

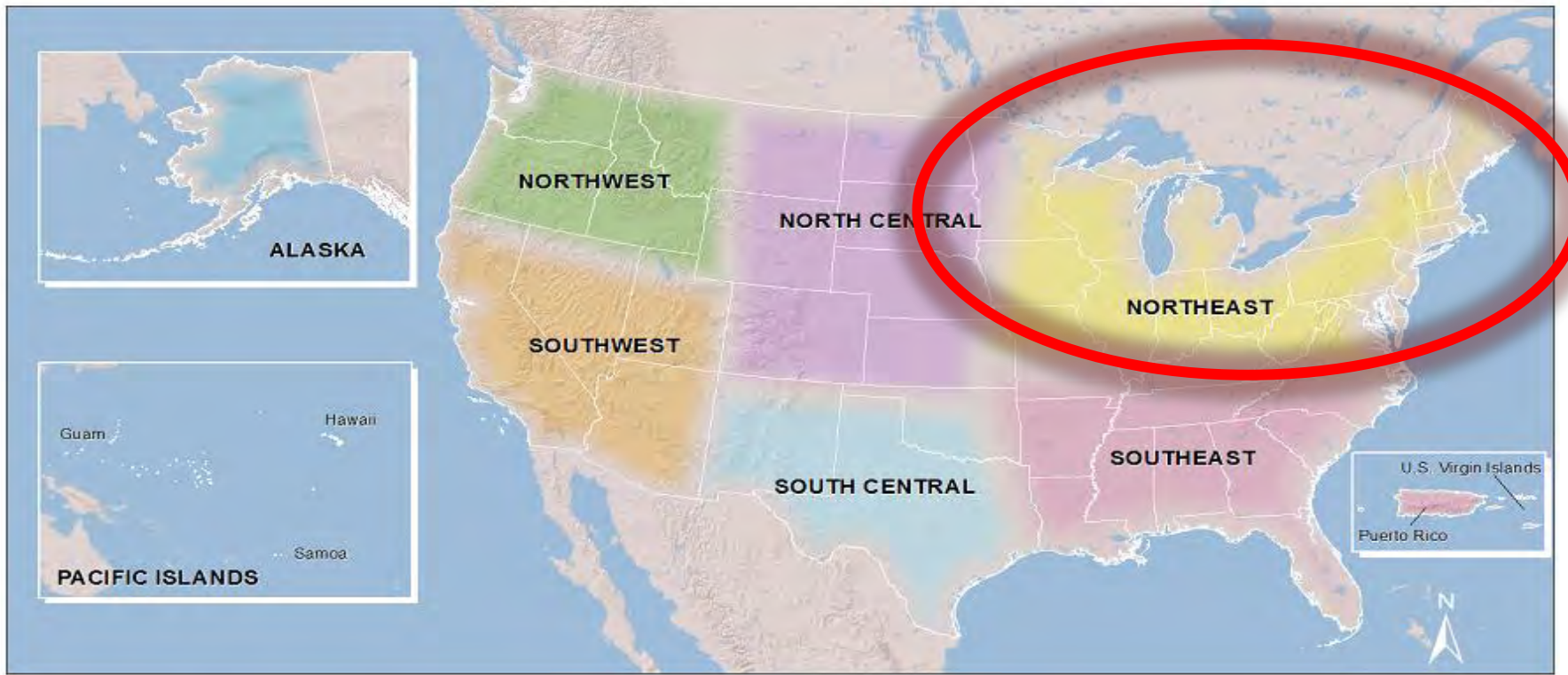
How to Prioritize Management Action in a Changing Climate: A Look at Climate Change Refugia

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USGS

Northeast Climate Science Center





- 1 of 8 CSCs
- Cover 22 states/130M people
- Overlap with 7 LCCs, including the North Atlantic LCC
- **Goal:** To assist natural resource managers in planning and development of climate adaptation strategies on local and regional scales

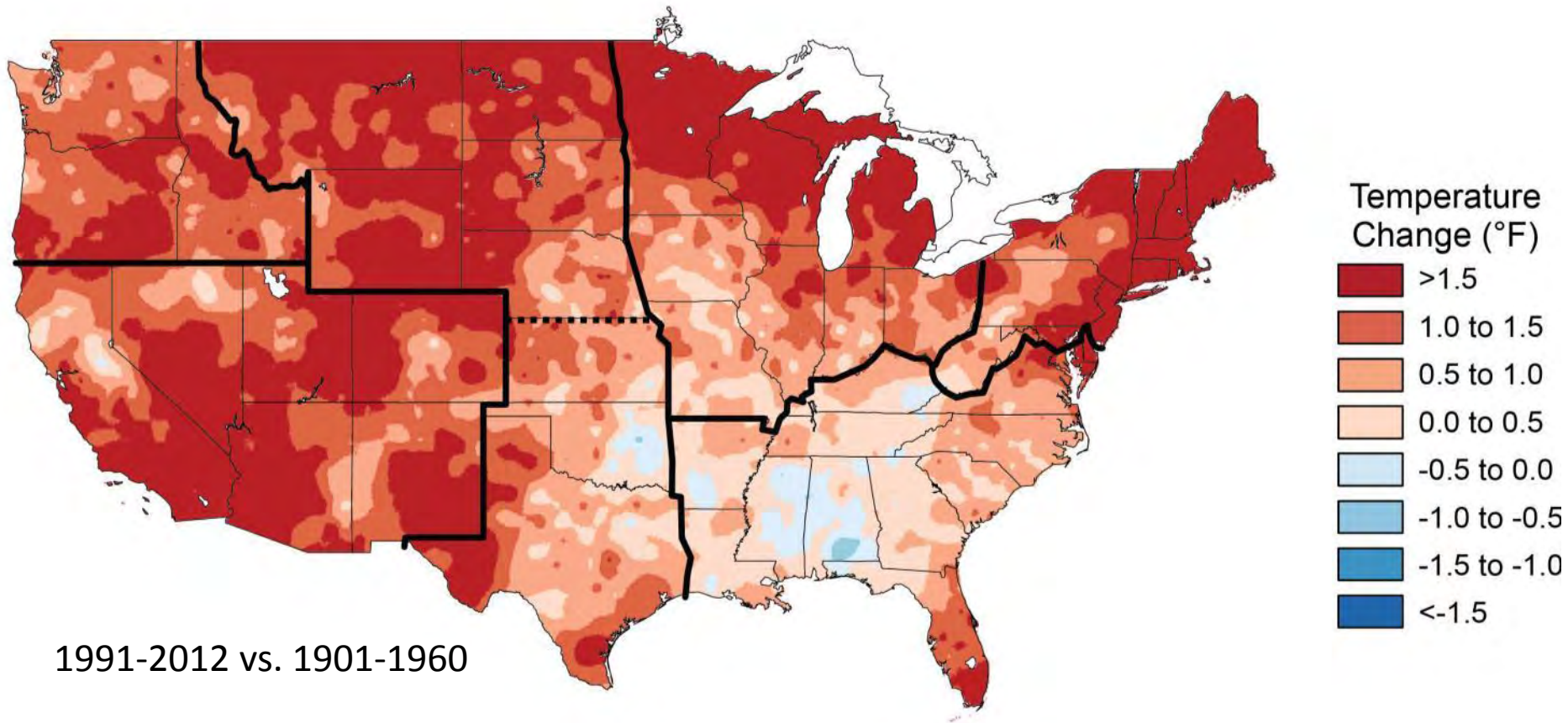


Prioritizing Climate Change Refugia for Conservation

- Climate is Changing
- Climate Adaptation Strategies
- Climate Change Refugia Conservation Cycle
- Identifying and Testing Climate Change Refugia
- Conclusions

Observed U.S. Temperatures

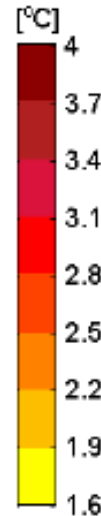
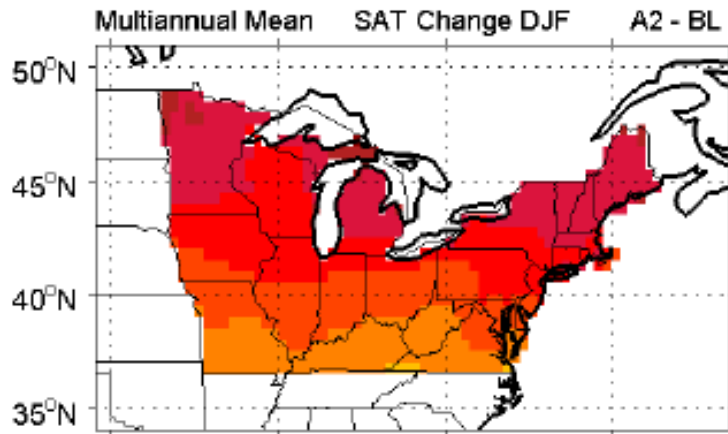
Warming in most places



