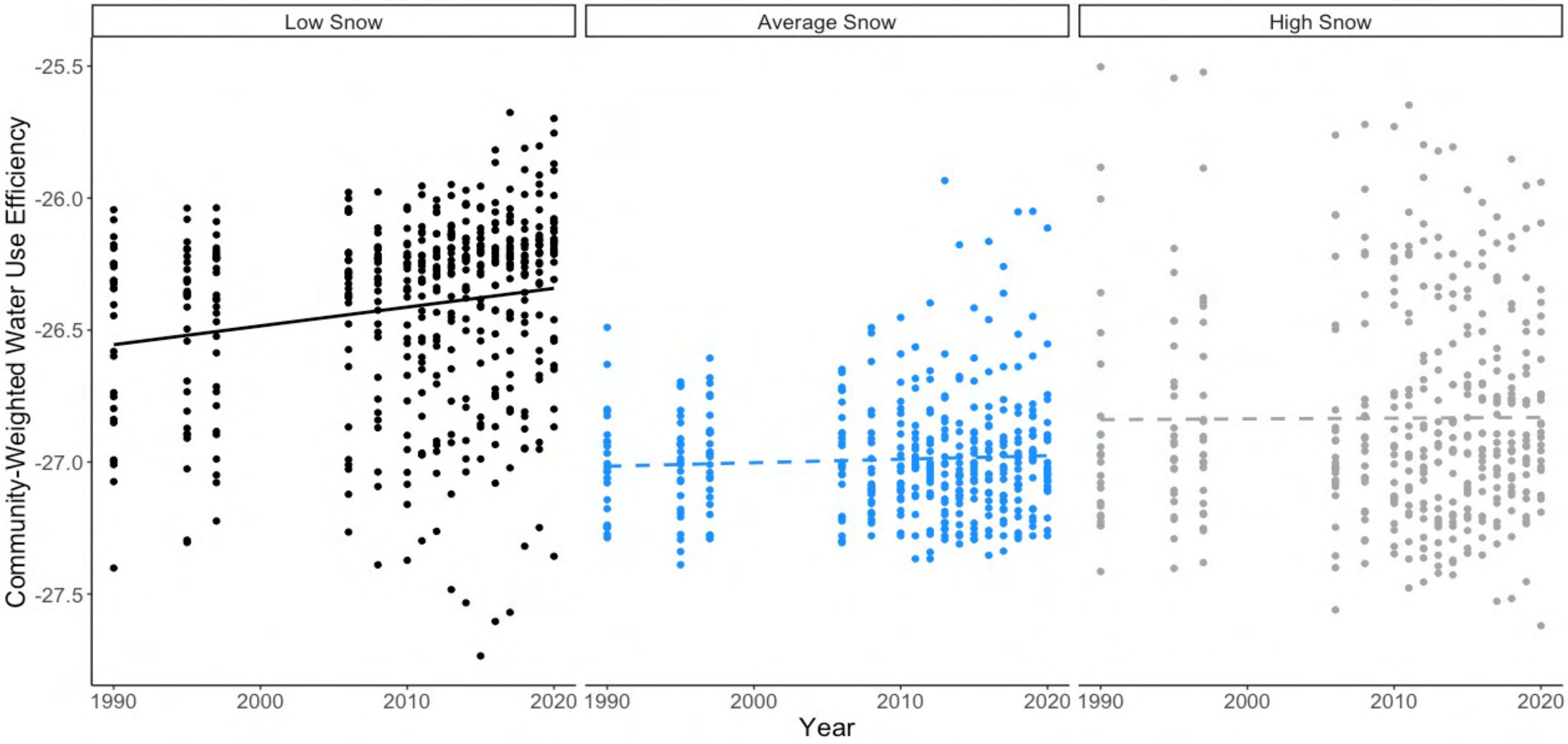
Increasing water-use efficiency in low snow sites



