

Climate Change Vulnerability Assessment for Rare Plants



Brian Anacker, Krystal Leidholm,
Steve Schoenig, Melanie Gogol-Prokurat,



Biogeographic Data Branch
California Department of Fish and Game

Research Funding Provided
By The California LCC





Talk Outline

- Project Objectives
- Botanical Background
- CC Vulnerability Analyses
- Our Methodology
- Results
- Applicability Of Current Results for Planning, Management and Regulation
- Next Steps



Initial Project Objective

Why plants?

Birds – PRBO Conservation Science (Gardali et al. 2012)

Mammals - Conservation Biology Institute

Reptiles & Amphibians – UC Davis

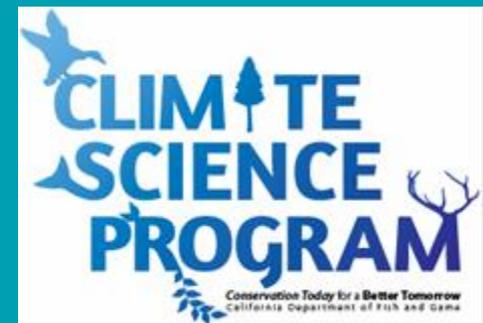
Fish – UC Davis

Ecoregional Summaries - PRBO Conservation Science (2011)

CA Department of Fish and Game Climate Science Program

dfg.ca.gov/Climate_and_Energy/Climate_Change

Dr. Amber Pairis
Whitney Albright



Initial Project Objective

Which rare plant species in California are most vulnerable to climate change?

OPEN ACCESS Freely available online 

Climate Change and the Future of California's Endemic Flora

Scott R. Loarie^{1*}, Benjamin E. Carter^{2,4,5}, Katharine Hayhoe³, Sean McMahon¹, Richard Moe⁴, Charles A. Knight², David D. Ackerly^{4,5}

¹Nicholas School of the Environment & Earth Sciences, Duke University, Durham, North Carolina, United States of America, ²Department of Biological Sciences, California Polytechnic State University San Luis Obispo, San Luis Obispo, California, United States of America, ³Department of Geosciences, Texas Tech University, Lubbock, Texas, United States of America, ⁴Jepson Herbarium, University of California Berkeley, Berkeley, California, United States of America, ⁵Department of Integrative Biology, University of California Berkeley, Berkeley, California, United States of America

Abstract

The flora of California, a global biodiversity hotspot, includes 2387 endemic plant taxa. With anticipated climate change, we project that up to 66% will experience >80% reductions in range size within a century. These results are comparable with other studies of fewer species or just samples of a region's endemics. Projected reductions depend on the magnitude of future emissions and on the ability of species to disperse from their current locations. California's varied terrain could cause species to move in very different directions, breaking up present-day floras. However, our projections also identify regions where species undergoing severe range reductions may persist. Protecting these potential future refugia and facilitating species dispersal will be essential to maintain biodiversity in the face of climate change.

Citation: Loarie SR, Carter BE, Hayhoe K, McMahon S, Moe R, et al. (2008) Climate Change and the Future of California's Endemic Flora. PLoS ONE 3(6): e2502. doi:10.1371/journal.pone.0002502

Editor: Craig R. McClain, Monterey Bay Aquarium Research Institute, United States of America

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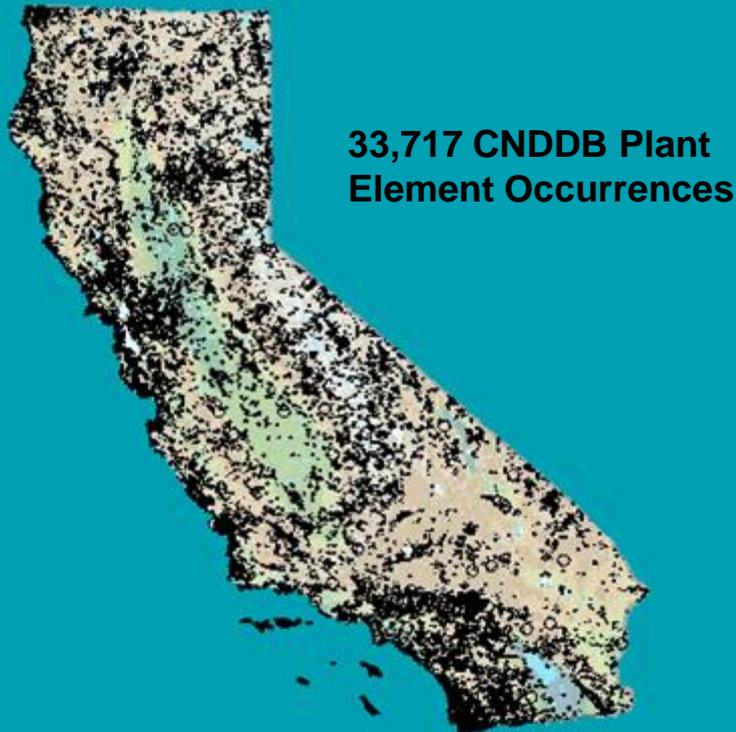
Copyright: © 2008 Loarie et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

“up to 66% will experience >80% reduction in range size within a century”