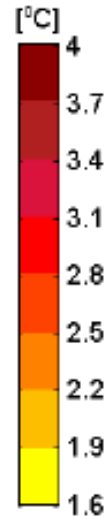
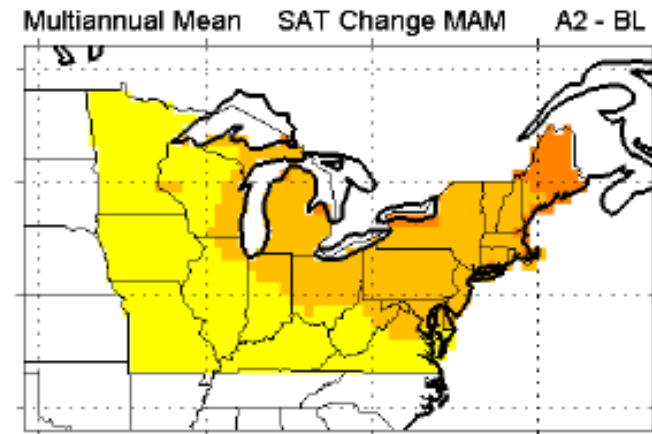
Projected U.S. Temperatures

Warming varies by season

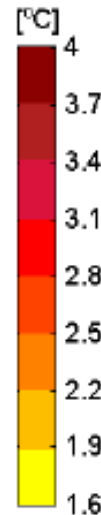
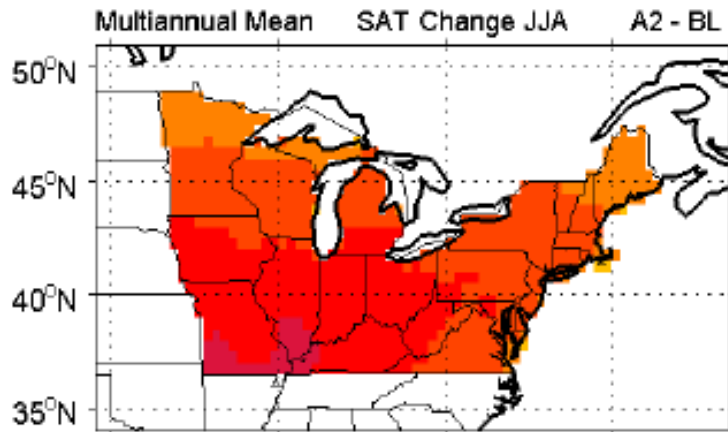
Winter



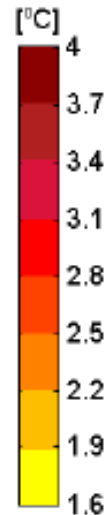
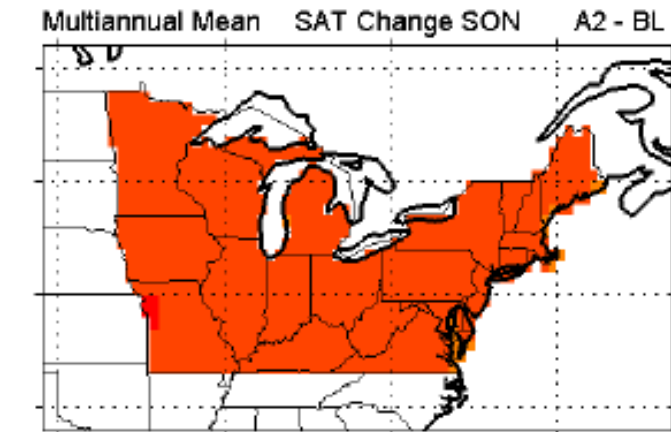
Spring



Summer



Fall





Climate Adaptation Options?



Climate Adaptation Options

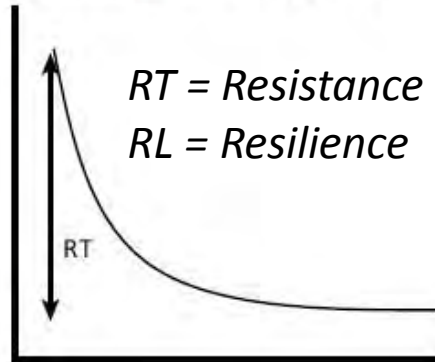
- Enable Response to Change
 - Promote connectivity
 - Diversify seed sources & activities
 - Translocations
- Promote Resilience to Change
 - Forest thinning
 - Restoration of incised banks
 - Make snow at ski areas
- Create Resistance to Change
 - Fire breaks
 - Intense removal of migrants
 - Reduce disturbances



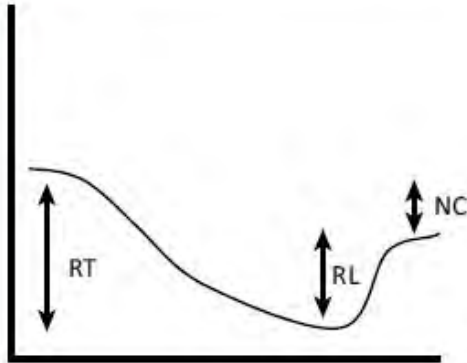
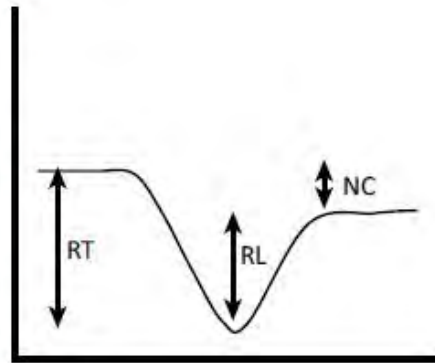
Examples



Ecological response



Ecological state variable



Time

TRENDS in Ecology & Evolution

Vive la resistance!

Nimmo et al. 2015

Climate Change Refugia

Journal of Biogeography (*J. Biogeogr.*) (2014) **41**, 837–841

**GUEST
EDITORIAL**

The ecological and evolutionary implications of microrefugia

Jonathan A. Mee^{1*} and Jean-Sébastien Moore²



1365-3113/2014/41/837-04



Review



Frontiers in Ecology and the Environment

The capacity of refugia for conservation planning under climate change

Gunnar Keppel, Karel Mokany, Grant W Wardell-Johnson, Ben L Phillips, Justin A Welbergen, and April E Reside

in fossil
and

³, Katy D. Heath⁴,
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Managing Climate Change Refugia for Climate Adaptation

TL Morelli, SP Maher, K Nydick, J Ebersole,
WB Monahan, C Daly, S Dobrowski, D Dulen,
ST Jackson, JD Lundquist, CI Millar, KT
Redmond, S Sawyer, S Stock, & SR Beissinger

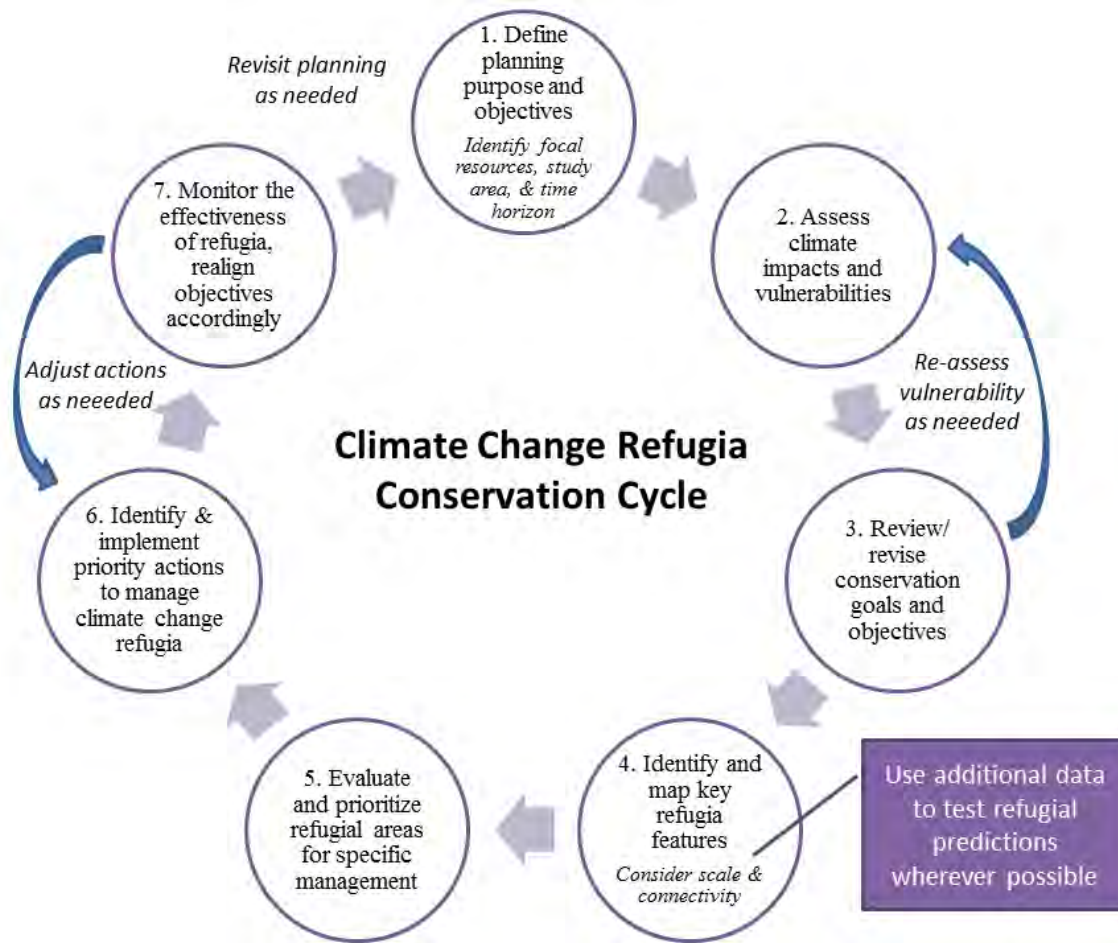


*Areas relatively buffered from contemporary climate change
that enable persistence of valued resources*

