Determining Landscape Connectivity and Climate Change Refugia Across the Sierra Nevada

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with Craig Moritz[4], Steven R. Beissinger[5], Michelle Hershey[1], Marisa Lim[1], Christina Kastely[1], Lindsey Eastman[1], Alan L. Flint[3] & Lorraine E. Flint[3]

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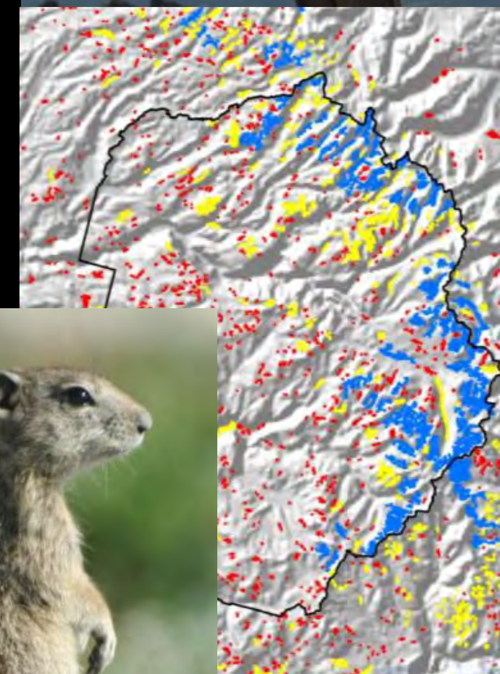

Outline

- Biological and Management Relevant Context
  - Climate Change Refugia
  - Metapopulation dynamics
  - California climate change trends
- Research Objectives
- Patterns of Connectivity in Meadows
  - How Sierra Nevada meadows have changed and will change
- Refugia Mapped
- Maps Tested – Montane Mammal Data
- Implications for Management

The Role of Climate Refugia

Biological Conservation 142 (2009) 3020–3029

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journal homepage: www.elsevier.com/locate/biocon

Biogeography and conservation of taxa from remote regions: An applicatio
ecological-niche based models and GIS to North-African Canids

José C. Brito [a,*], André L. Acosta [a], Francisco Álvares [a], Fabrice Cuzin [b]

Journal of Applied Ecology

Journal of Applied Ecology 2008, 45, 1722–1731 doi: 10.1111/j.1365-2664.2008.01569.x

Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones

Claire C. Vos[1*], Pam Berry[2], Paul Opdam[1,3], Hans Baveco[1], Bianca Nijhof[1], Jesse O'Hanley[2]†,

The Role of Climate Refugia

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2012) **21**, 393–404

RESEARCH REVIEWS

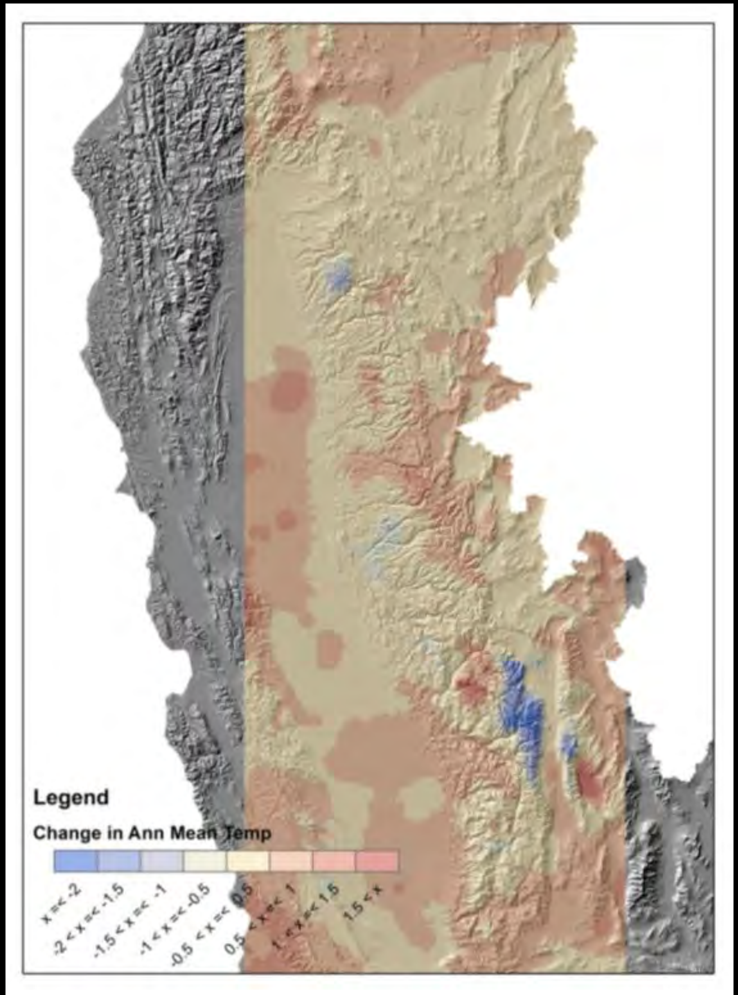
Refugia: identifying and understanding safe havens for biodiversity under climate change

Gunnar Keppel[1*], Kimberly P. Van Niel[2], Grant W. Wardell-Johnson[1], Colin J. Yates[3], Margaret Byrne[3], Ladislav Mucina[1], Antonius G. T. Schut[1], Stephen D. Hopper[4] and Steven E. Franklin[5]

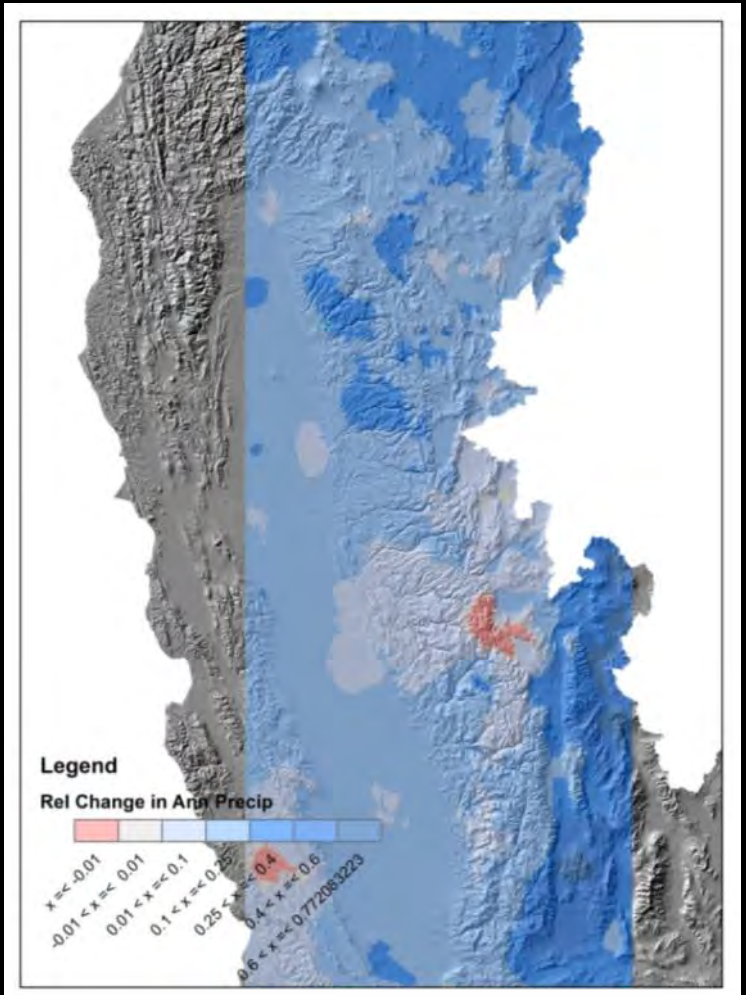
"Refugia are habitats that components of biodiversity retreat to, persist in and can potentially expand from under changing environmental conditions…applicable to biodiversity under potential future climates arising from the enhanced greenhouse effect."

Climate change in 20th Century

Annual Temperature (Actual)

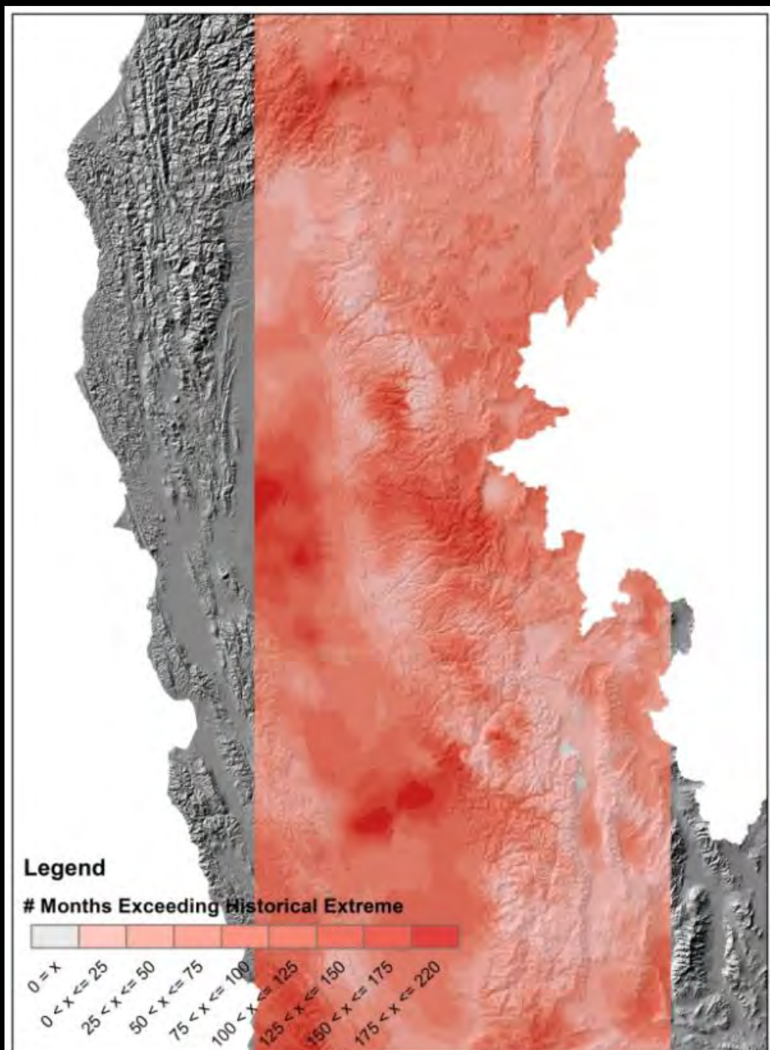


Annual Precipitation (Relative)

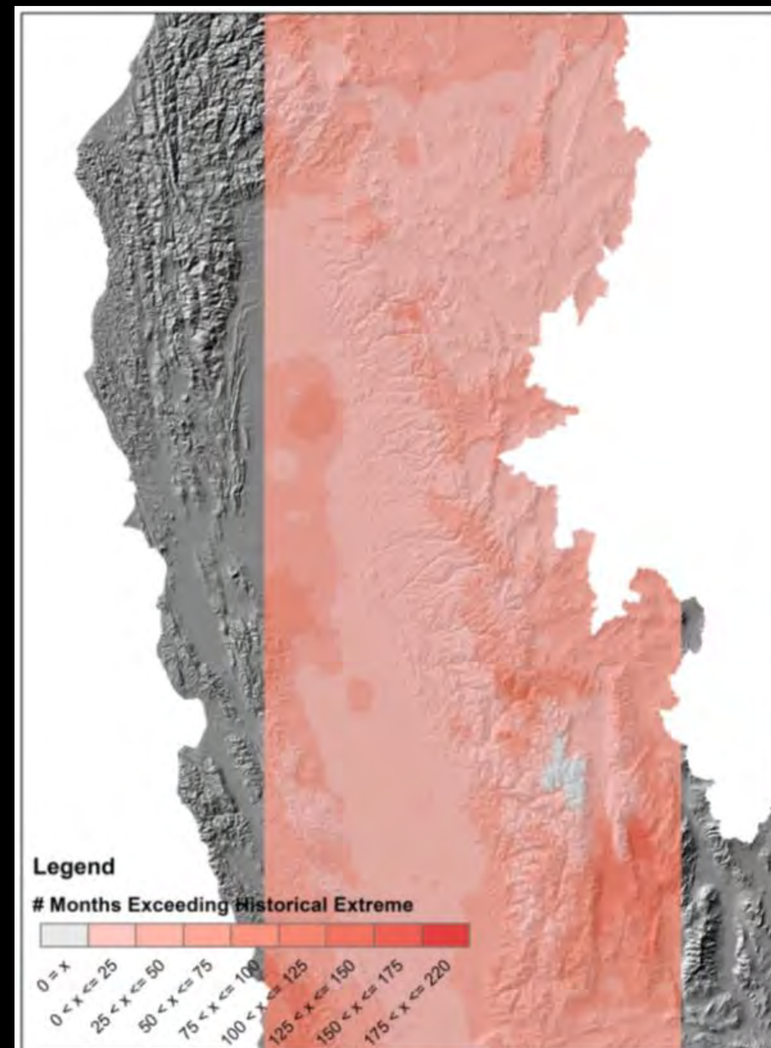


Do patterns differ between variables?

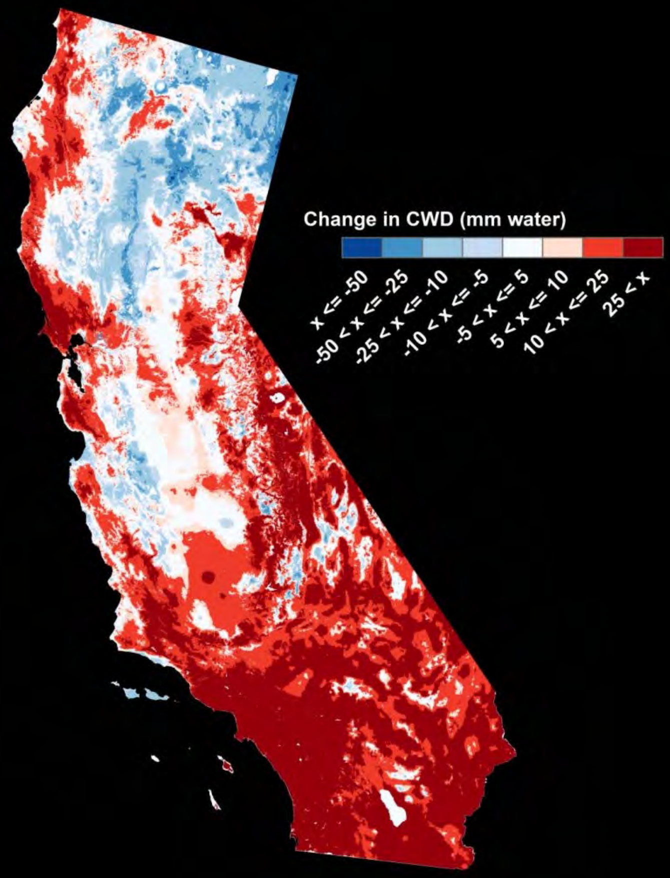
Minimum Temp

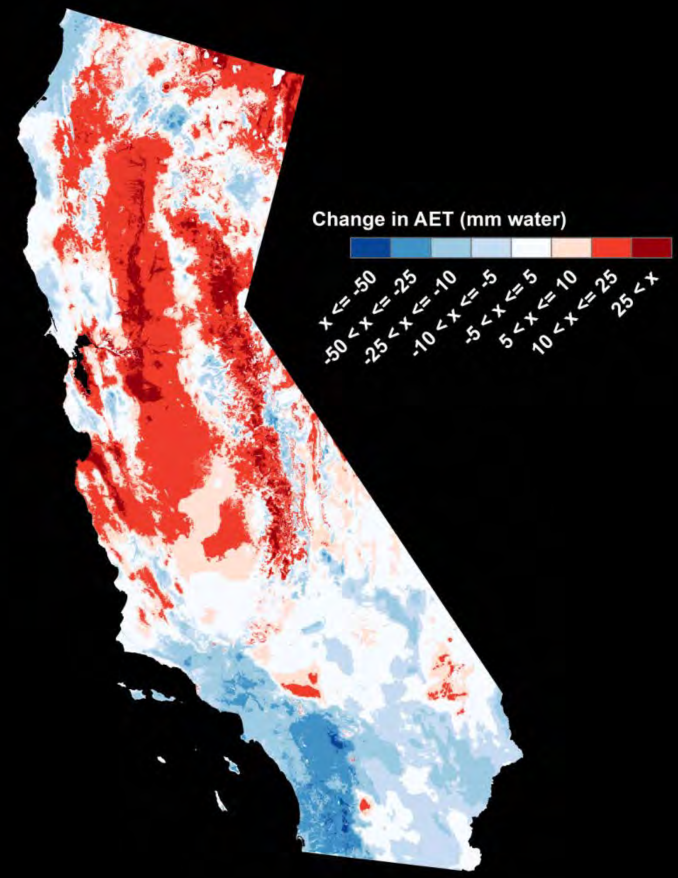


Maximum Temp

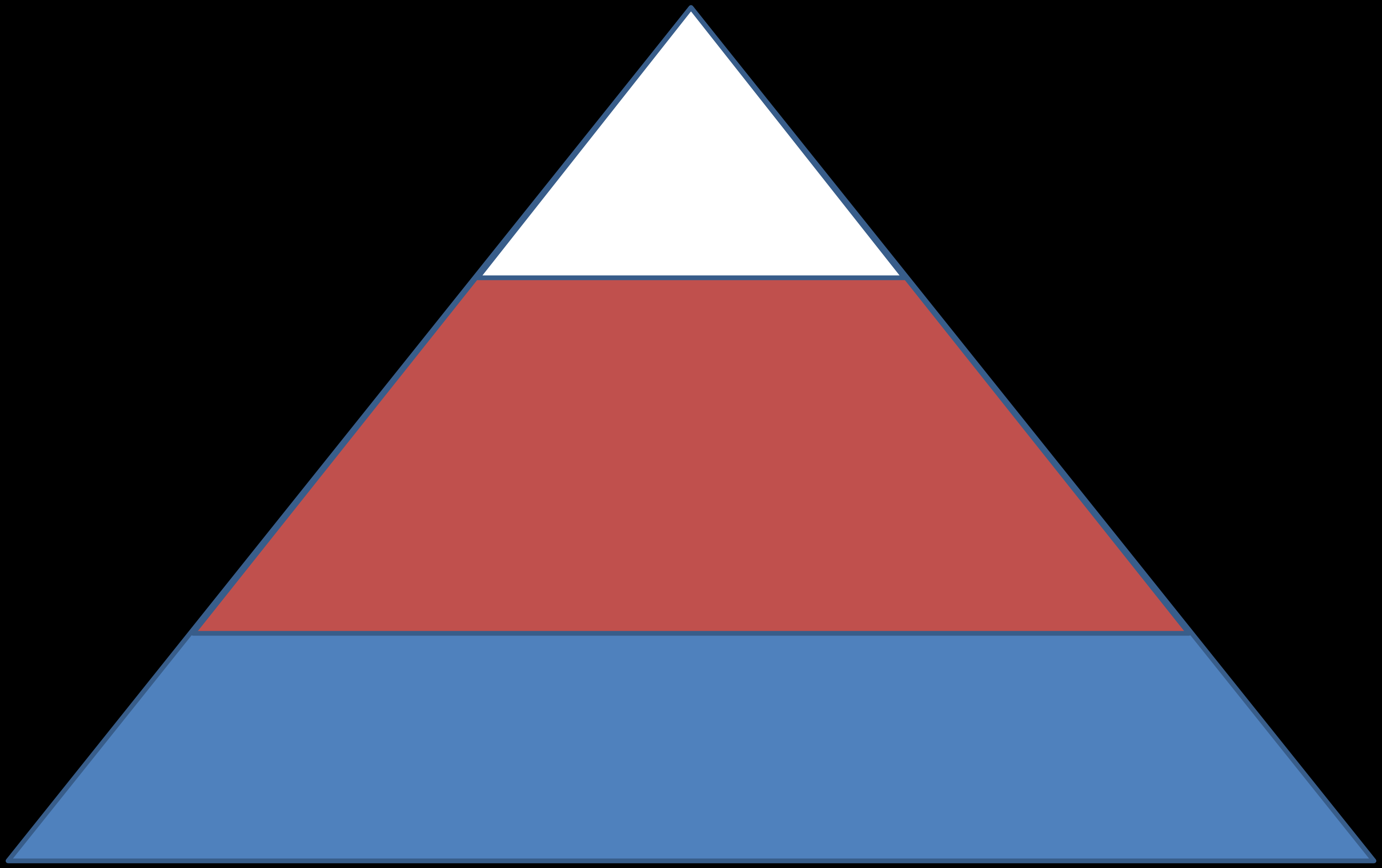


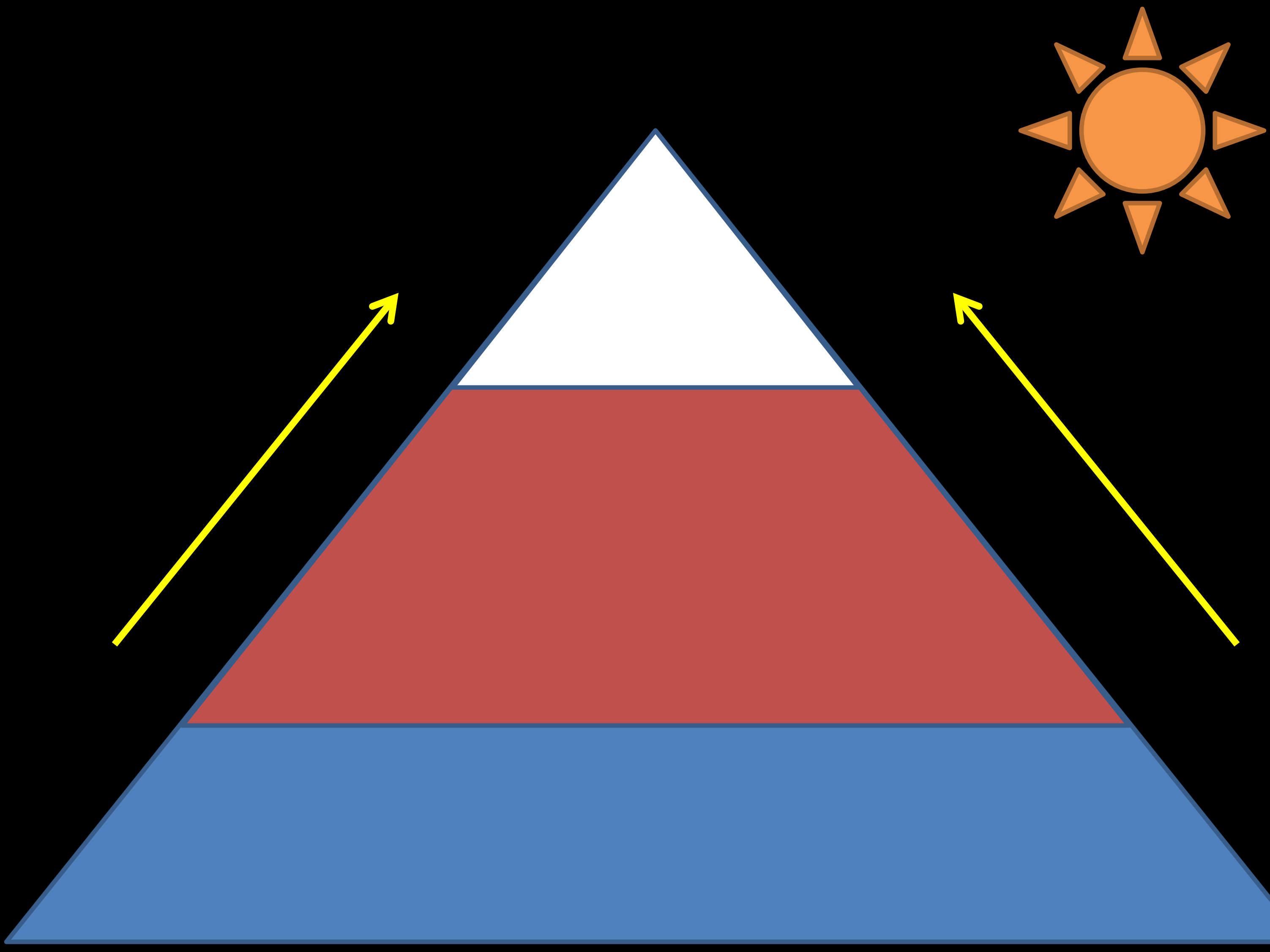
Water balance variables are more striking