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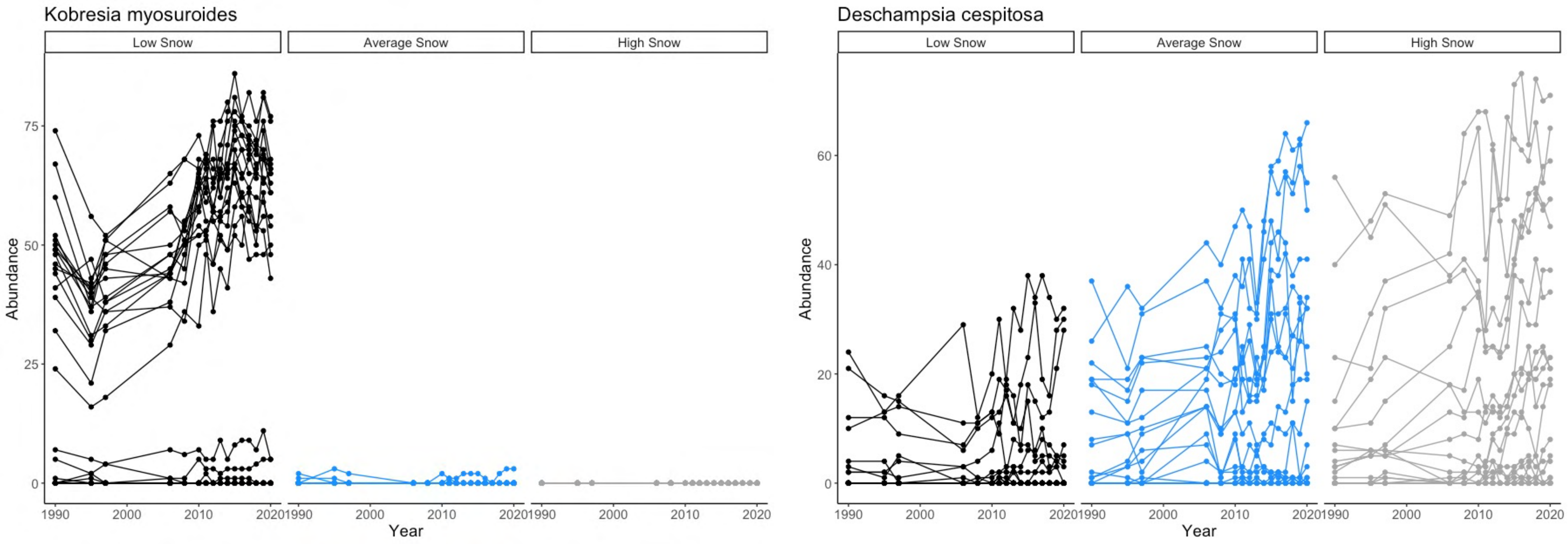
Community dynamics largely driven by changes in abundance