Morelli et al. In Review

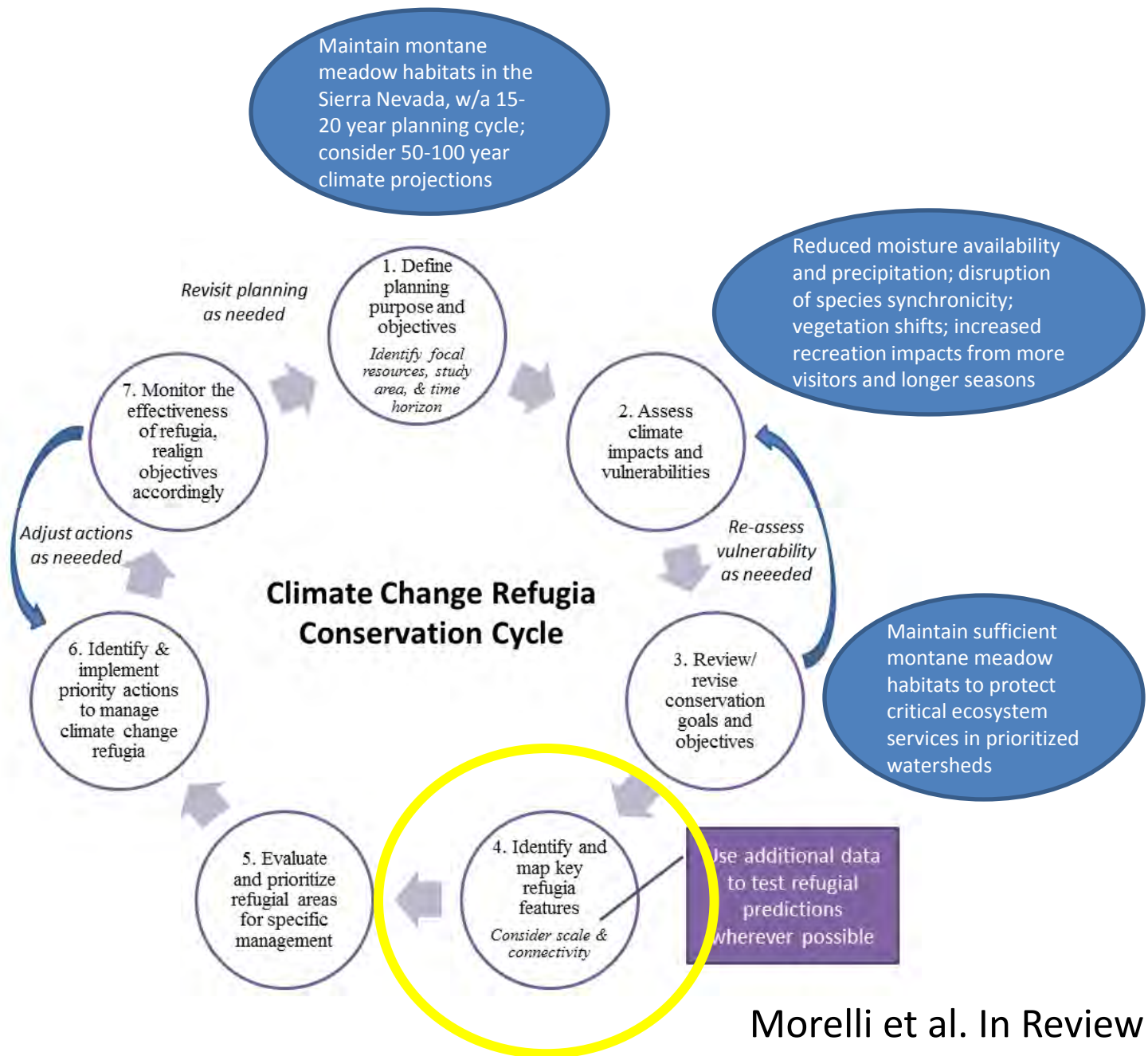
PLOS ONE

Climate change refugia conservation cycle



Morelli et al. In Review

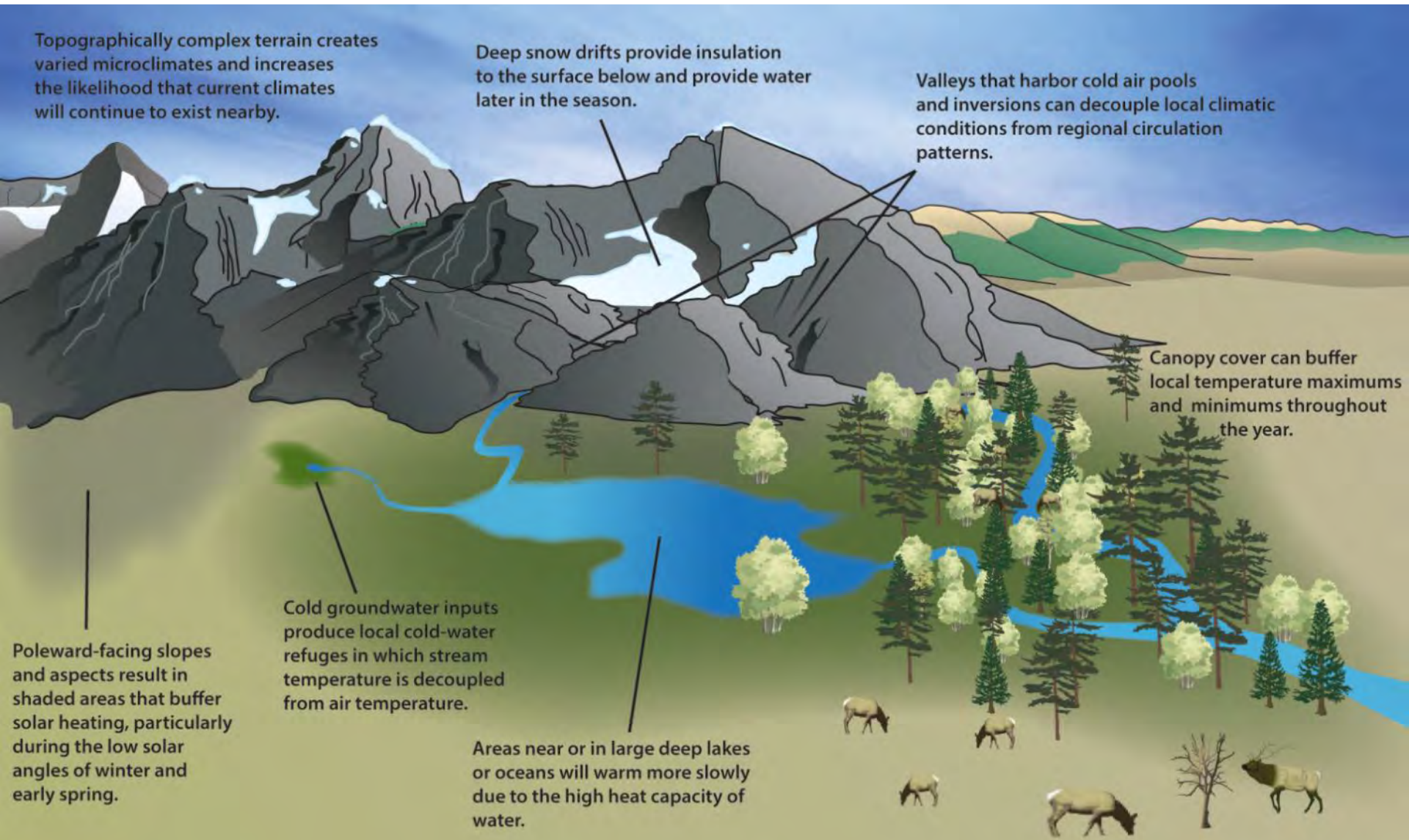
PLOS ONE



Identify Climate Change Refugia

a) Target Refugial Processes

Examples of the physical basis for climate refugia



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.

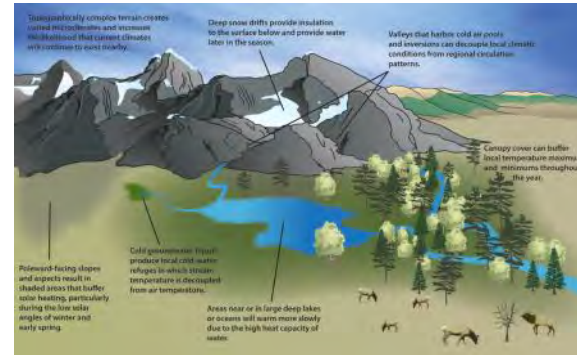
Poleward-facing slopes and aspects result in shaded areas that buffer solar heating, particularly during the low solar angles of winter and early spring.