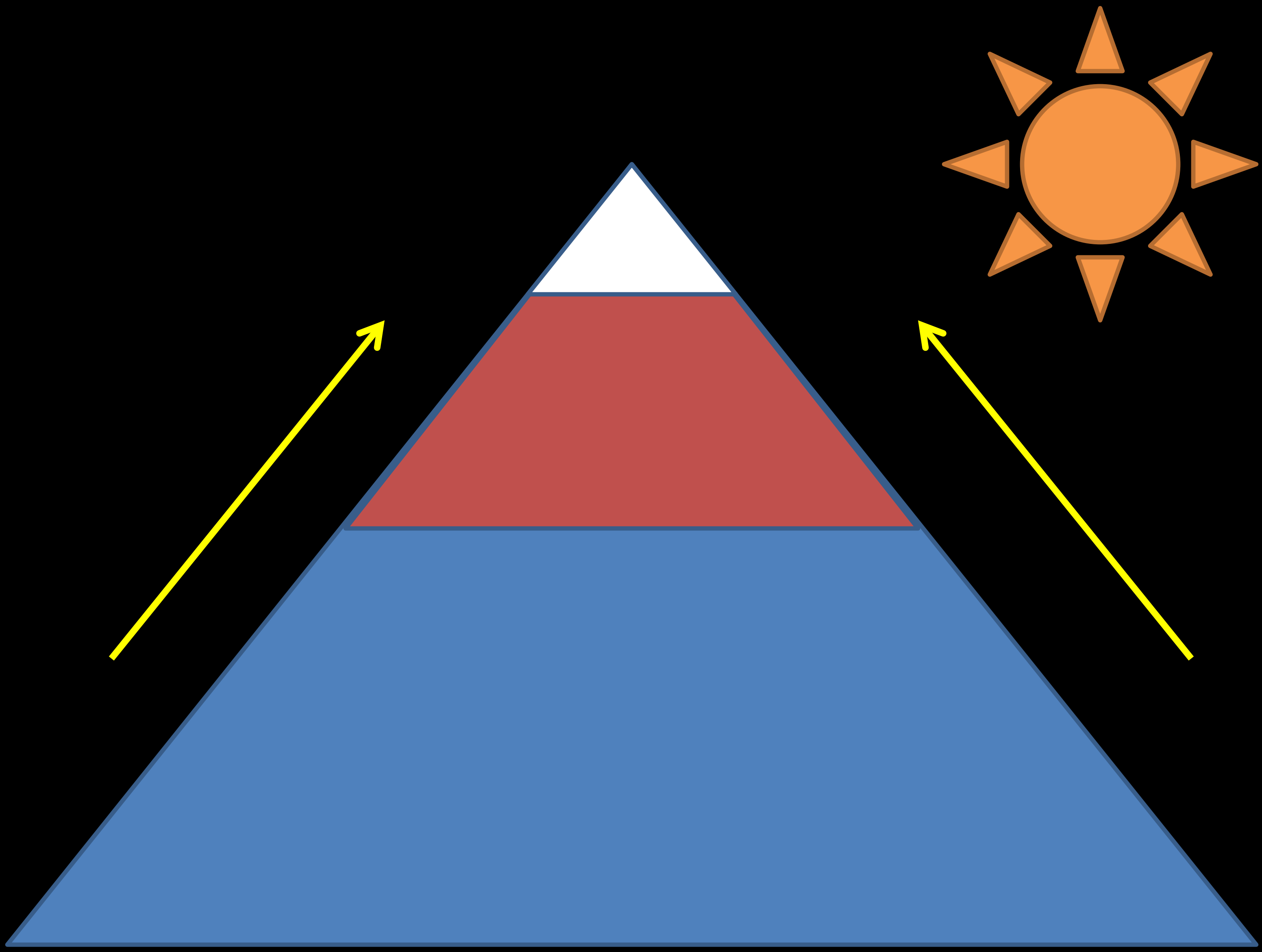


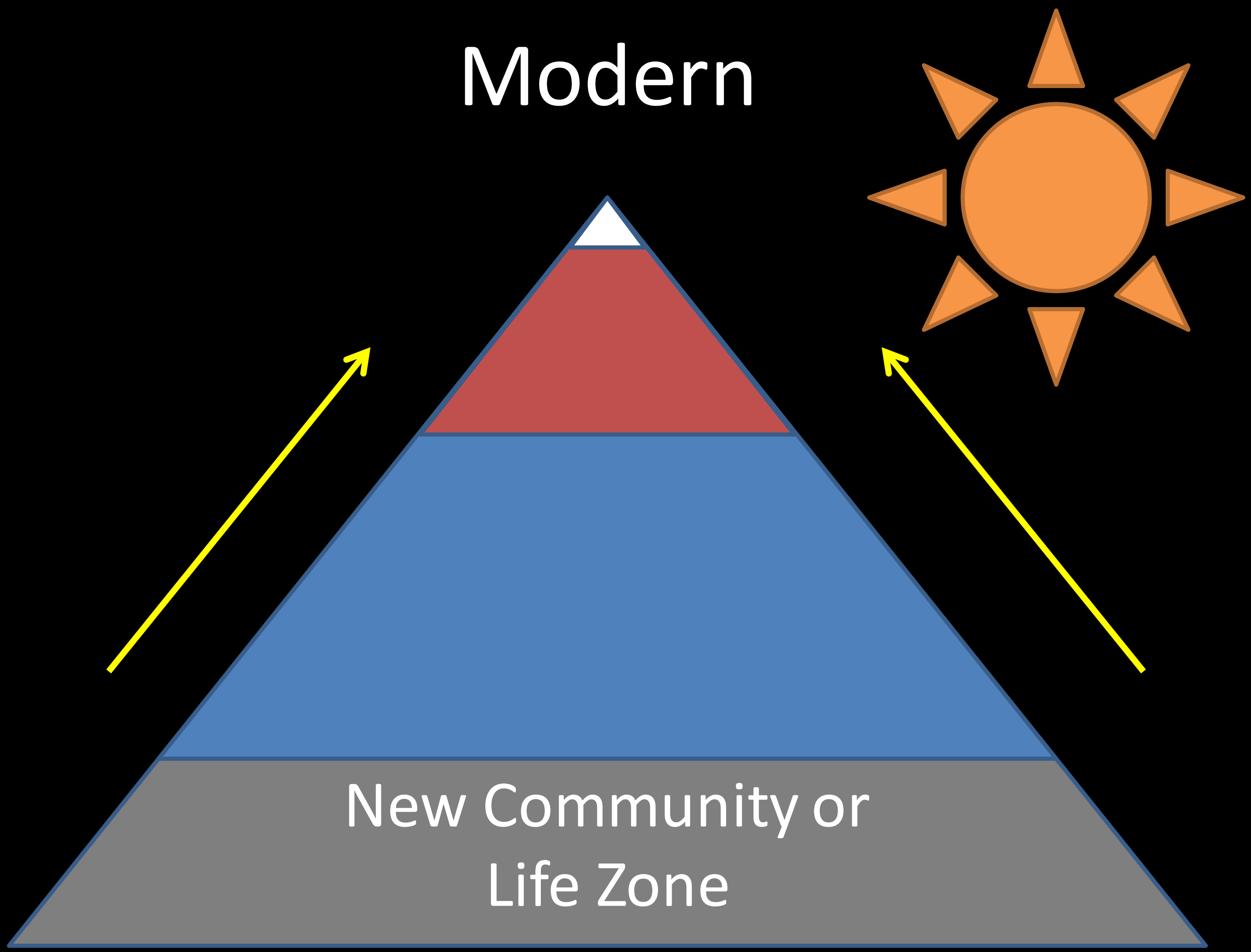


Historic

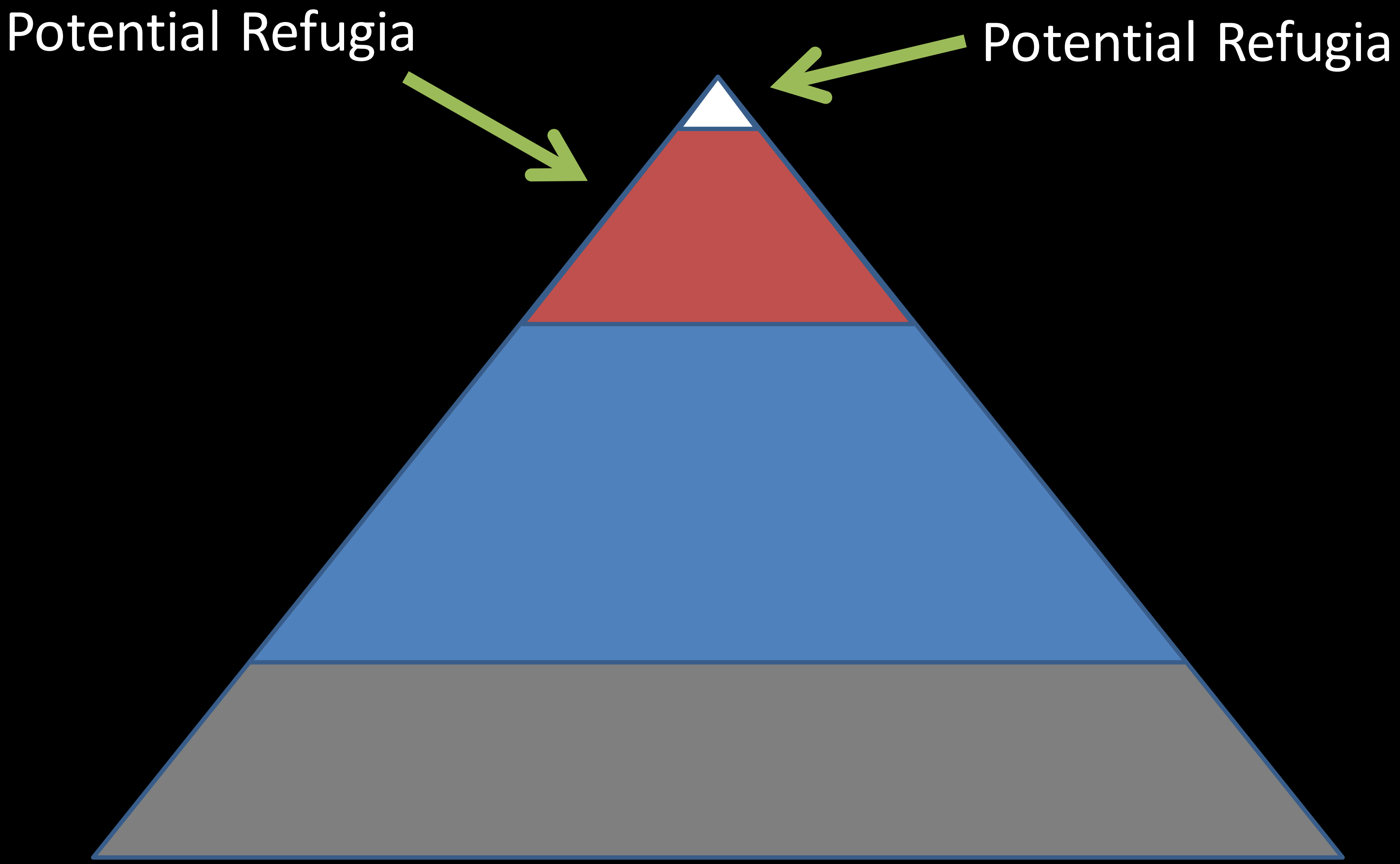






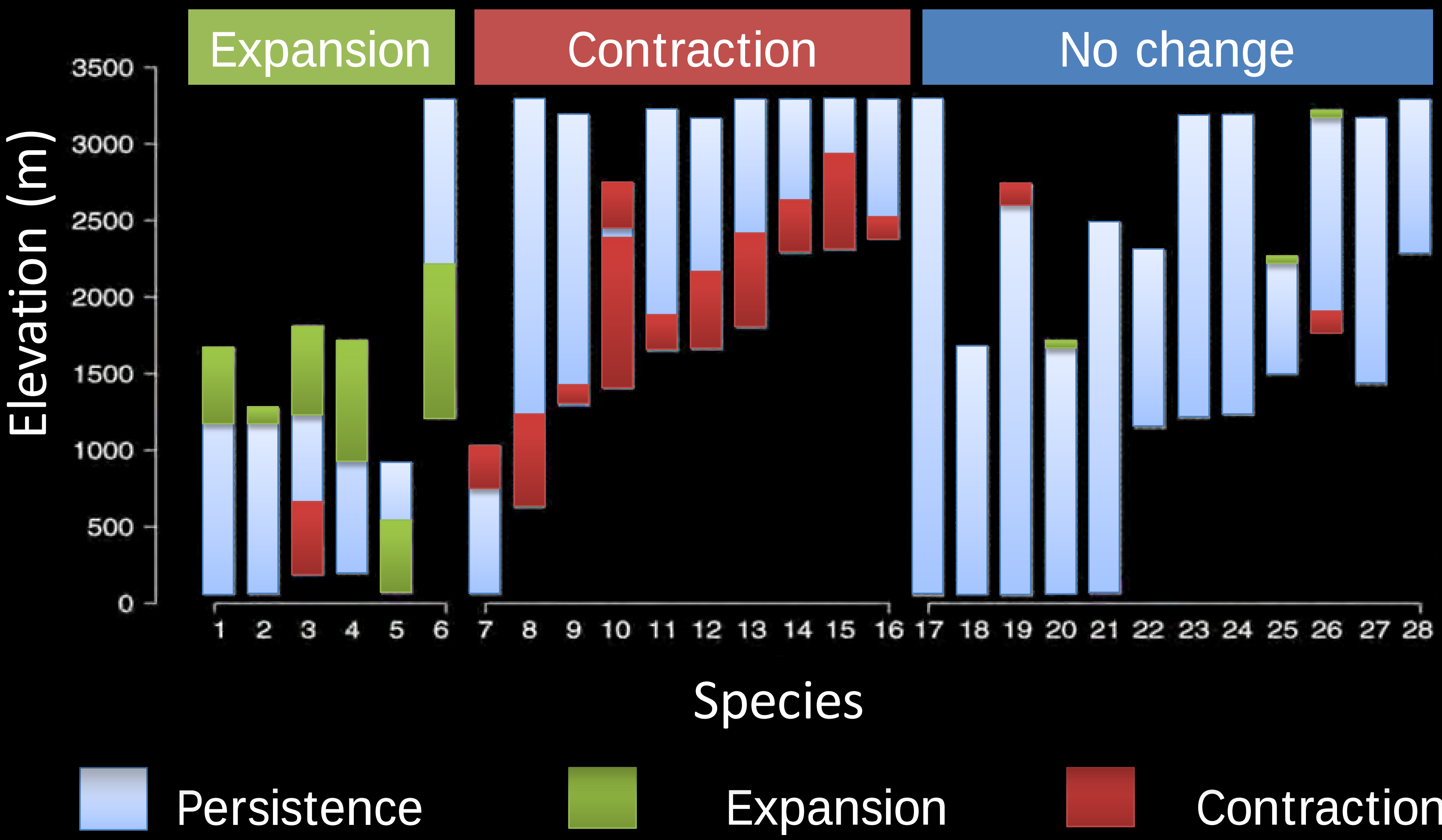

Modern
New Community or
Life Zone

Modern



Moritz et al. 2008
Science

Grinnell Resurvey Project



Populations and species responses to change

- Range shift
  - Elevationally (per our example)
  - Latitudinally
- Population shift
  - Range is stable, but distribution of individuals has changed
  - Change in age structure
- Genetic shift
  - Selection and adaptation

What characteristics would allow refugia to maintain a population?

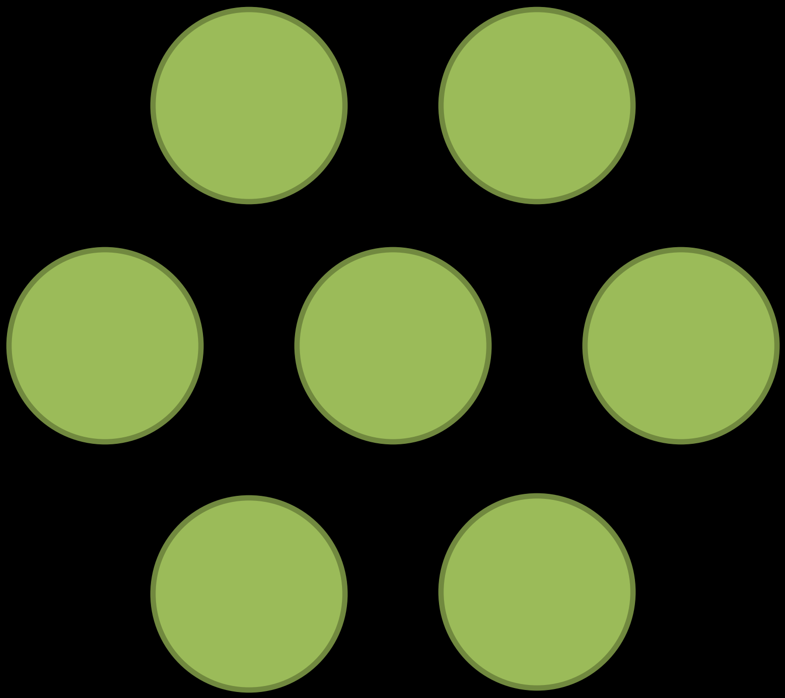
- Size
  - Larger area, maybe more species or individuals
  - Perhaps a SLOSS-type debate
- Access
  - Easy to “find”
- Orientation and arrangement
  - Permit and facilitate movement between patches

Measures of connectivity can help assess Access and Orientation

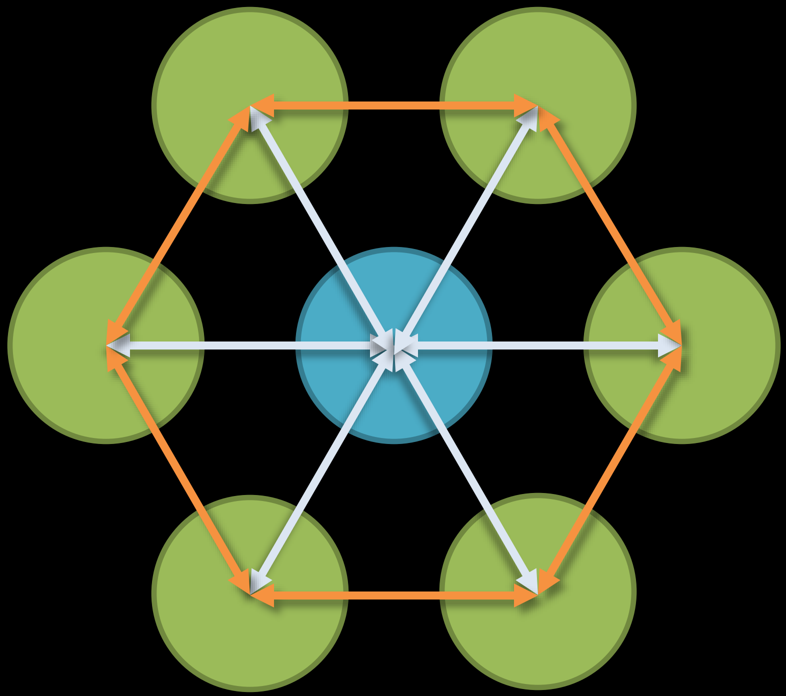
What do we mean by “connectivity”?

