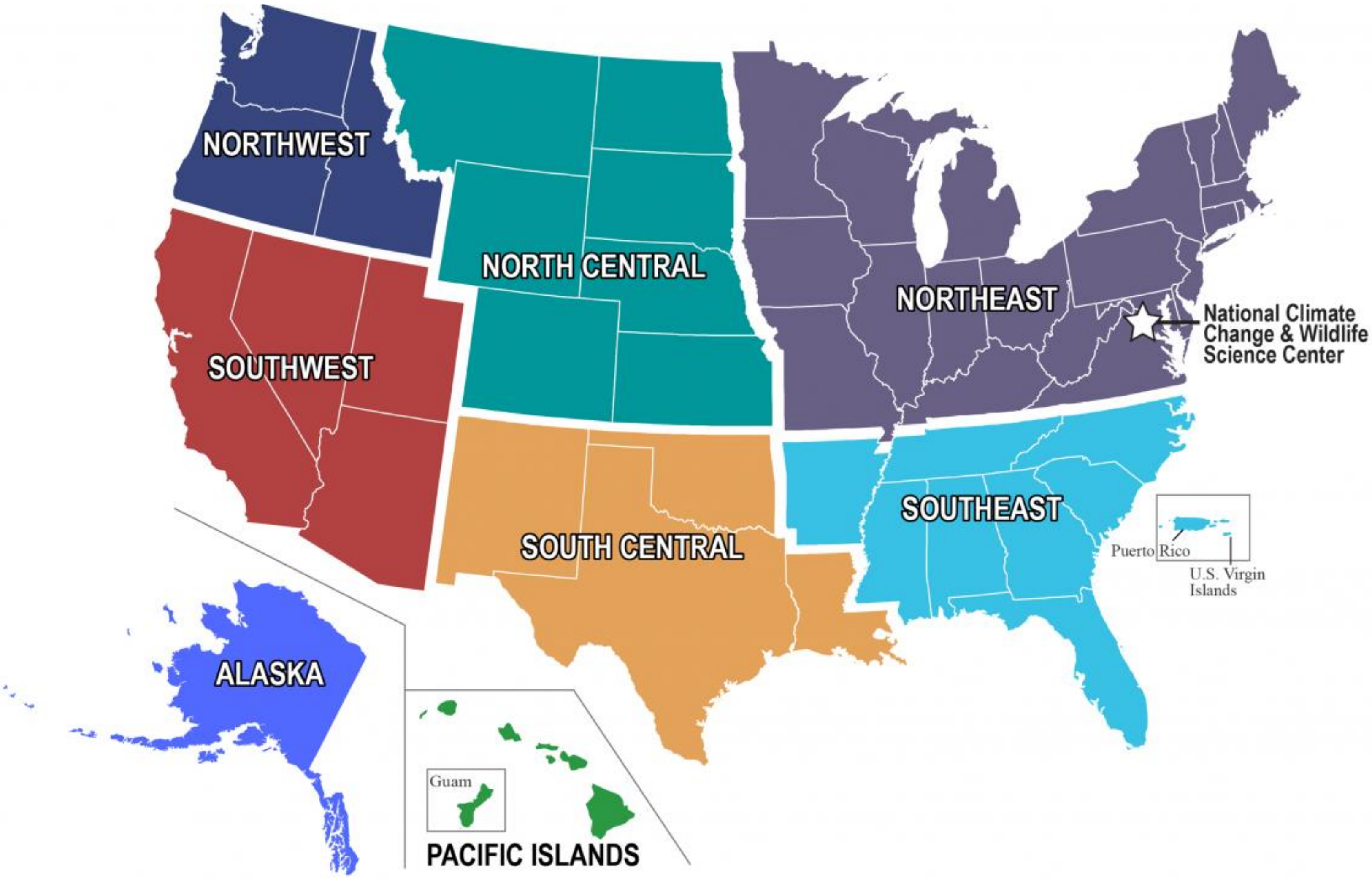
Sierra Climate Change Refugia Conservation Workshop

Southwest Climate Adaptation Science Center

USGS
science for a changing world

Refugia Research Coalition
RRC
connecting science to actions

NE CASC
Northeast Climate Adaptation Science Center



DOI Climate Science Centers

Sierra Nevada Climate Change Refugia - Workshop Goals

- Learn about Climate Change Refugia Conservation
- Draft a priority resource list
- Identify relevant decision points and management actions
- Begin gathering relevant resources
- Initiate the SW RRC!

RRC

Search

RRC Refugia Research Coalition

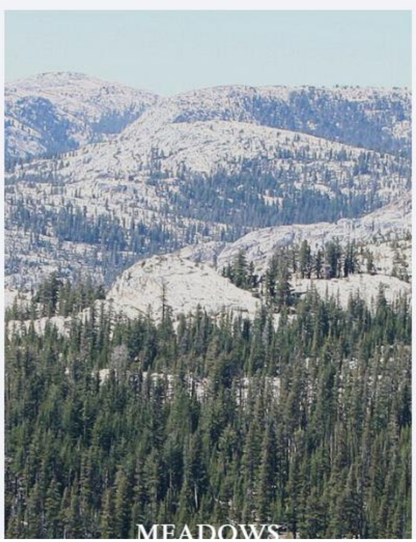
Home What are Climate Refugia? Publications News Events Our Team Contact Us

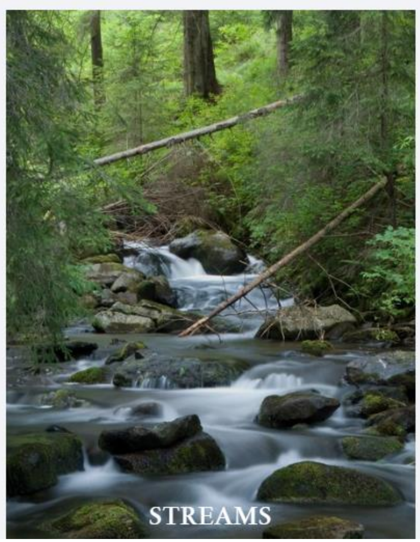
— ECOSYSTEMS IN THE SIERRA NEVADA—

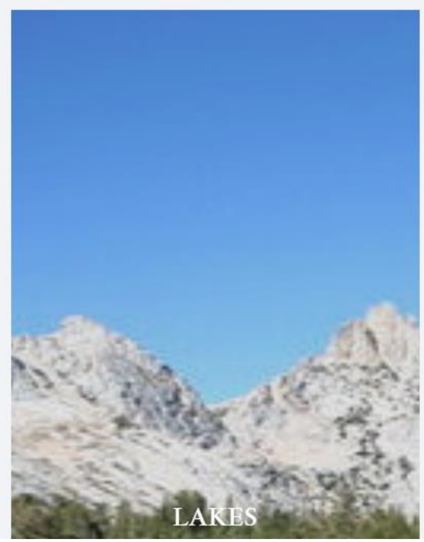
The goal of the SW RRC is to bring together natural resource managers and scientists from across the region who are interested in managing climate change refugia as a tactic for conserving species and other resources in the face of climate change.

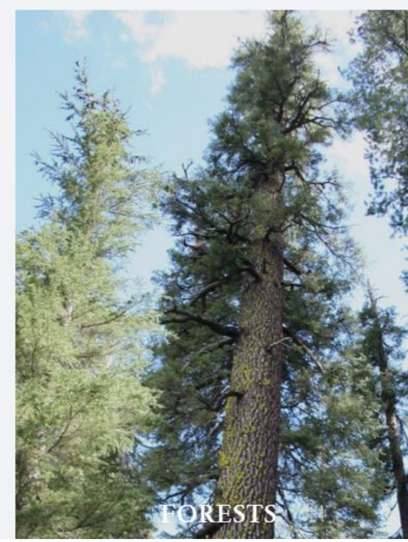
One of the first steps, which we are conducting at our kickoff workshop at the Yosemite National Park on November 8, 2019, is to develop a preliminary short list of species and ecosystems to focus Sierra Nevada refugia identification and conservation on. Through a process of real-time voting and discussion we will settle on a short list of ecosystems and species and discuss actions related to each of these areas

.

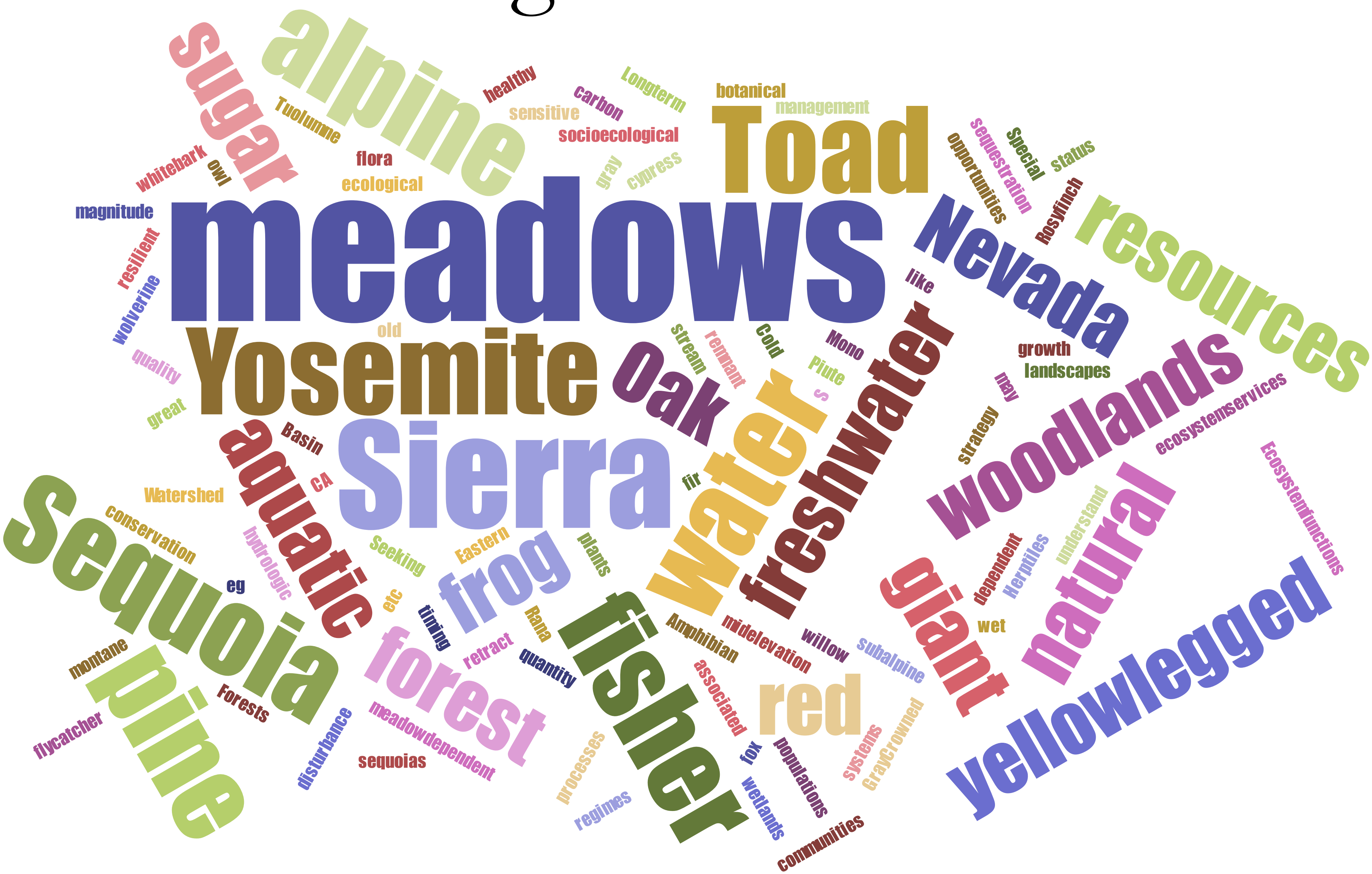








What Species/Resources to Focus Refugia Conservation on?



Translational Ecology

An intentional process by which ecologists, stakeholders, and decision-makers work collaboratively to develop scientific research via joint consideration of the sociological, ecological, & political contexts of an environmental problem that results in improved decision-making.

Enquist et al.
Frontiers in Ecol. & the Environ. 2017


Climate
Change
Adaptation
1054

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

Millar et al. 2007 *Eco Apps*

PLOS | ONE

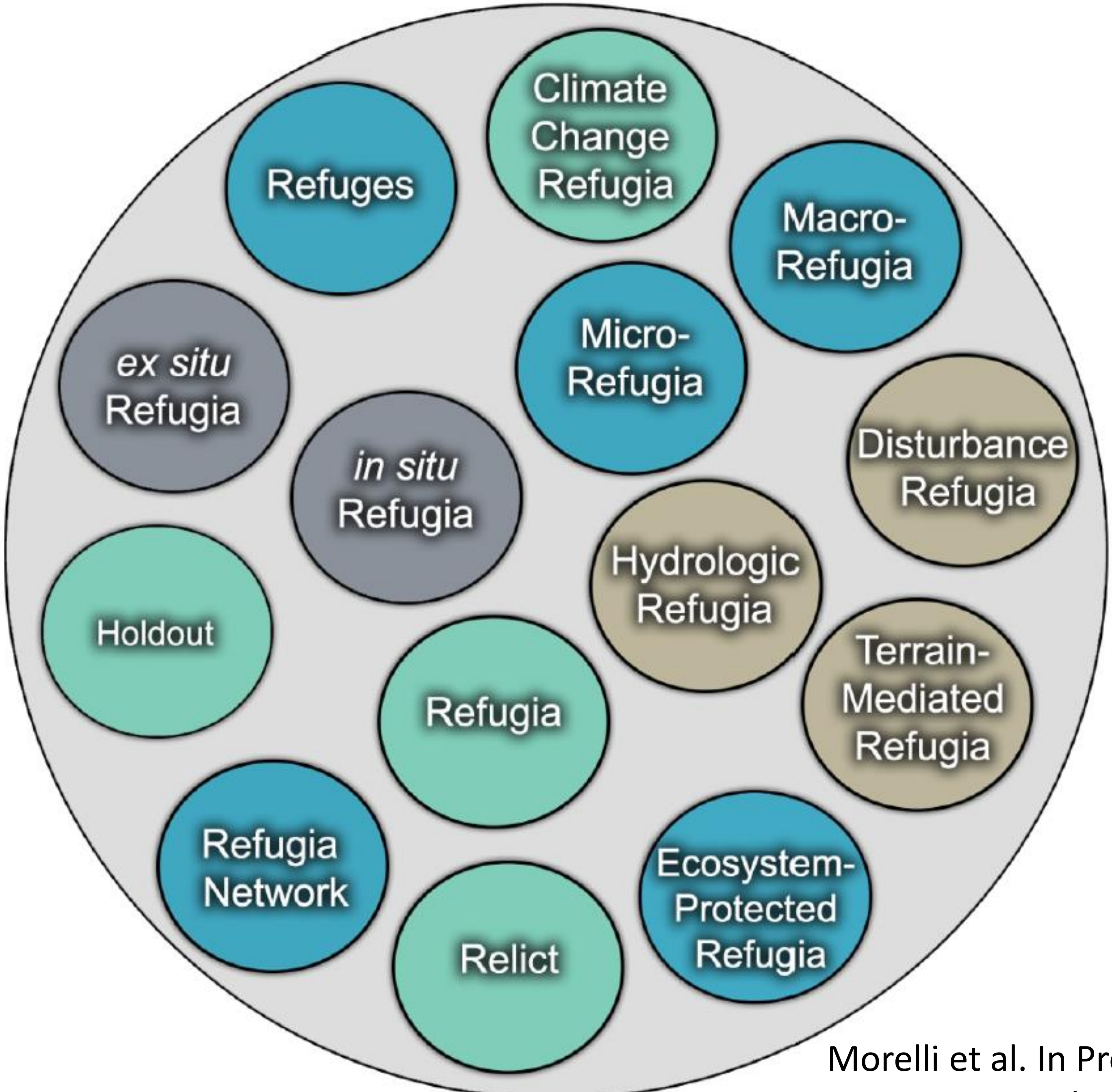
COLLECTION REVIEW

Managing Climate Change Refugia for Climate Adaptation

Toni Lyn Morelli[1,2,3]*, Christopher Daly[4], Solomon Z. Dobrowski[5], Deanna M. Dulen[6], Joseph L. Ebersole[7], Stephen T. Jackson[8,9], Jessica D. Lundquist[10], Constance I. Millar[11], Sean P. Maher[2,3,12], William B. Monahan[13], Koren R. Nydick[14], Kelly T. Redmond[15], Sarah C. Sawyer[16], Sarah Stock[17], Steven R. Beissinger[2,3]