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

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

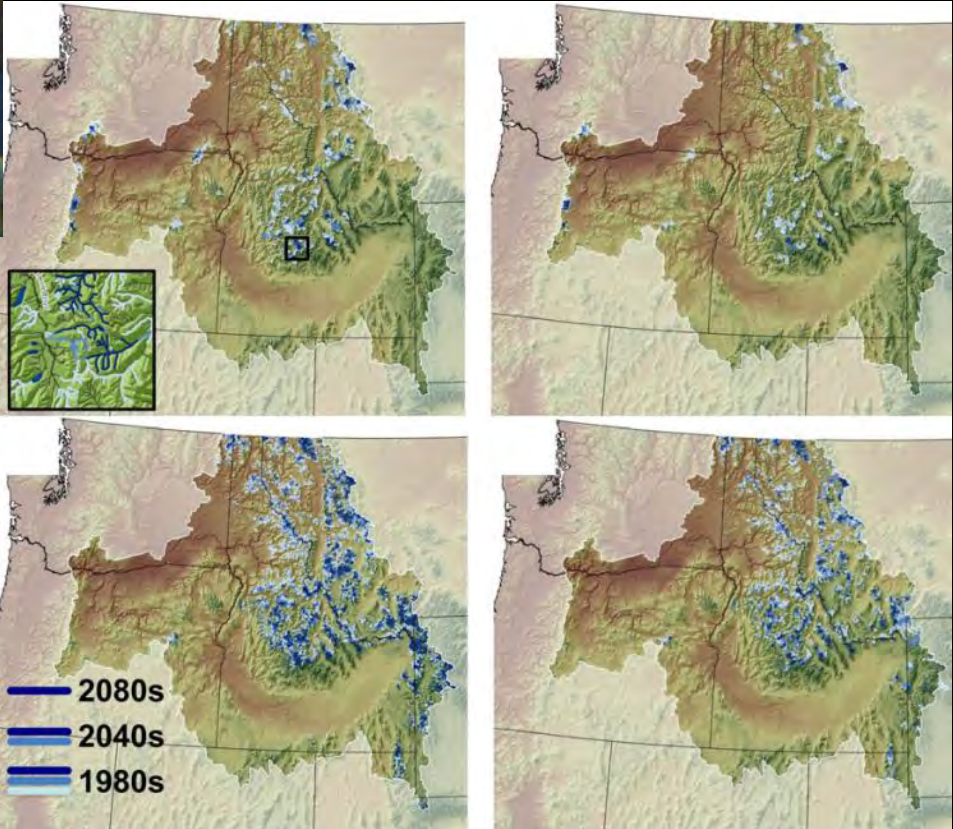
Identify Climate Change Refugia

a) Target Refugial Processes



b) Model Stability Based on Recent or Future Climate

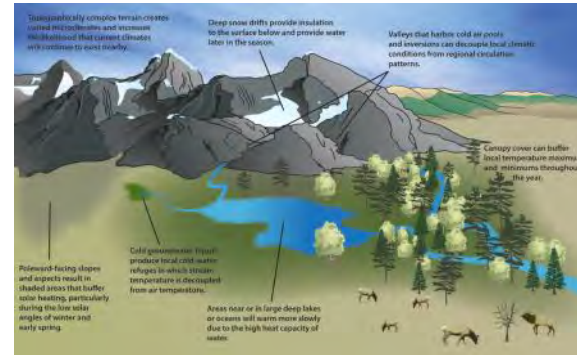
“Climate Shield”