Oldfather et al. 2023 Journal of Ecology

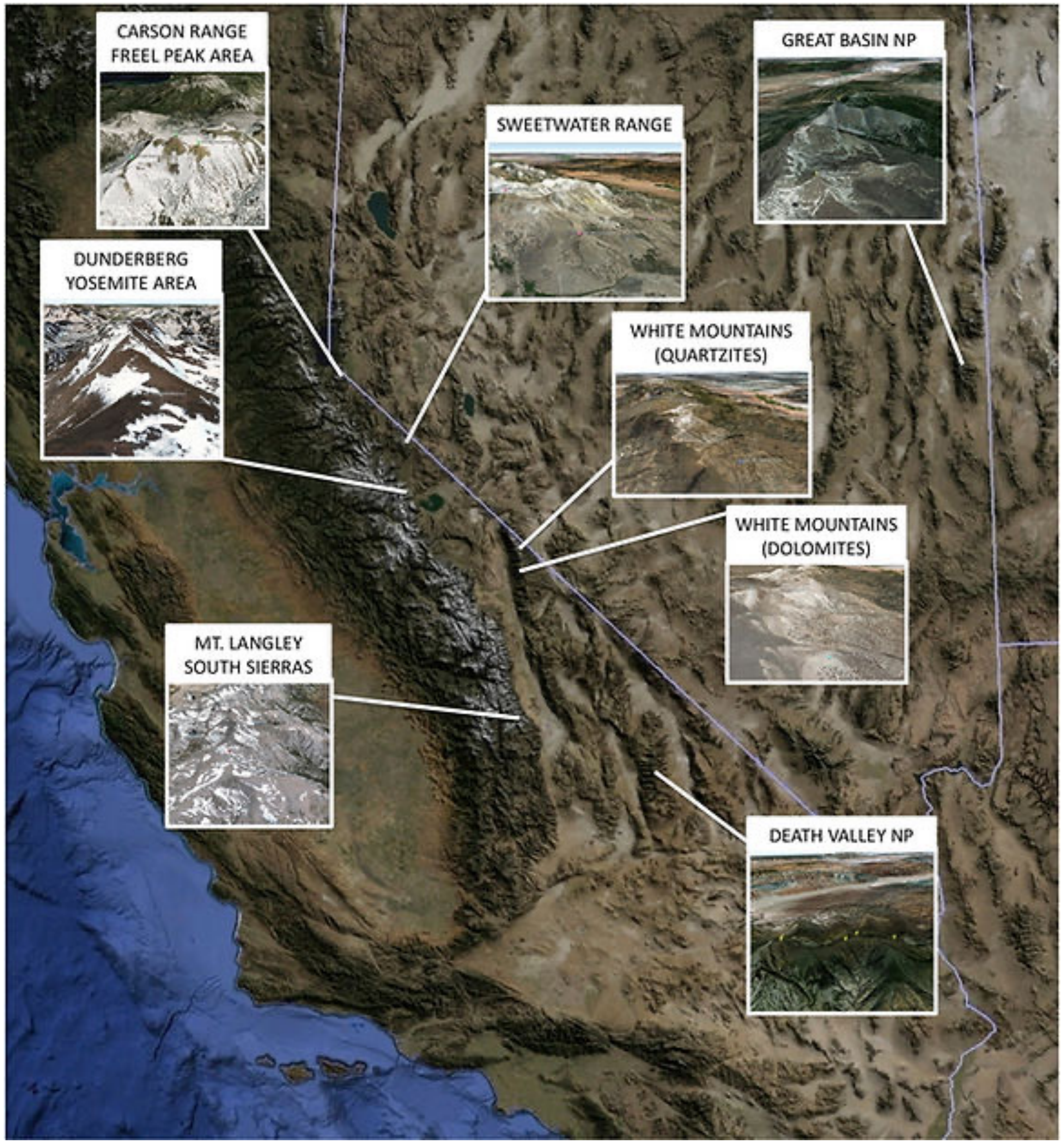
Take-aways

- Snow gradients can drive divergent community trajectories with the type of species successful with climate change shifting over the scale of meters.
- Abundance shifts across topographic gradients may be initial climate impacts