- Abstract measurement, so values can be relative to the system or analysis
- Mapped routes of expected dispersal
  - Based upon some friction surface
  - Would assist in identifying corridors of retraction
  - Least-cost distance, for instance
- Estimated value of movement through an area
  - Identify well-traveled node in network
  - Provide an additional quantity of value

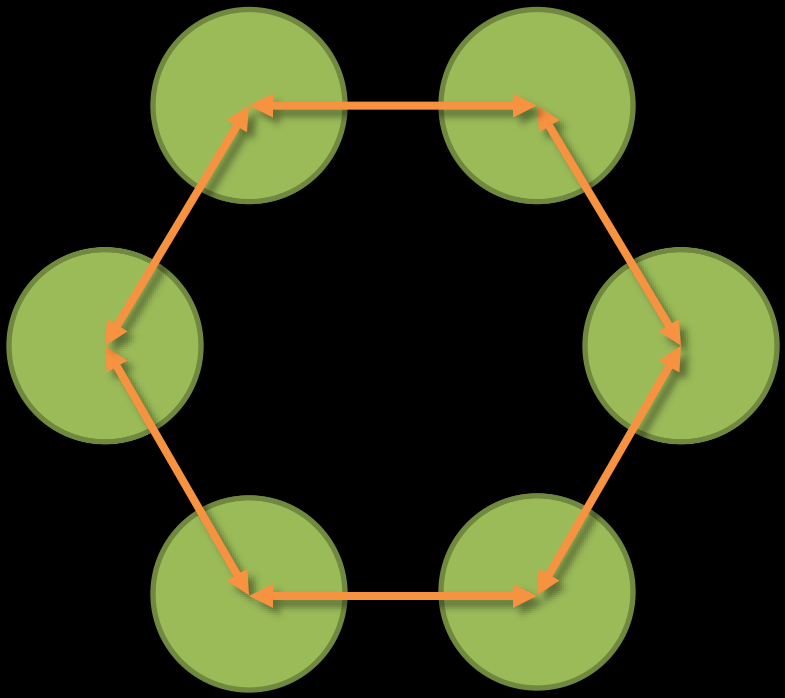
Metapopulations and connectivity



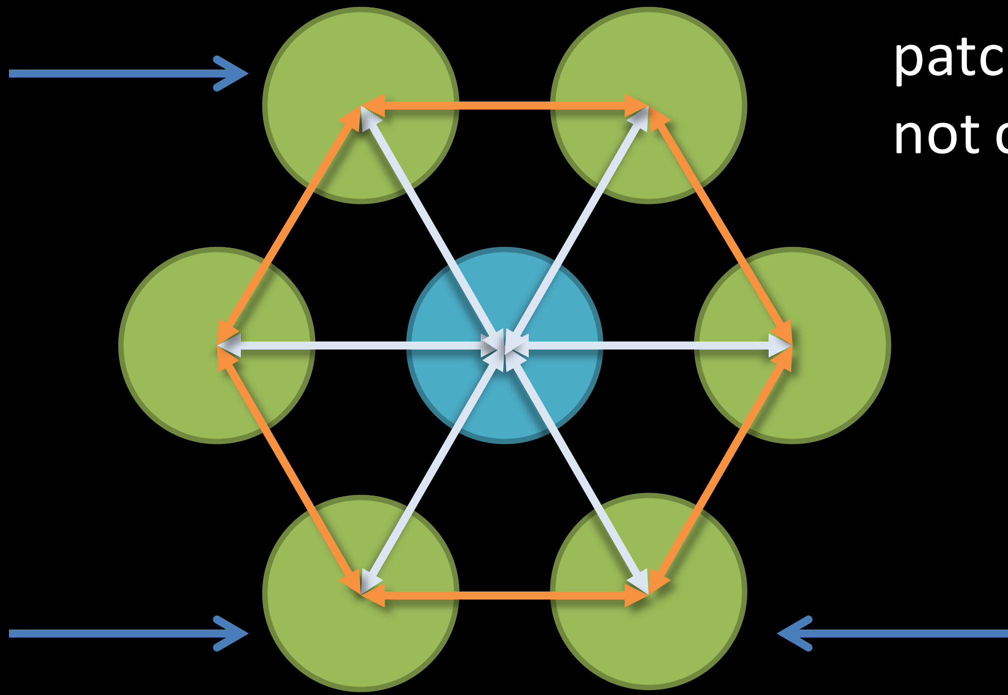
Metapopulations and connectivity



Metapopulations and connectivity

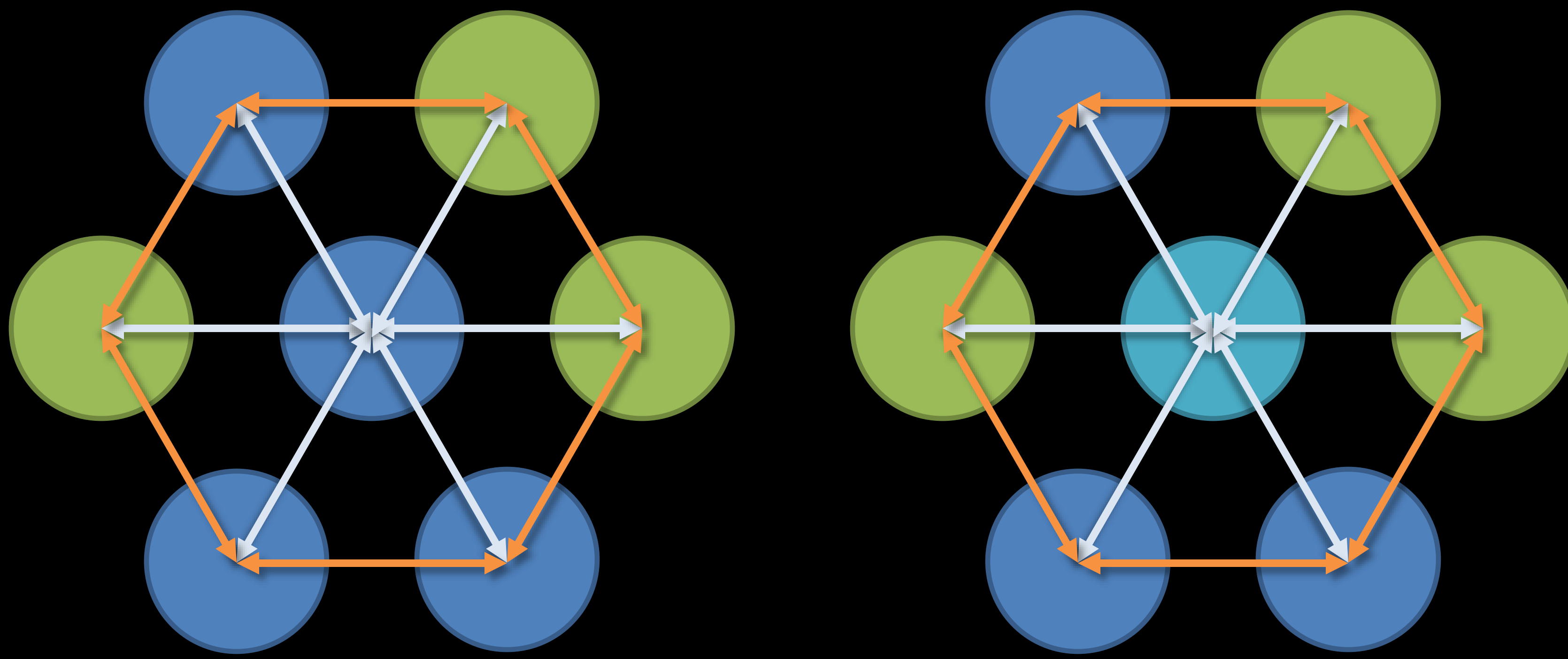


Refugia and connectivity

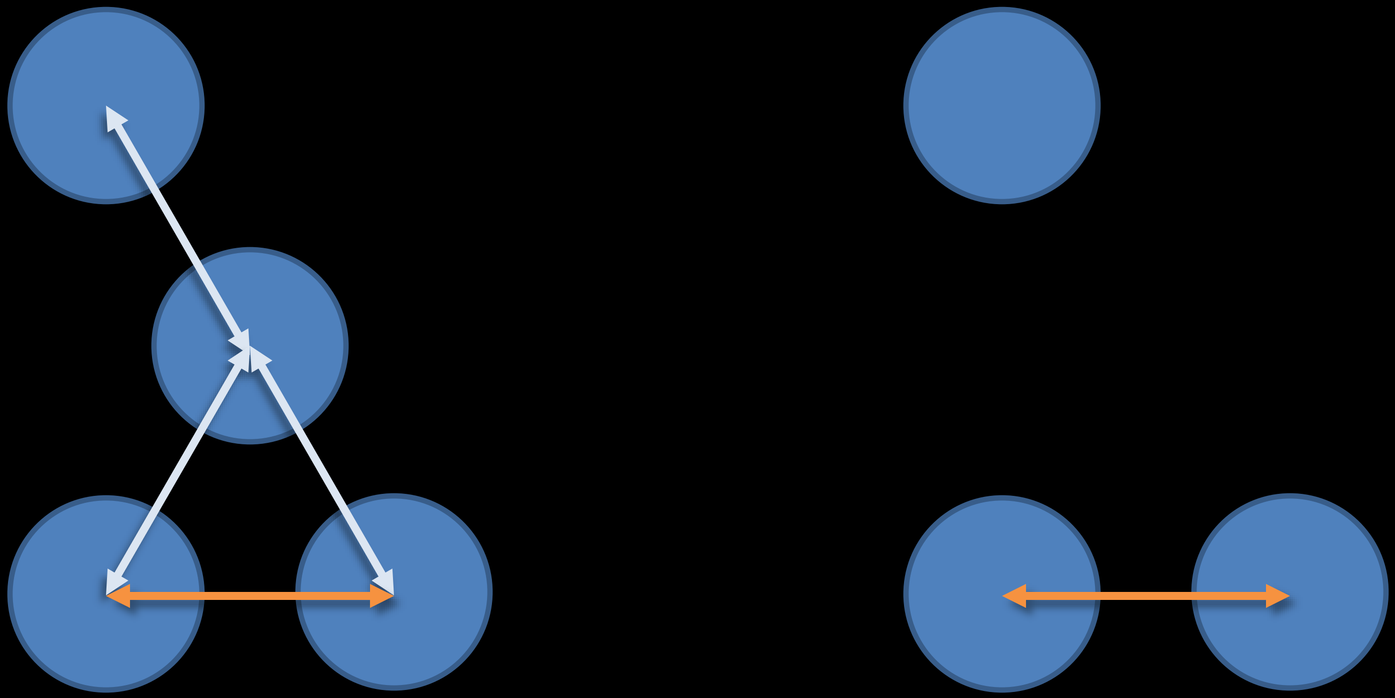


Refugia defined as patches that do not change (a lot)

Refugia and connectivity



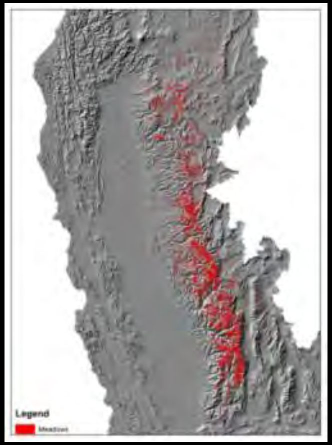
Refugia and connectivity

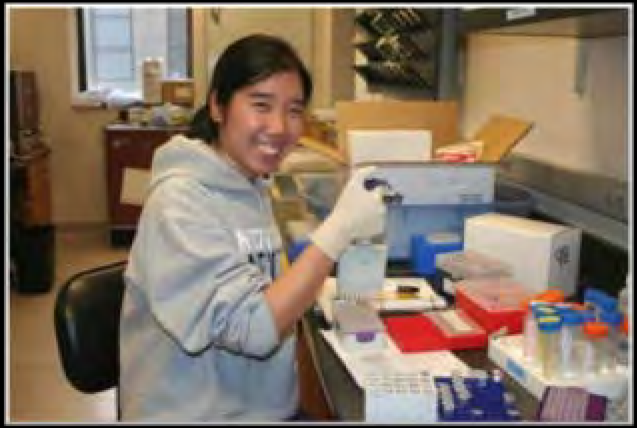


Well-connected refugial sites are likely to be important for occupancy of populations and gene flow

PROJECT OBJECTIVES

- Map hypothetical connectivity of meadows in the Sierra Nevada
- Map hypothetical climate change refugia in the Sierra Nevada
- TEST mapped connectivity and refugia using occupancy and genetic data





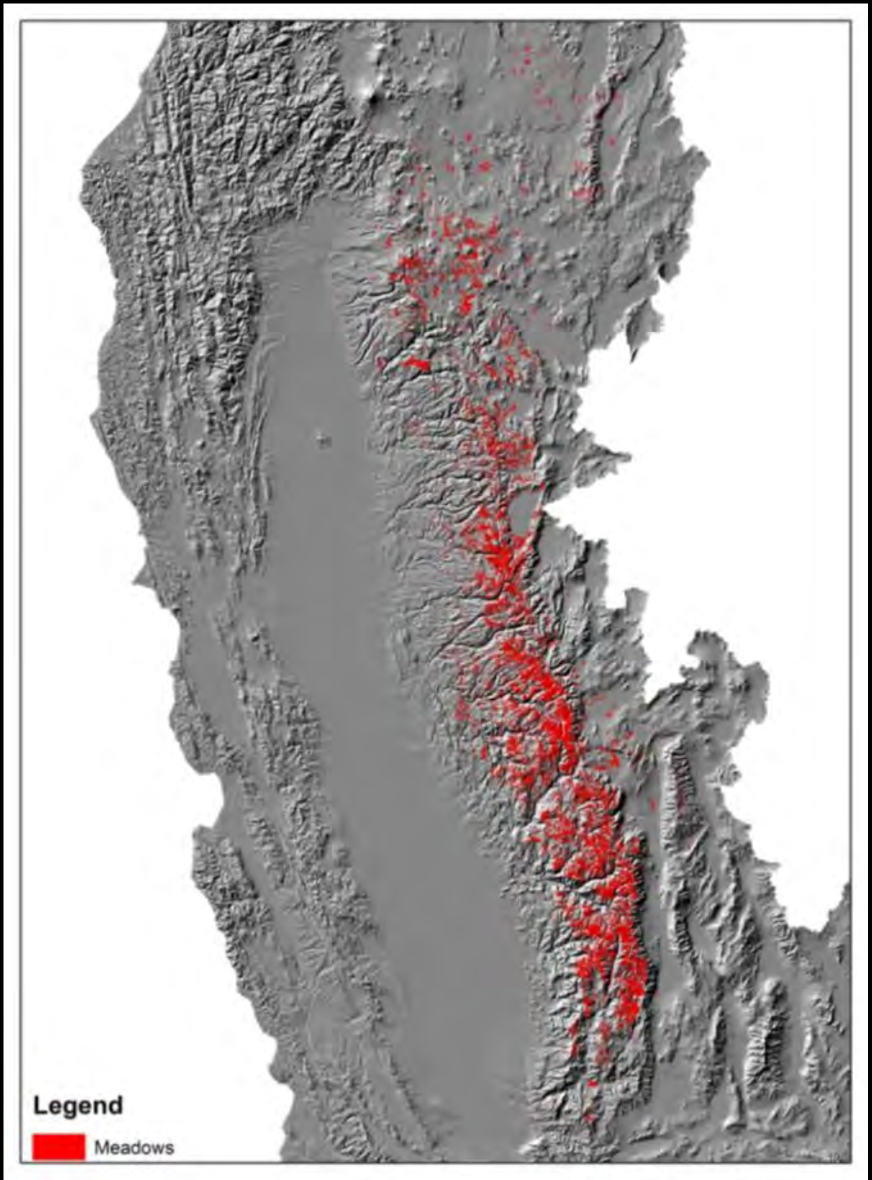
Hypotheses of connectivity to test

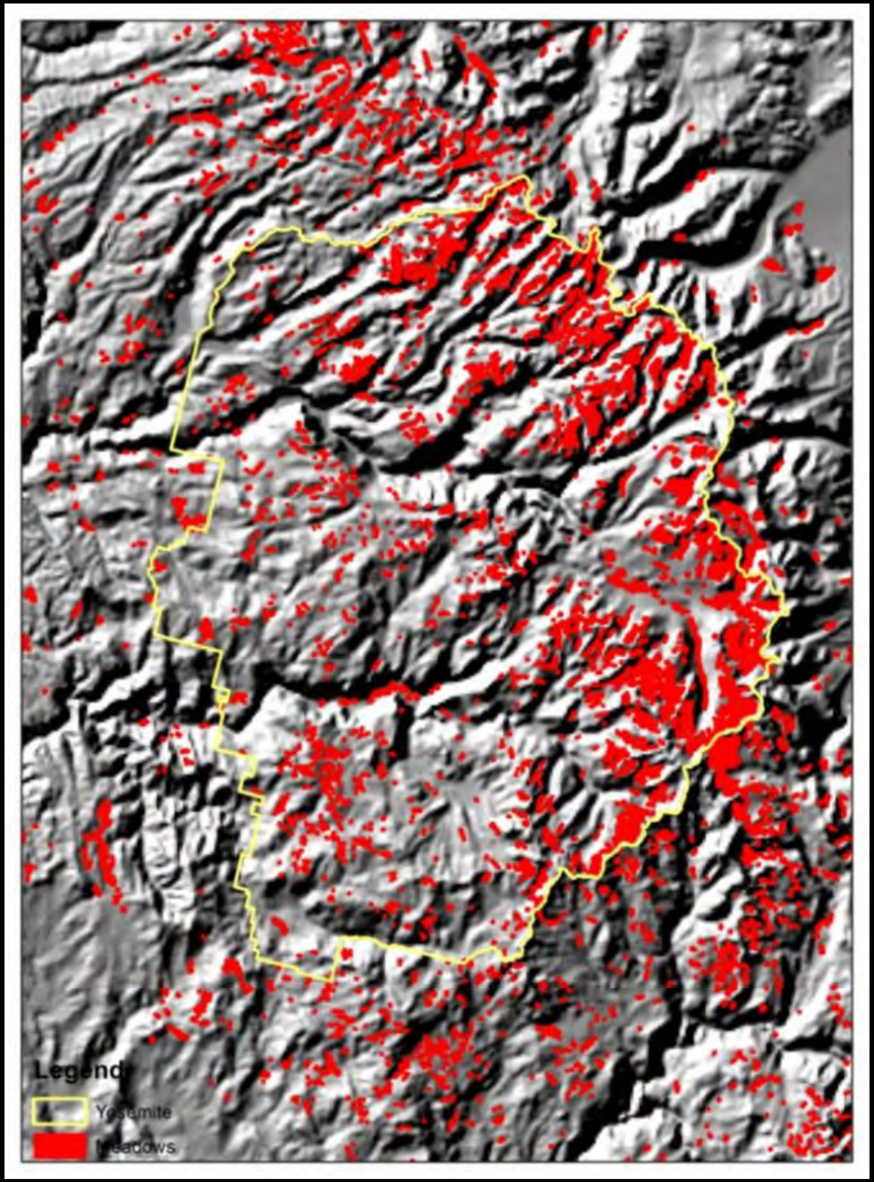
1. Isolation by **distance**
2. Isolation by **topography**
3. Isolation by **watercourses**
4. Isolation by **roads**
5. Isolation by **environmental heterogeneity**

How are meadows connected and how is their environment changing?