Isaak et al. 2015
GCB

Identify Climate Change Refugia

a) Target Refugial Processes

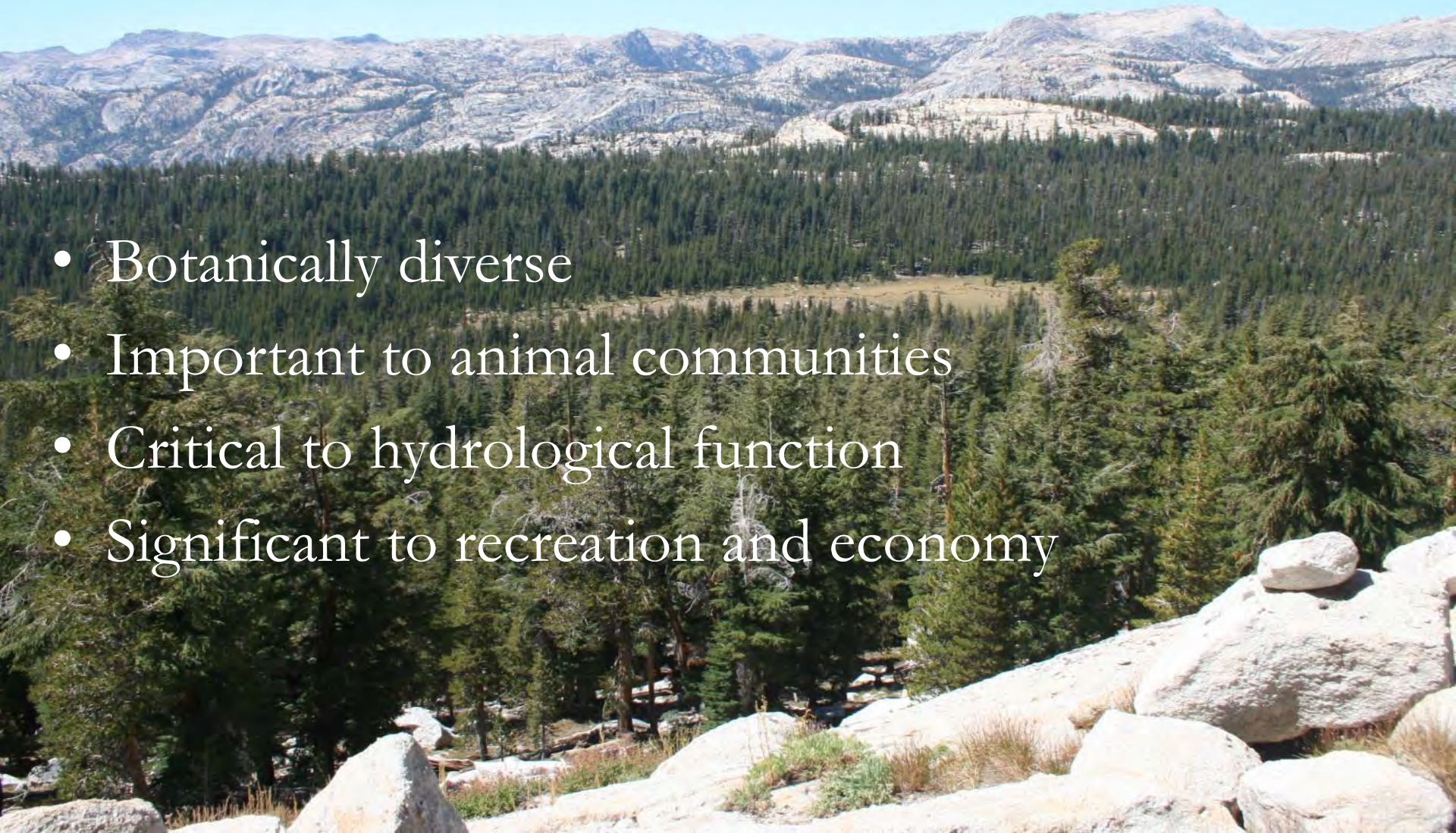


b) Model Stability Based on Recent or Future Climate

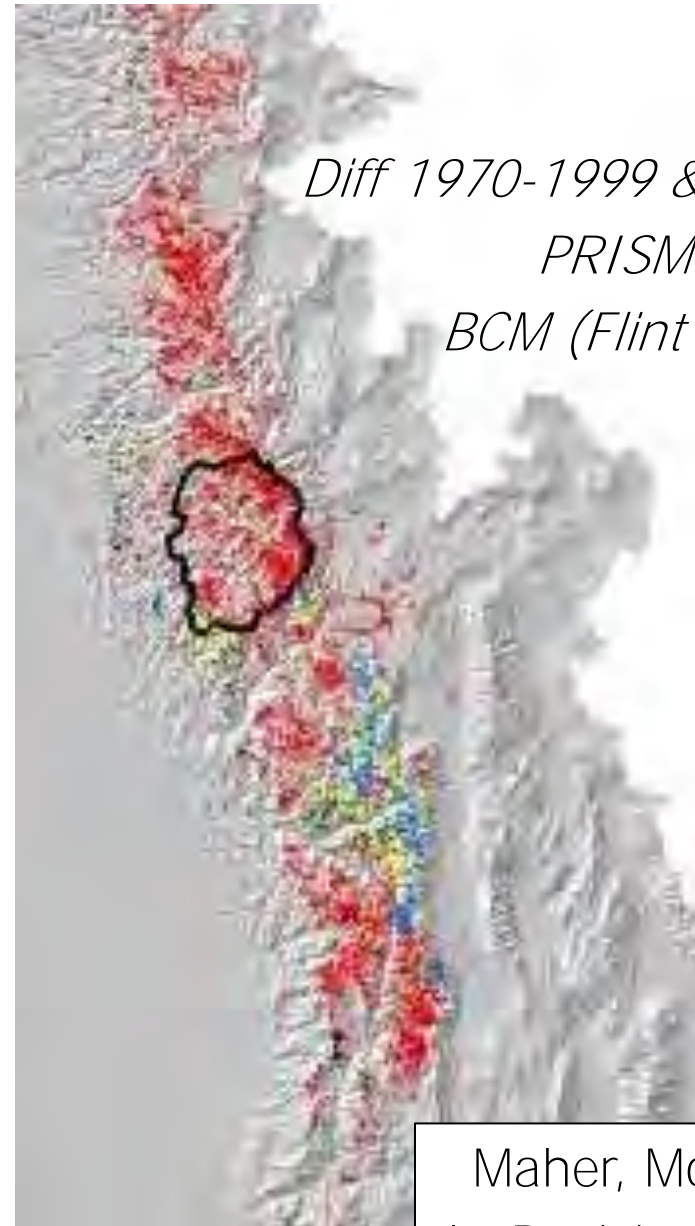
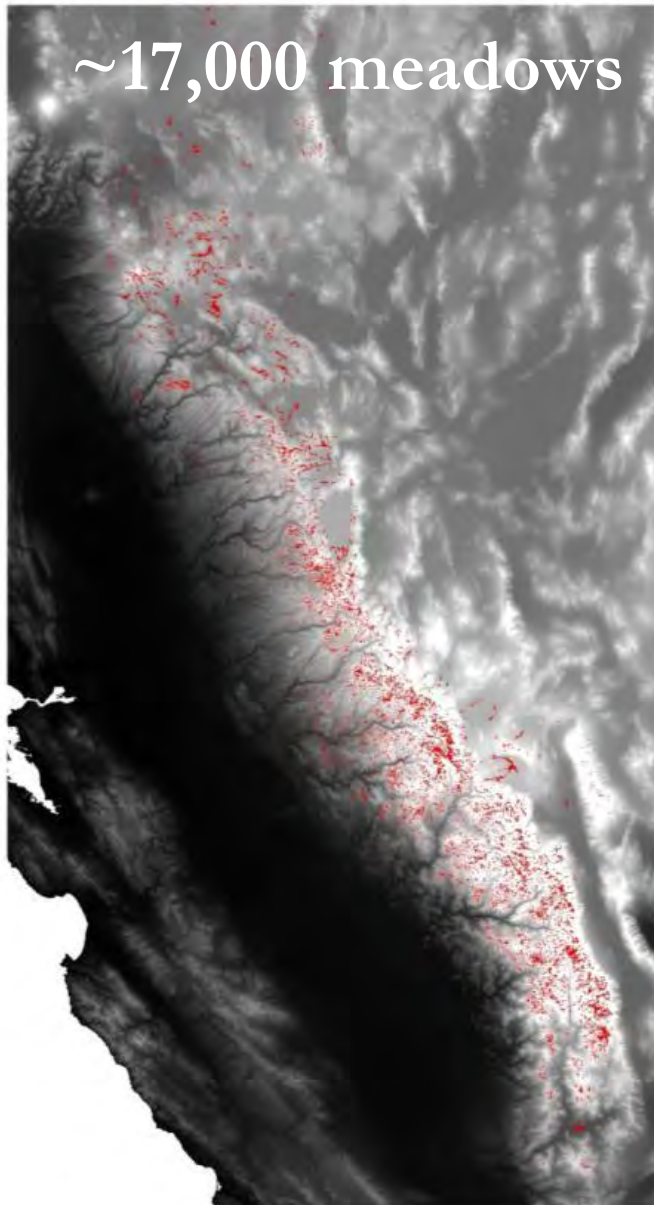
c) Locate Areas of High Resource Persistence or Diversity

Montane Meadows

- Botanically diverse
- Important to animal communities
- Critical to hydrological function
- Significant to recreation and economy