California Botanical Background

- 6502 Native Plants (minimum-rank taxa)
- 2291 Plants on the DFG Sensitive Plant List
- 1587 ranked S1 or S2



'Adaptive' Project Objectives

- 1) For a carefully chosen 10% sub-set of California rare plant taxa, which are most vulnerable to climate change? And, can these formal vulnerability scores derived from the NatureServe CCVI and spatial modeling be predicted from more easily obtained data.
- 2) How sensitive are the spatial modeling results to climate data inputs or modeling algorithms?
- 3) Are the current spatial modeling frameworks masking opportunities for local migration and survival utilizing local heterogeneity in topography



Selecting 10% of the Rare Flora

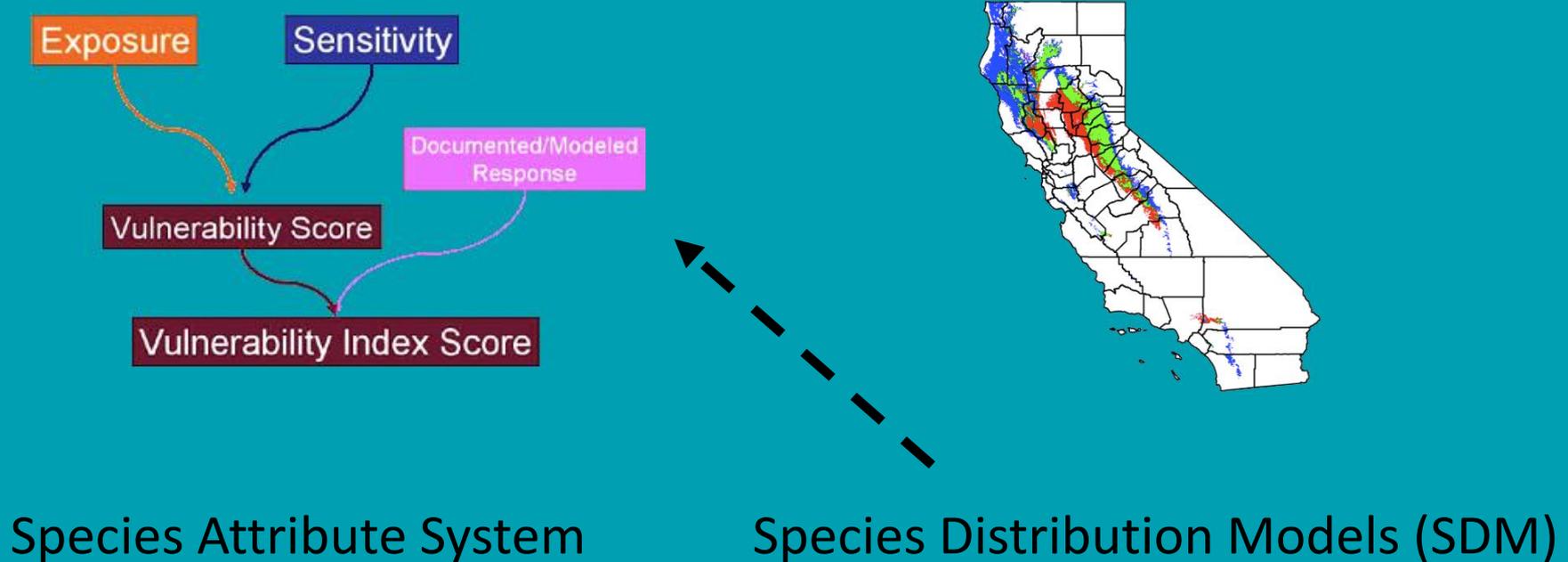
		Geographic Range			
		Large		Small	
	Somewhere Large	Common (not rare)	Locally abundant over a large range in a specific habitat type	Locally abundance in several habitats, but restricted geographically	Locally abundant in a specific habitat, but restricted geographically
Population Size					
	Everywhere Small	Constantly sparse over a large range and in several habitats	Constantly sparse in a specific habitat, but over a large range	Constantly sparse and geographically restricted in several habitats	Constantly sparse and geographically restricted in a specific habitat
		Broad	Restricted	Broad	Restricted

7 types of rarity (Rabinowitz 1981)

- CA Rare Plant Rank
- Intrinsically rare vs. anthropogenically rare
- Ecoregion
- Perennial vs. annual
- Botanical family

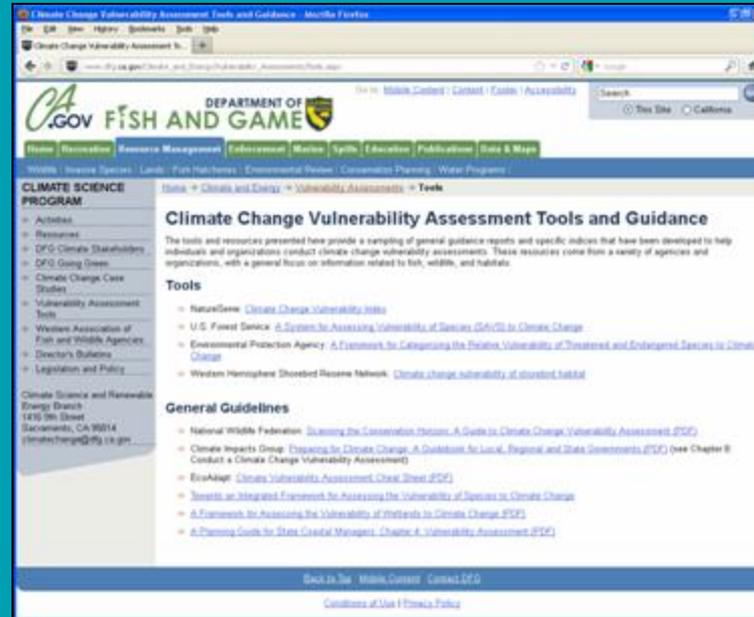
Stratification

Assessing Vulnerability



NatureServe CCVI

Why NatureServe Climate Change Vulnerability Index?