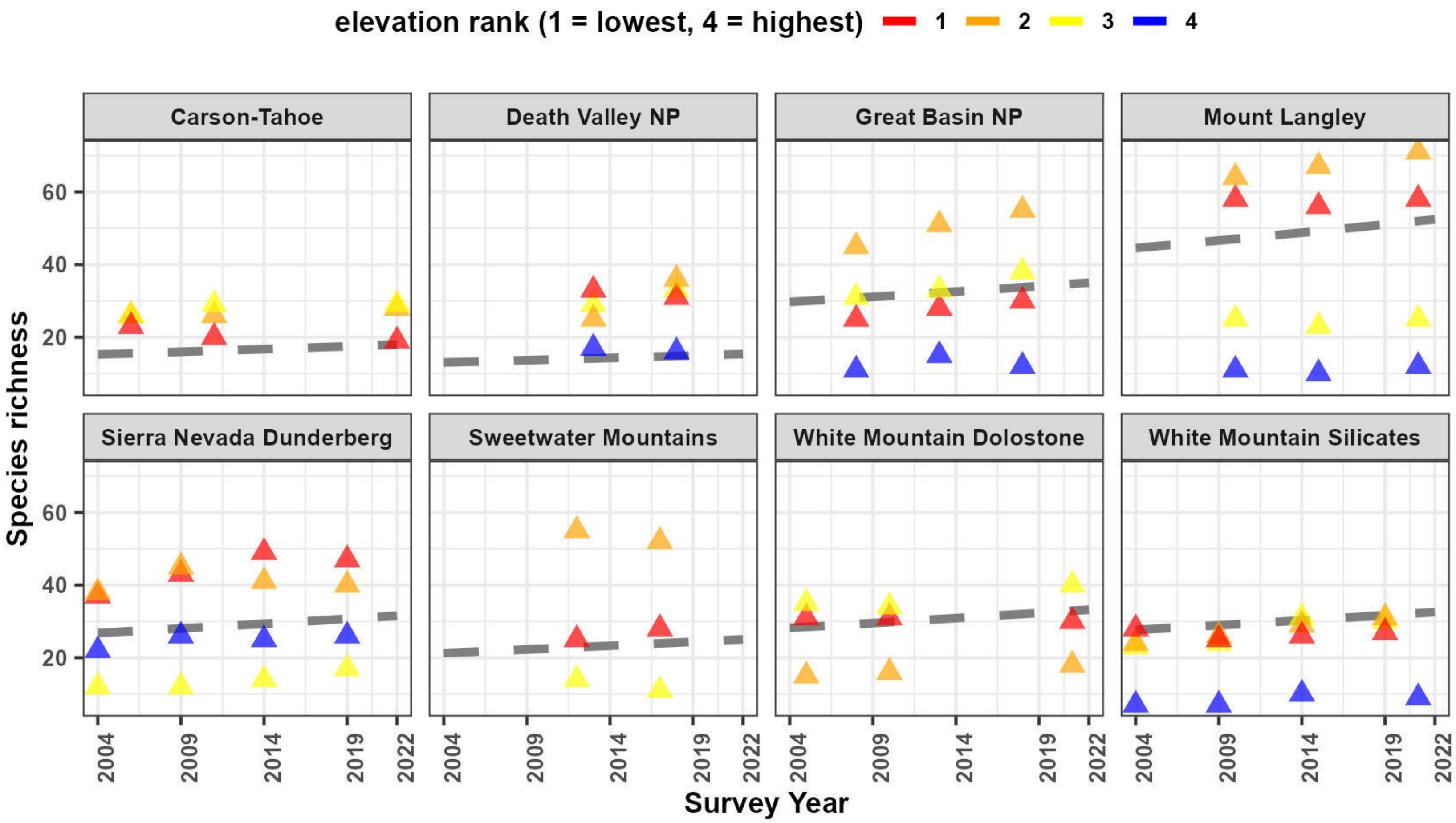
Photo Credit: J. Morse

GLORIA GREAT BASIN

- Long-term monitoring of mountain peak communities across the Western US since 2004
- Volunteer since 2009!



Stability in richness across Great Basin mountain ranges



Goff et al. *In Prep*

Big picture take-away's from examples

- Climate and geographic distance needs to be considered together for quantifying and predicting the biogeographic impacts of climate change
- Different strategies at both the community and population level may be successful in response to changing climate
- Abundance shifts (as opposed to colonization/extinctions) across topographic gradients may be the first evidence of climate change impacts in these 'slow' systems

Climate adaptation in North Central mountains synthesis project

What are our knowledge gaps of mountain ecosystem responses to climate change that limit our ability to perform successful climate adaptation?