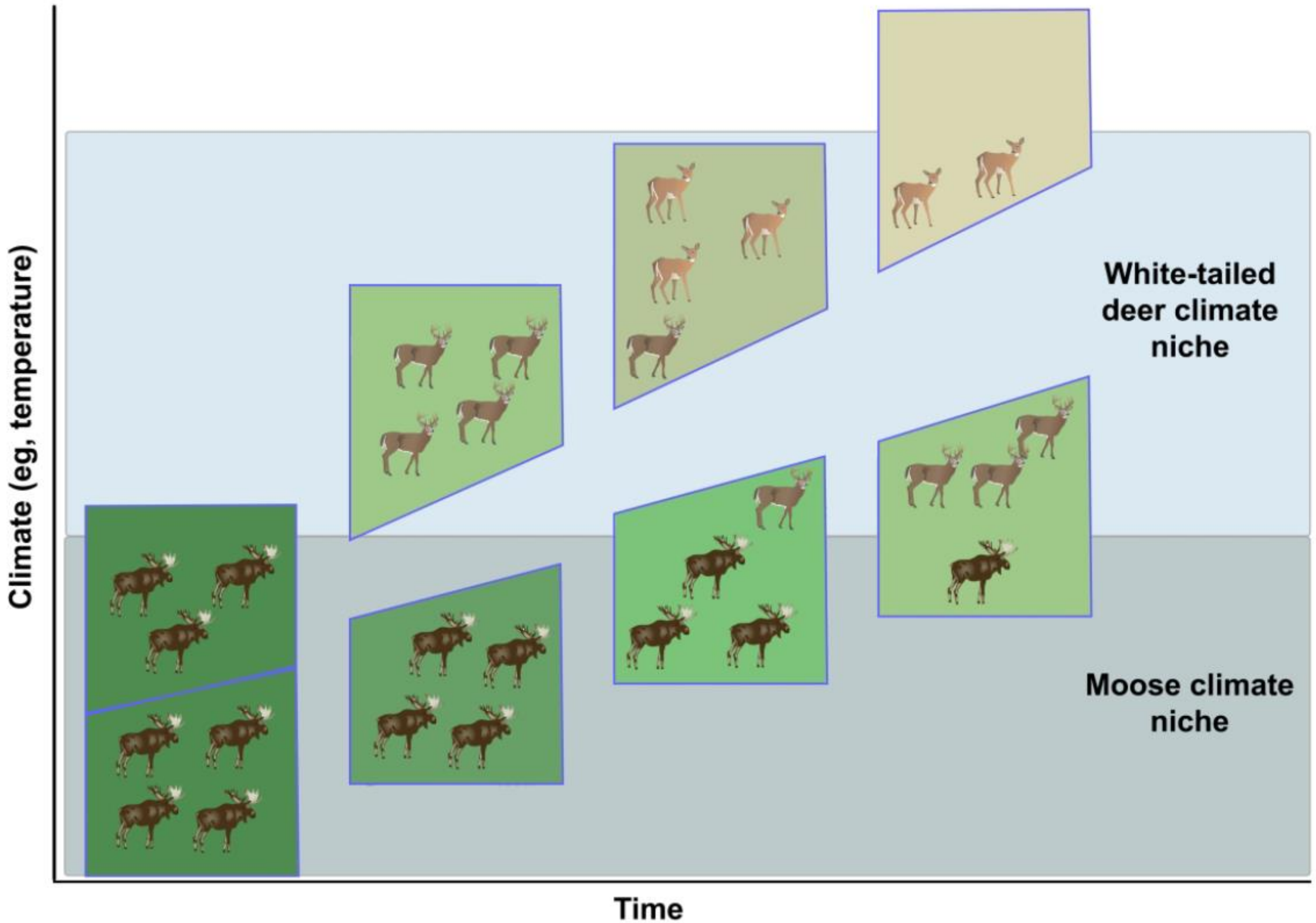
1 U.S. Geological Survey, DOI Northeast Climate Science Center, Amherst, MA, United States of America, **2** Department of Environmental Science, Policy and Management, University of California, Berkeley, CA, United States of America, **3** Museum of Vertebrate Zoology, University of California, Berkeley, CA, United States of America, **4** College of Engineering, Oregon State University, Corvallis, OR, United States of America, **5** College of Forestry and Conservation, University of Montana, Missoula, MT, United States of America, **6** U.S. National Park Service, Devils Postpile National Monument, Mammoth Lakes, CA, United States of America, **7** U.S. Environmental Protection Agency, Western Ecological Division, Corvallis, OR, United States of America, **8** U.S. Geological Survey, DOI Southwest Climate Science Center, Tucson, AZ, United States of America, **9** Department of Geosciences and School of Natural Resources and Environment, University of Arizona, Tucson, AZ, United States of America, **10** Department of Civil and Environmental Engineering, University of Washington, Seattle, WA, United States of America, **11** USDA Forest Service, Pacific Southwest Research Station, Albany, CA, United States of America, **12** Department of Biology, Missouri State University, Springfield, MO, United States of America, **13** USDA Forest Service, Forest Health Technology Enterprise Team, Fort Collins, CO, United States of America, **14** U.S. National Park Service, Sequoia & Kings Canyon National Parks, Three Rivers, CA, United States of America, **15** Western Regional Climate Center, Desert Research Institute, Reno, NV, United States of America, **16** USDA Forest Service, Pacific Southwest Region, Vallejo, CA, United States of America, **17** U.S. National Park Service, Yosemite National Park, El Portal, CA, United States of America

Areas relatively buffered from contemporary climate change that enable persistence of valued physical, ecological, and socio-cultural resources

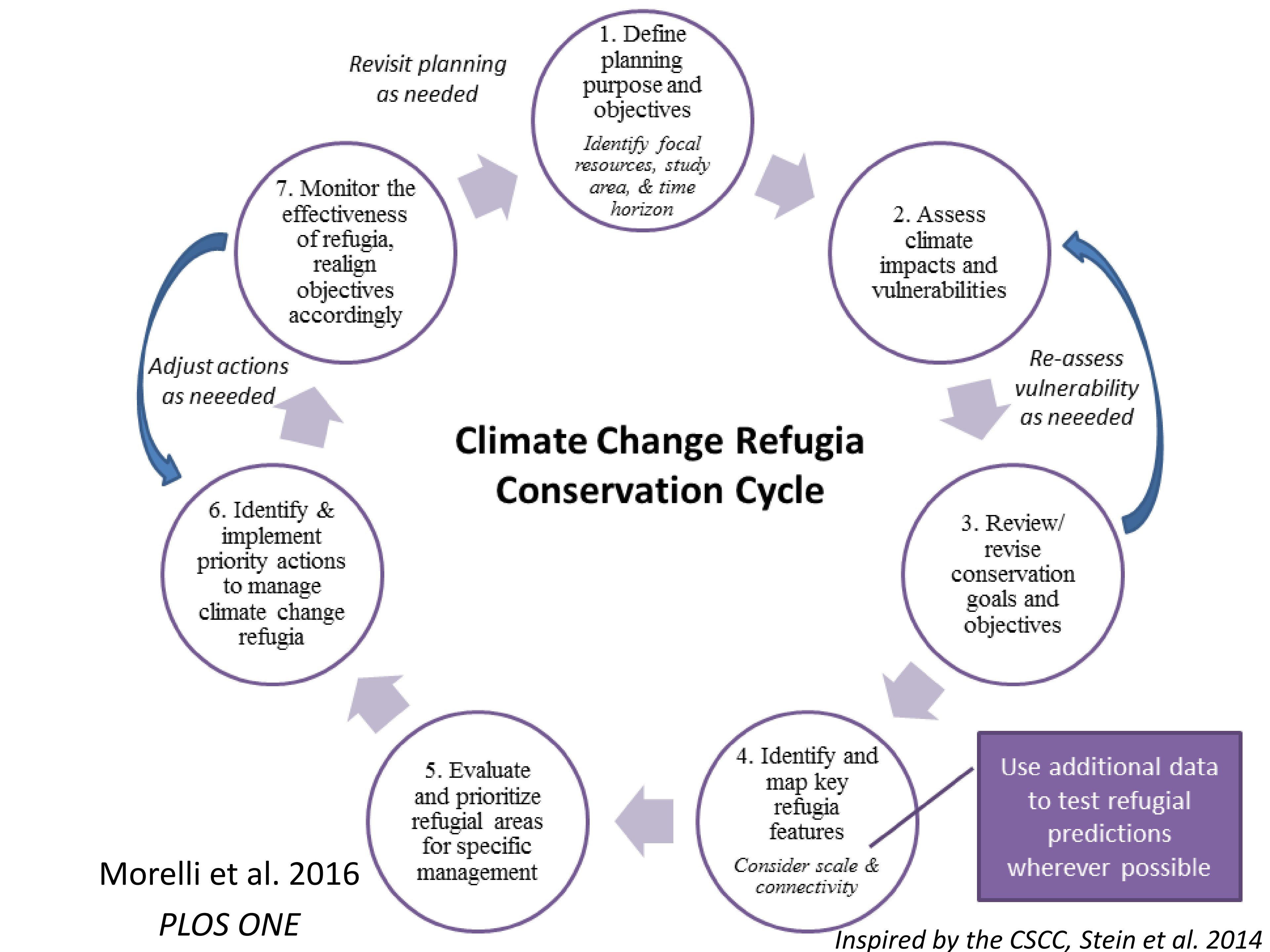


Morelli et al. In Press
Frontiers in Ecology & Evolution

Biodiversity in the Slow Lane



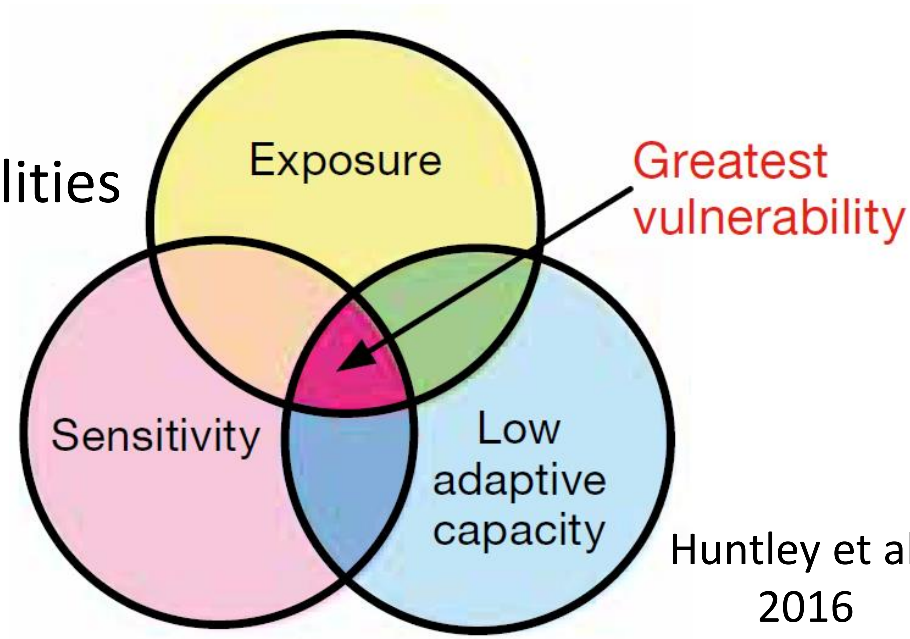
Morelli et al. In Press
Frontiers in Ecology & Evoluti



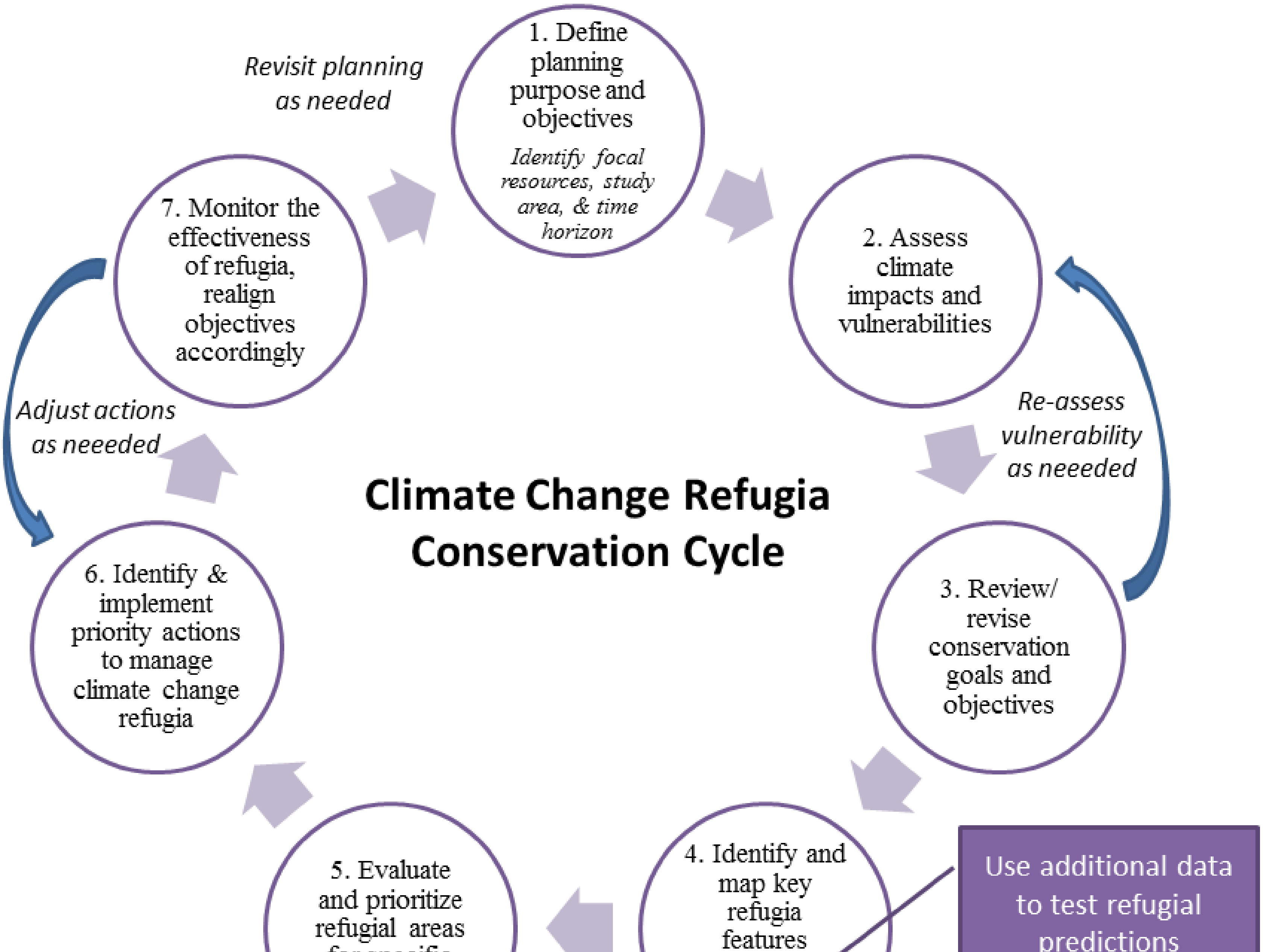
Climate Change Refugia Conservation Cycle
1. Define planning purpose and objectives
Identify focal resources, study area, & time horizon
2. Assess climate impacts and vulnerabilities
3. Review/ revise conservation goals and objectives
4. Identify and map key refugia features
Consider scale & connectivity
5. Evaluate and prioritize refugial areas for specific management
6. Identify & implement priority actions to manage climate change refugia
7. Monitor the effectiveness of refugia, realign objectives accordingly
Revisit planning as needed
Re-assess vulnerability as neeeded
Adjust actions as neeeded
Use additional data to test refugial predictions wherever possible
Morelli et al. 2016
PLOS ONE
Inspired by the CSCC, Stein et al. 2014

Climate Change Vulnerability Assessments

- Used as an initial step in adaptation planning
- *Identify* species and habitats at greatest risk from climate change
- Descriptions of *why* species/habitats are vulnerable
- Provide index of *relative* vulnerabilities
- *Inform* conservation strategies
designed to reduce those vulnerabilities