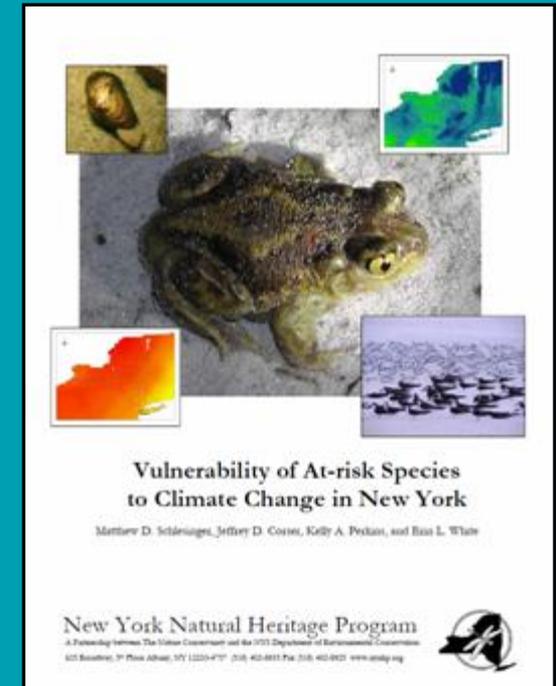
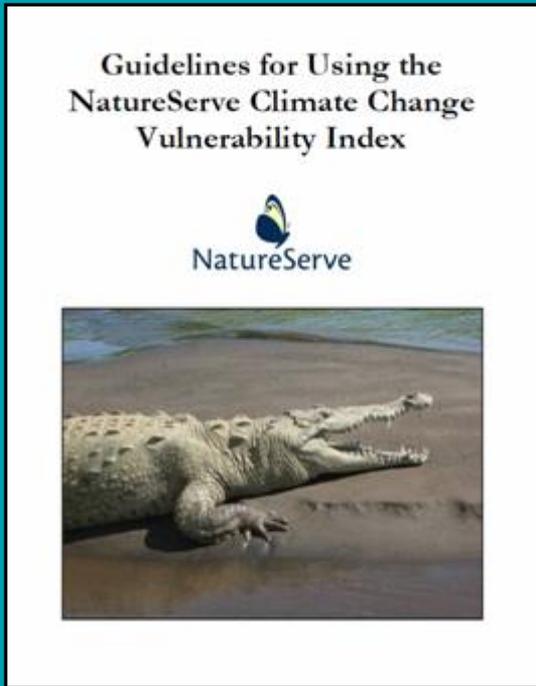


- DFG is part of the NatureServe-coordinated natural heritage system.
- Good to test out different methodologies (if crosswalkable).
- Transparent, fact based, easily revised.



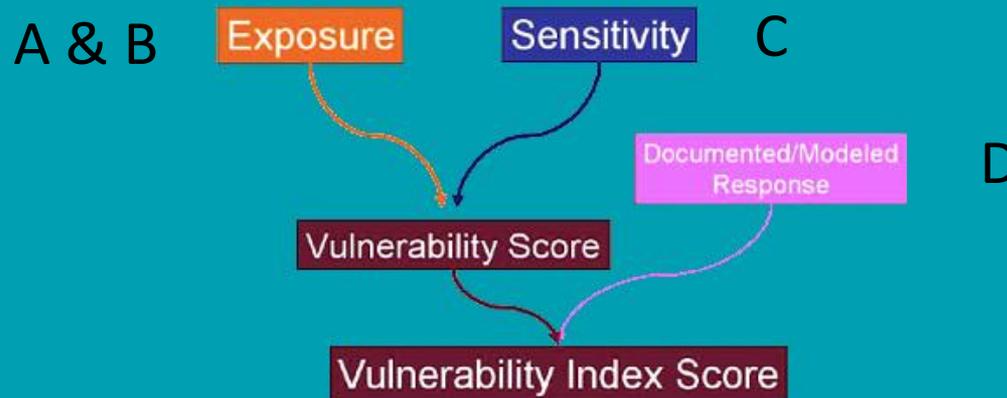
NatureServe CCVI

www.natureserve.org



Young, B. E., K. R. Hall, E. Byers, K. Gravuer, G. Hammerson, A. Redder, and K. Szabo. 2012. **Rapid assessment of plant and animal vulnerability to climate change.** In *Conserving wildlife populations in a changing climate*, edited by J. Brodie, E. Post, and D. Doak. University of Chicago Press, Chicago, Illinois.