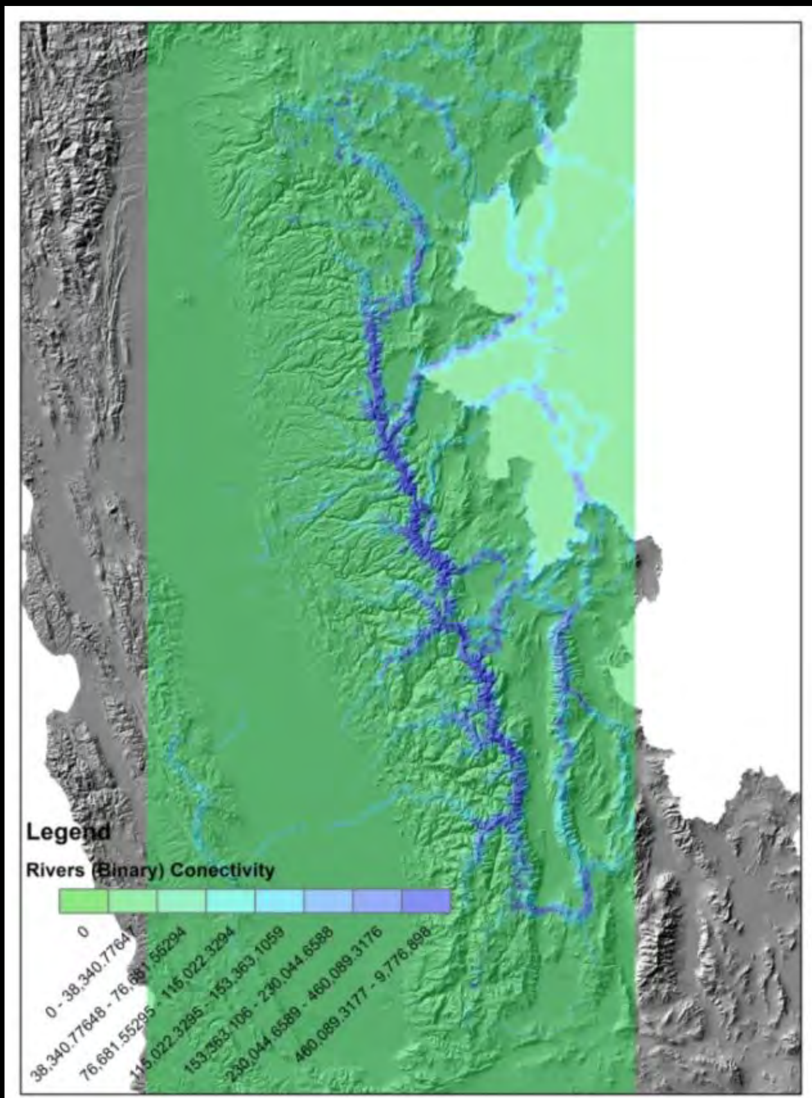
- Spatial layer of meadows – ICE at UC Davis
- Estimate the connectivity between them using Circuitscape based upon resistance and conductance surfaces
- Plotted forward in time to assess how meadows are expected to change

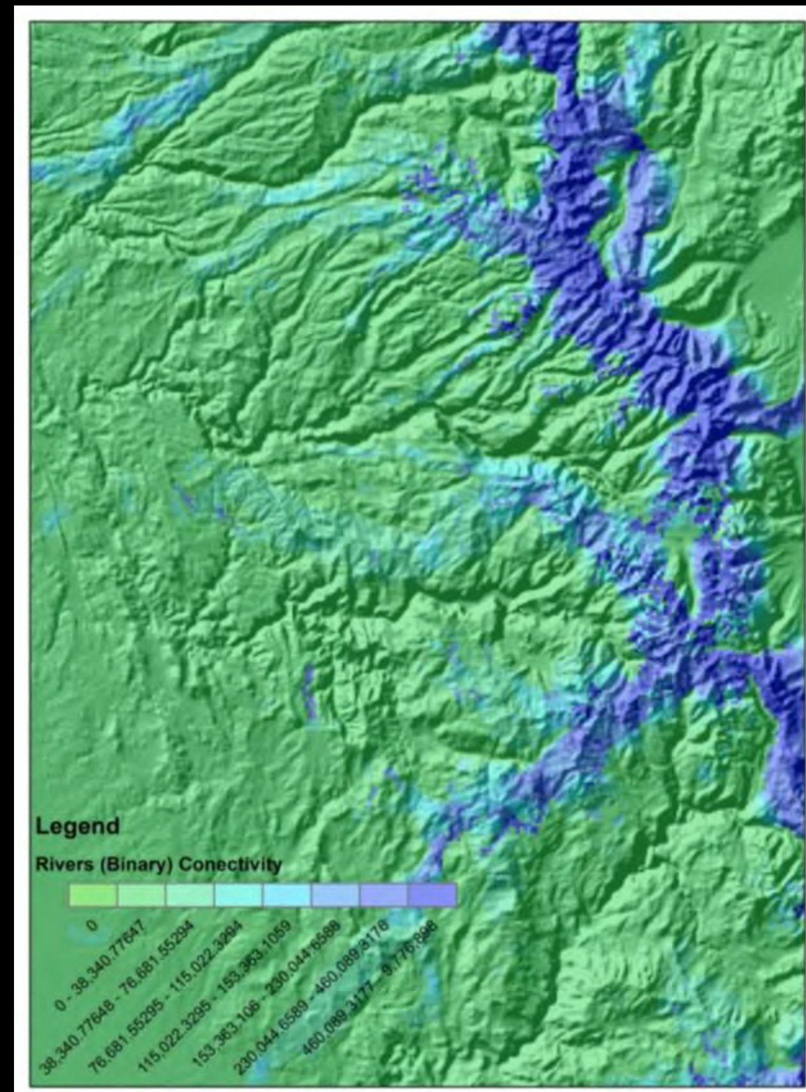
Meadows



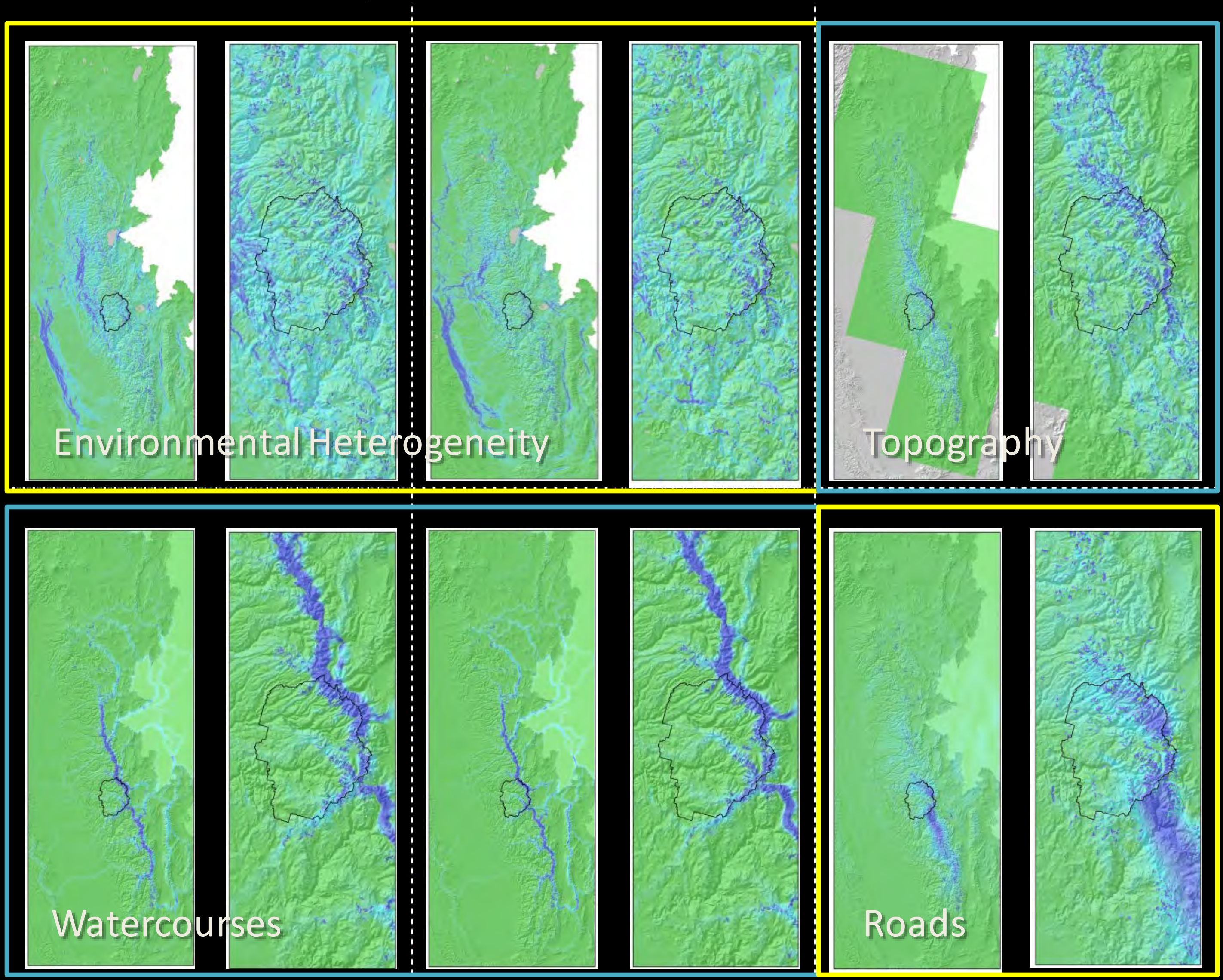


Connectivity based on presence or absence of watercourses (Hyp #3)



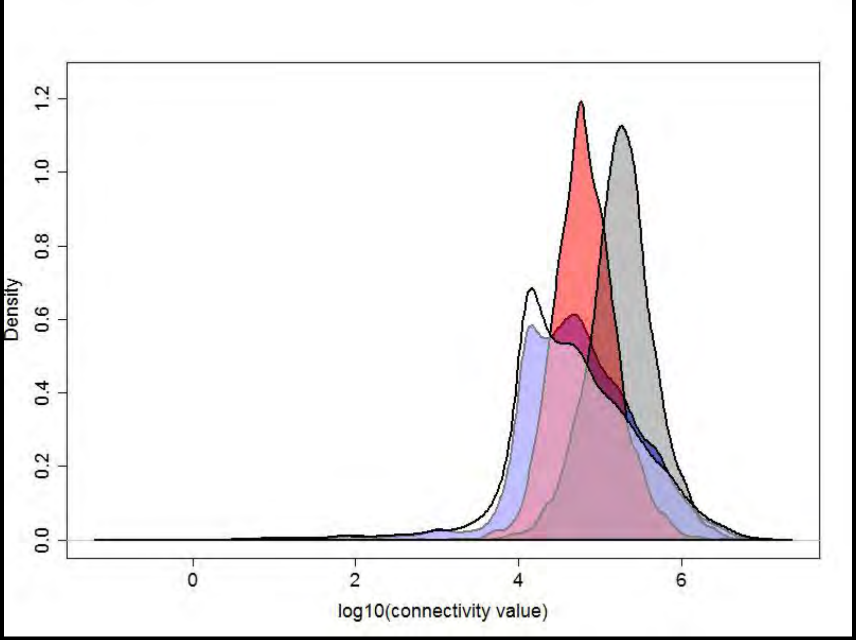


Overall patterns of connectivity depends on surface

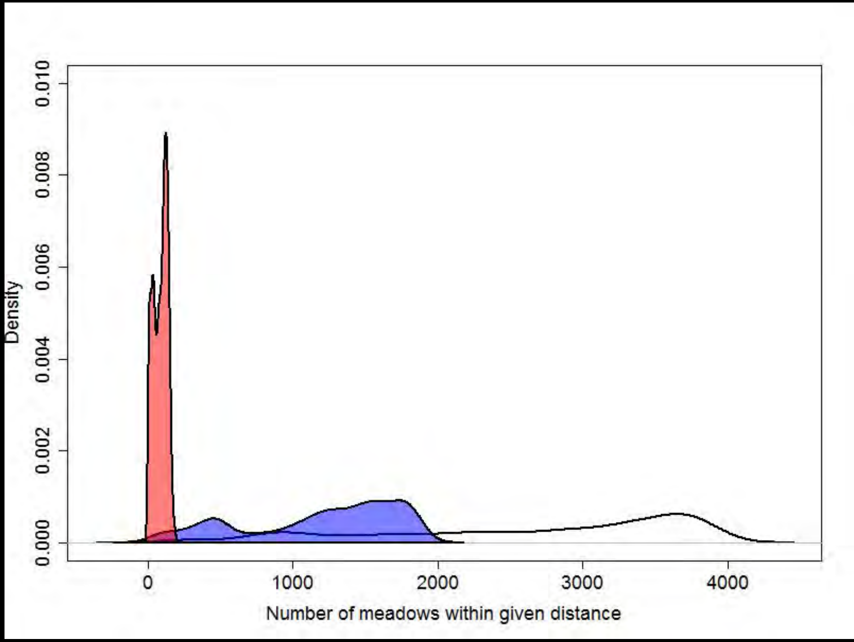


Distribution of values of connectivity

Four of the Circuitscape layers

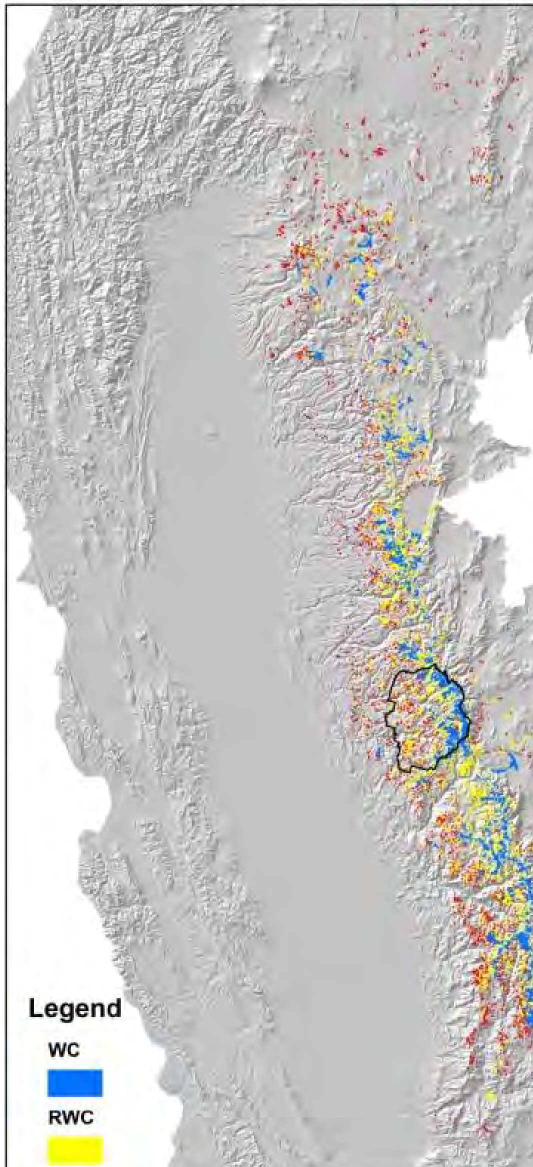


Arrangement of meadows

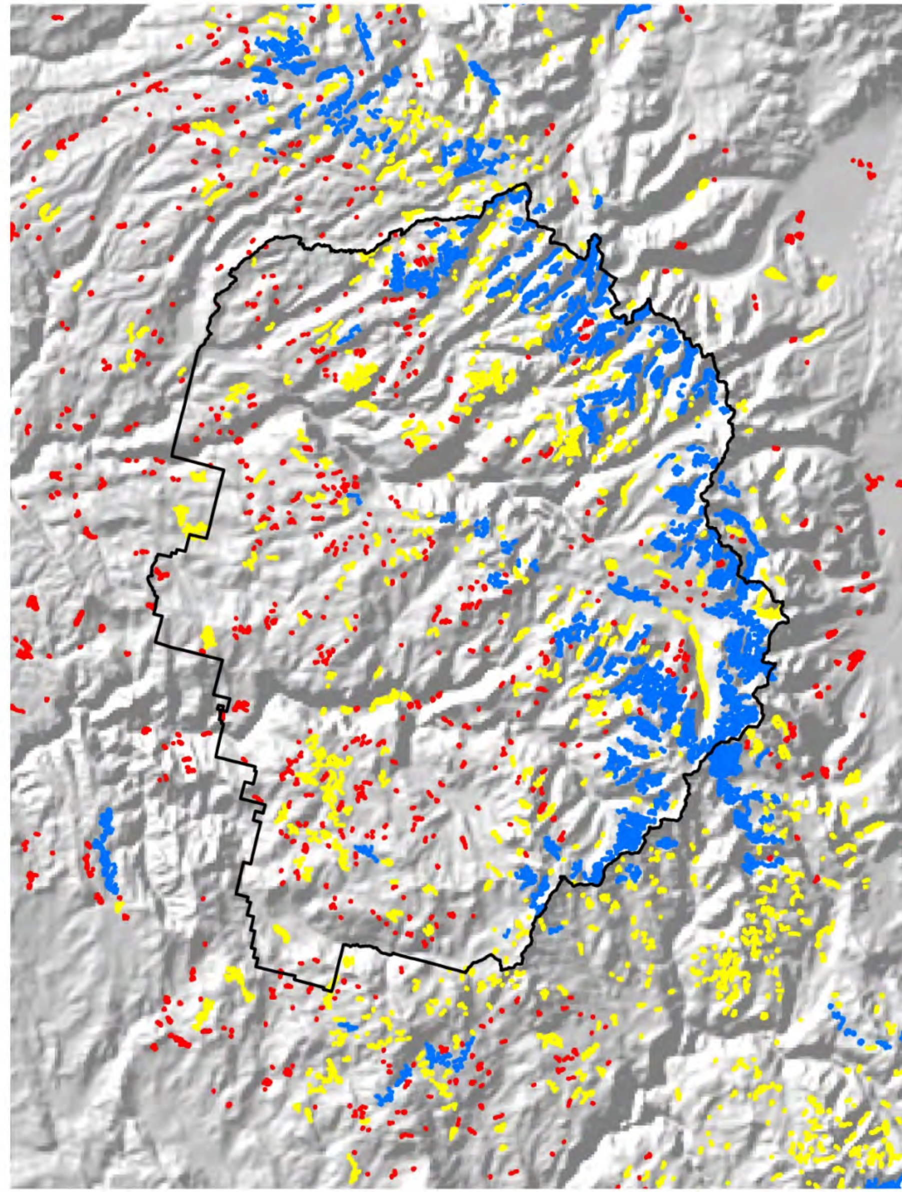


	Distance (10km)	Distance (50km)	Distance (100km)	Topography	Rivers (Distance)	Rivers (Presence)	Roads
Distance (10km)	1	0.788	0.638	0.326	0.154	0.169	0.322
Distance (50km)	0.788	1	0.935	0.236	0.102	0.116	0.297
Distance (100km)	0.638	0.935	1	0.218	0.113	0.129	0.280
Topography	0.326	0.236	0.218	1	0.584	0.637	0.770
Rivers (Distance)	0.154	0.102	0.113	0.584	1	0.960	0.591
Rivers (Presence)	0.169	0.116	0.129	0.637	0.960	1	0.645
Roads	0.322	0.297	0.280	0.770	0.591	0.645	1

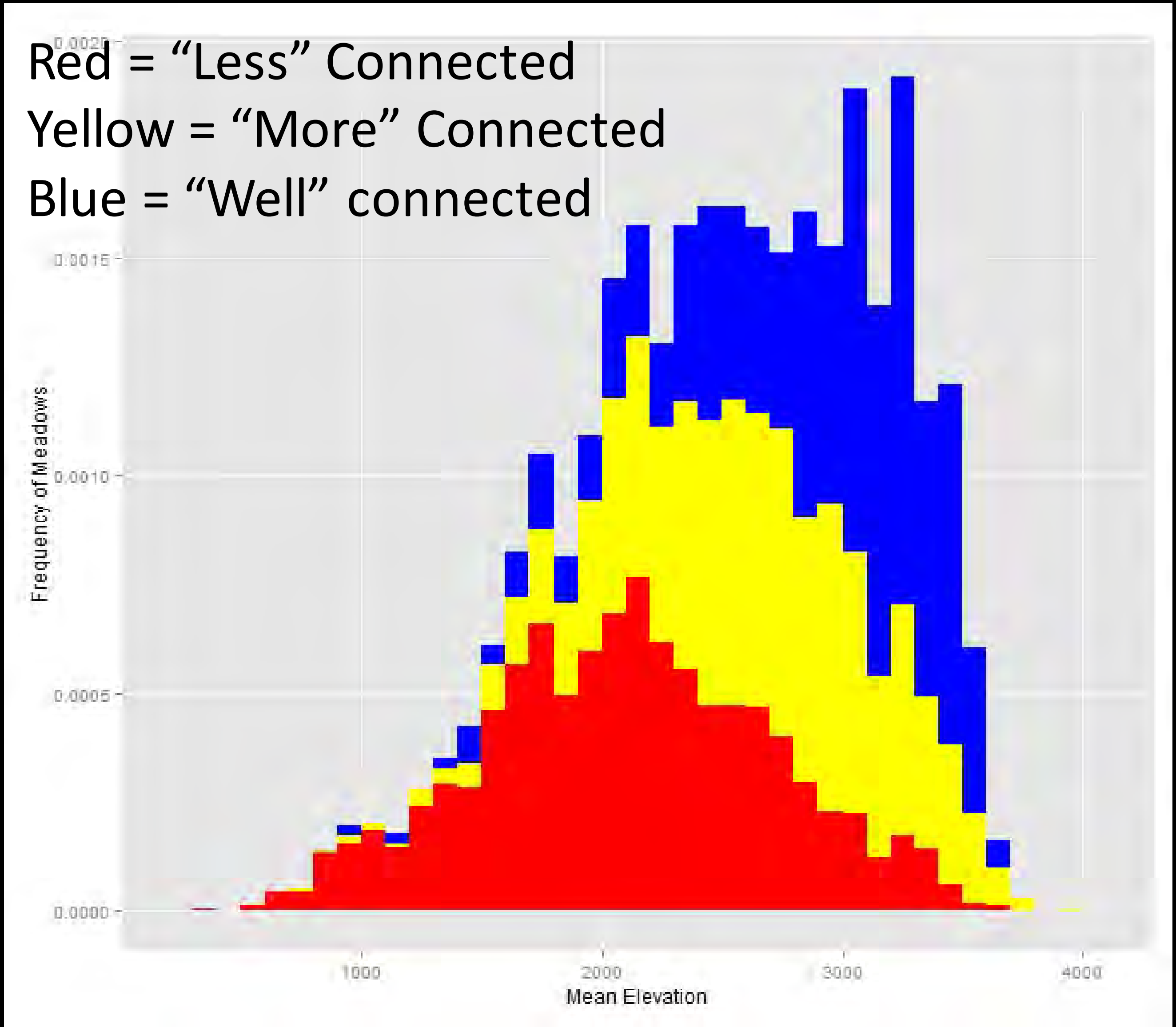
Where are the Well-Connected Meadows?