Huntley et al. 2016

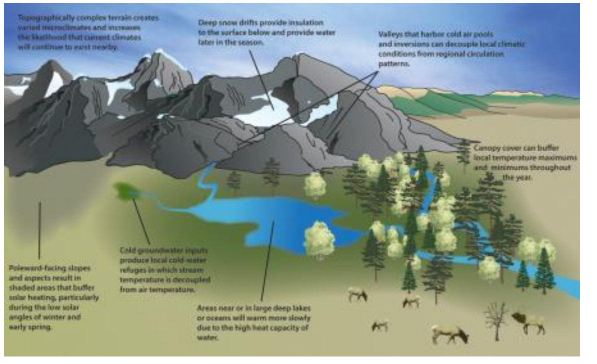


Morelli et al. 2016
PLOS ONE

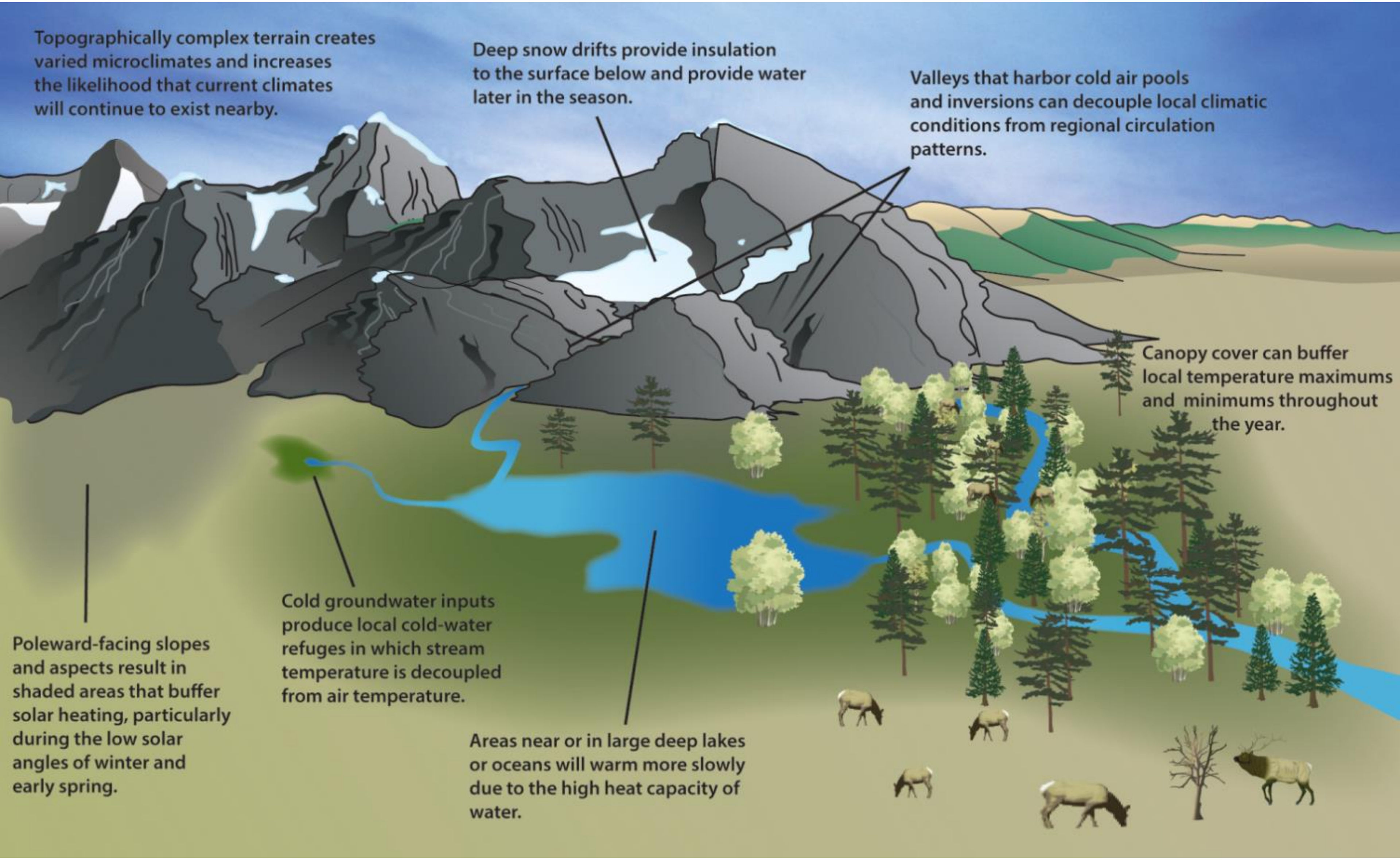
Inspired by the CSCC, Stein et al. 2014

Identify Climate Change Refugia

a) Target Refugial Processes



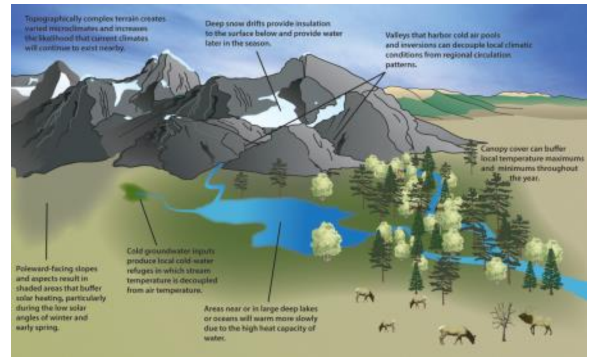
Examples of the physical basis for climate refugia



Morelli et al. 2016

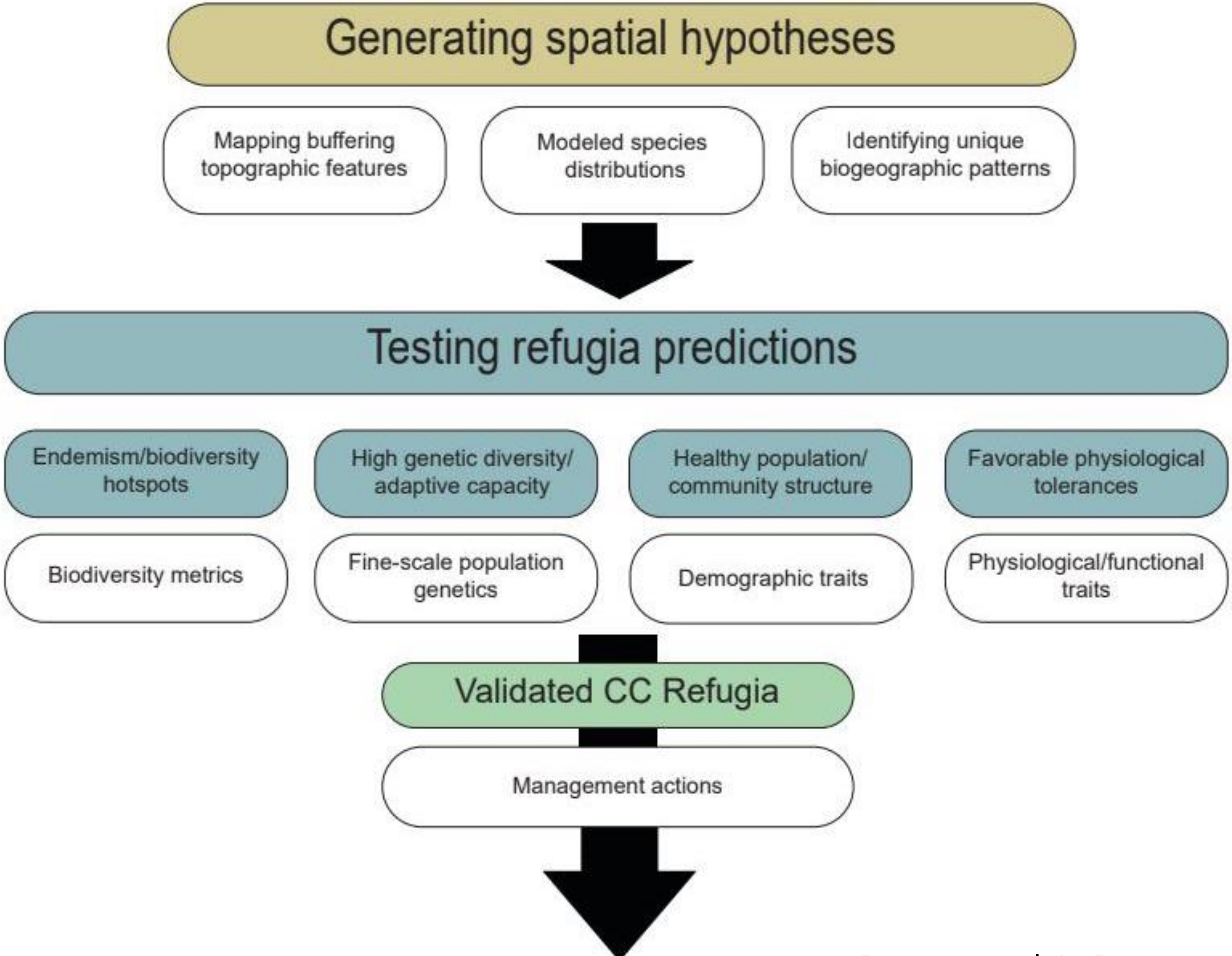
Identify Climate Change Refugia

a) Target Refugial Processes

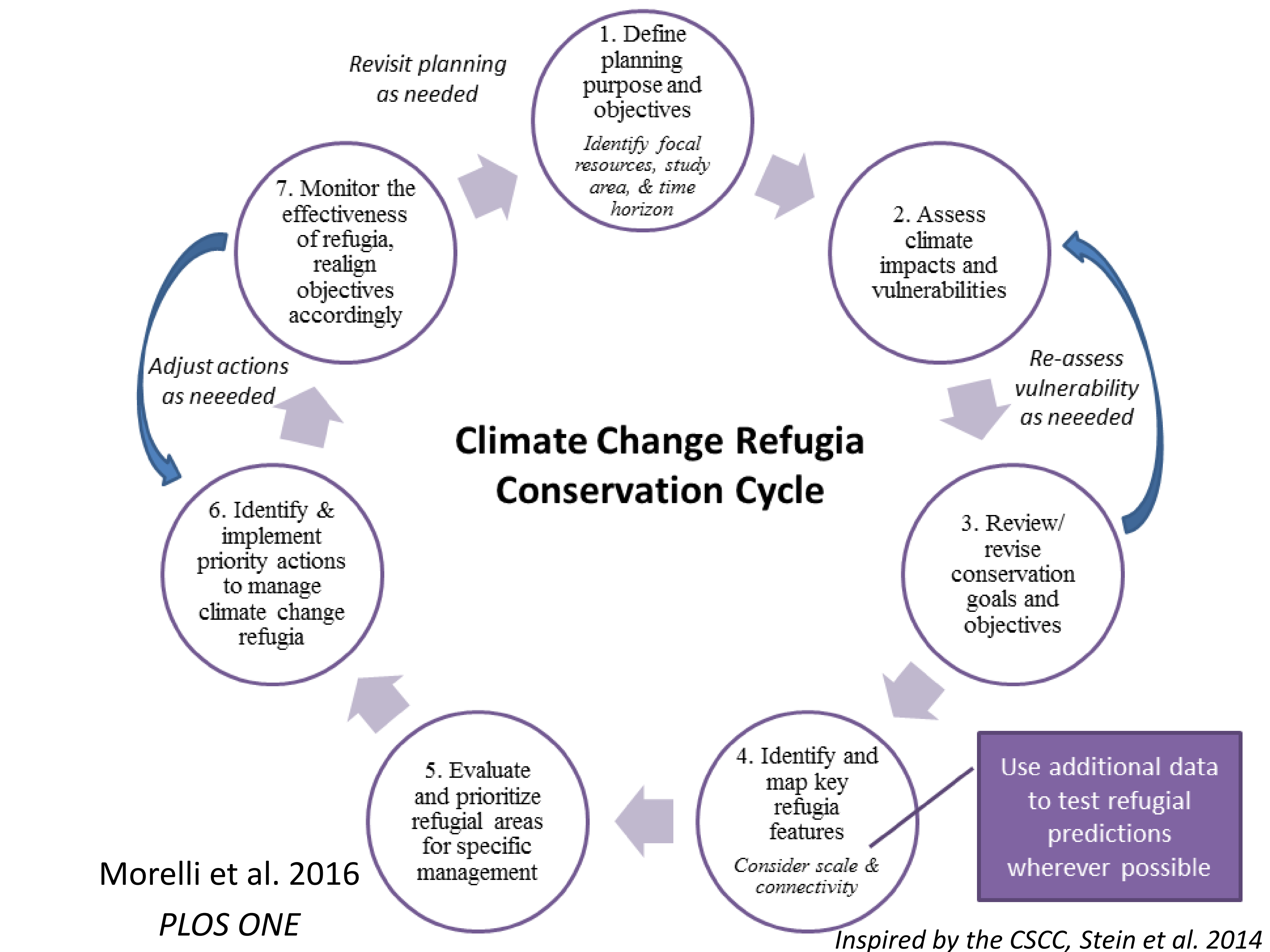


b) Model Stability Based on Recent or Future Climate

c) Locate Areas of High Resource Persistence or Diversity

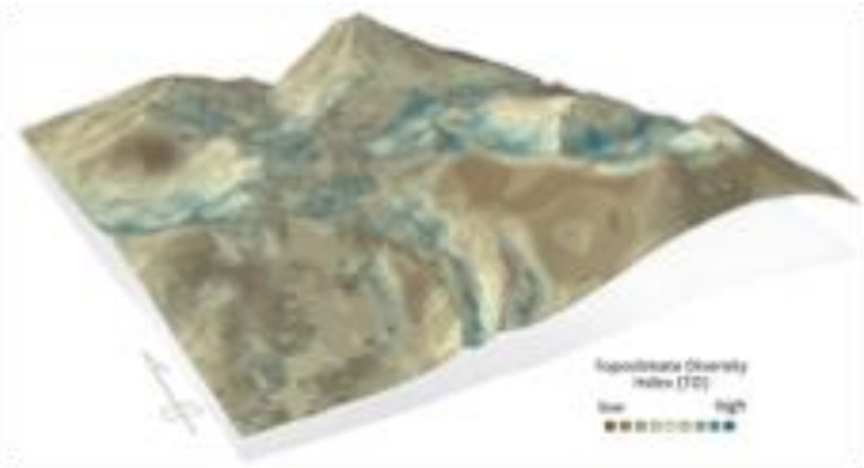


Barrows et al. In Press
Frontiers in Ecology & Evolution



Climate Change Refugia Conservation Cycle
1. Define planning purpose and objectives
Identify focal resources, study area, & time horizon
2. Assess climate impacts and vulnerabilities
3. Review/ revise conservation goals and objectives
4. Identify and map key refugia features
Consider scale & connectivity
5. Evaluate and prioritize refugial areas for specific management
6. Identify & implement priority actions to manage climate change refugia
7. Monitor the effectiveness of refugia, realign objectives accordingly
Revisit planning as needed
Re-assess vulnerability as neeeded
Adjust actions as neeeded
Use additional data to test refugial predictions wherever possible
Morelli et al. 2016
PLOS ONE
Inspired by the CSCC, Stein et al. 2014

Mapping resilient landscapes across the Northwest



Identifying complex, connected landscapes that are resilient to climate change

topoclimate diversity + permeability = terrestrial resilience

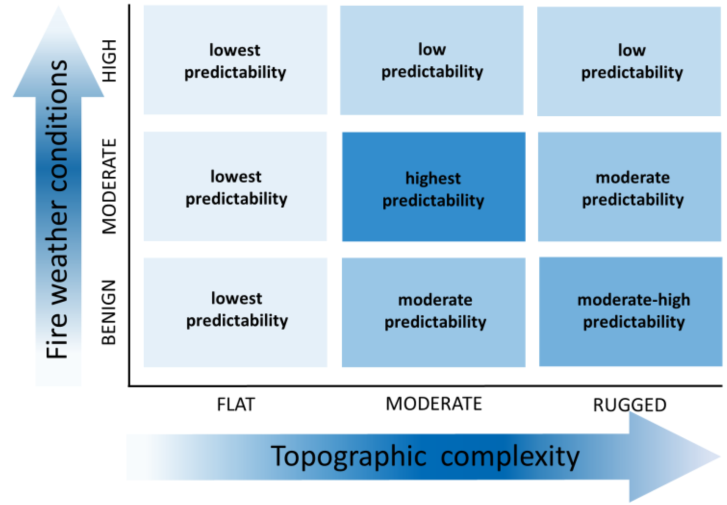
The Nature Conservancy

Protecting nature. Preserving life.™

For more information: kpopper@TNC.org

Mapping and modeling of fire refugia

- Mapping of unburned or lightly burned islands of vegetation—fire refugia.
- Recently completed for 2300 fires across the Northwest.
- Meddens *et al.* 2016



- Framework for predicting fire refugia from fire weather and topography
- Links fire refugia to enduring landscape features
- Krawchuk *et al.* 2016

University of Idaho

Oregon State University

For more information: ameddens@uidaho.edu; meg.Krawchuk@oregonstate.edu

Disturbance Refugia

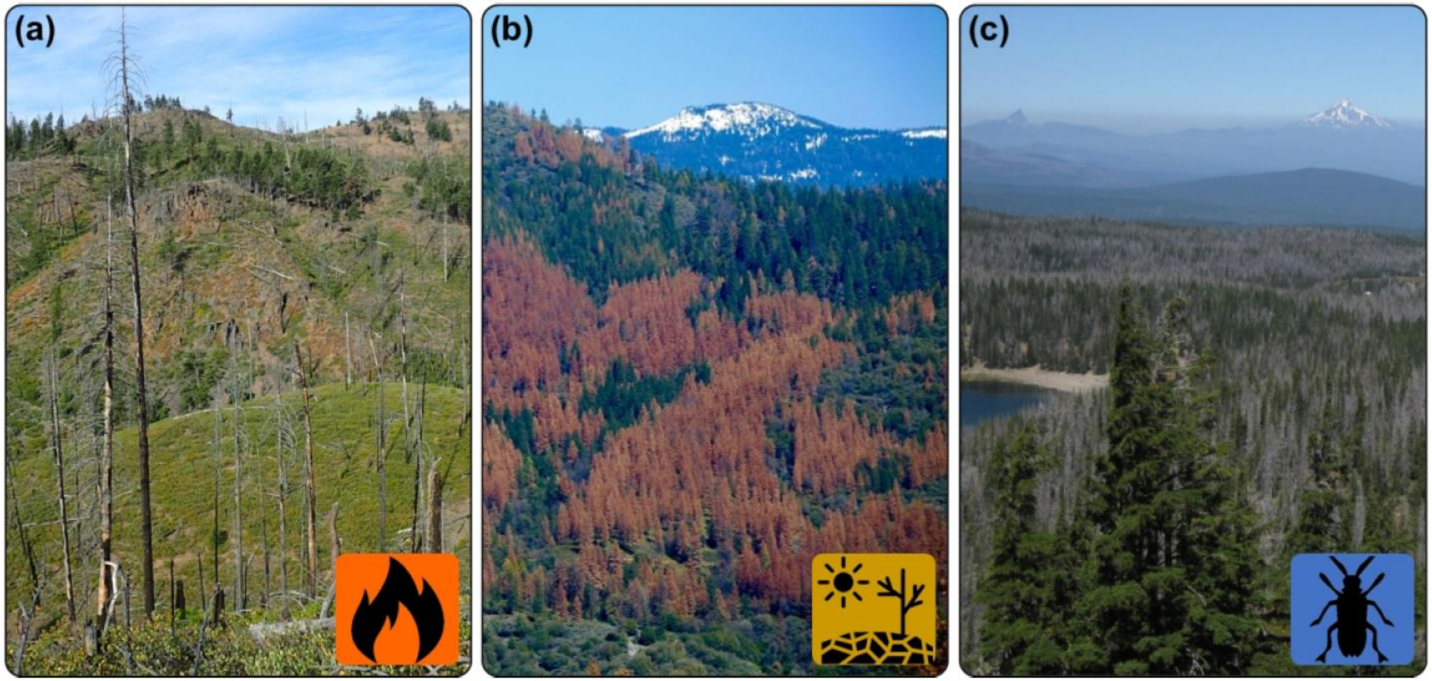


Figure 1. Examples of disturbance refugia in forests of western North America: (a) Fire refugia in the Mill Creek Wilderness, Oregon, USA, 15 years post-fire (photo M. Krawchuk, 2018); (b) Drought refugia in the Sierra National Forest California, USA, during peak tree mortality (photo US Forest Service, 2016); (c) Insect outbreak refugia in the Cascade Range of Oregon, USA, 10 years after mountain pine beetle outbreak (photo G. Meigs, 2011). The most prominent feature of disturbance refugia in forests is persistent live canopy--green "islands"--embedded within a mosaic of more severe effects. Some refugia are relatively concentrated in their spatial pattern e.g., in (a) and (b), whereas others are more diffuse, e.g., (c). US Forest Service photo used under creative commons license CC BY 2.0 and available online:

Krawchuk/Meigs et al. In Press
Frontiers in Ecology & Evolution

forests

Article

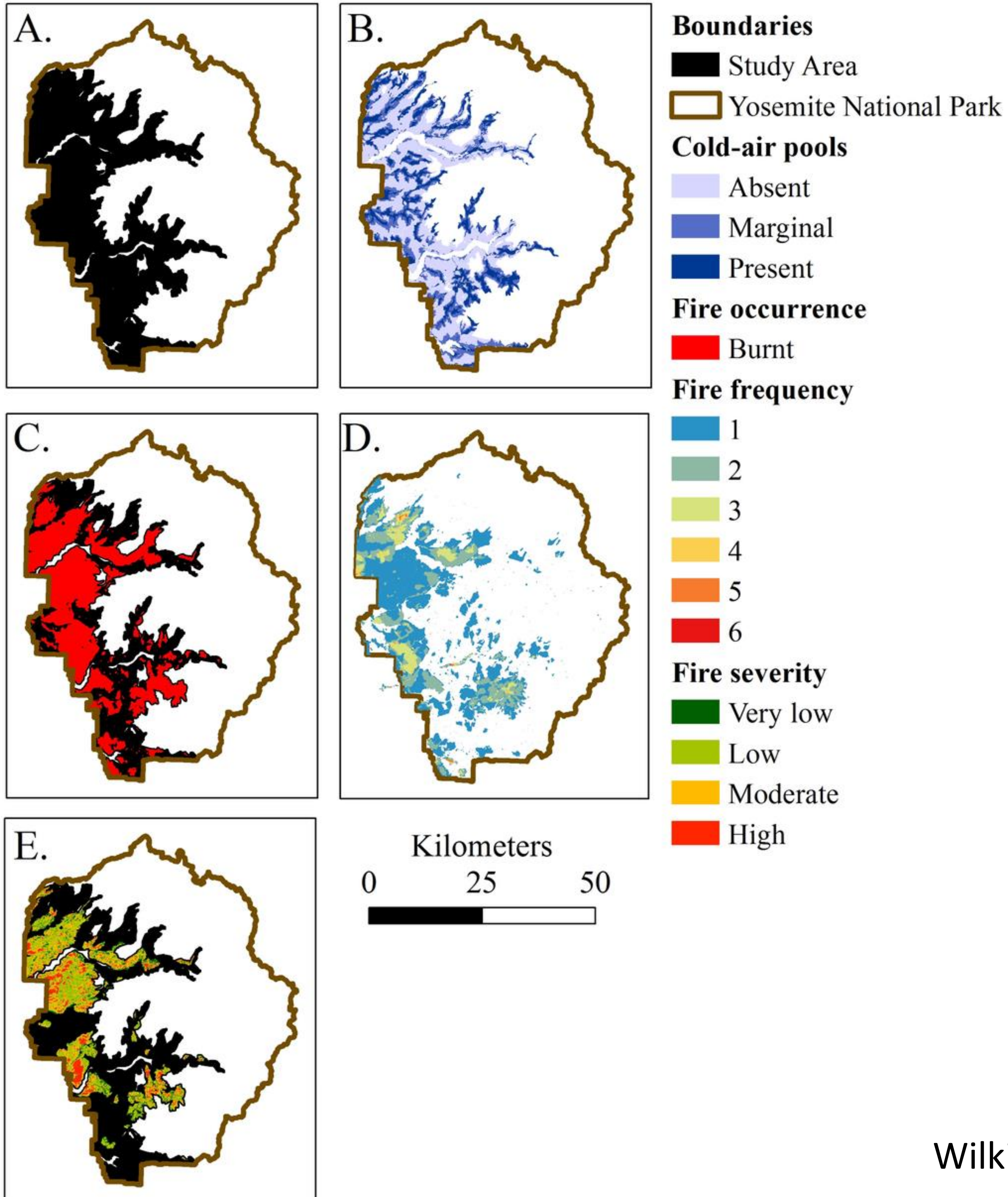
Climate Change Refugia, Fire Ecology and Management

Kate M. Wilkin [1,*], David D. Ackerly [2] and Scott L. Stephens [1]

1 Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720, USA; sstephens@berkeley.edu
2 Department of Integrative Biology, University of California, Berkeley, CA 94720, USA; dackerly@berkeley.edu
* Correspondence: Kate.Wilkin@berkeley.edu; Tel.: 510-642-4934

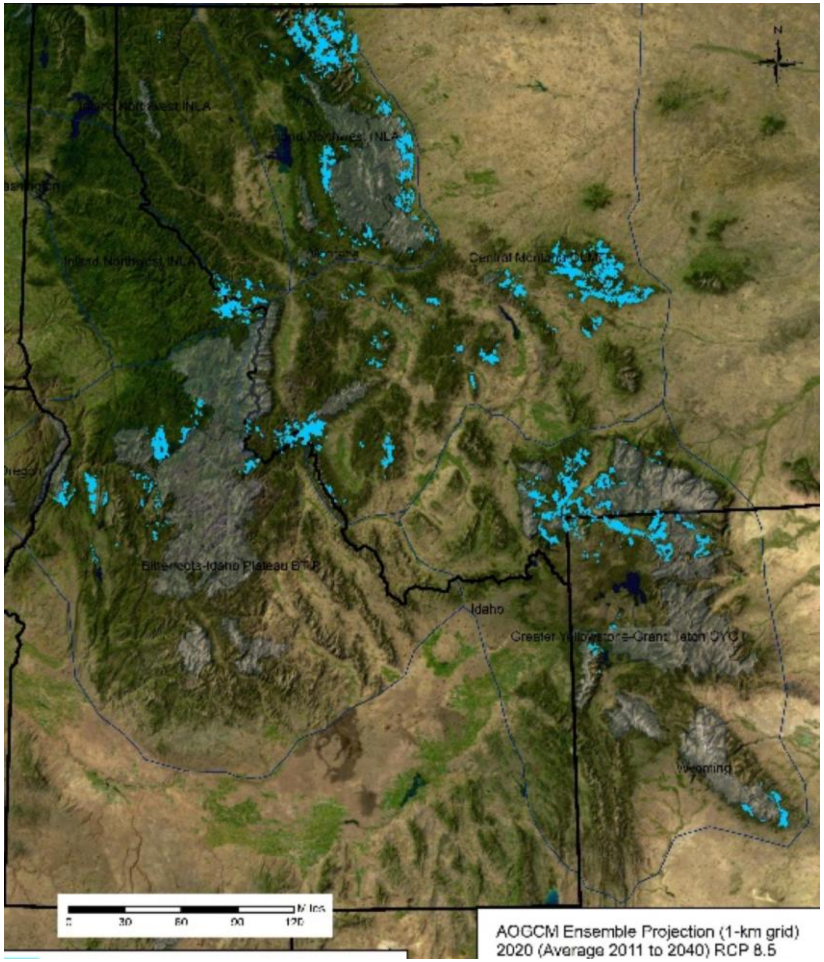
Academic Editors: Yves Bergeron and Sylvie Gauthier
Received: 29 January 2016; Accepted: 23 March 2016; Published: 30 March 2016

Abstract: Early climate change ideas warned of widespread species extinctions. As scientists have



Wilkin et al. 2016

Mapping “genetic refugia” in whitebark pine forests



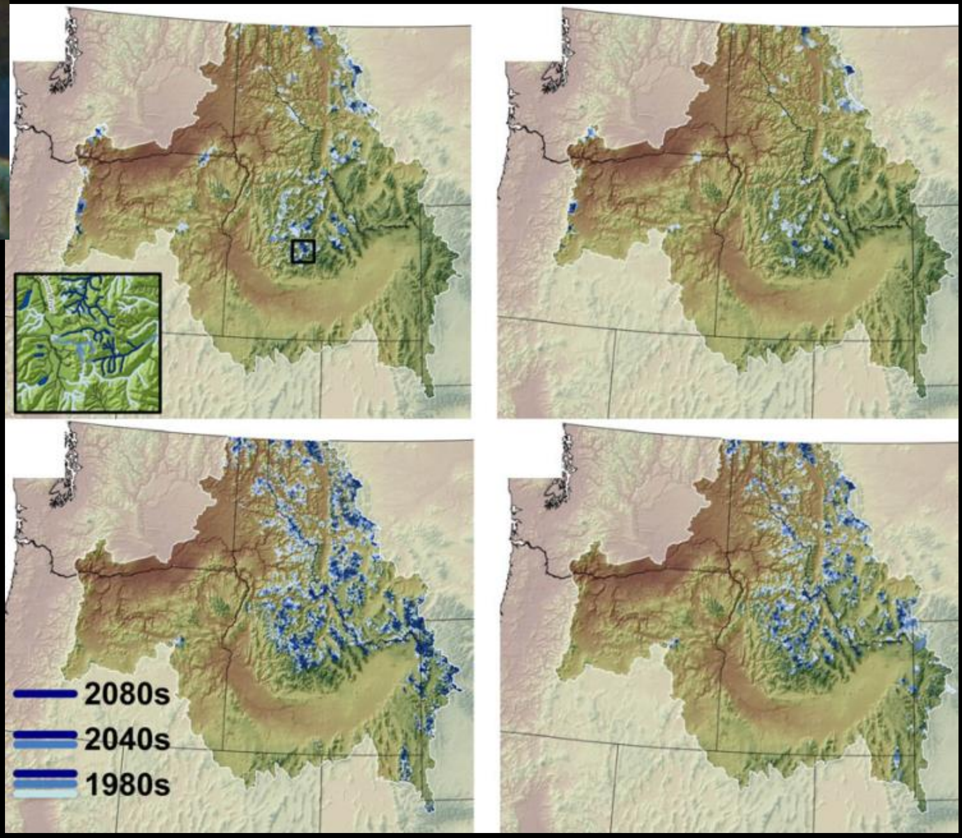
Identification of refugia (**blue** areas) based on favorable genetic attributes:

- blister rust resistance
- cold hardiness
- drought tolerance
- genetic diversity

Only 1% of refugia occur in designated wilderness areas

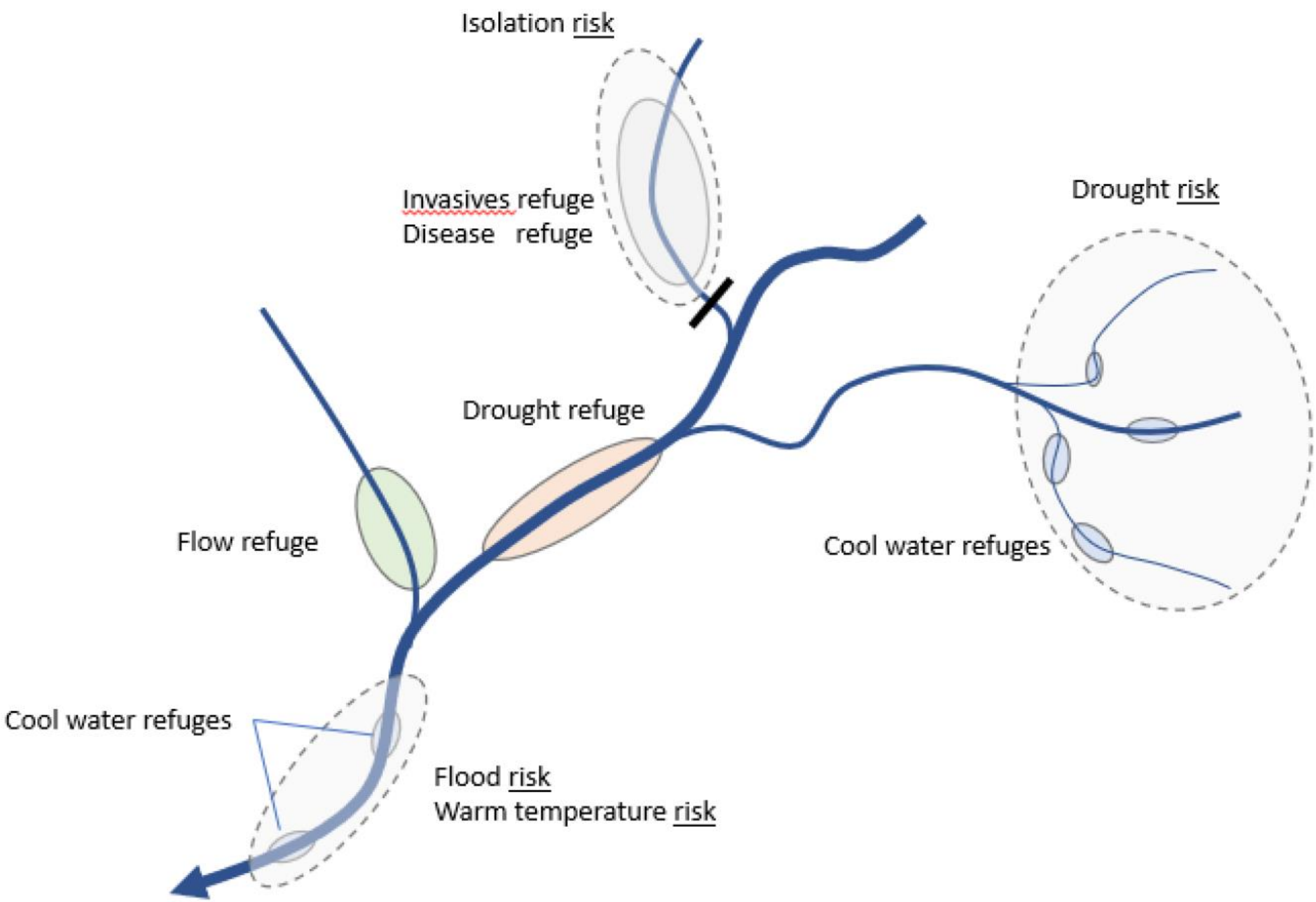
For more information: mmahalovich@fs.fed.gov

"Climate Shield"



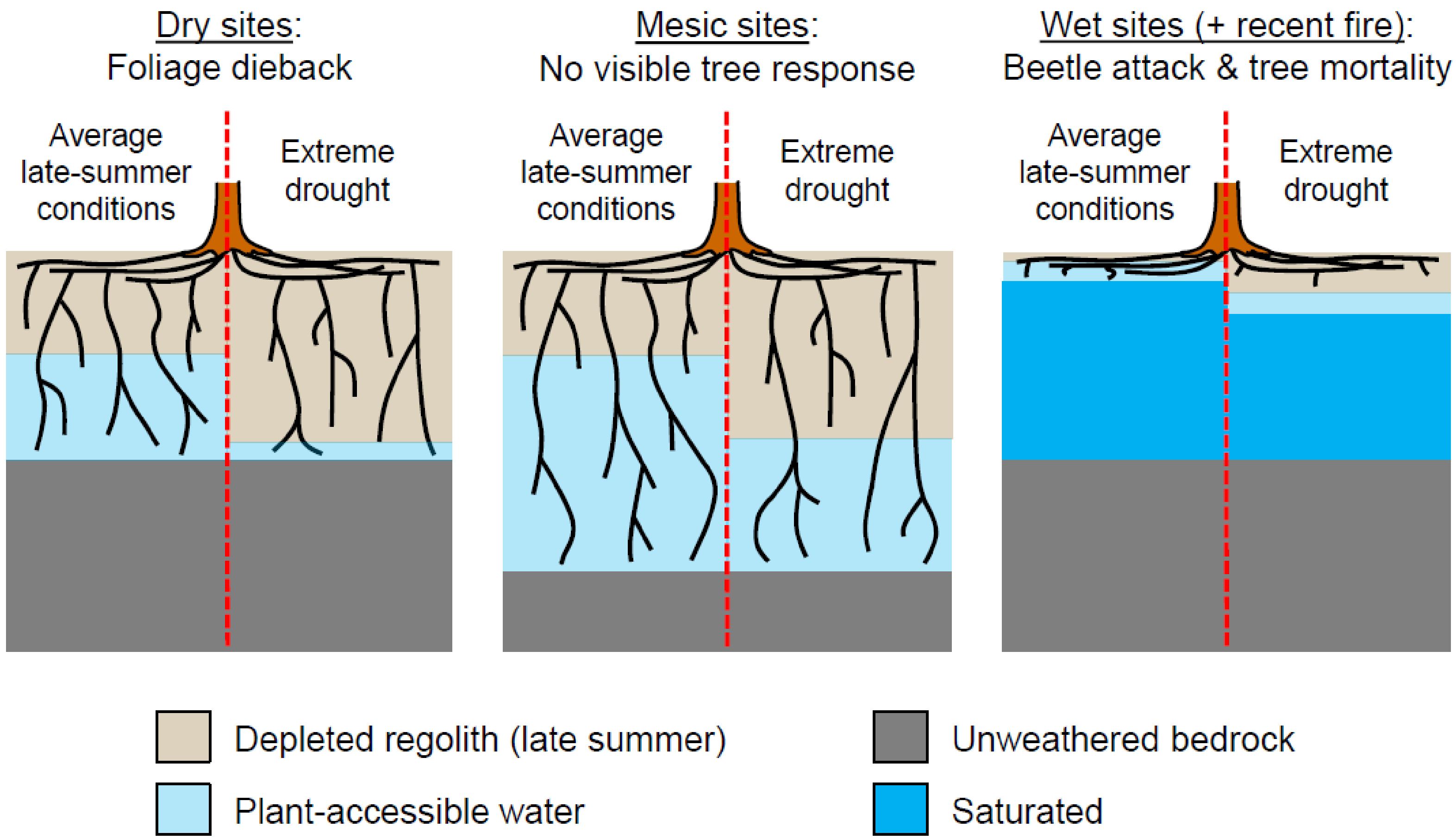
Isaak et al. 2015
GCB

Networks of cold water refuges



Ebersole et al. In Press
Frontiers in Ecology & Evolution

Sequoia Groves as Refugia?