NatureServe CCVI



A) Direct climate exposure: Temperature, moisture (TNC Climate Wizard)

B) Indirect exposure: Sea level rise, dispersal barriers, land changes

C) Sensitivity (ecology): Dispersal, climate niche, soil endemism, interactions, etc...

D) Modeled response: Range size change, range overlap

NatureServe CCVI

Sensitivity variables

- Dispersal capability
- Past climate regime and reliance on specific thermal and hydrological conditions
- Dependence on disturbance
- Dependence on snow or ice cover
- Restriction to certain geological types
- Reliance on interspecific interactions (e.g. herbivory and pollination relationships)
- Genetic variation
- Climate-related changes in phenology



NatureServe CCVI

Microsoft Excel - CCVI_release_2.01.xls

The NatureServe Climate Change Vulnerability Index

Release 2.01 10 May 2010; Bruce Young, Elizabeth Byers, Kelly Gravuer, Kim Hall, Geoff Hammerson, Alan Redder
 With input from: Jay Cordeiro, Kristin Szabo
 Funding for Release 2.0 generously provided by the Duke Energy Corporation.

NatureServe

* = Required field

Geographic Area Assessed:

Assessor:

Species Scientific Name: English Name:

Major Taxonomic Group: G-Rank:

Relation of Species' Range to Assessment Area: S-Rank:

Check if species is an obligate of caves or groundwater aquatic systems: (Must be marked with an "X" for accurate scoring of these species)

Assessment Notes (to document special methods and data sources)

Section A: Exposure to Local Climate Change (Calculate for species' range within assessment area)

Temperature *		Hamon AET:PET Moisture Metric *	
Severity	Scope (percent of range)	Severity	Scope (percent of range)
>5.5° F (3.1° C) warmer	<input type="text"/>	< -0.119	<input type="text"/>
5.1-5.5° F (2.8-3.1° C) warmer	<input type="text"/>	-0.097 - -0.119	<input type="text"/>
4.5-5.0° F (2.5-2.7° C) warmer	<input type="text"/>	-0.074 - -0.096	<input type="text"/>
3.9-4.4° F (2.2-2.4° C) warmer	<input type="text"/>	-0.051 - -0.073	<input type="text"/>
< 3.9° F (2.2° C) warmer	<input type="text"/>	-0.028 - -0.050	<input type="text"/>
Total: <input type="text"/> (Must sum to 100)		Total: <input type="text"/> (Must sum to 100)	

Section B: Indirect Exposure to Climate Change (Evaluate for specific geographical area under consideration)

Mark an "X" in all boxes that apply.

Effect on Vulnerability						
Greatly increase	Increase	Somewhat increase	Neutral	Somewhat decrease	Decrease	Unknown
<input type="checkbox"/>	<input checked="" type="checkbox"/>					
<input type="checkbox"/>	<input checked="" type="checkbox"/>					
<input type="checkbox"/>	<input checked="" type="checkbox"/>					

Factors that influence vulnerability (* at least three required)

- Exposure to sea level rise
- Distribution relative to barriers
 - Natural barriers
 - Anthropogenic barriers
- Predicted impact of land use changes resulting from human responses to climate change

NatureServe CCVI

Microsoft Excel - CCVI_release_2.1.xlsm

File Edit View Insert Format Tools Data Window Help Adobe PDF

1 The NatureServe Climate Change Vulnerability Index release 2.1

2 Definitions and Guidelines for Scoring Risk Factors - Section C

3 Response required for at least 10 factors.

4

5

6 C. Sensitivity, or Species-Specific Factors

7 Notes: These factors relate to characteristics of the species only. Anthropogenic effects, such as on the availability of dispersal corridors, should NOT be considered in this section.

8

9 1) Dispersal and Movements

10 NOTES: This factor pertains to known or predicted dispersal or movement capacities and characteristics and ability to shift location in the absence of barriers as conditions change over time as a result of climate change. Species in which individuals exhibit substantial dispersal, readily move long distances as adults or juveniles, or exhibit flexible movement patterns should be better able to track shifting climate envelopes than are species in which dispersal and movements are more limited or inflexible. This factor is assessed conservatively and pertains specifically to dispersal through unsuitable habitat, which, in most cases, is habitat through which propagules or individuals may move but that does not support reproduction or long-term survival. If all habitat is regarded as suitable (i.e., species can reproduce and persist in every habitat in which it occurs), then dispersal ability is assessed for suitable habitat. If appropriate, scoring of species whose dispersal capacity is not known can be based on characteristics of closely related species (or species of similar body size in the same major group), which are here defined as features or areas that completely or almost completely block dispersal, are treated in Factor B2. If a species requires other species for propagule dispersal, please also complete factor C4d. The following categorization for plants is loosely based on Vitousek, P., and R. Engler, 2007. Seed dispersal distances: a typology based on dispersal modes and plant traits. *Botanica Helvetica* 117: 109-124.

11 A small number of species are confined by barriers to areas that are smaller than the species' potential dispersal distance (fishes in small isolated springs are a classic example). Most if not all of the fish species that occur in the smallest such habitat patches could disperse farther than the greatest extent of the occupied patch if a larger extent of habitat were available to them. For the purposes of this factor, the dispersal ability of these species is scored as if the species occurred in a large patch of habitat (longer than the dispersal distance), based on dispersal or movement patterns or capabilities of closely related species (or species of similar body size in the same major group).