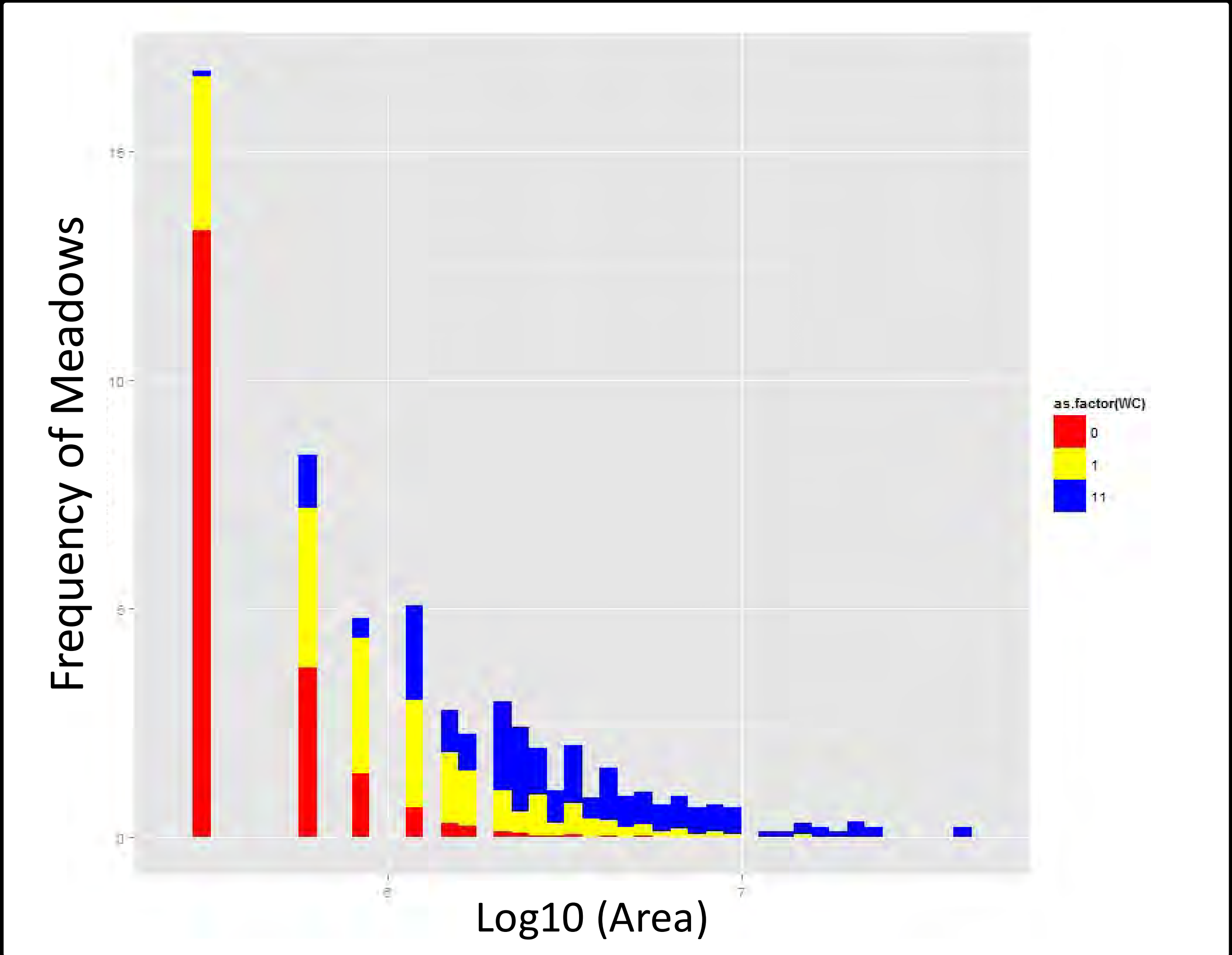
Within 75th percentile of all estimates



Are Well-Connected Meadows at higher elevations?

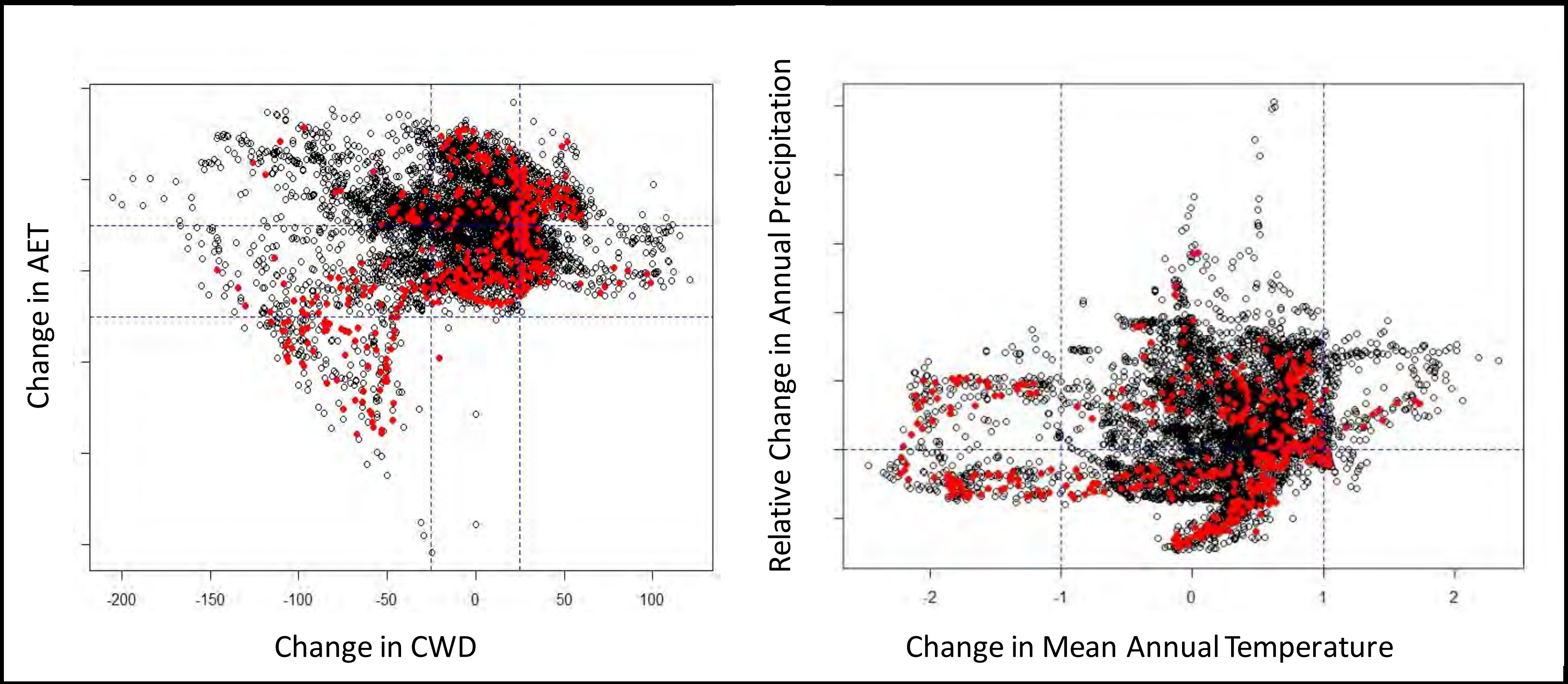


Are larger meadows more connected?



Of the 5894 meadows, 470 were classified as WC (8.0%), and 2266 were classified as rWC (38.4%), and 3158 meadows (53.6%) were unclassified. However, the amount of area represented by the WC meadows was much larger (31.9%), while rWC meadows represent a similar proportion (35.6%), such that WC meadows tended to be those that are larger than other meadows.

Change within meadows is variable

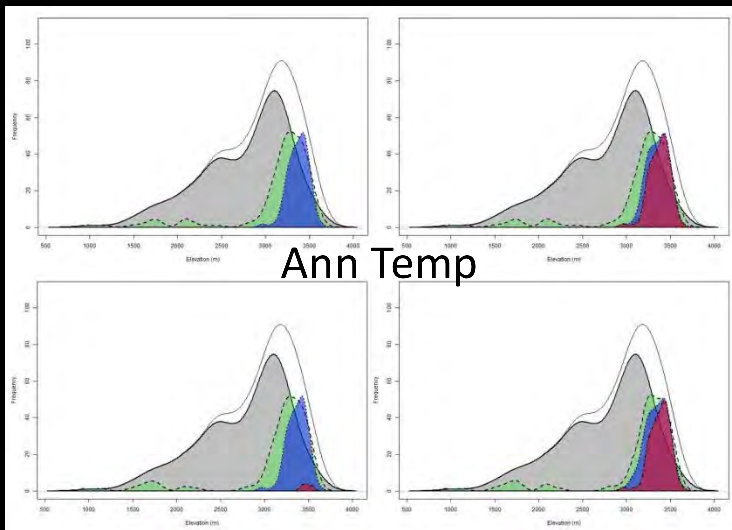


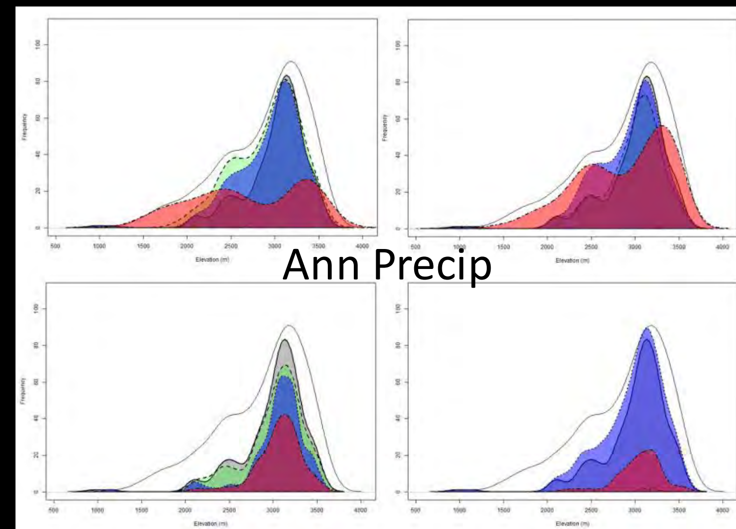
WC meadows are red points

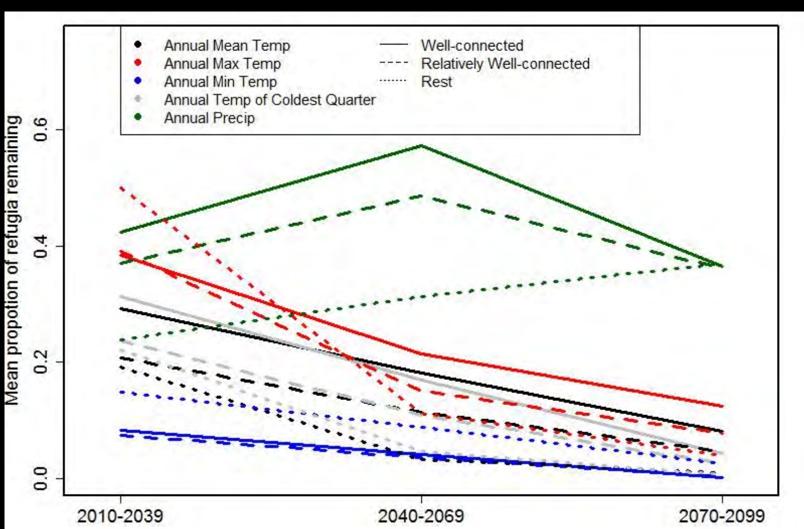
Differences in proportion of refugia within network of meadows

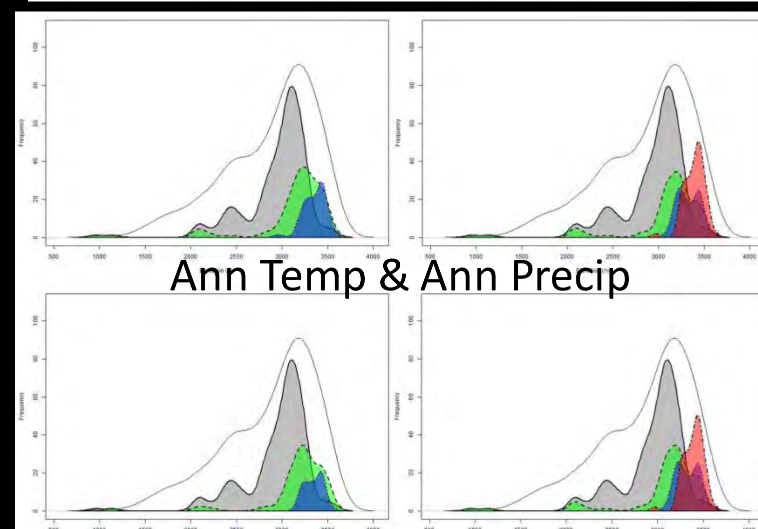
Variable	Measure (Threshold)	WC	rWC	Rest	Binomial test	Direction
CWD	Central Tendency (10%)	0.289	0.467	0.640	P < 0.001	Lower
SWE	Central Tendency (10%)	0.472	0.458	0.287	P < 0.001	Higher
Annual Temp.	Central Tendency (1°C)	0.791	0.817	0.934	P < 0.001	Lower
Annual Precip.	Central Tendency (10%)	0.538	0.453	0.302	P < 0.001	Higher
Max. Temp.	Central Tendency (1°C)	0.636	0.662	0.705	P = 0.019	Lower
Min. Temp.	Central Tendency (1°C)	0.330	0.237	0.316	P = 0.028	Higher
Mean. Temp. of Coldest Quarter	Central Tendency (1°C)	0.696	0.658	0.805	P = 0.020	Lower
Monthly Min. Temp.	Extreme Warming (30 Months)	0.332	0.226	0.212	P < 0.001	Higher
Monthly Min. Temp.	Extreme Warming (60 Months)	0.570	0.482	0.507	P = 0.001	Higher
Monthly Precip.	Extreme Wet (30 Months)	0.021	0.008	0.003	P < 0.001	Higher
Monthly Precip.	Extreme Wet (60 Months)	0.968	0.961	0.904	P < 0.001	Higher
Monthly Precip.	Extreme Dry (30 Months)	0.174	0.221	0.290	P < 0.001	Lower
Annual Temp. & Annual Precip.	Central Tendencies	0.419	0.363	0.291	P < 0.001	Higher
SWE & Monthly Min. Temp	Central Tendency & Extreme (30 Months)	0.094	0.067	0.033	P < 0.001	Higher

Erosion of the network in the (near) future

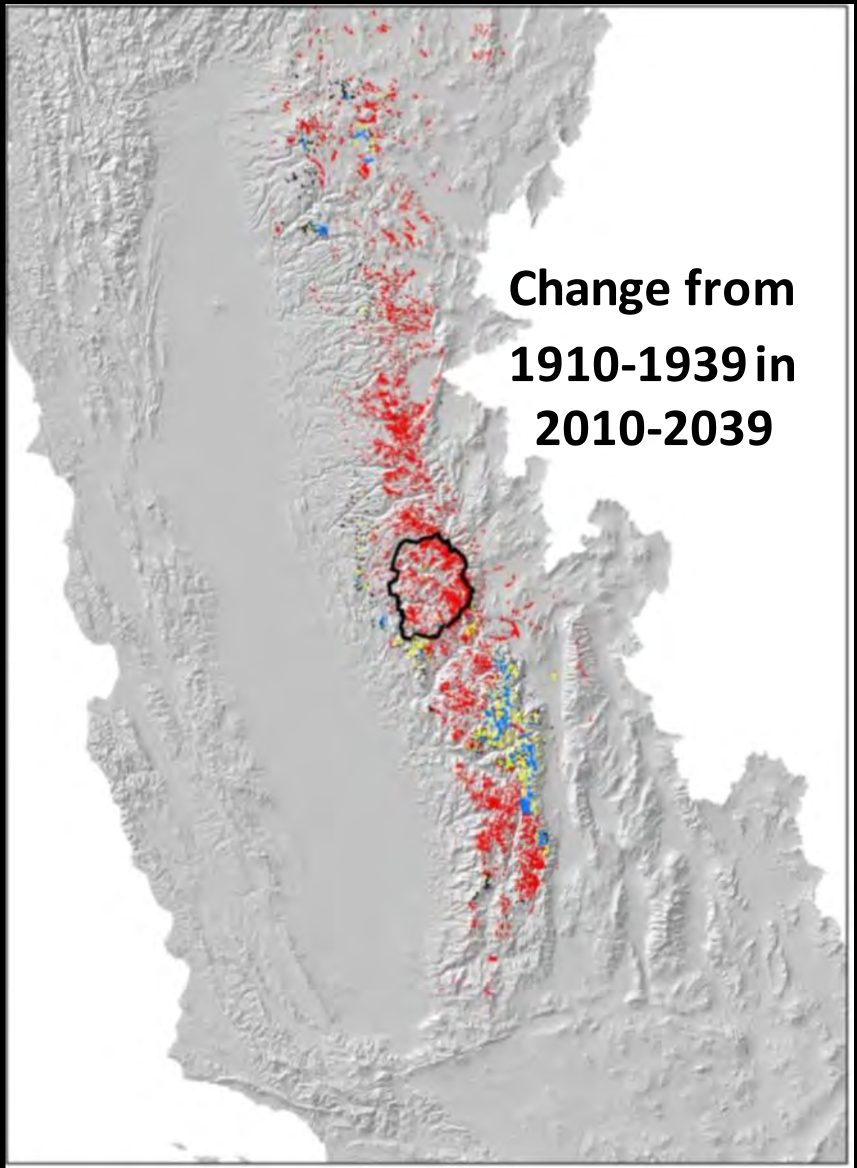


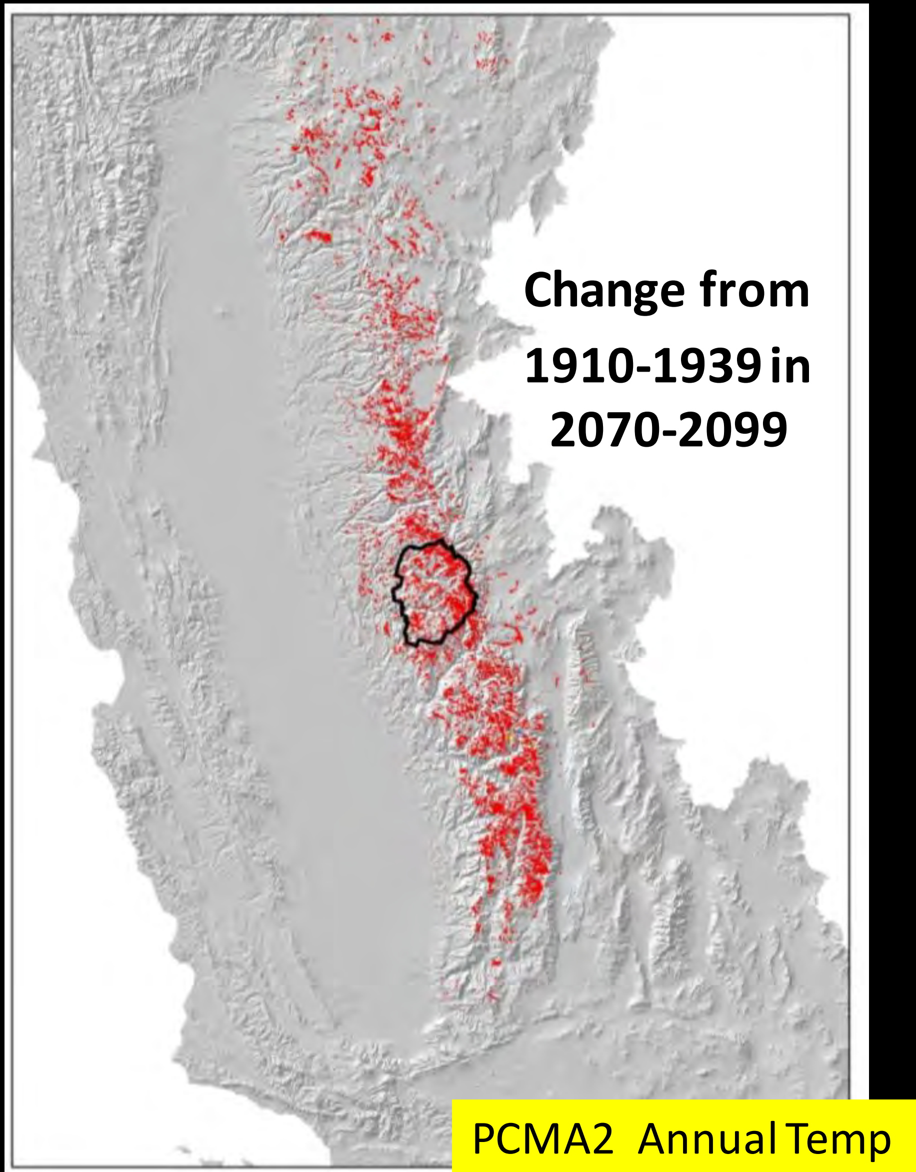






So how do we expect climate to change in well-connected meadows?