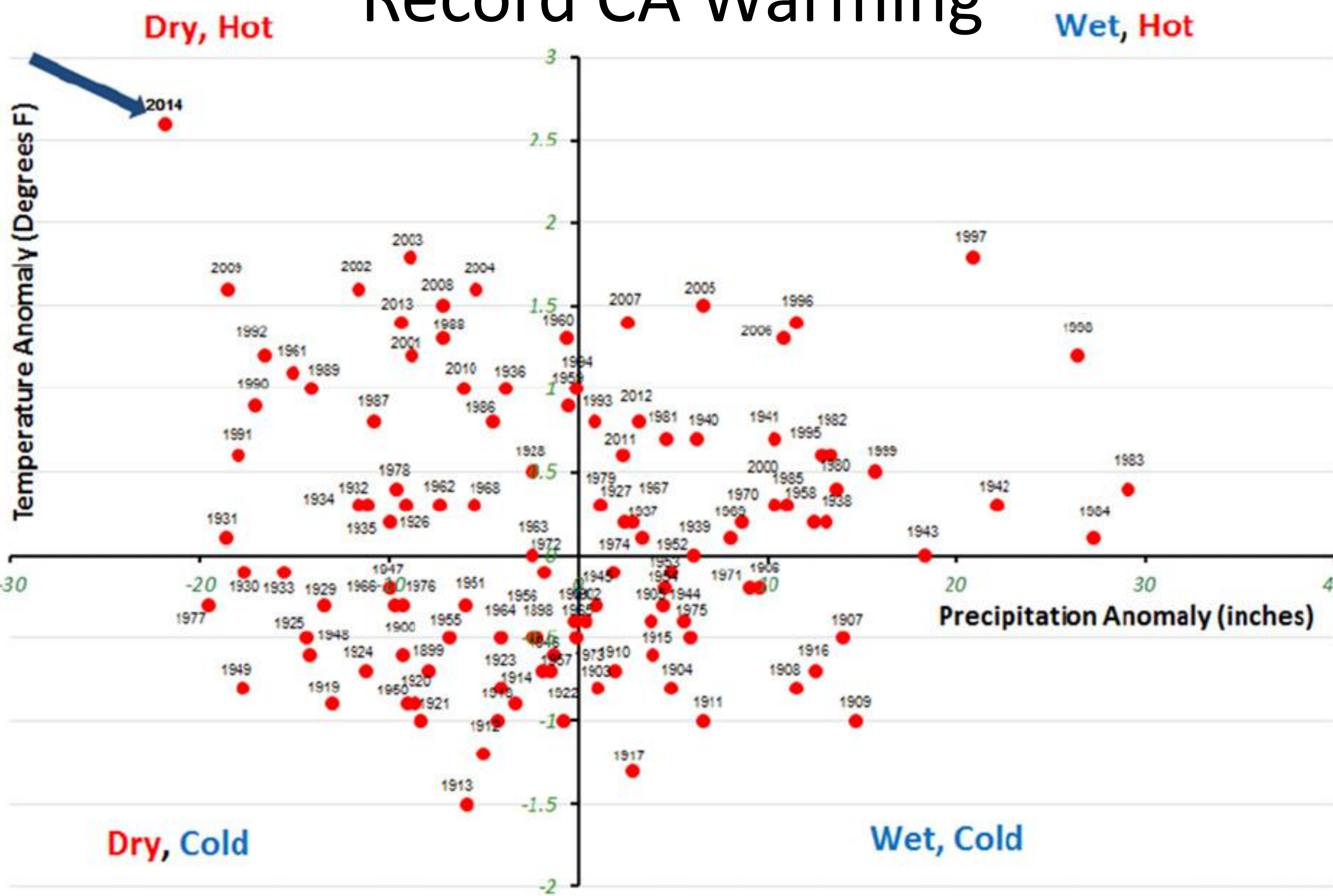


Stephenson et al.

What 4 resources (species, etc.) should be the focus of refugia planning?

Go to www.menti.com and use the code 50 75 8

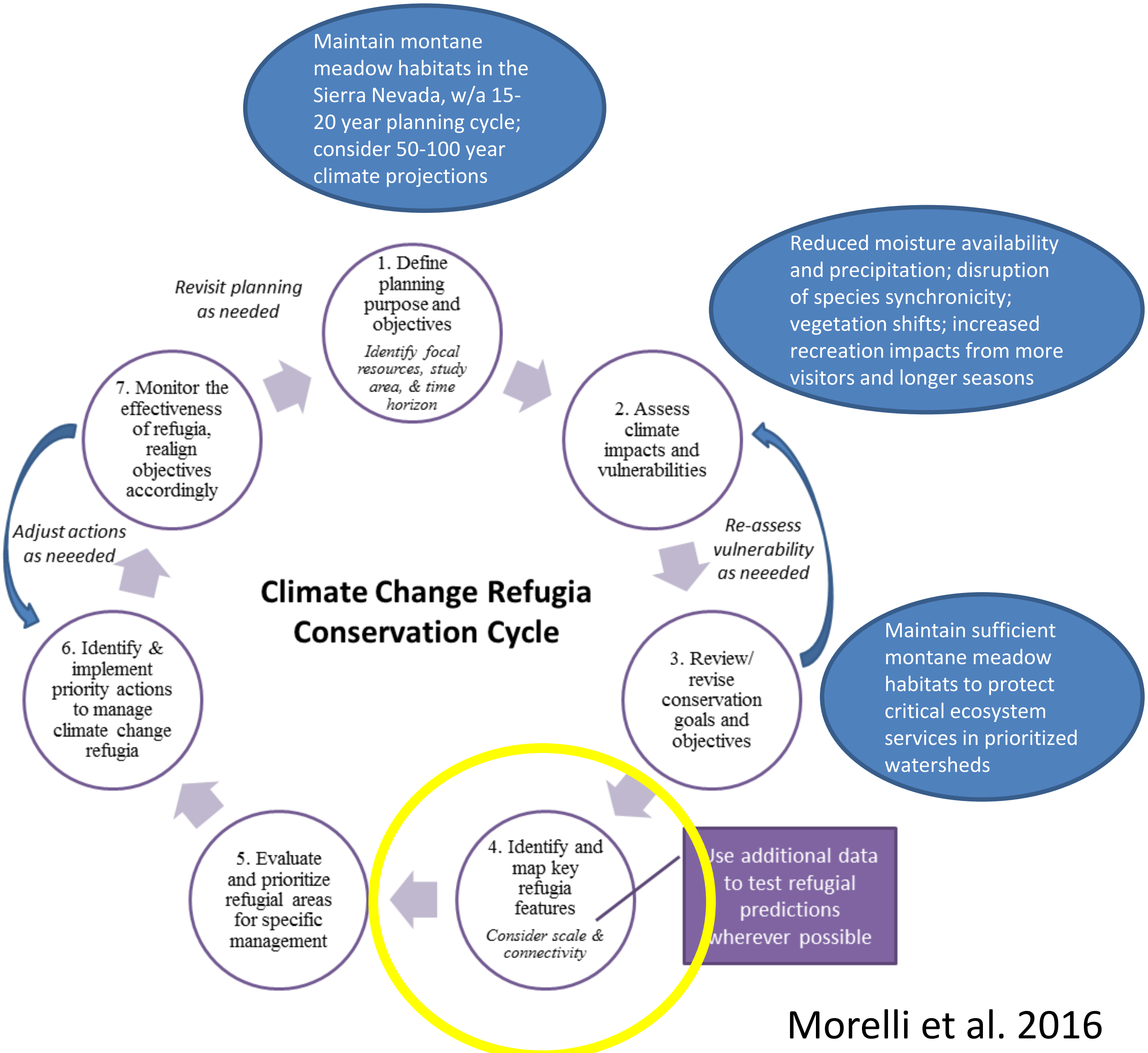
Record CA Warming



Mann & Gleick 2015 *PNAS*

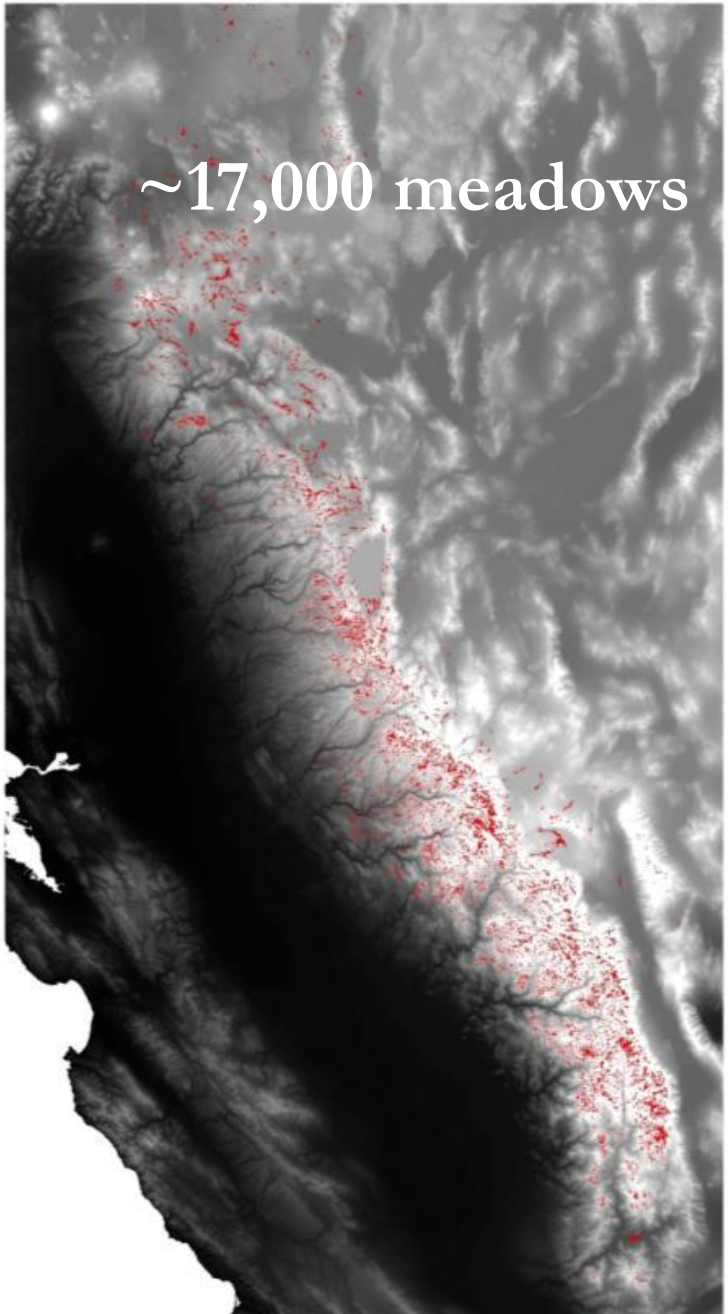
Montane Meadows

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



Morelli et al. 2016

PLOS ONE



Modeling Climate Stability

- *Diff 1970-1999 & 1910-1939*
- *PRISM ds to 270m*
- *Basin Characterization Model (Flint et al. 2013)*

esa ECOSPHERE

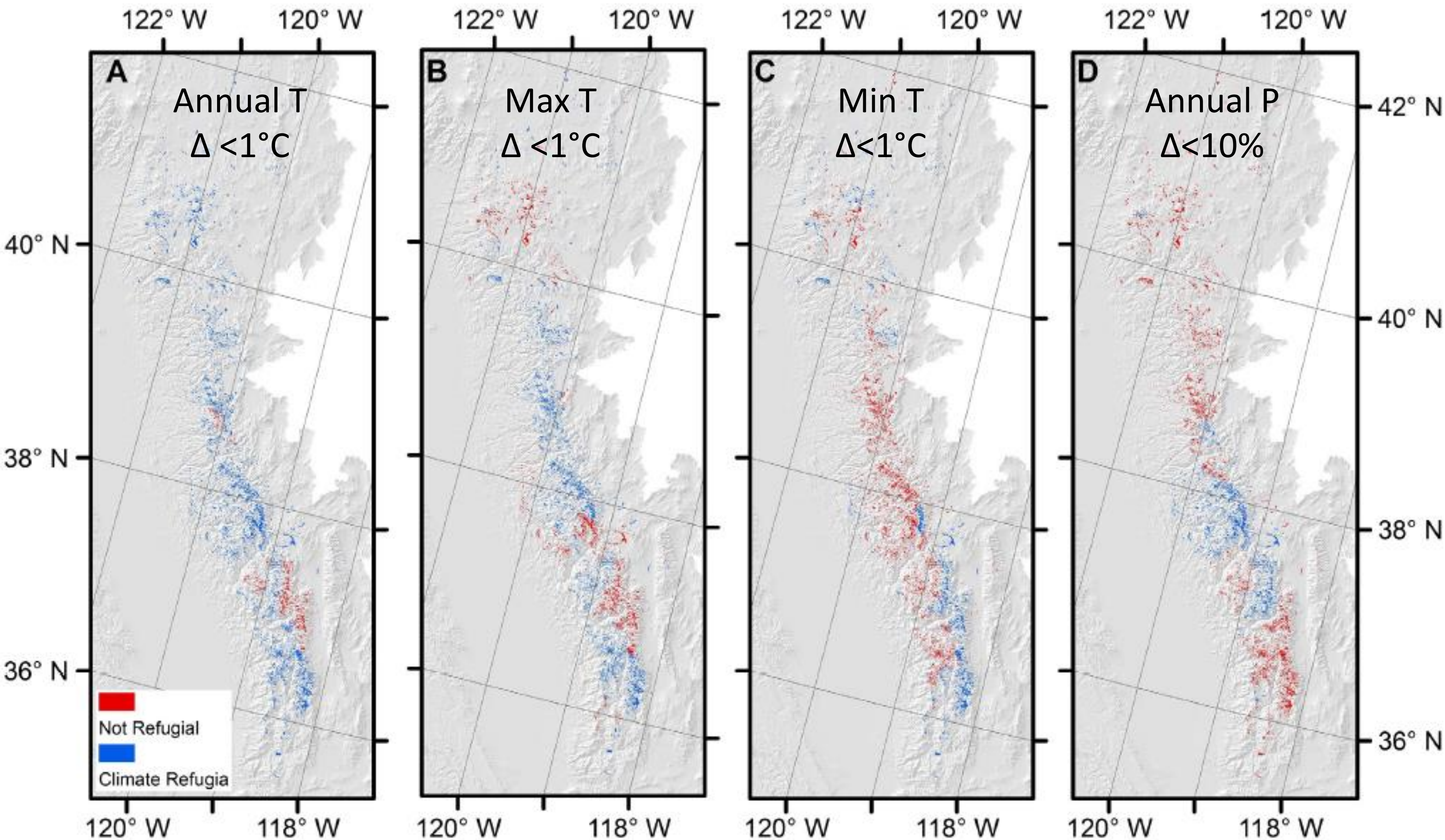
Erosion of refugia in the Sierra Nevada meadows network with climate change

Sean P. Maher,[1,2,3,†] Toni Lyn Morelli,[1,2,4] Michelle Hershey,[1] Alan L. Flint,[5] Lorraine E. Flint,[5] Craig Moritz,[1,6] and Steven R. Beissinger[1,2]