12 Most migratory species will satisfy criteria for the decrease vulnerability criteria. Use their ability to shift their distribution within the assessment during the period of occupation or from one year to the next (whichever is larger) as the measure of dispersal distance.

13 Species in which propagule dispersal is both synchronous among all members of the population in the assessment area and infrequent (average of several years between successful reproduction events) should be scored as one category more vulnerable than the category that would otherwise apply. An example is the monocarpic giant cane (*Arundinaria gigantea*), a bamboo species that reproduces synchronously every 25-50 years and then dies.

14 Greatly Increase Vulnerability: Species is characterized by severely restricted dispersal or movement capability. This category includes species represented by sessile organisms that almost never disperse more than a few meters per dispersal event. Examples include: plants with large or heavy propagules for which the disperser is extinct or so rare as to be ineffective; species with dispersal limited to vegetative shoots, buds, or similar structures that do not survive (at least initially) if detached from the parent.

15 Increase Vulnerability: Species is characterized by highly restricted dispersal or movement capability. This category includes species that rarely disperse through unsuitable habitat more than about 10 meters per dispersal event, and species in which dispersal beyond a very limited distance (or outside a small isolated patch of suitable habitat) periodically or irregularly occurs but is dependent on highly fortuitous or rare events. Examples include: plants dispersed ballistically; branchiopods whose resting stages sometimes are transported in mud attached to duck or deer feet or legs; small clams that may disperse while clamped onto bird feathers or frog toes; plant or animal species with free-living propagules or individuals that may be carried more than 10 meters by a tornado or unusually strong hurricane or large flood but that otherwise rarely disperse more than 10 meters; plants that do not fit criteria for Greatly Increase but lack obvious dispersal adaptations (i.e., propagules lack any known method for moving more than 10 meters away from the source plant).

16 Somewhat Increase Vulnerability: Species is characterized by limited but not severely or highly restricted dispersal or movement capability. A significant percentage (at least approximately 5%) of propagules or individuals disperse approximately 10-100 meters per dispersal event (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include some small, nonvolar animals of relatively low vagility (including small, slow-moving animals such as slugs, snails, and the smallest terrestrial salamanders that regularly (albeit perhaps infrequently) move more than 10 meters when conditions are favorable; species that exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are up to 100 meters (rarely farther) apart; many ant-dispersed plant species; plants whose propagules are dispersed primarily by small animals (e.g., some rodents) that typically move propagules approximately 10-100 meters from the source (propagules may be cached or transported incidentally on fur or feathers); plants dispersed by wind with low vagility (e.g., species with inefficiently plumed seeds or fruits that occur predominantly in forests).

17 Neutral: Species is characterized by moderate dispersal or movement capability. A significant percentage (at least approximately 5%) of propagules or individuals disperse approximately 100-1,000 meters per dispersal event (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: many small but somewhat vagile animals (e.g., many small mammals and lizards); species whose individuals exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are 100-1,000 meters (rarely farther) apart; many plant species dispersed by wind with high efficiency (e.g., species with efficiently plumed seeds or very small propagules that occur predominantly in open areas); plant and animal species whose propagules or individuals are dispersed by small animals (e.g., rodents, grouse) that regularly (but perhaps infrequently) move propagules approximately 100-1,000 meters from the source; many denning snakes and some pond-breeding amphibians that are otherwise terrestrial as adults) (note that these short-distance migratory animals may exhibit strong fidelity to natal areas but nevertheless generally disperse 1-10 kilometers from natal or source areas (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: many medium-sized mammals (e.g., certain rabbit species) that commonly disperse up to several kilometers; plant species regularly dispersed up to 10 km (rarely farther) by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated by birds); species whose individuals are dispersed by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated by birds).

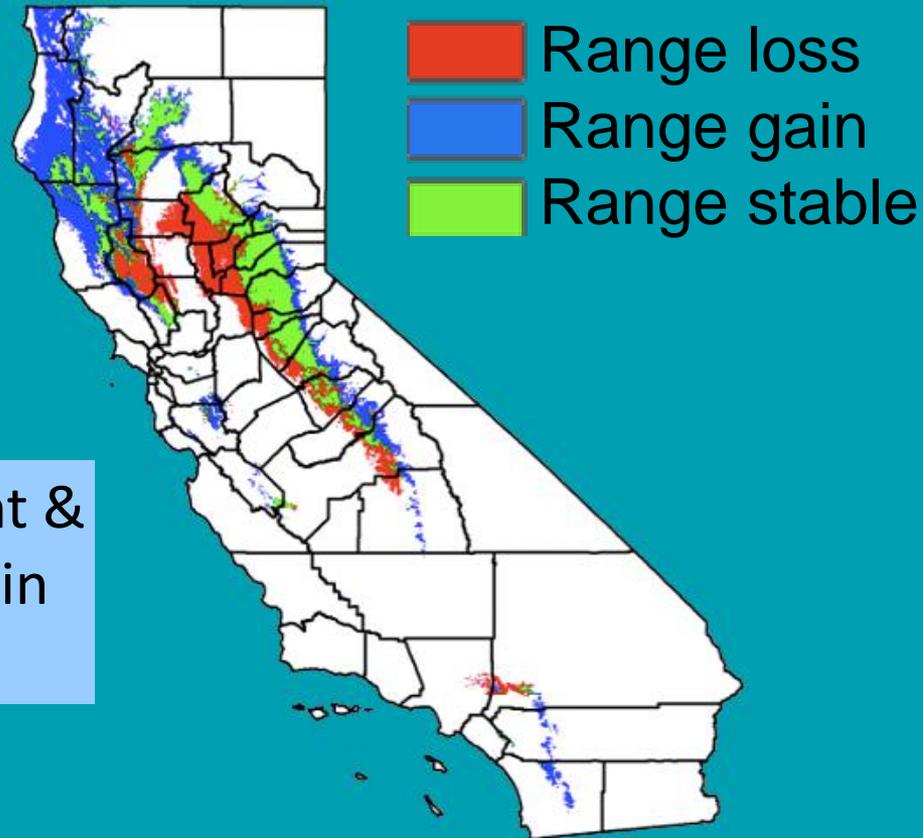
18 Somewhat Decrease Vulnerability: Species is characterized by good dispersal or movement capability. Species has propagules or dispersing individuals that readily move 1-10 kilometers from natal or source areas (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: many medium-sized mammals (e.g., certain rabbit species) that commonly disperse up to several kilometers; plant species regularly dispersed up to 10 km (rarely farther) by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated by birds); species whose individuals are dispersed by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated by birds).