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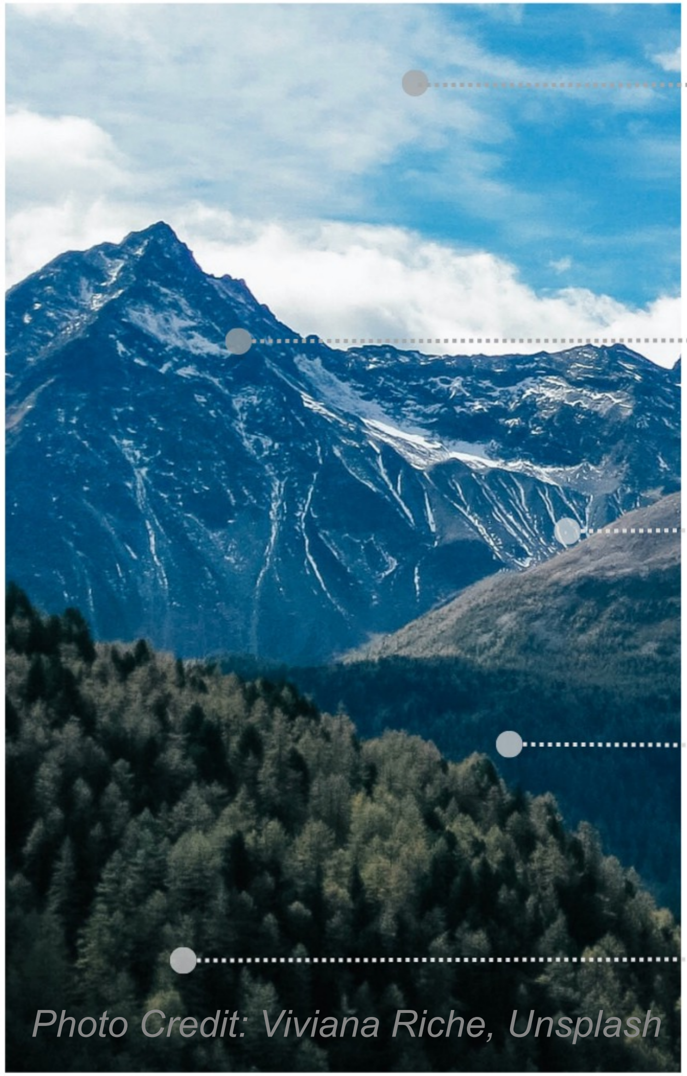
Literature synthesis – alpine & treeline



Climate: warmer spring and winter temperatures; higher fall streamflows indicates glacial and permafrost melt.

Wildlife: earlier arrival and emergence of migrating and hibernating species; decline in snowpack affect denning and habitat connectivity; local extirpations at warm, dry range margins.

Lakes: ice thickness is thinning and ice-off dates are occurring earlier in the year; phytoplankton community composition is changing.

Vegetation: loss of species at their warm, dry range margins, but slow responses due to large biological lags in the dispersal, establishment, and extinction of alpine plants.

Treeline: upslope movement of treeline is spatially variable, largely driven by densification, and slower than rate of climate warming.

Climate adaptation in the alpine

1. Alpine species may have limited opportunities to move uphill to newly suitable areas; however the complex topography may allow species to track suitable climate within the landscape, driving slower overall ecosystem response.
2. The highly variable temperature and precipitation in the alpine may also dampen the speed at which climate change impacts occur.
3. The life histories of alpine plant and wildlife species may lead to extinction debt (future extinction of species due to past events).
4. Potential actions to mitigate biodiversity and ecosystem services loss in the alpine include preservation of species refugia and migratory pathways, and management of recreation impacts.

Future research questions for climate adaptation in North Central mountains

How do we best manage systems with large biological lags?

Do we expect different types of extreme events or disturbances to impact the alpine tundra in the future (e.g., fire in the tundra)?

Can we anticipate areas of transformational change vs. area that may provide refugia?

What is relationship between direct climate impacts on flora and fauna and interactive impacts, such as through forage quality?

How much transferability is there in observed trends observed or lessons learned in one area to other mountainous regions?

What are the implications of the observed & predicted climate change impacts on the valuable resources provided by the alpine ecosystem?

Thank you! Questions?

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