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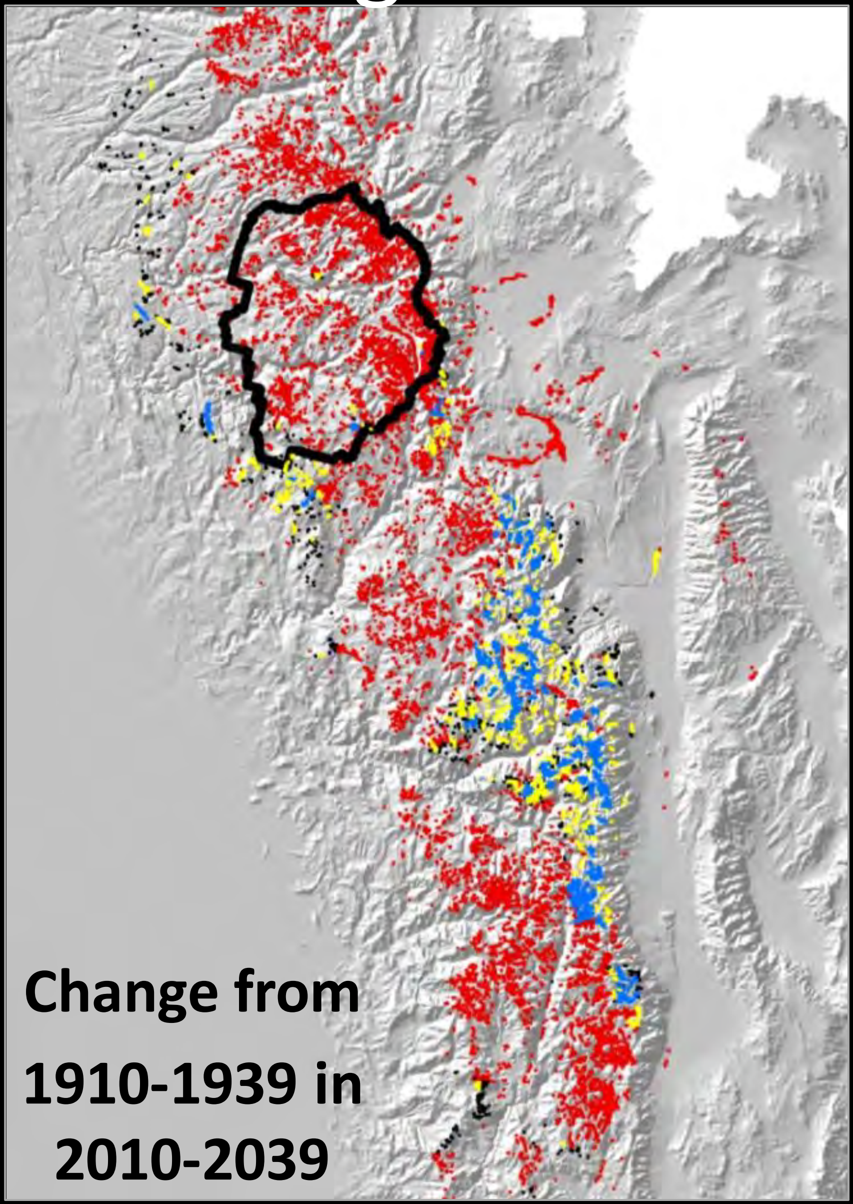

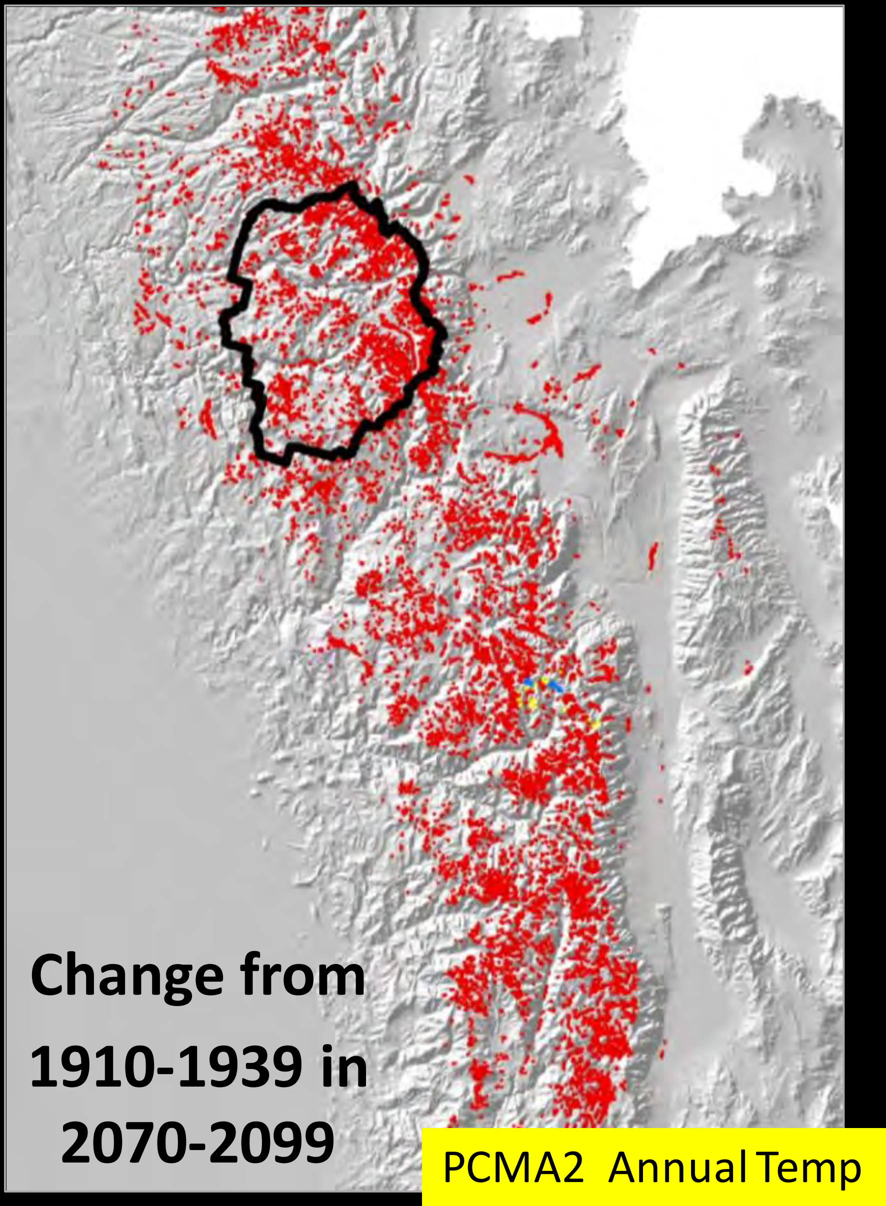

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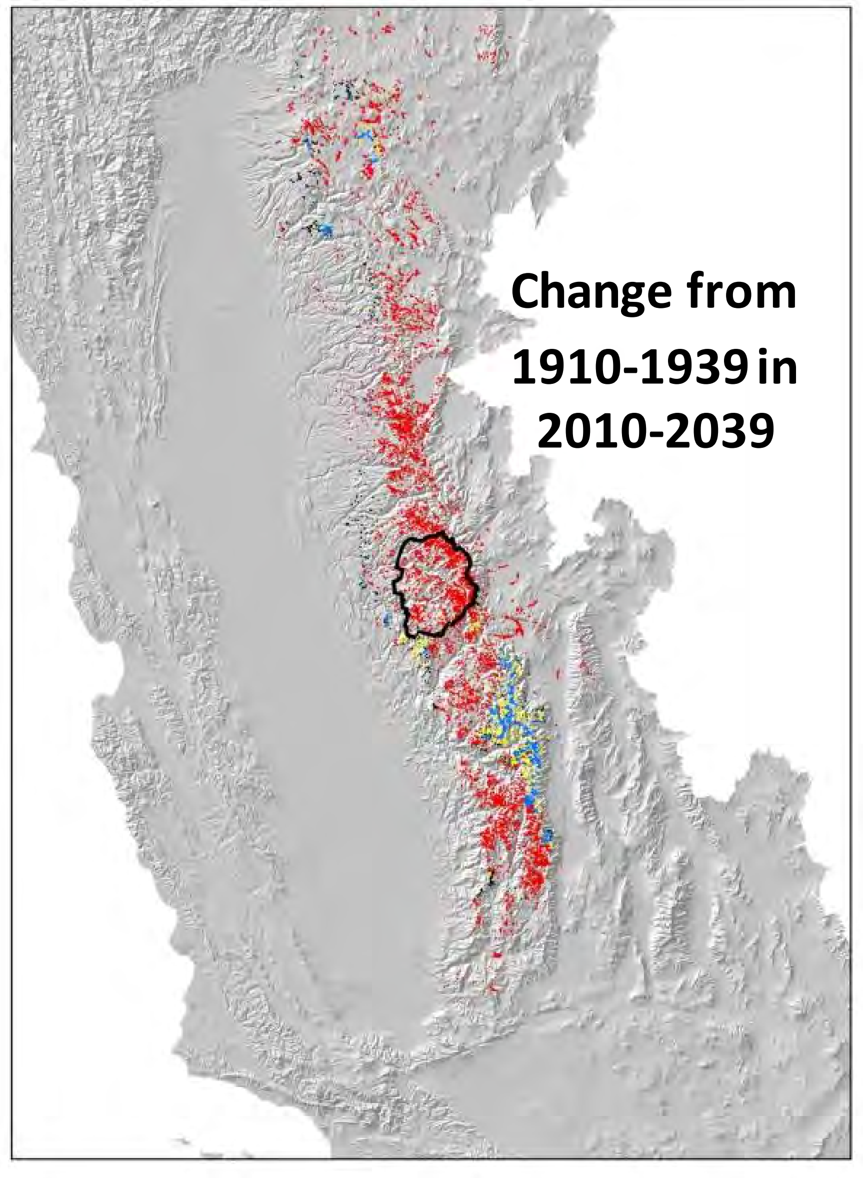
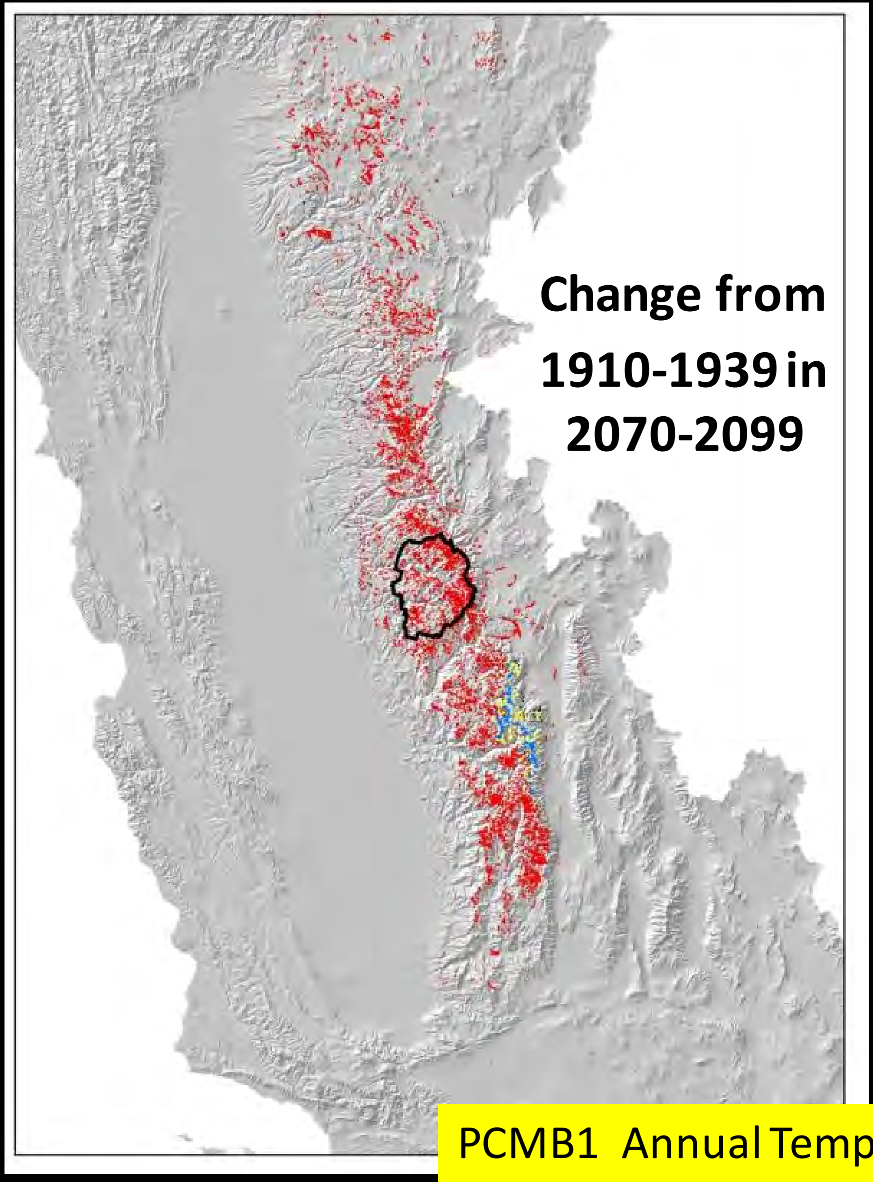
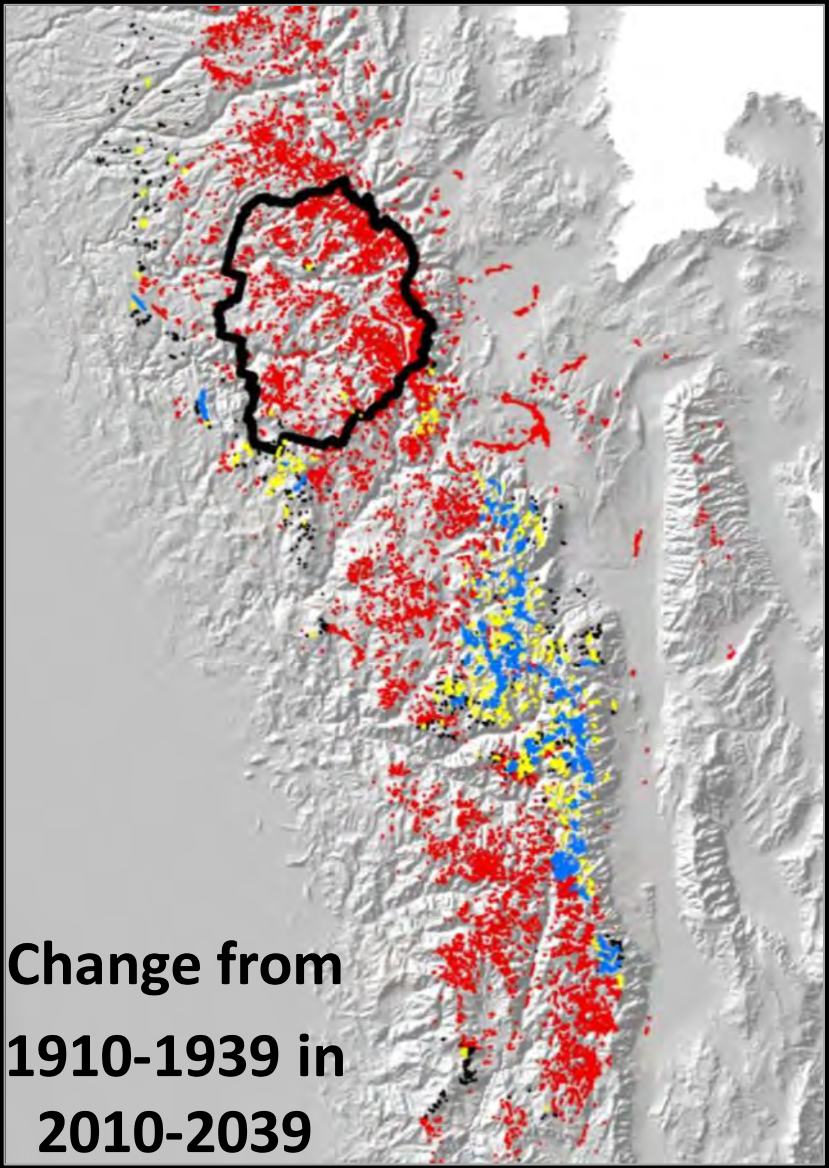
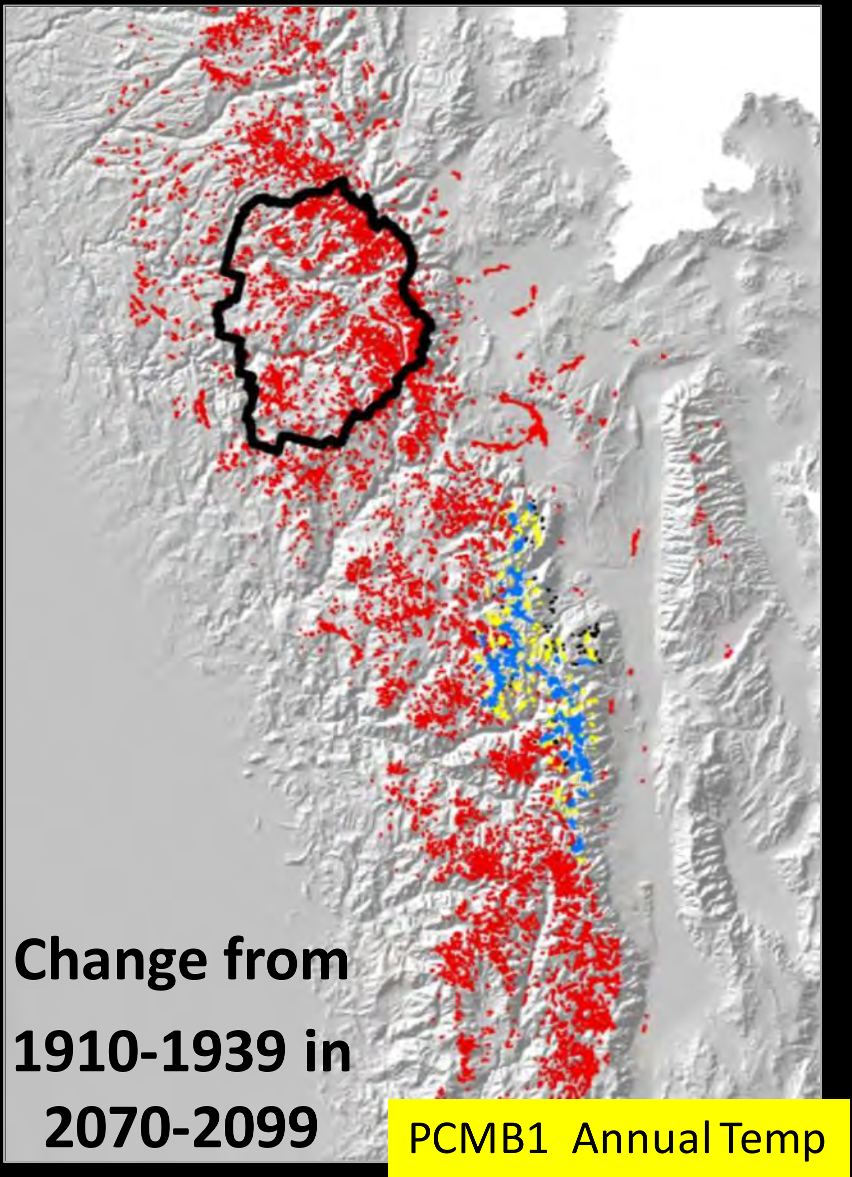




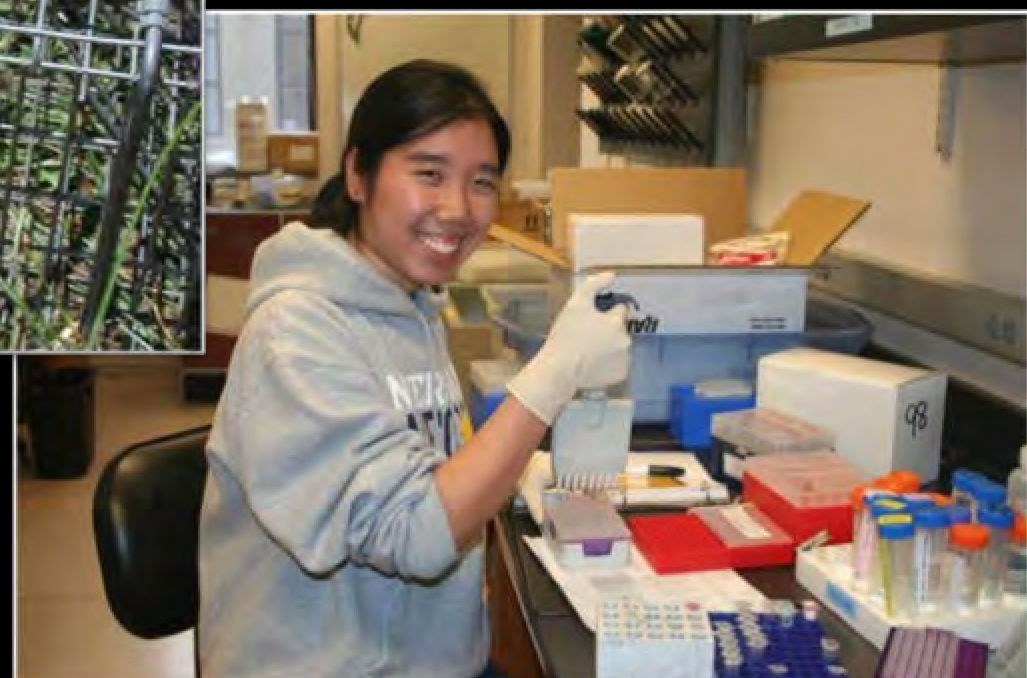
PCMB1 Annual Temp

So how do we expect climate to change in well-connected meadows?