Calculator Results Table

Draw AutoShapes

Ready NUM

Modeled Range Change Predictions



Used Both MaxEnt &
RandomForests in
R script

“Prediction is very difficult, especially if it's about the future.”
-Niels Bohr (physicist)

High Variability in Modeled Range Change Predictions

20+ models per species

4 climate variables (bioclim 1, 4, 12, 15)

13 GCM*ES

soil type

soil properties

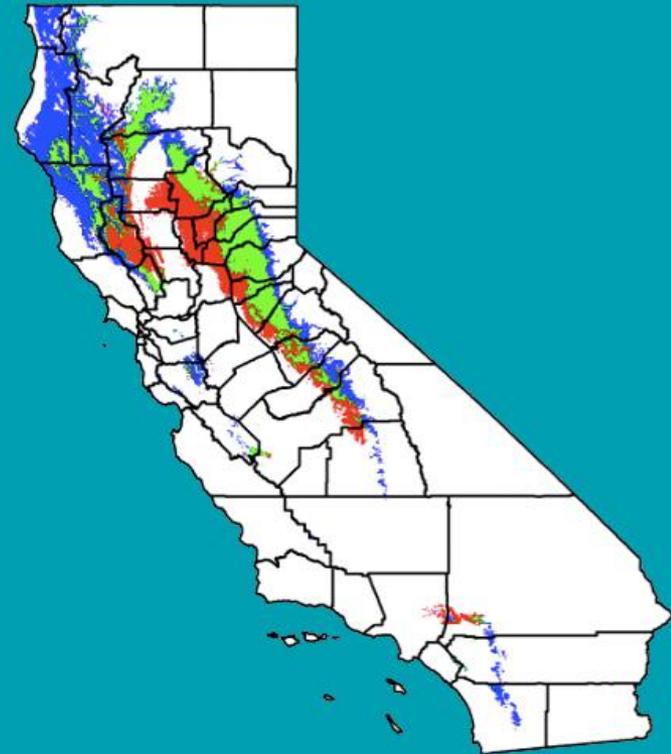
random forest

boosted regression tree

19 climate variables (bioclim 1 - 19)