[1]Museum of Vertebrate Zoology, University of California Berkeley, Berkeley, California 94720 USA
[2]Department of Environmental Science, Policy & Management, University of California Berkeley, Berkeley, California 94720 USA
[3]Department of Biology, Missouri State University, Springfield, Missouri 65897 USA
[4]Department of Interior Northeast Climate Science Center, U.S. Geological Survey, Amherst, Massachusetts 01003 USA
[5]California Water Science Center, U.S. Geological Survey, Sacramento, California 95819 USA
[6]Research School of Biology, Australia National University, Canberra, Australian Capital Territory 2601 Australia

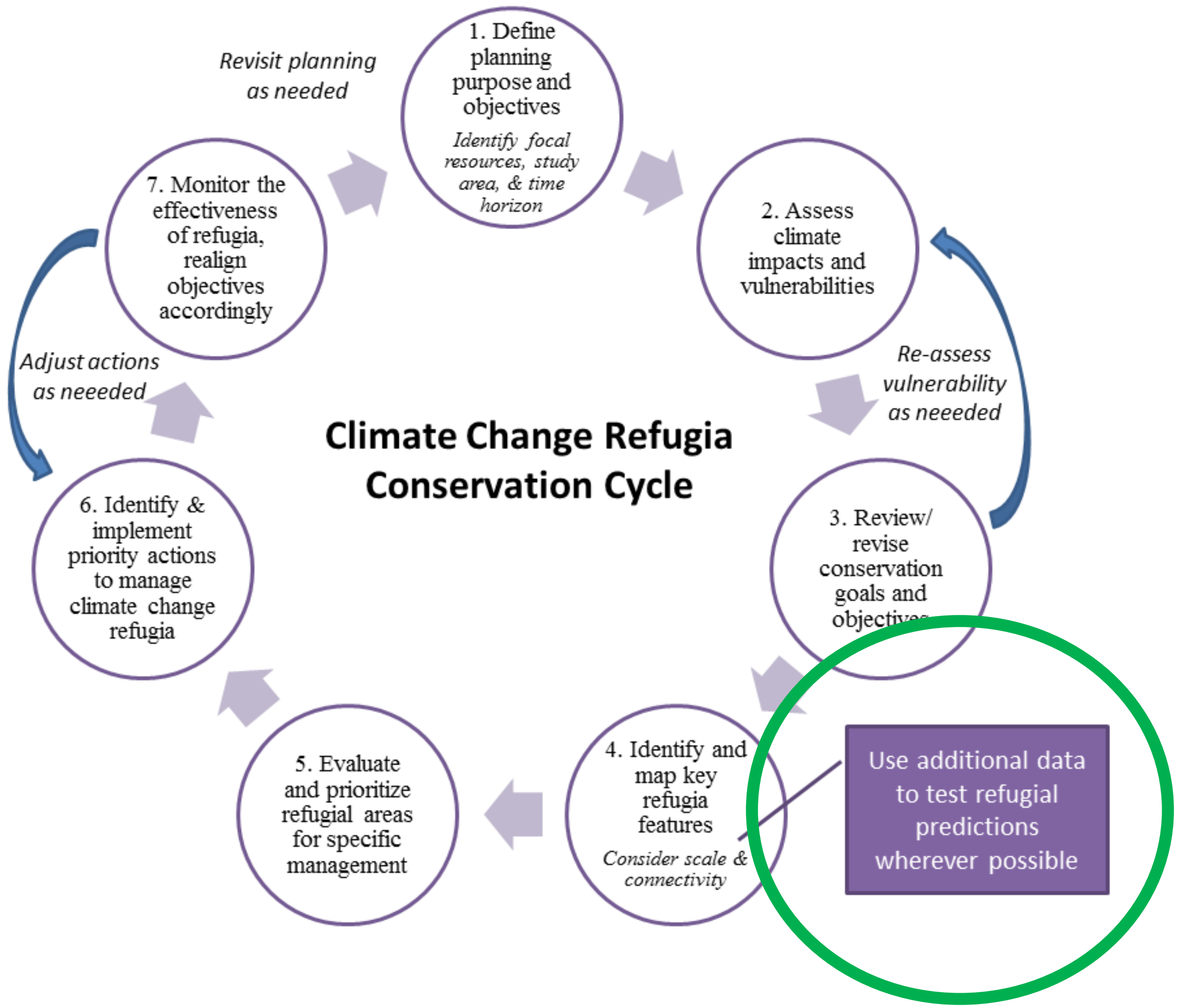
Fryjoff-Hung & Viers, 2012. http://meadows.ucdavis.edu/

Mapping Climate Change Refugia

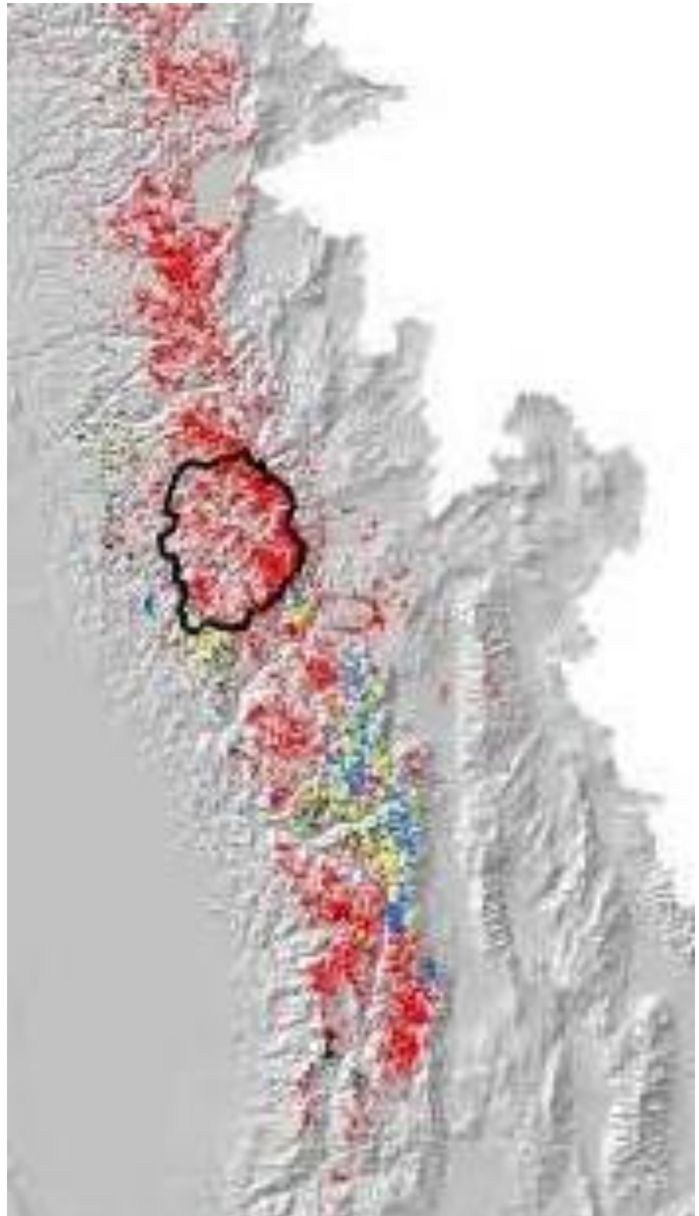


Maher, Morelli et al. 2017
Ecosphere

Steps for Managing Climate Change Refugia



Testing the Climate Refugia Map



Belding's Ground Squirrel (*Urocitellus beldingi*)

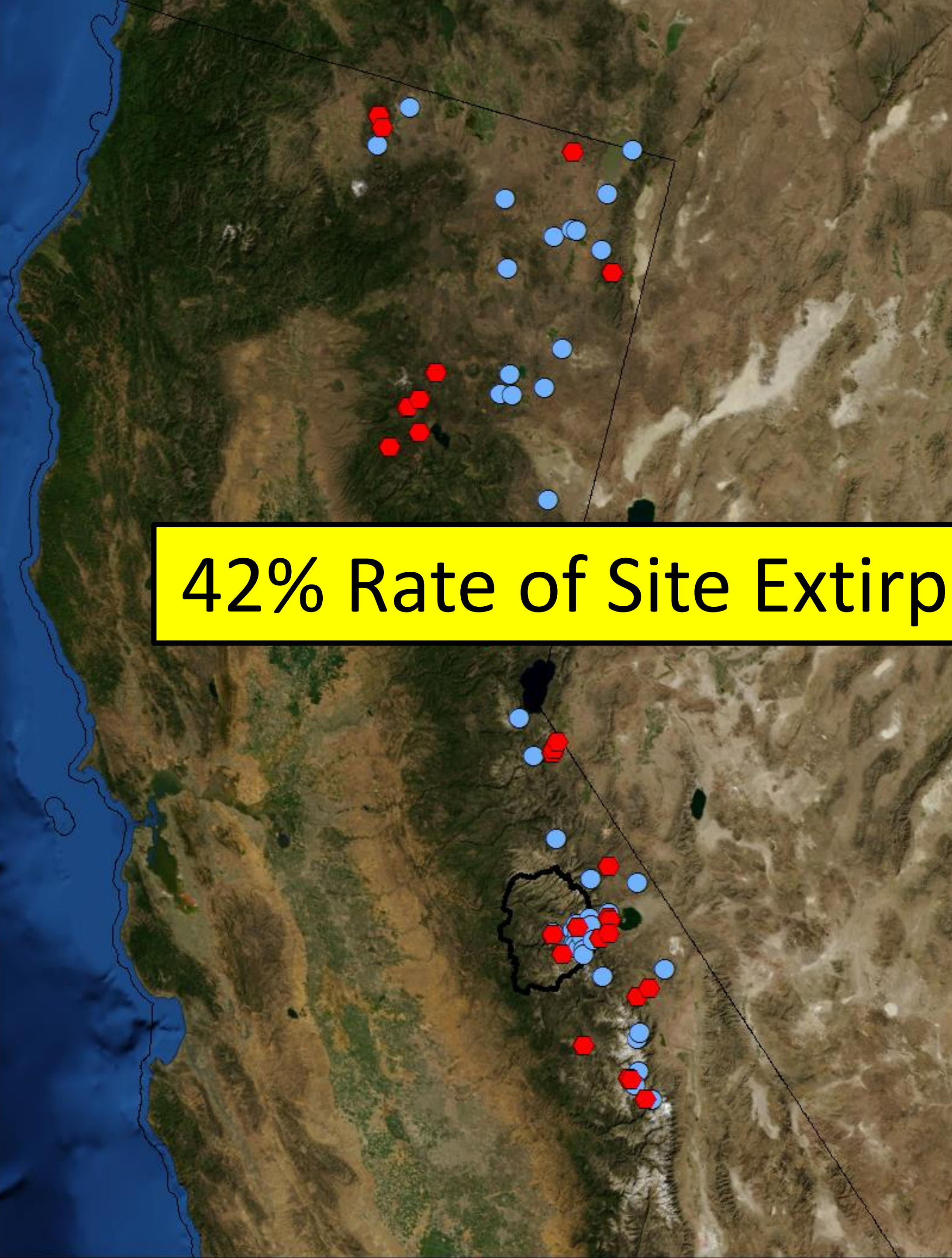
- Habitat specialist
- Group-living
- Highly detectable
- Hibernator

Grinnell Surveys (1900-1939)

Grinnell - 1911 May 25 Yosem

Besides the ever-present ground squirrels, Citellus Beecheyi (observed up to 6000 ft.) the only other mammal we have seen was a Gray squirrel at the village, walking across the road with a mouthful of forage.

Grinnell Resurveys (2003-2011)



Site Extirpations (N=31)

Site Persistence (N=43)