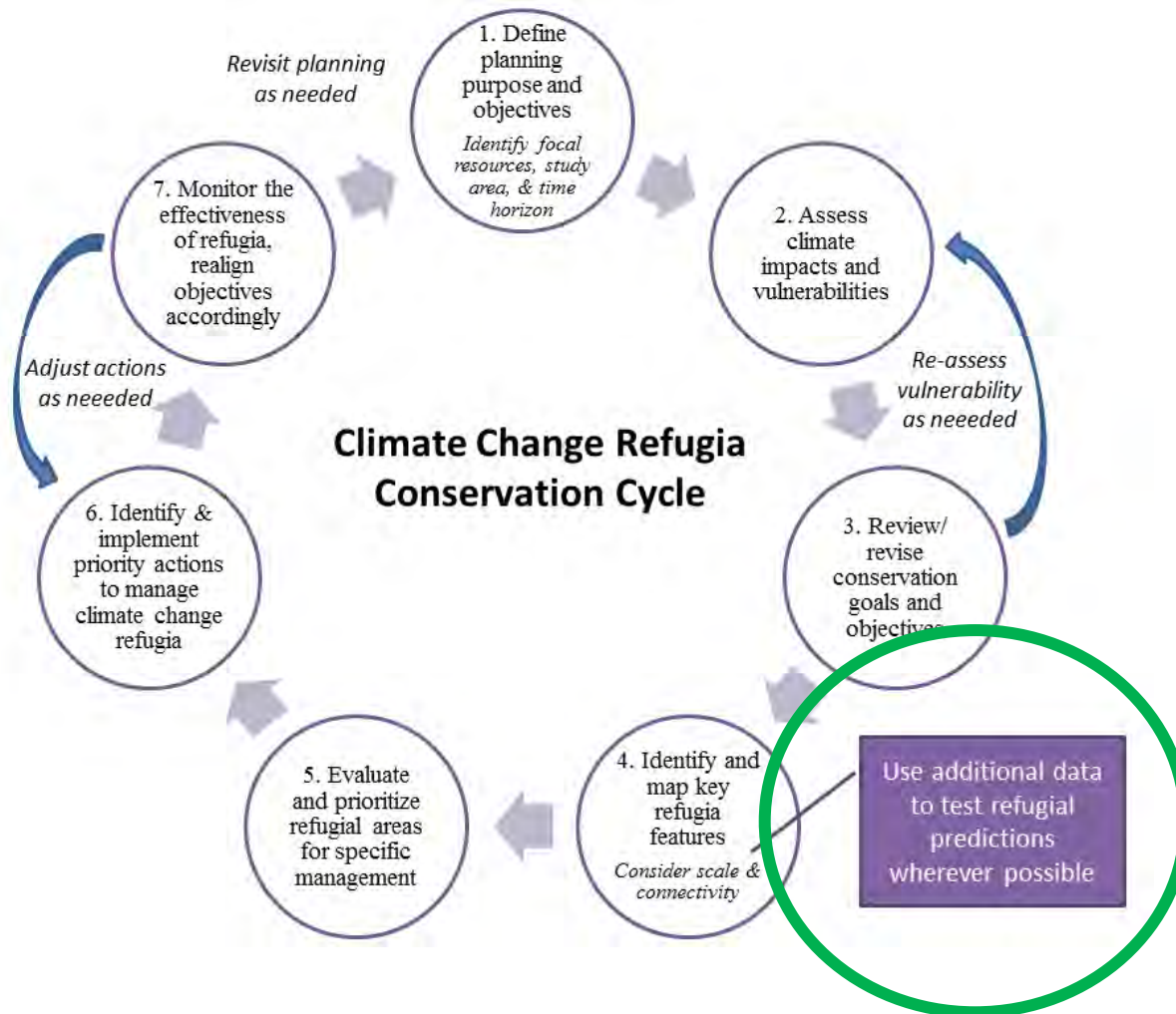


Modeling Climate Stability

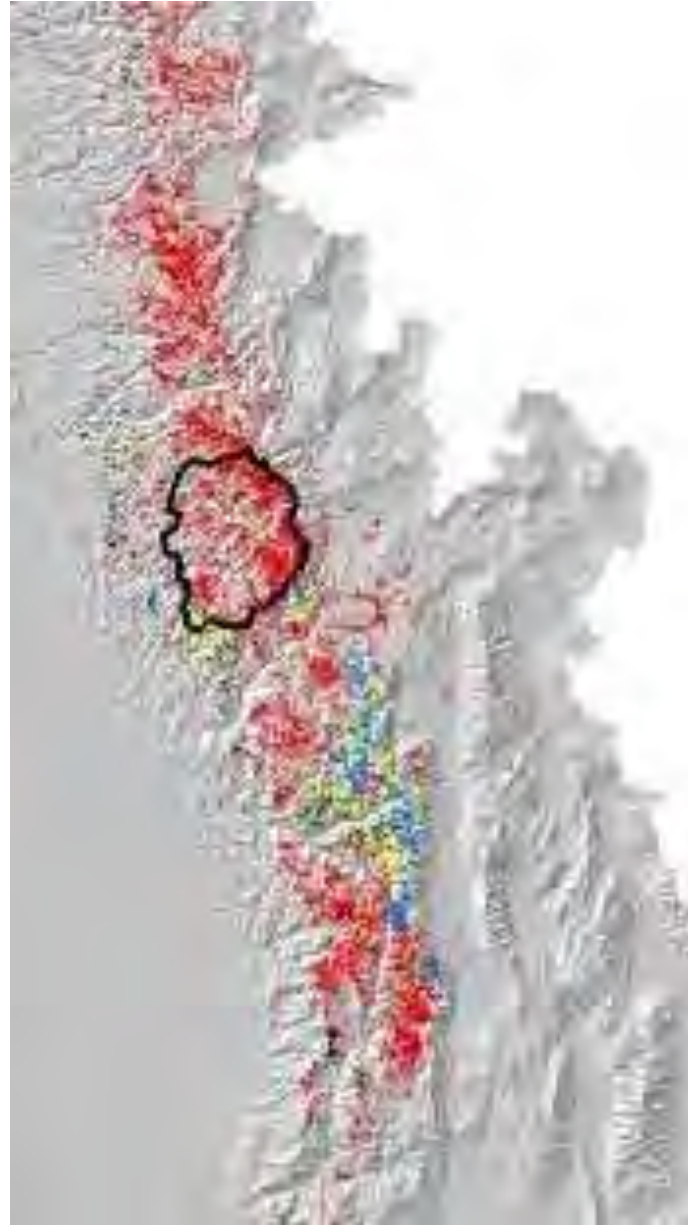


Maher, Morelli et al.
In Revision Ecosphere

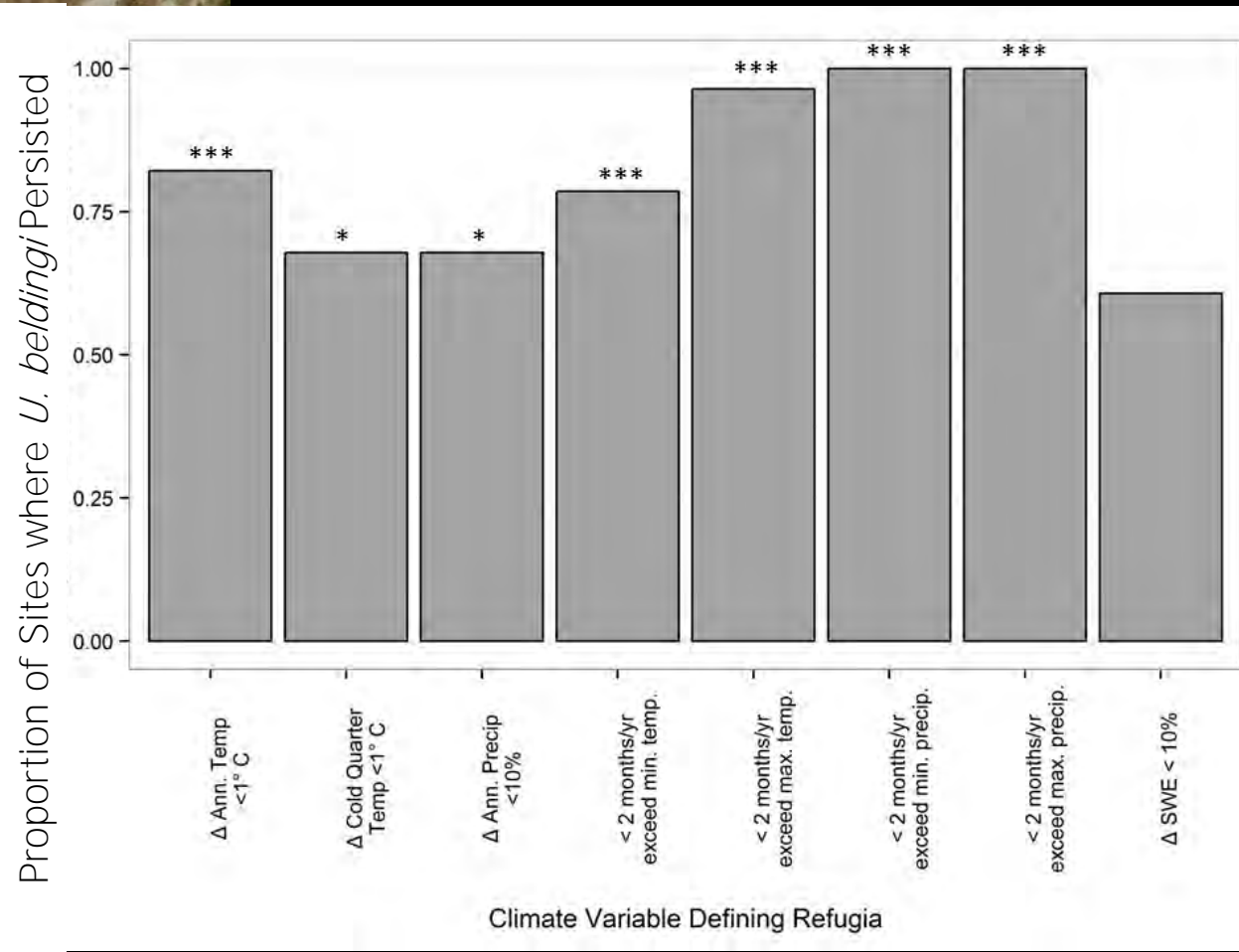
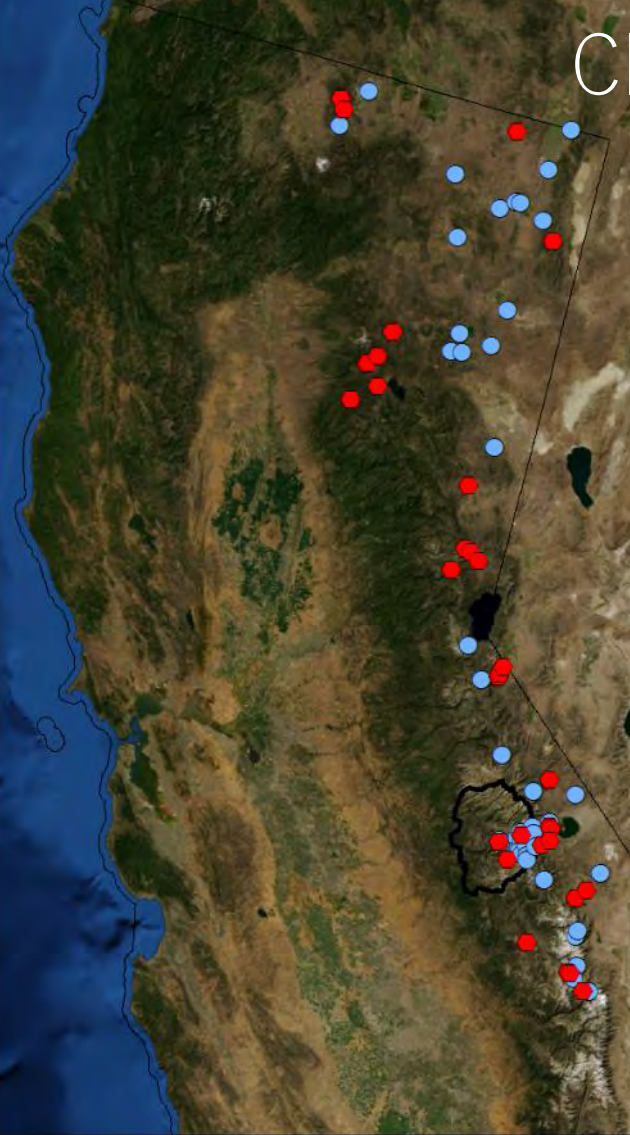
Steps for Managing Climate Change Refugia