soil type

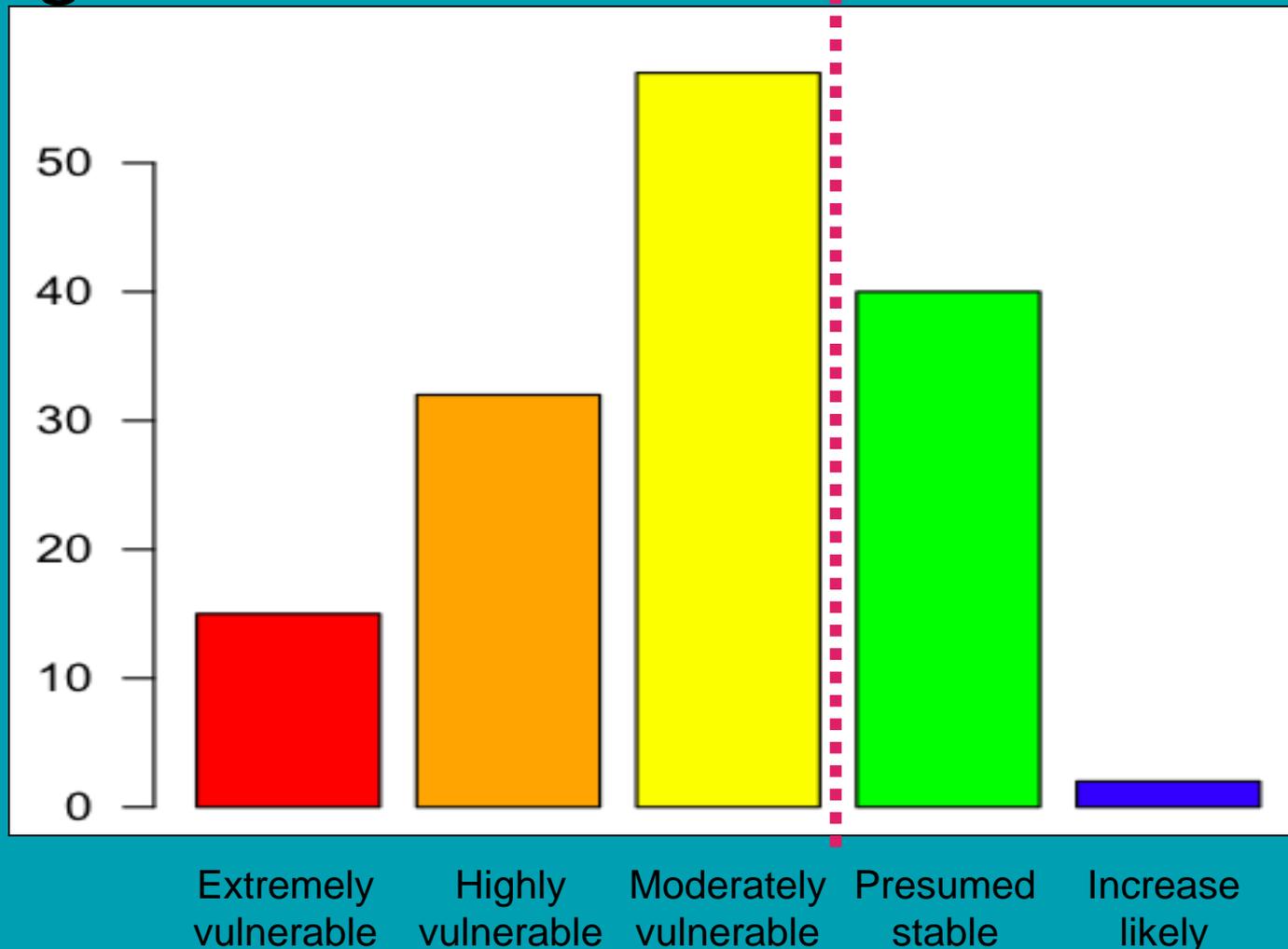
soil properties



Three Major Results

1. 99 of the 156 plants are classified as ‘vulnerable’ to climate change
2. Range change predictions show mean trends, but are extremely variable and uncertain.
3. Not accounting for local topographic complexity may be overstating vulnerability predictions from spatial modeling