42% Rate of Site Extirpations Across CA

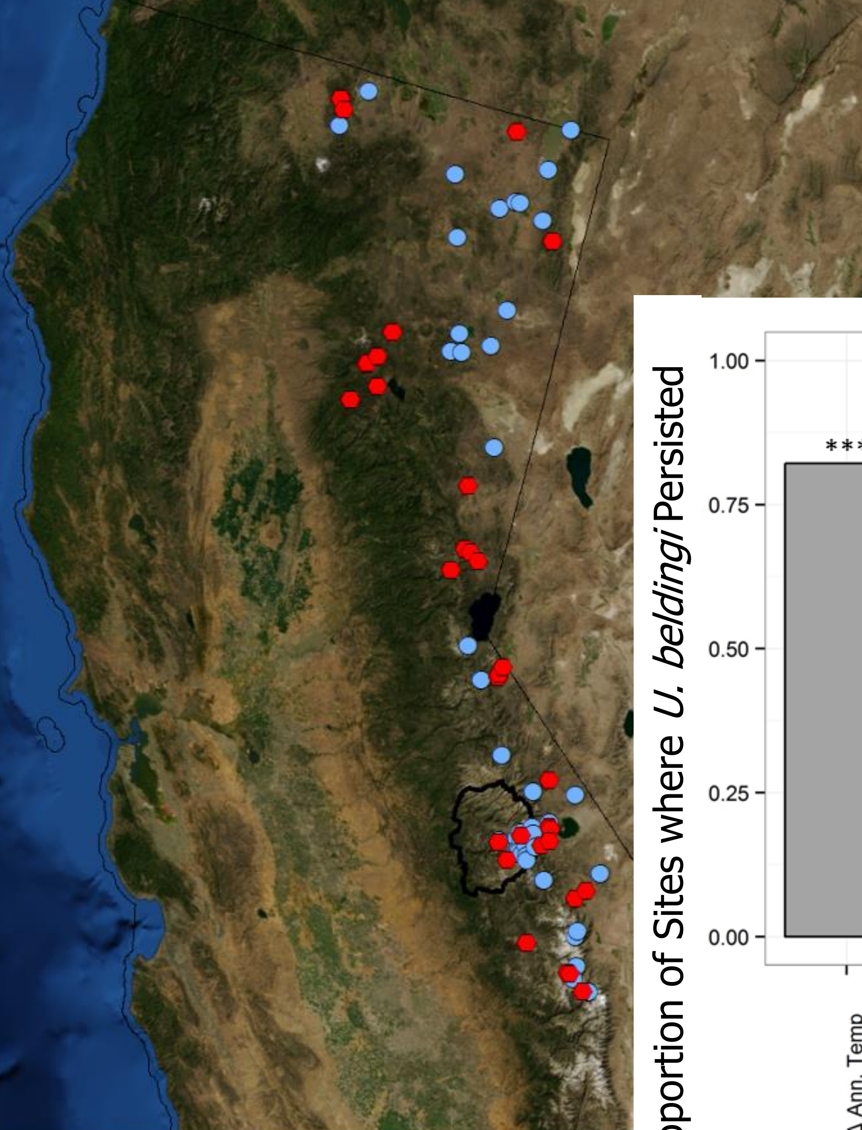
Original Surveys: 1902-1966

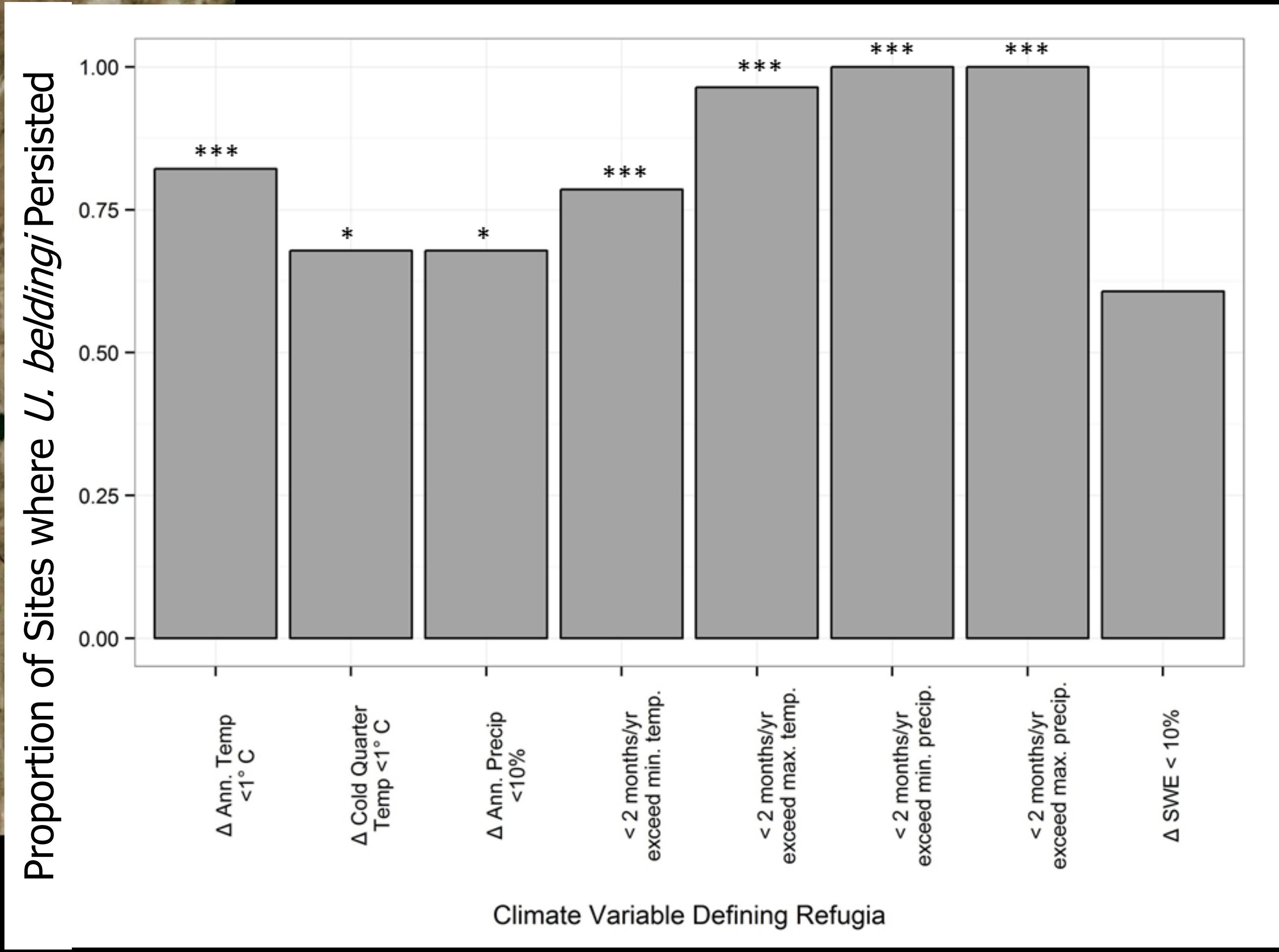
Resurveys: 2003-2011

Detectability (p) > 0.995 for 2+ visits

Morelli et al. 2012 *Proc B*

Climate Change Refugia Predict Persistence

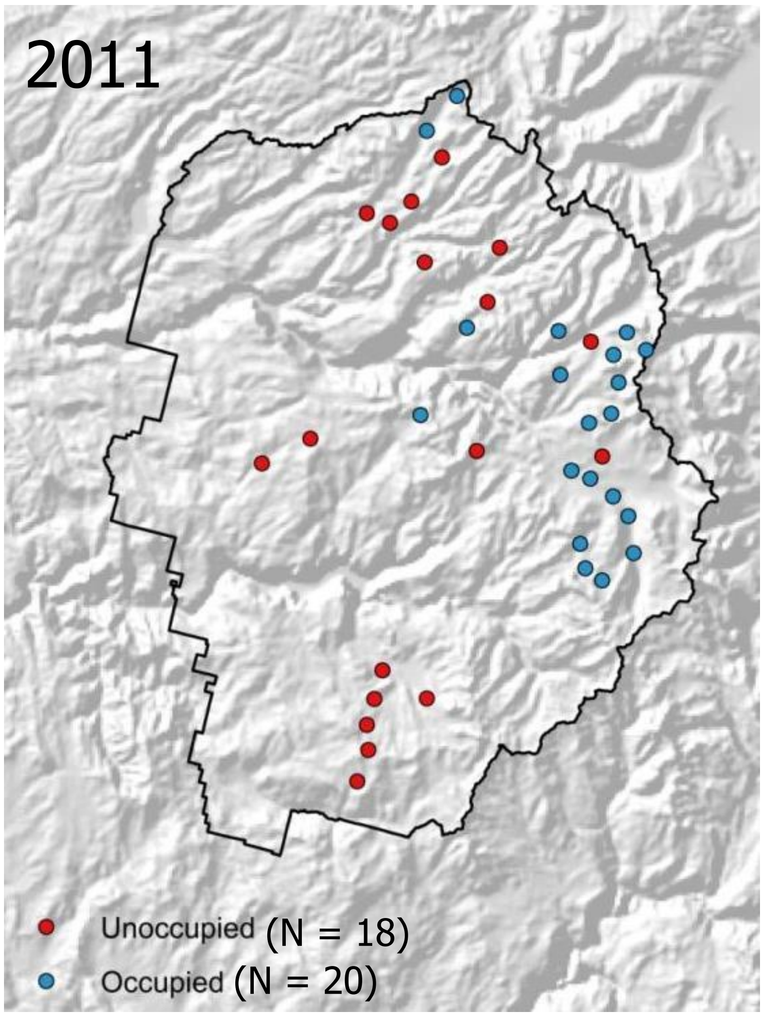


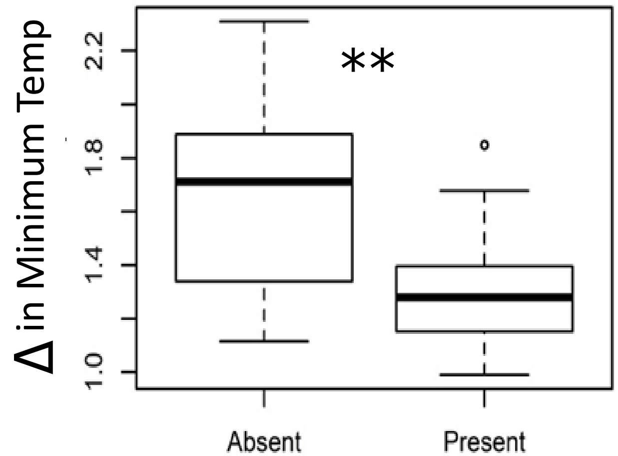


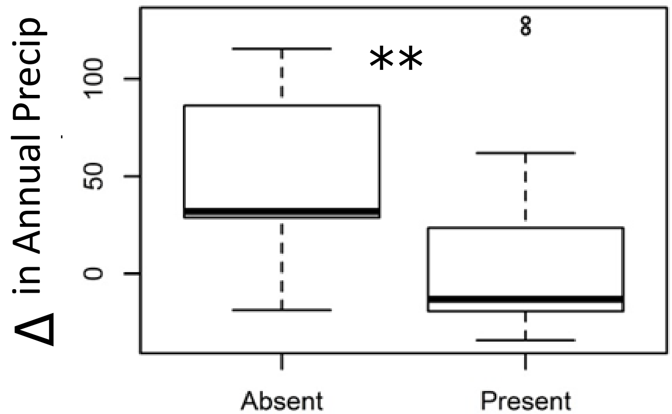
Morelli et al. *2017*
Climate Change Responses