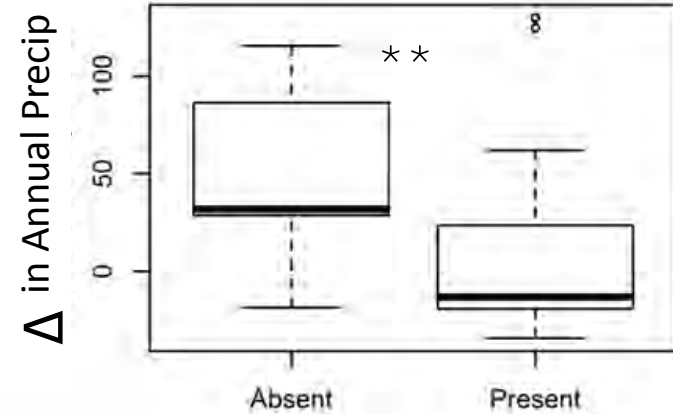
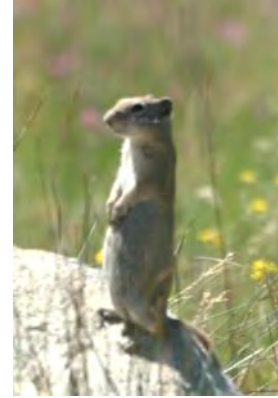
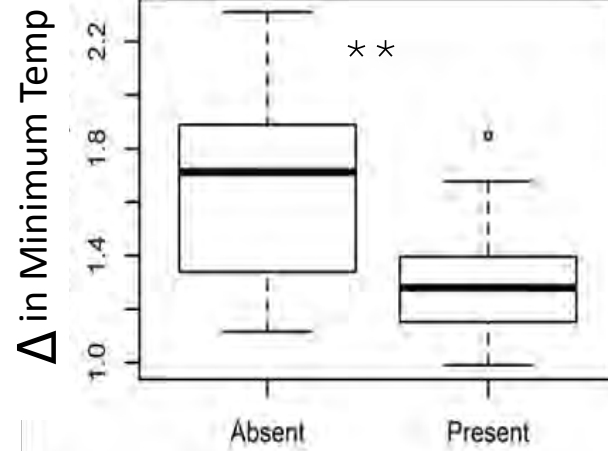
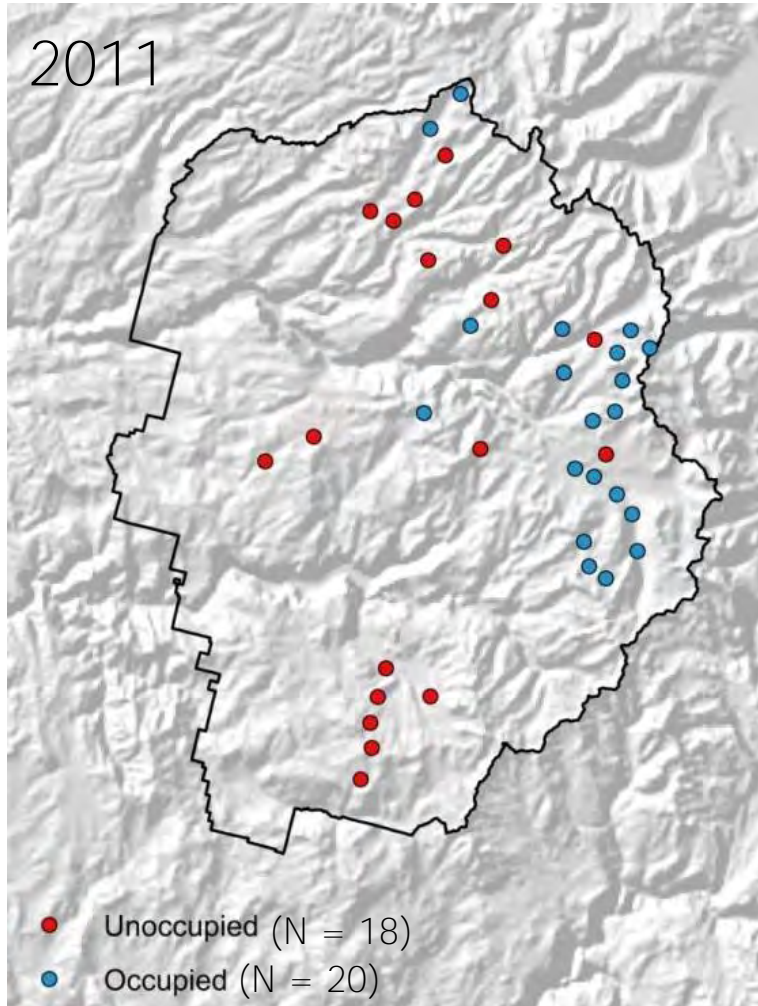
Testing the Climate Refugia Map



Climate Refugia Predict Persistence

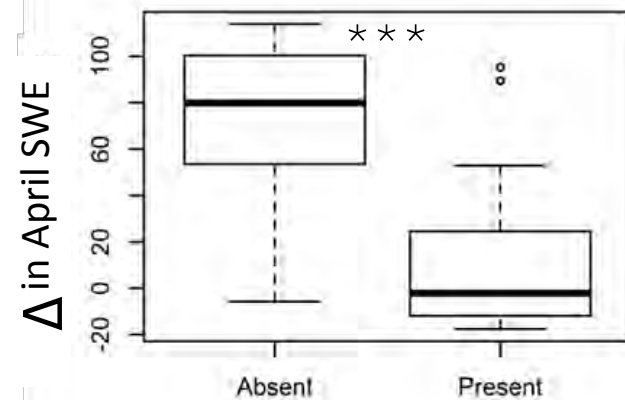


Climate Refugia Predict Occupancy

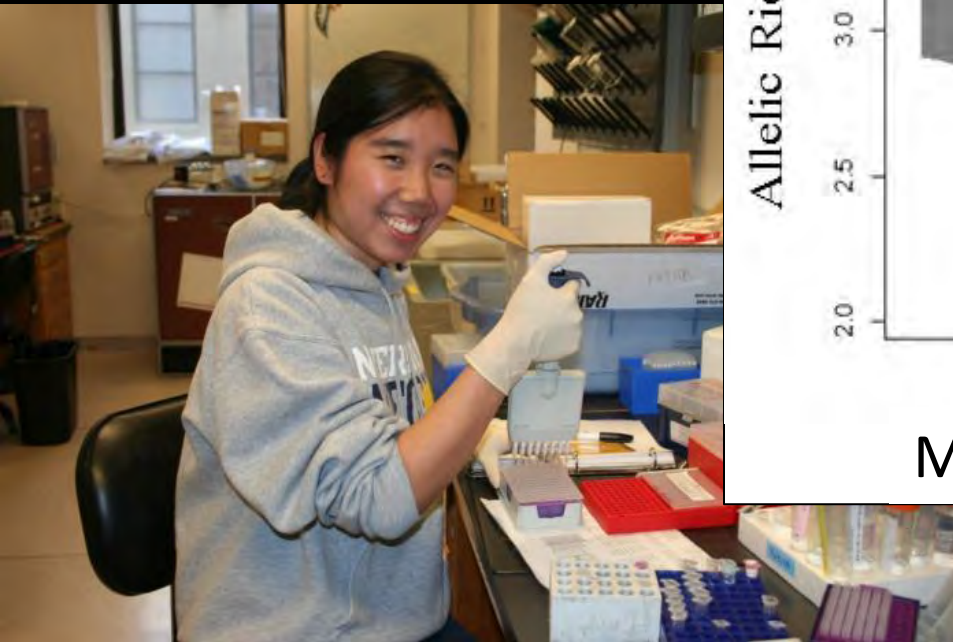
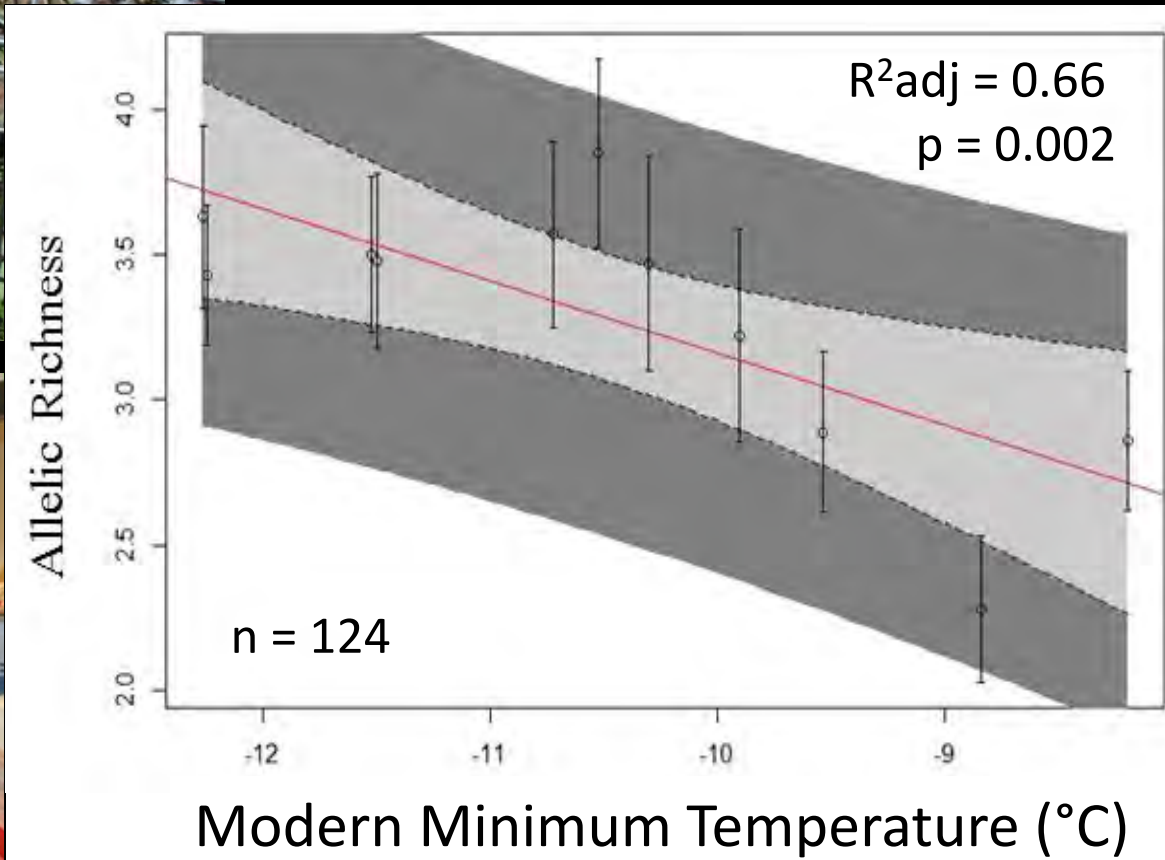


2-Samp Wilcox.
Test

** $p < 0.001$
*** $p < 0.0001$



Temperature correlates with Genetic Diversity



Morelli et al. *In Review*
Global Change Biology

Maintain montane meadow habitats in the Sierra Nevada, w/a 15-20 year planning cycle; consider 50-100 year climate projections