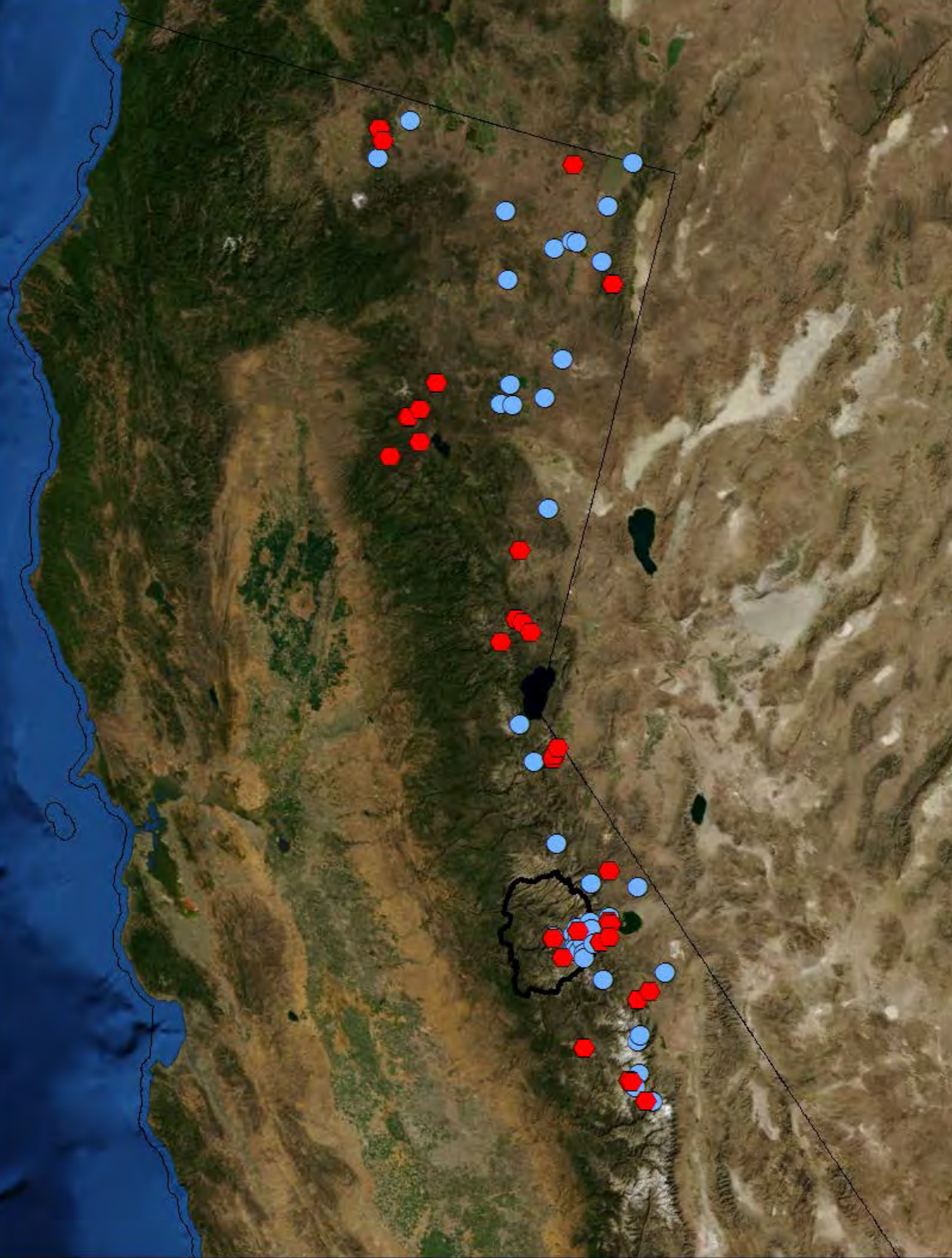


Testing the
Refugia and Connectivity Maps



Belding's Ground Squirrel (*Urocitellus beldingi*)

- Montane meadow specialist
- Highly detectable
- Group-living
- Habitat specialist



Site Extirpations (N=31)

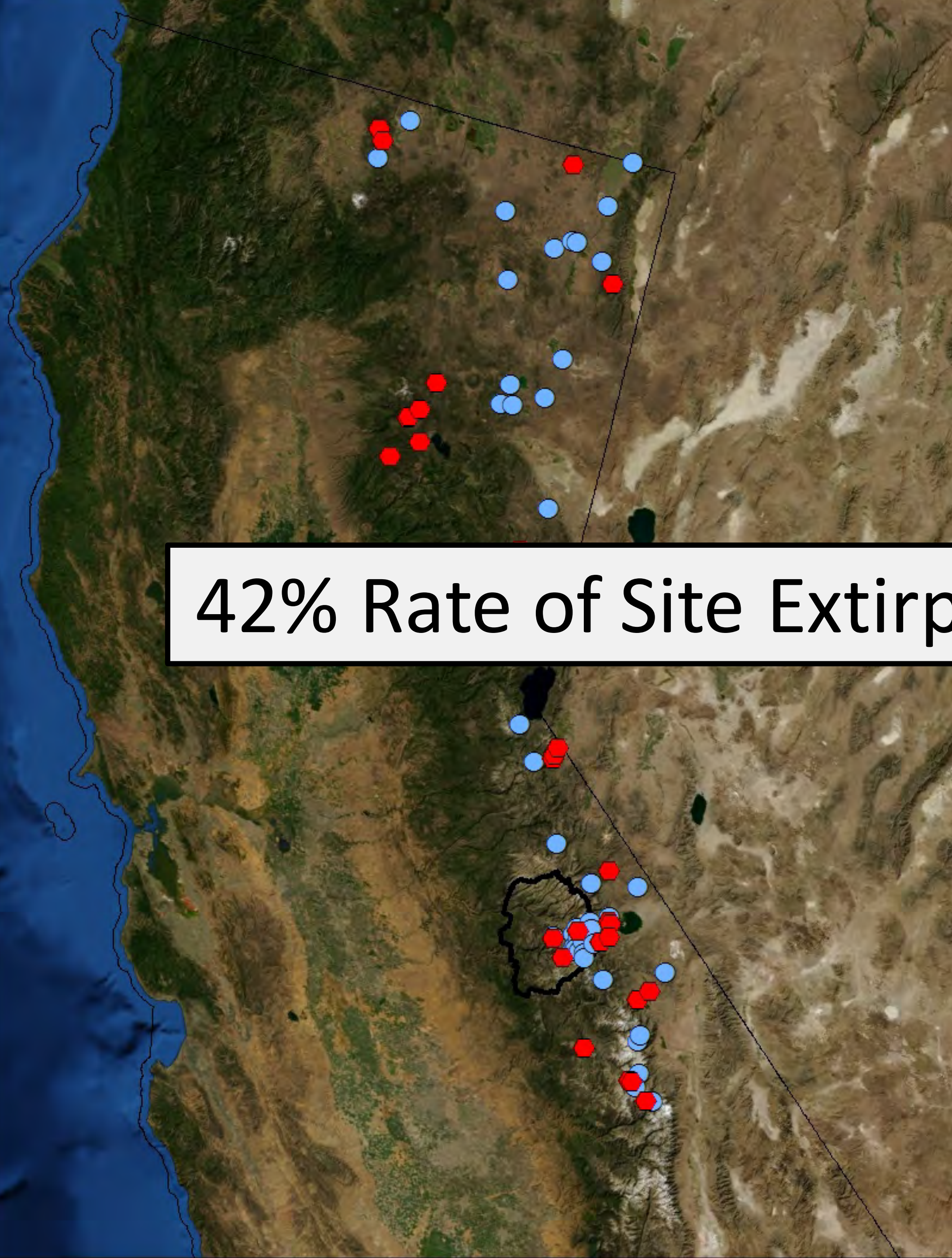
Site Persistence (N=43)

Original Surveys: 1902-1966

Resurveys: 2003-2011

Detectability (p) > 0.995 for 2+ visits

42% Rate of Site Extirpations Across CA

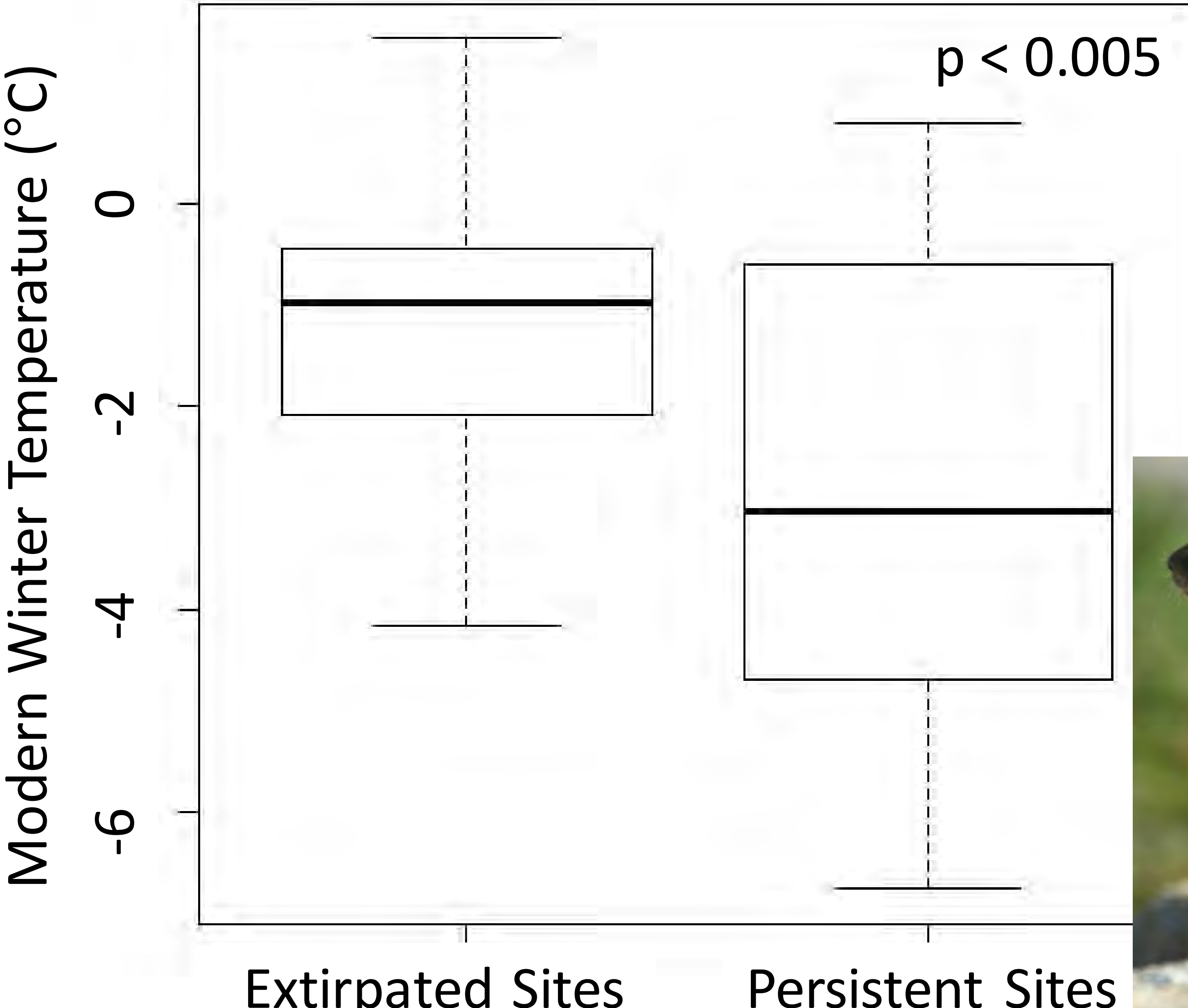


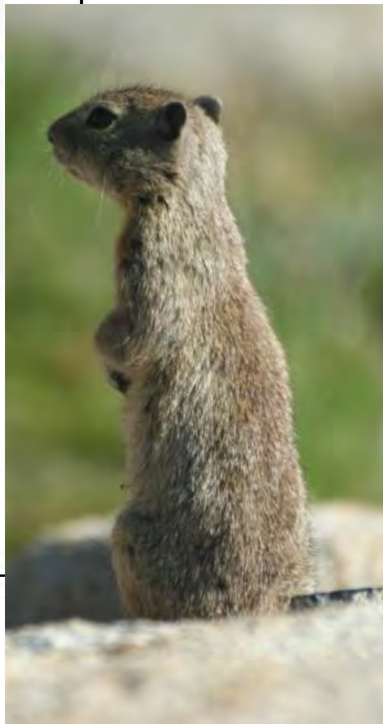
Site Extirpations (N=31)

Site Persistence (N=43)

Morelli *et al*. 2012 Proc. B

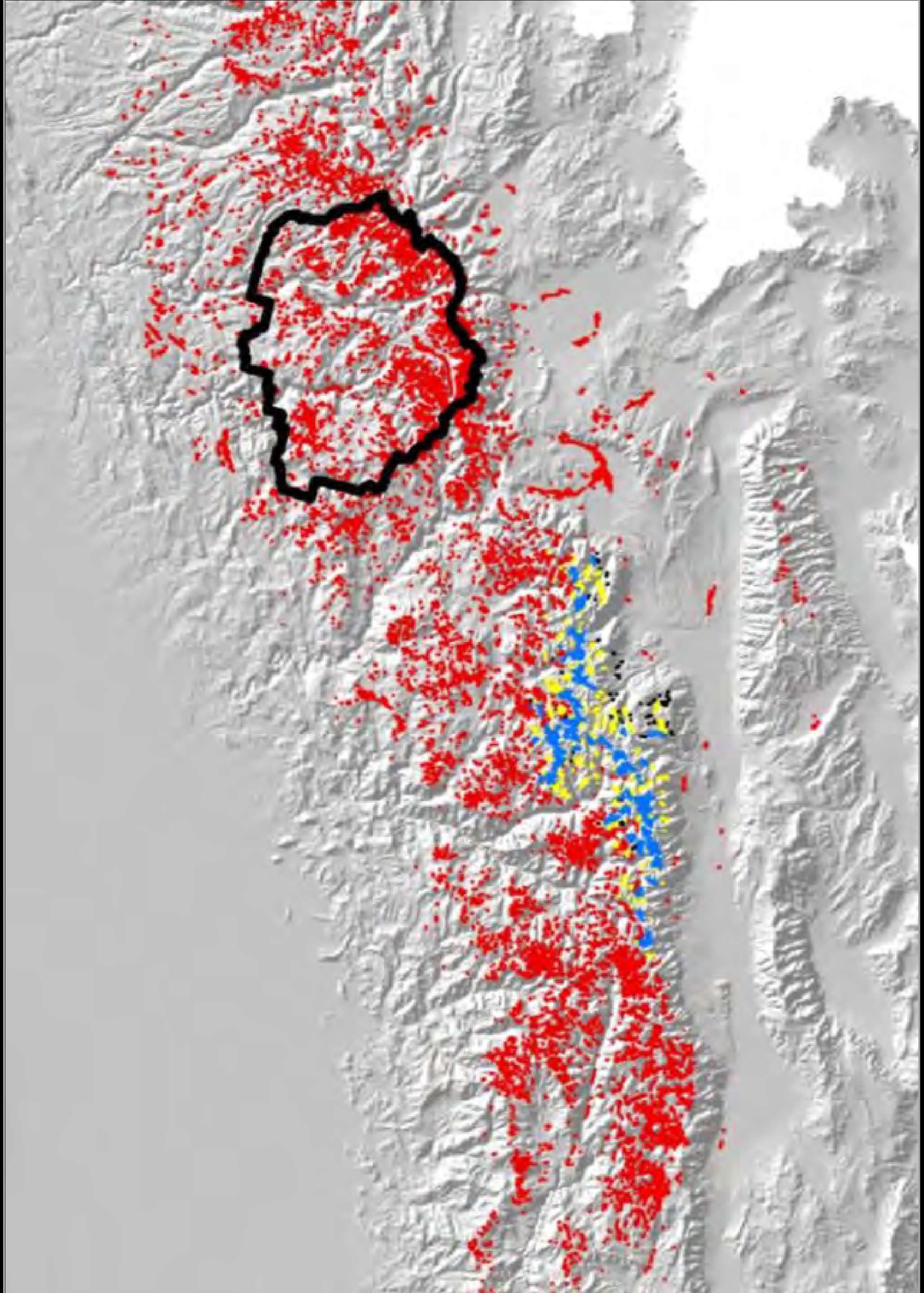
Site Extinction at Hotter Sites





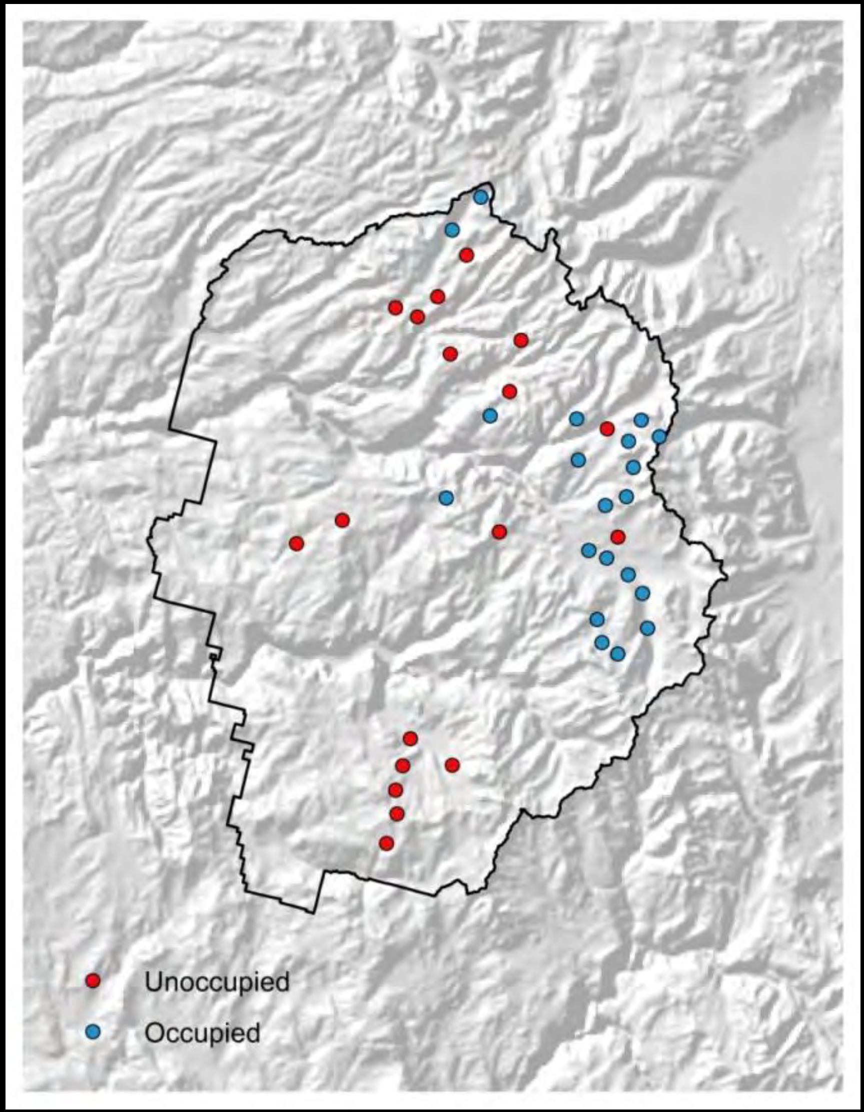
Anthropogenic Refugia?