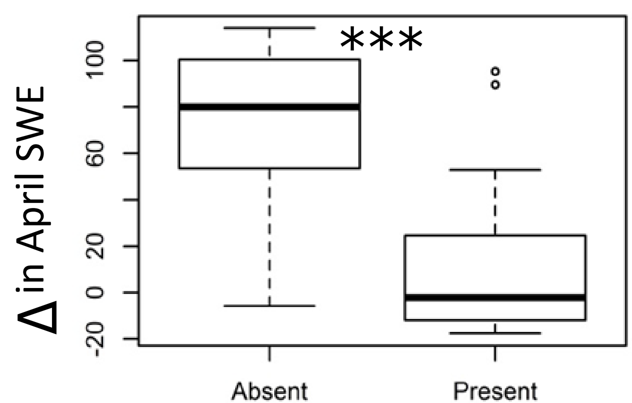
* All Sig at $p < 0.05$ except SWE

Climate Change Refugia Predict Occupancy







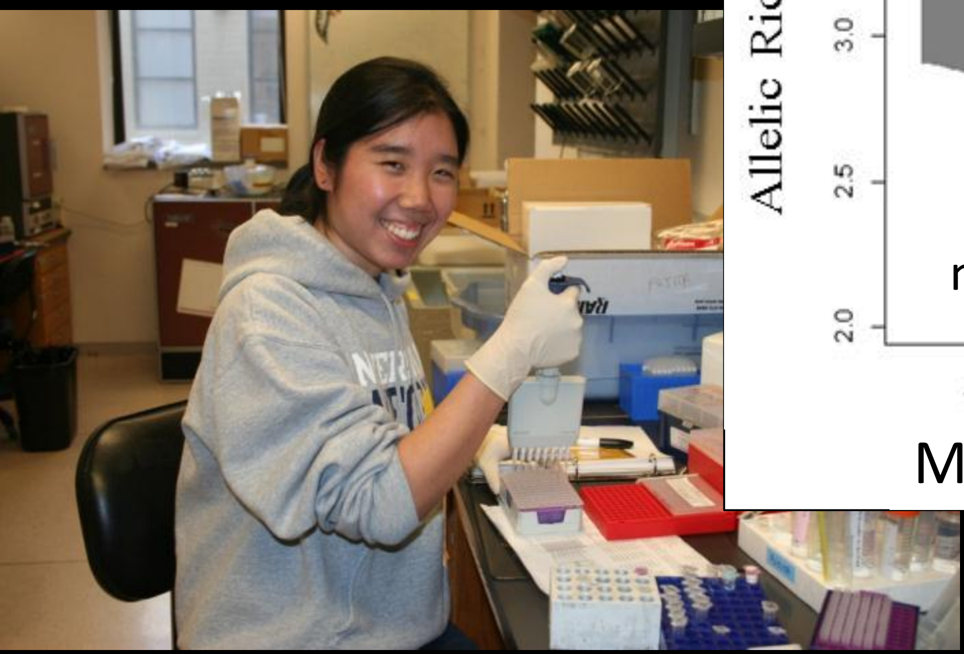


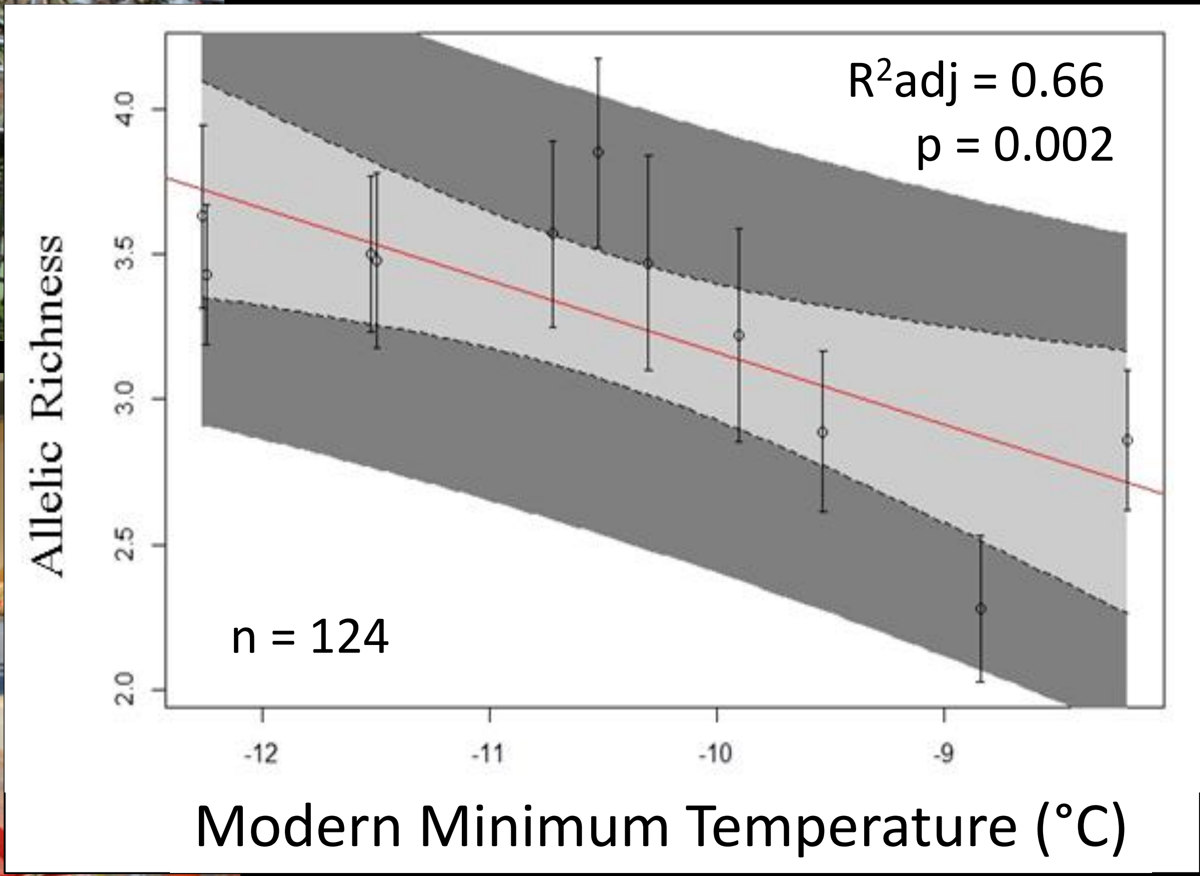
2-Samp Wilcox. Test

$**p < 0.001$

$***p < 0.0001$

Temperature correlates with Genetic Diversity

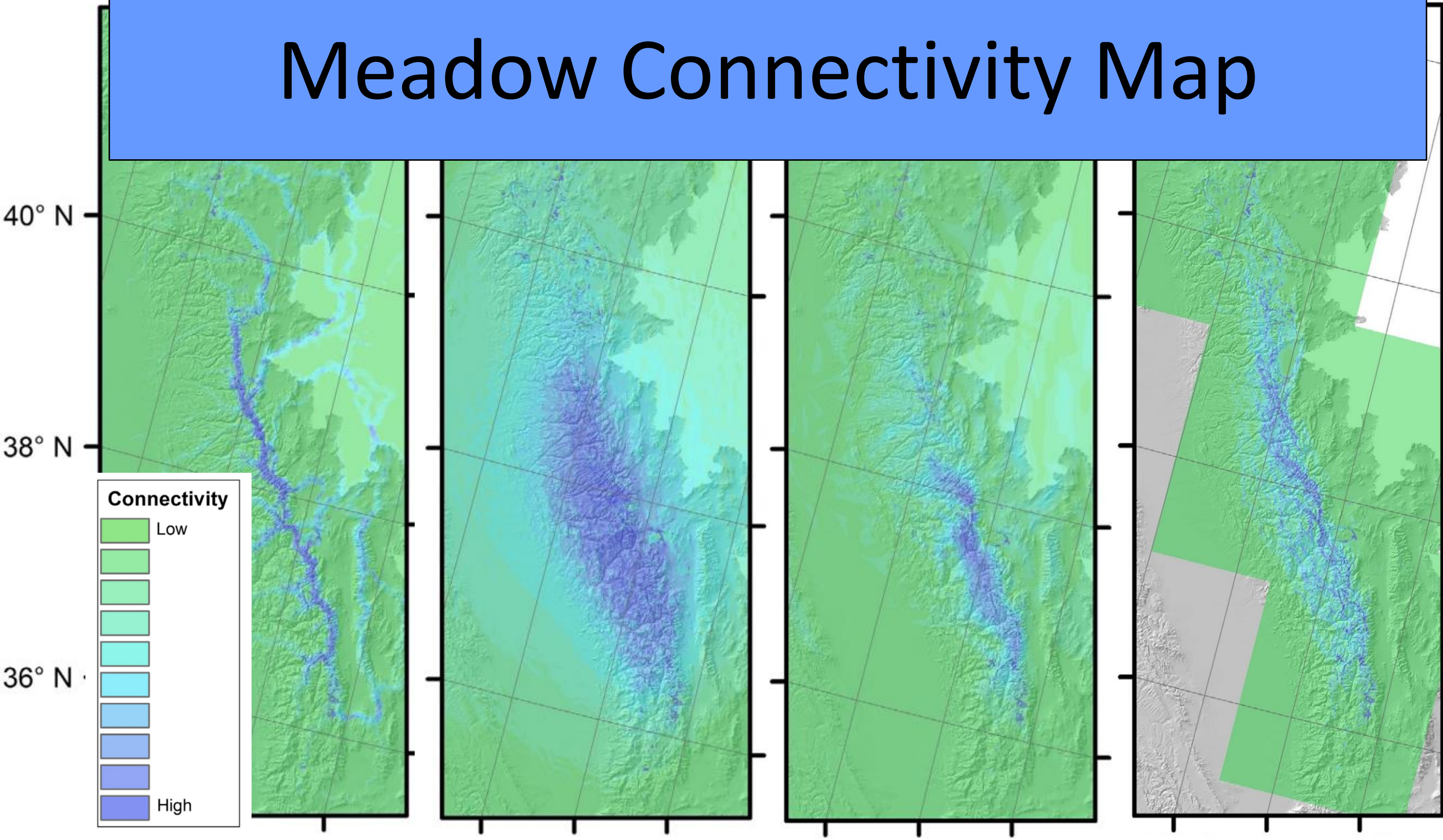




Morelli et al. 2017

Climate Change Responses

Meadow Connectivity Map



Rivers as barriers

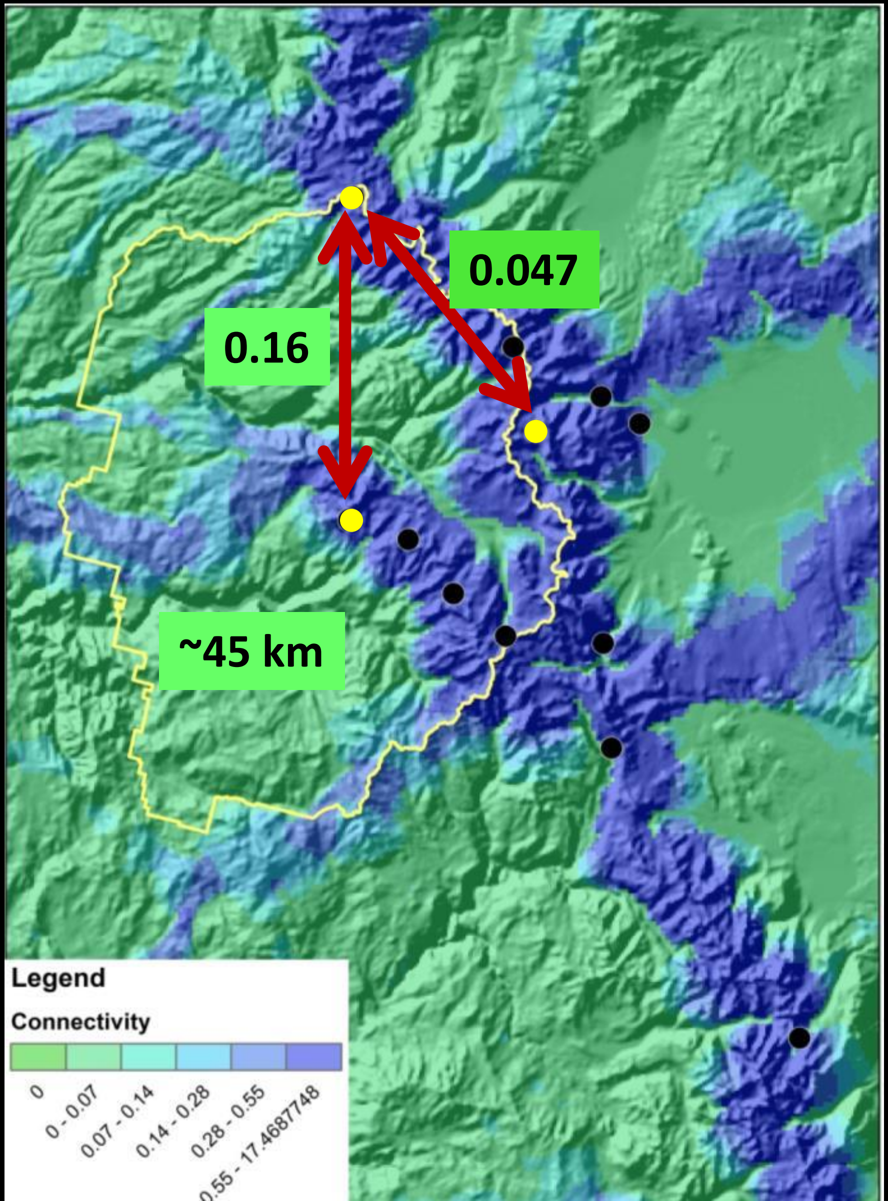
Rivers as vectors

Roads as barriers

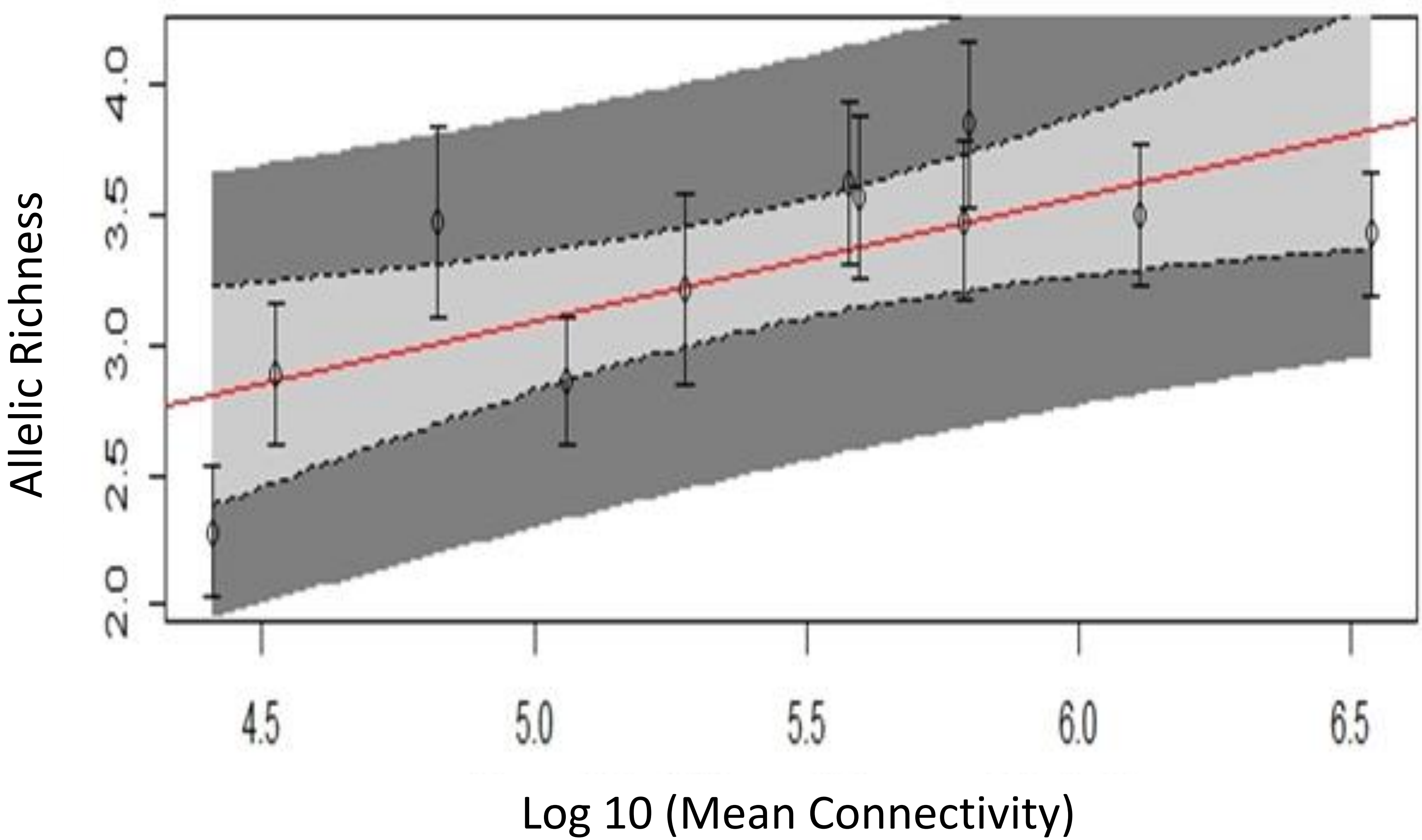
Topographic barriers

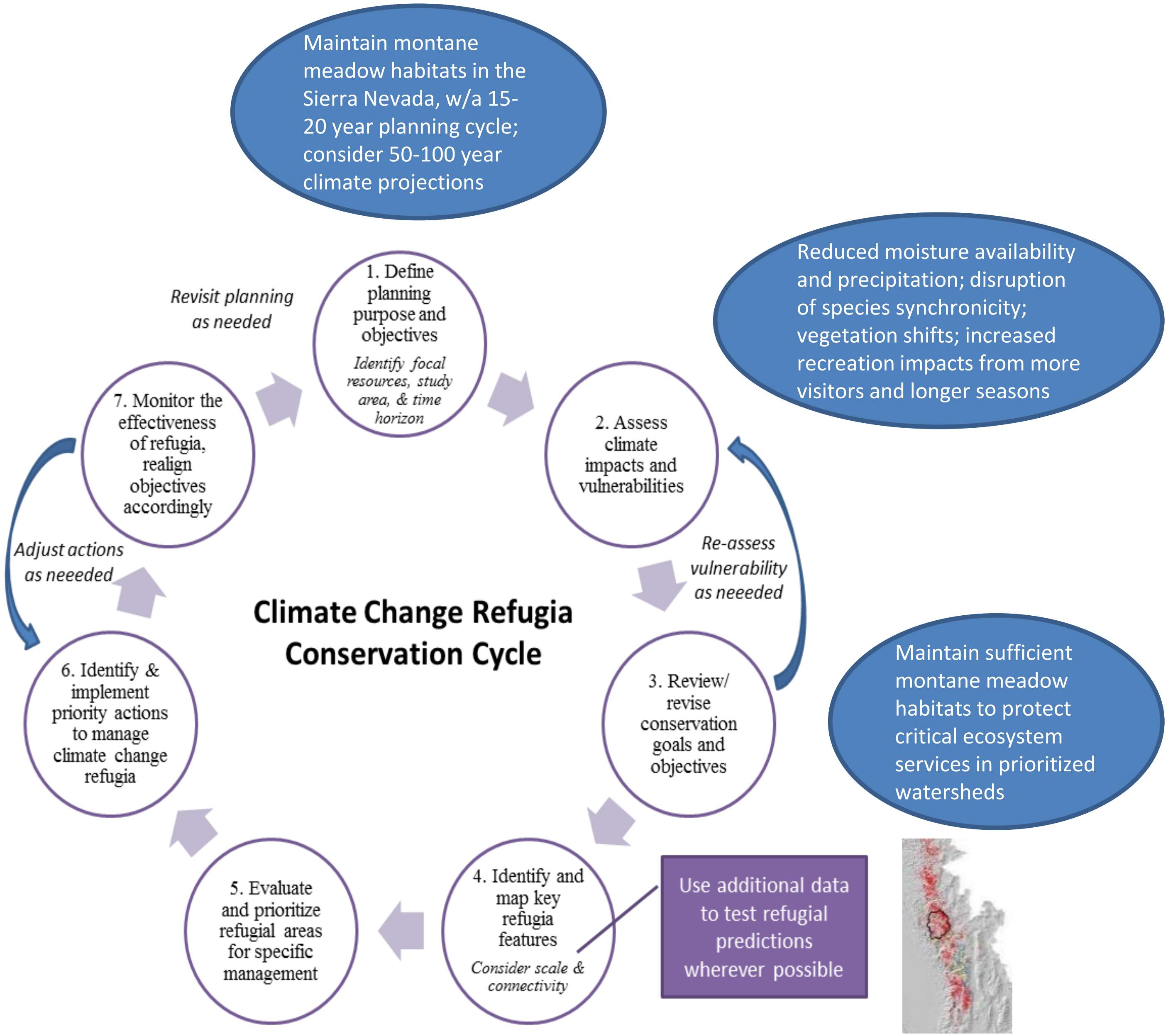
Maher, Morelli et al. 2017 *Ecosphere*

Connectivity hypothesis predicts gene flow



Connectivity predicts allelic richness

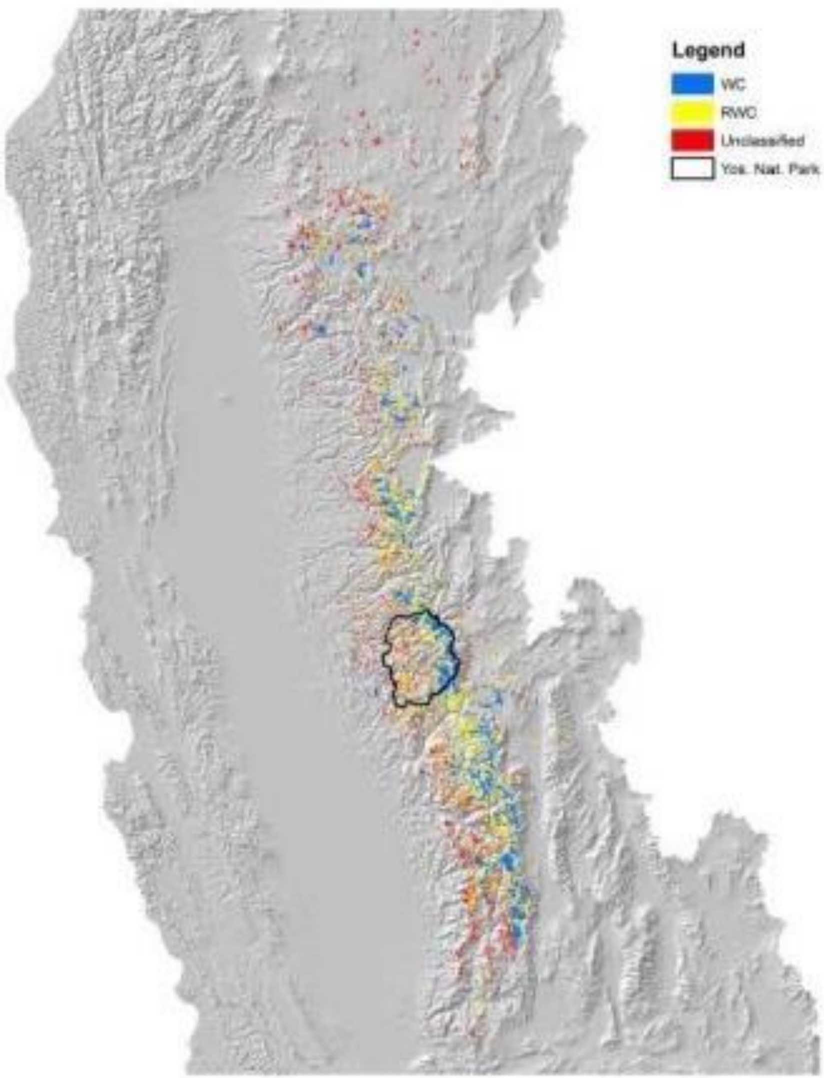




Morelli et al. 2016

PLOS ONE

Management Tools and Actions



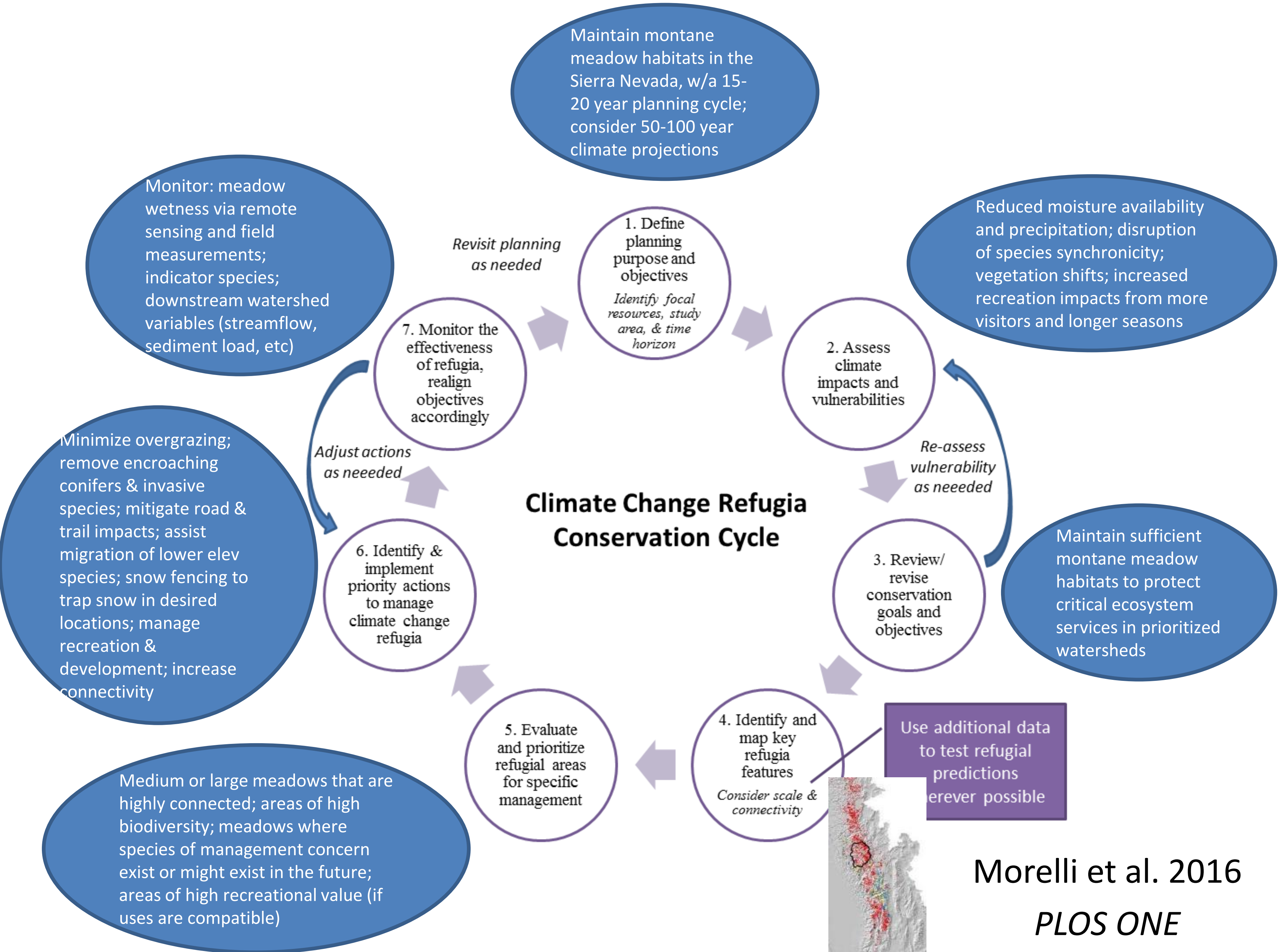
Increase Connectivity

Improved culvert design

Road crossings

Reroute trails

Assisted migration?


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
Maintain sufficient montane meadow habitats to protect critical ecosystem services in prioritized watersheds
Use additional data to test refugial predictions
erever 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)
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
Monitor: meadow wetness via remote sensing and field measurements; indicator species; downstream watershed variables (streamflow, sediment load, etc)
Climate Change Refugia Conservation Cycle
1. Define planning purpose and objectives
Identify focal resources, study area, & time horizon
2. Assess climate impacts and vulnerabilities
Re-assess vulnerability as neeeded
3. Review/ revise conservation goals and objectives
4. Identify and map key refugia features
Consider scale & connectivity
5. Evaluate and prioritize refugial areas for specific management
6. Identify & implement priority actions to manage climate change refugia
Adjust actions as neeeded
7. Monitor the effectiveness of refugia, realign objectives accordingly
Revisit planning as needed
Morelli et al. 2016
PLOS ONE