Reduced moisture availability and precipitation; disruption of species synchronicity; vegetation shifts; increased recreation impacts from more visitors and longer seasons

Monitor: meadow wetness via remote sensing and field measurements; indicator species; downstream watershed variables (streamflow, sediment load, etc)

1. Define planning purpose and objectives
Identify focal resources, study area, & time horizon

2. Assess climate impacts and vulnerabilities

Maintain sufficient montane meadow habitats to protect critical ecosystem services in prioritized watersheds

7. Monitor the effectiveness of refugia, realign objectives accordingly

Climate Change Refugia Conservation Cycle

3. Review/revise conservation goals and objectives

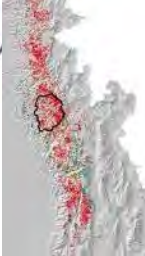
6. Identify & implement priority actions to manage climate change refugia

Minimize overgrazing; remove encroaching conifers & invasive species; mitigate road & trail impacts; assist migration of lower elev species; snow fencing to trap snow in desired locations; manage recreation & development; increase connectivity

5. Evaluate and prioritize refugial areas for specific management

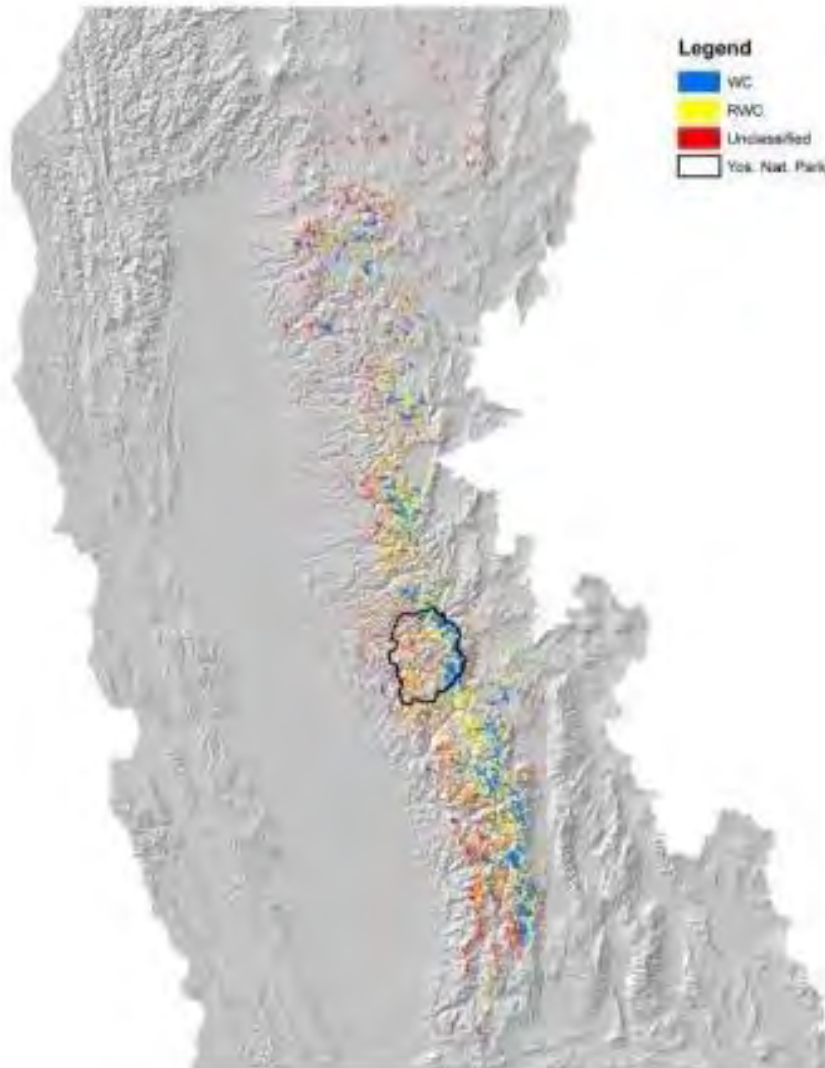
4. Identify and map key refugia features
Consider scale & connectivity

Use additional data to test refugial predictions wherever possible



Medium or large meadows that are highly connected; areas of high biodiversity; meadows where species of management concern exist or might exist in the future; areas of high recreational value (if uses are compatible)

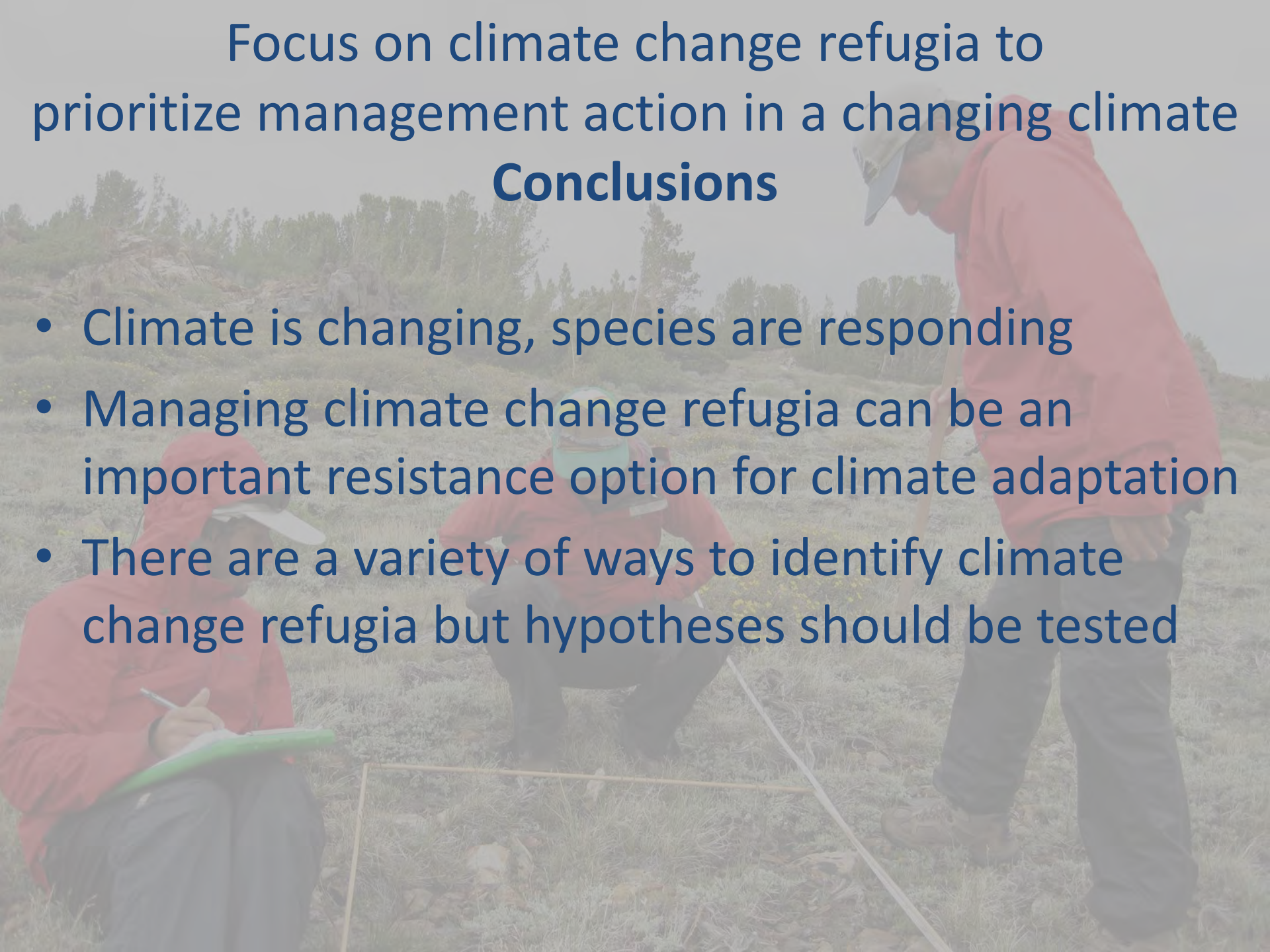
Management Tools and Actions



Increase Connectivity
Improved culvert design
Road crossings
Reroute trails
Assisted migration?

Focus on climate change refugia to prioritize management action in a changing climate

Conclusions

- Climate is changing, species are responding
 - Managing climate change refugia can be an important resistance option for climate adaptation
 - There are a variety of ways to identify climate change refugia but hypotheses should be tested
- 
- A photograph of three researchers in red jackets and hats conducting field research in a grassy area. One researcher is kneeling on the left, writing on a clipboard. Another is kneeling in the center, looking at the ground. A third is standing on the right, looking down. A measuring tape is stretched across the ground in front of them. The background shows a grassy field with some trees and a hazy sky.

Thanks!

- Co-authors
- Funders
- NECSC colleagues
- Moritz Lab
- Beissinger Lab
- Michelle Koo
- Michelle Hershey
- Christina Kastely, Ilaria Mastroserio, Matt Pfannenstiel, & other field assistants



UC Davis
Information Center for the
Environment (ICE)



climate.calcommons.org

northeastclimate.org