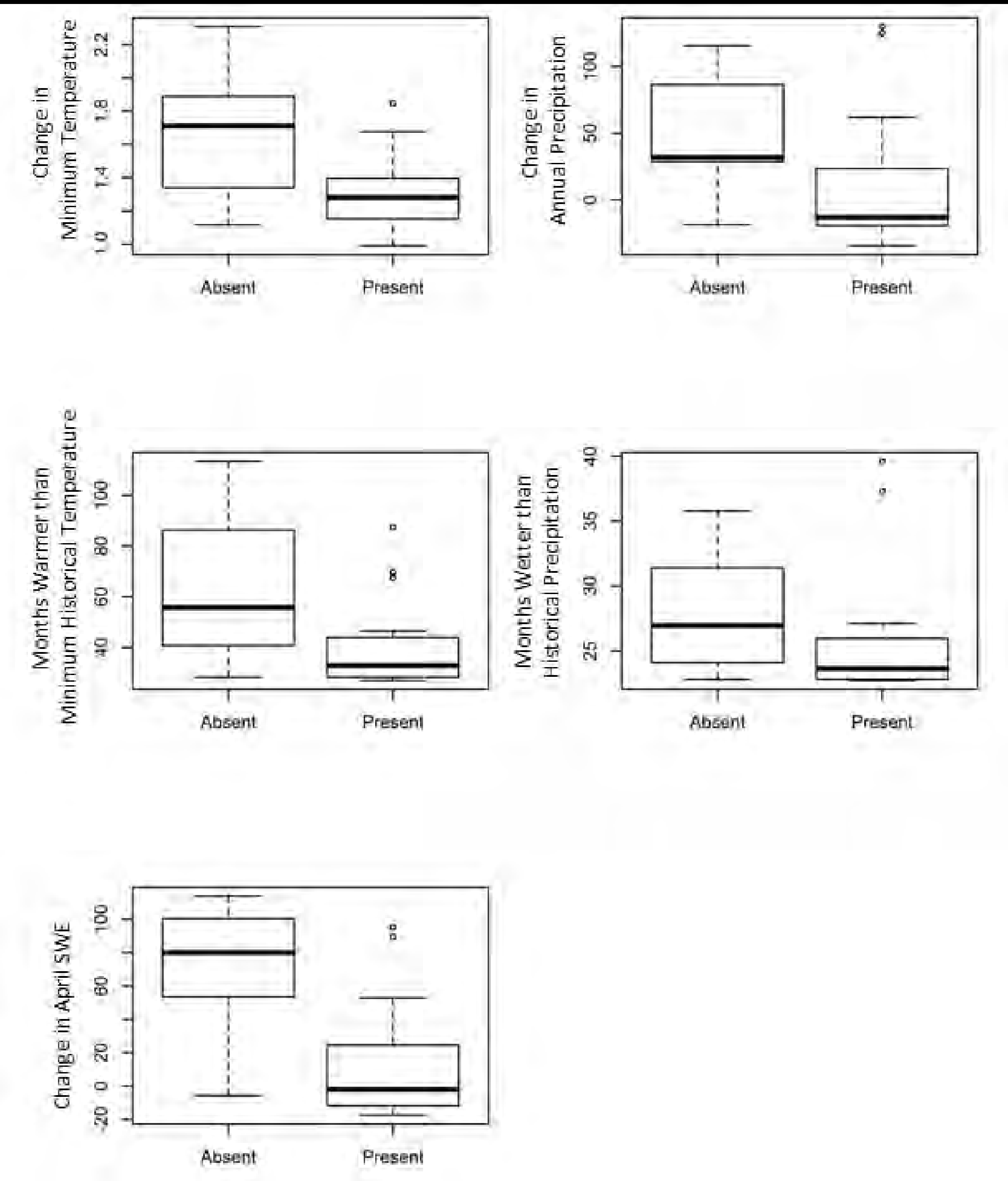
Morelli *et al.* 2012 Proc. B



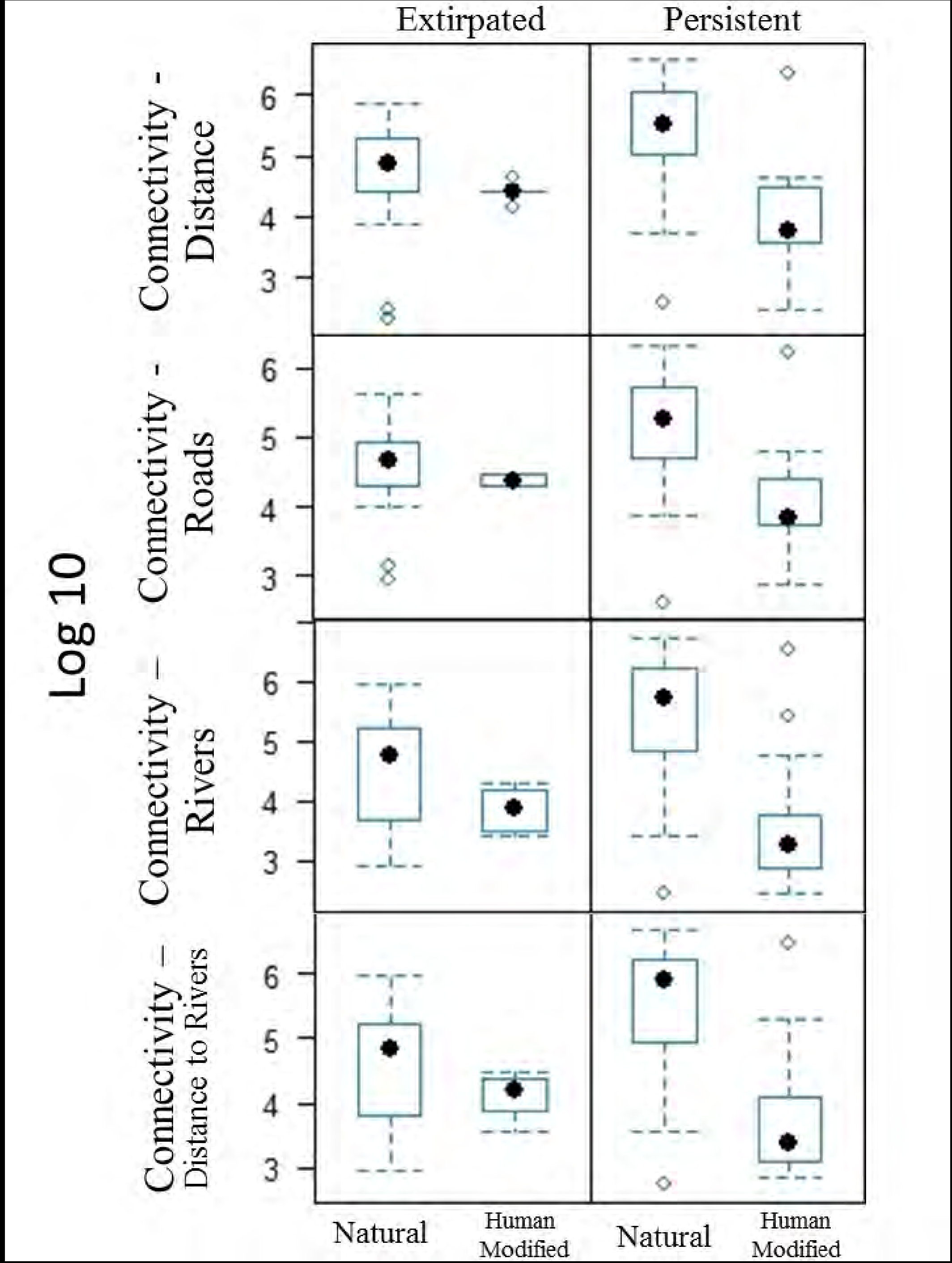
2011 Surveys for Belding's Ground Squirrel

- Independent data set
- 38 sites, distributed throughout YNP
- 20 occupied, 18 unoccupied





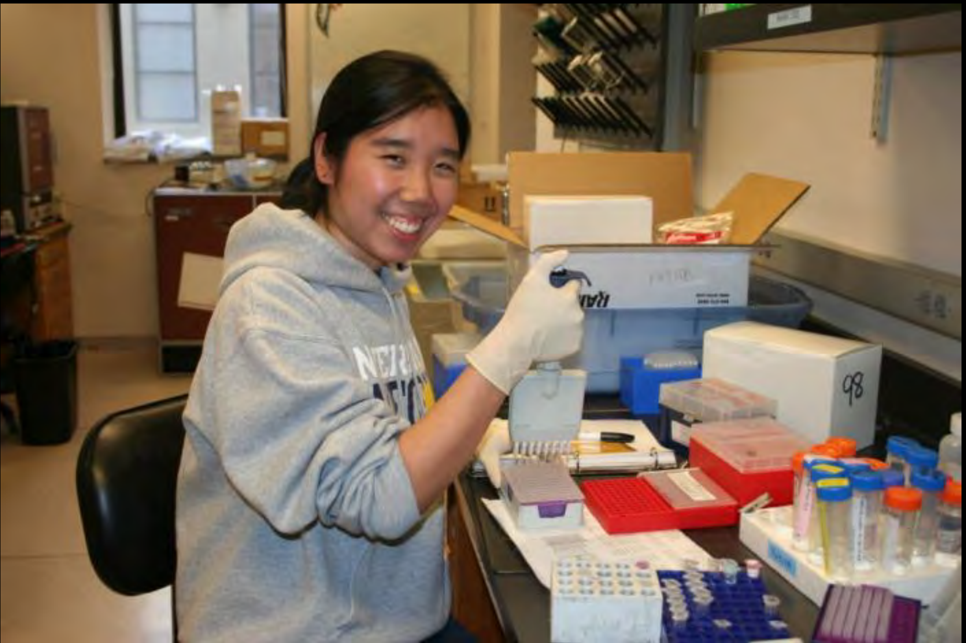
Change in
Minimum Temperature
1.0
1.4
1.8
2.2
Absent
Present
Change in
Annual Precipitation
0
50
100
Absent
Present
Months Warmer than
Minimum Historical Temperature
40
60
80
100
Absent
Present
Months Wetter than
Historical Precipitation
25
30
35
40
Absent
Present
Change in April SWE
-20
0
20
60
100
Absent
Present



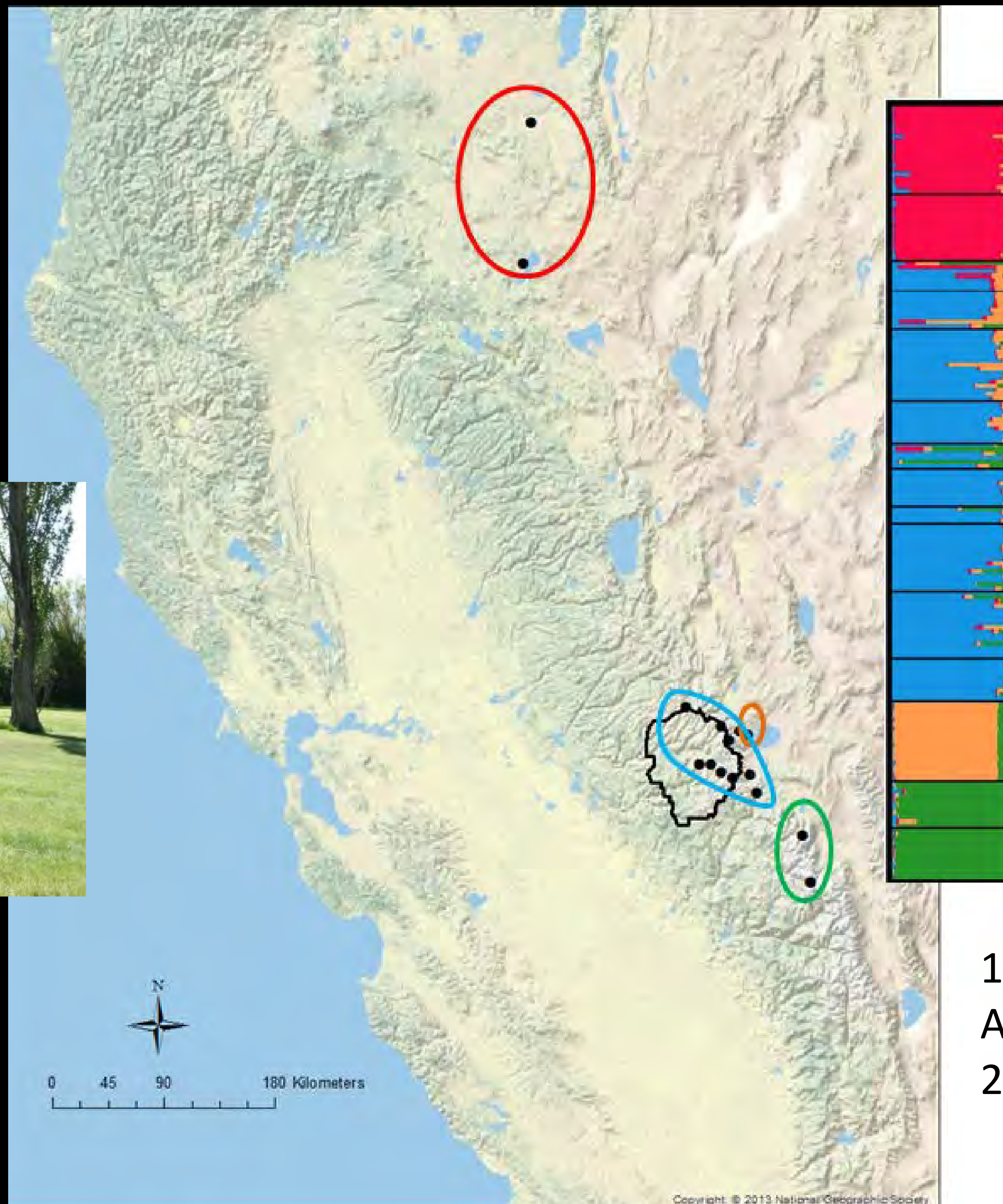
Extirpated
Persistent
Log 10
Connectivity - Distance
Connectivity - Roads
Connectivity – Rivers
Connectivity – Distance to Rivers
6
5
4
3
Natural
Human Modified
Natural
Human Modified

Genetic Analysis

- 187 tissue samples
- Qiagen extraction
- 12 nuclear microsatellite loci

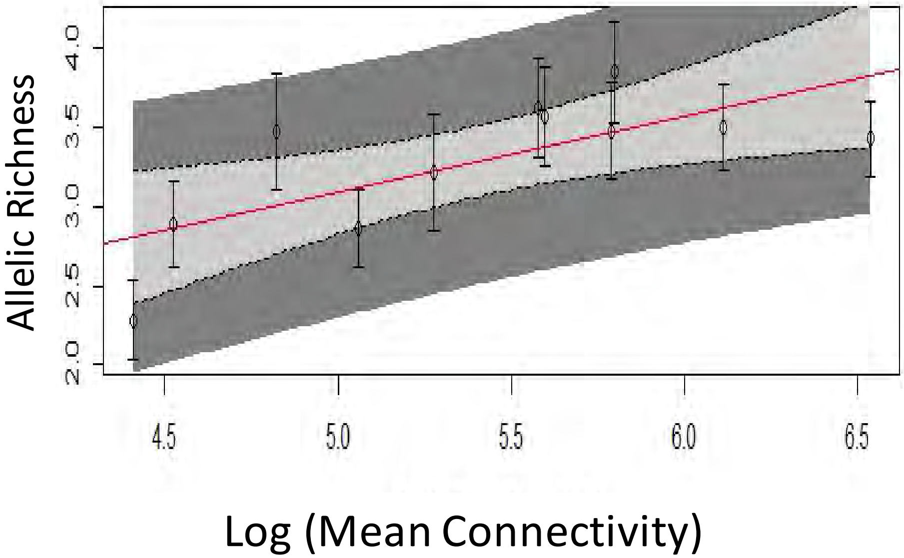


- Genepop
- FSTAT
- STRUCTURE
  - –Model-based clustering method
- BayesAss

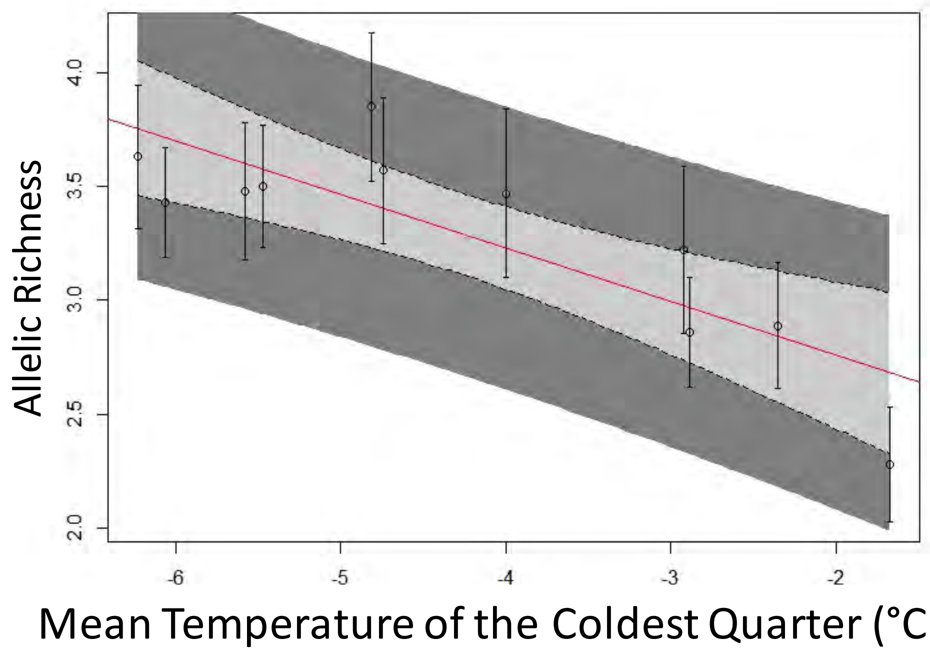

N
0 45 90 180 Kilometers
Copyright © 2013 National Geographic Society

18
At
20

Is allelic richness related to connectivity or climate?



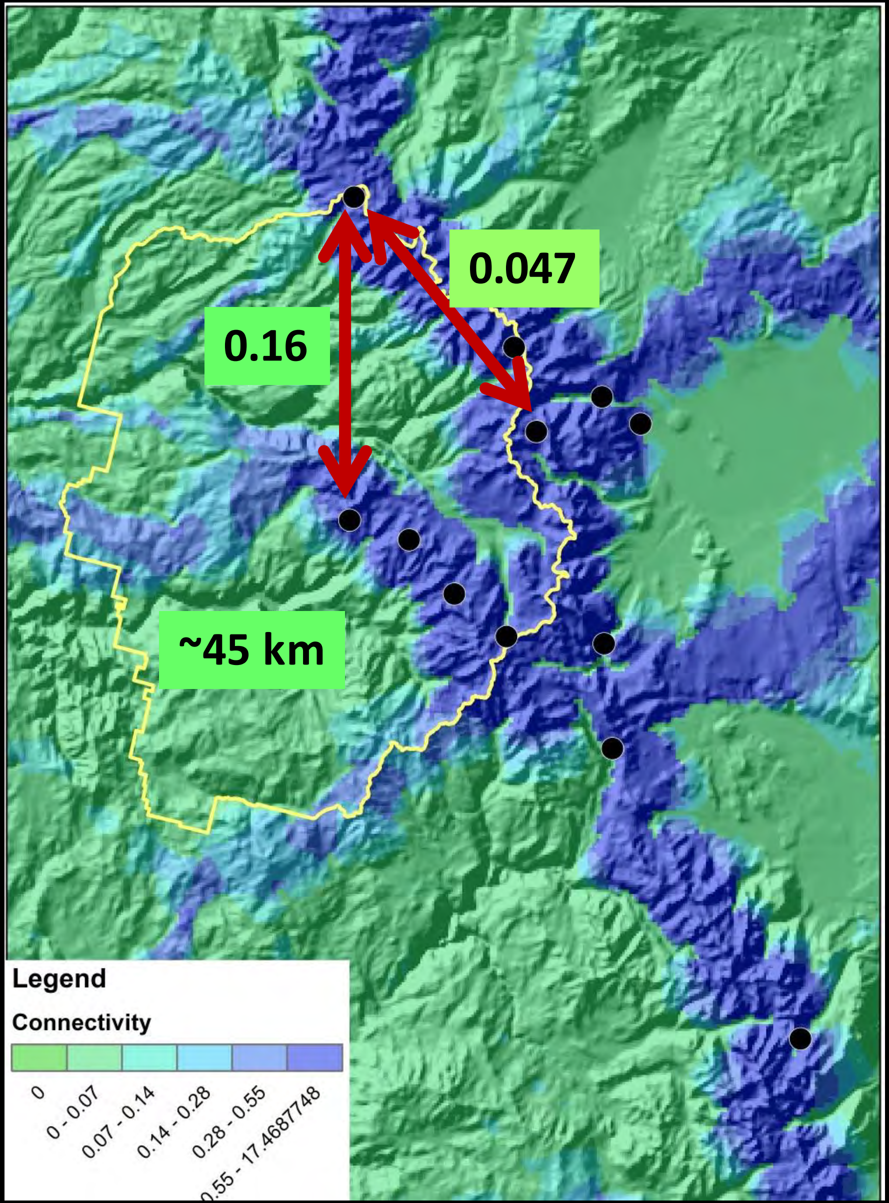
Positive relationship between AR and Connectivity – More alleles in well-connected meadows



Negative relationship between AR and Refugia – Fewer alleles in warmer meadows

Is genetic distance related to isolation?

- Permutations to examine patterns of Fst
- Support for dispersal limitation by watercourses



Conclusions and Implications

- Climate may be changing more rapidly than species can move or adapt
- Inclusion of connectivity within climate change research with empirical data is important
- Climate refugia concept supported
- Opportunities for California managers to focus limited resources on critical areas?

Funding & Data Sources

UC Davis
Information Center for the Environment (ICE)

Comments & Assistance

- Michelle Koo
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- Moritz Lab
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- BIGCB working group
- Biotic Responses to Climate Change in California working group

Thanks!