99 of 156 are 'Vulnerable' to Climate Change

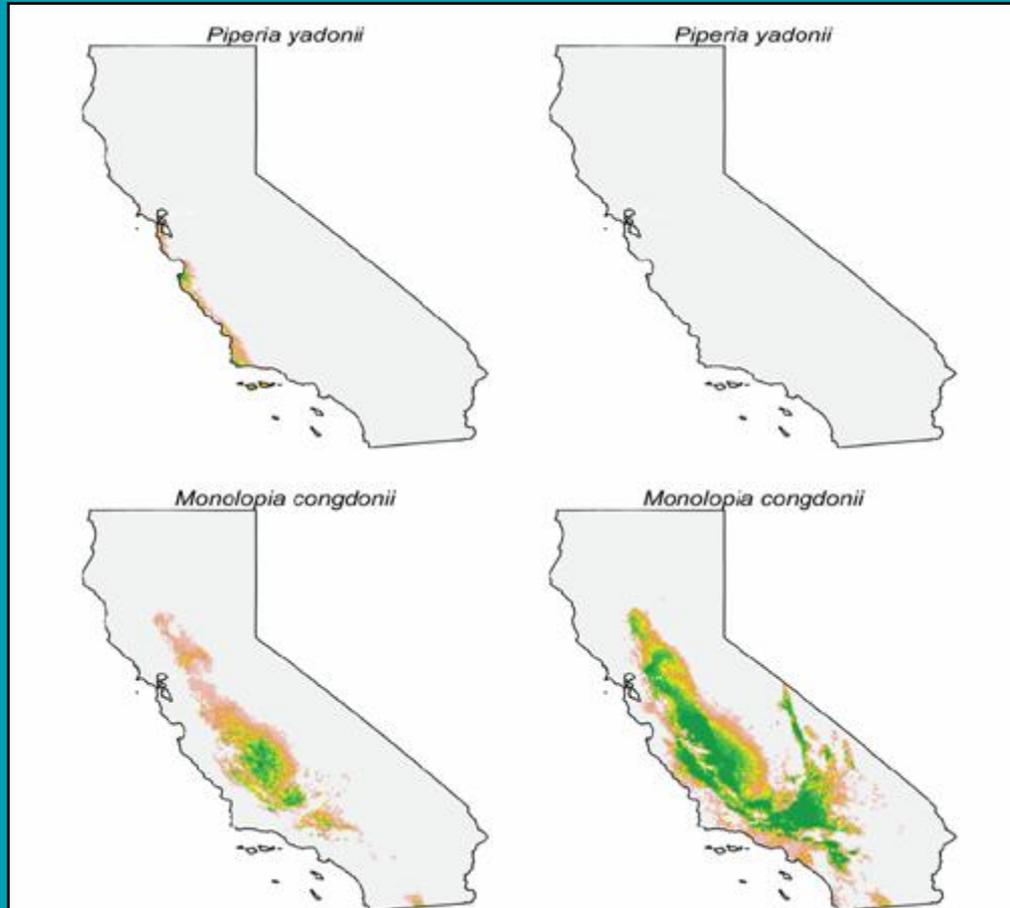


99 of 156 are 'Vulnerable' to Climate Change

Species	CCVI	CCVI (without D)
Top 5 based on CCVI		
1 <i>Piperia yadonii</i>	EV	HV
2 <i>Mimulus purpureus</i>	EV	HV
3 <i>Calliandra eriophylla</i>	HV	MV
4 <i>Limosella subulata</i>	HV	HV
5 <i>Taraxacum californicum</i>	HV	MV
Top 5 based on CCVI (without D)		
1 <i>Monolopia congdonii</i>	MV	EV
2 <i>Orcuttia viscida</i>	HV	EV
3 <i>Pogogyne abramsii</i>	MV	EV
4 <i>Symphyotrichum lentum</i>	HV	EV
5 <i>Mimulus purpureus</i>	EV	HV



99 of 156 are 'Vulnerable' to Climate Change



Current Predicted

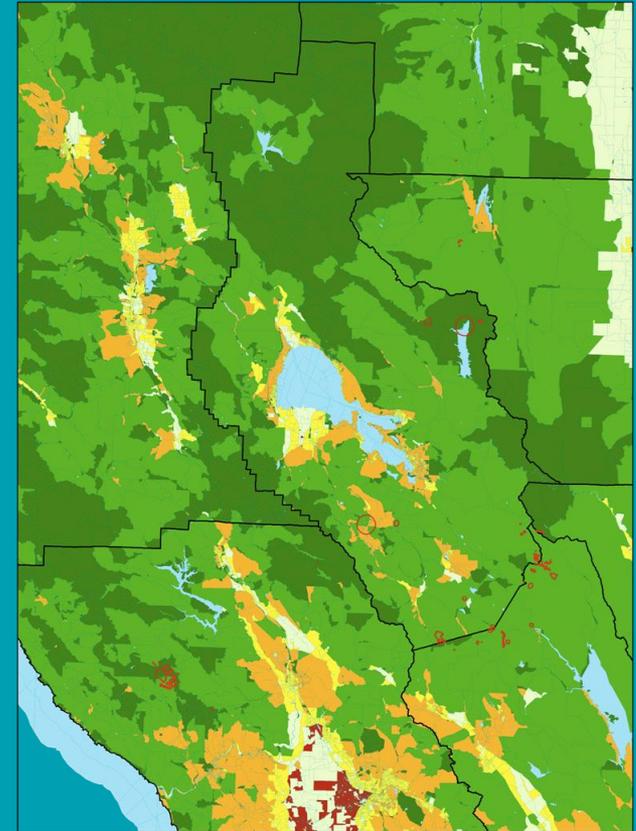
Future Predicted



99 of 156 are 'Vulnerable' to Climate Change

Important factors

- anthropogenic barriers (99 taxa)
- renewable energy development (80 taxa)
- historical temperature exposure (80 taxa)



Land Use Map

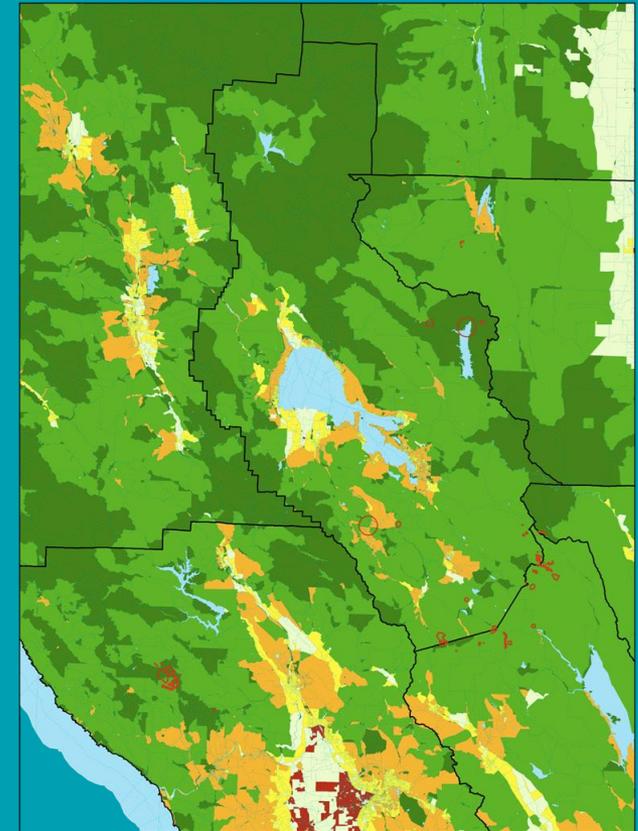
Correlation of CCVI scores with component factors

A set of correlations was run relating vulnerability scores to each of the stratification factors and each of the individual components of the score.

Unfortunately, this means that there are no shortcuts in assessing vulnerability. The full analysis must be run on each species uniquely.

Marginally significant factors (low R^2)

- anthropogenic barriers (99 taxa)
- renewable energy development (80 taxa)
- historical temperature exposure (80 taxa)



Land Use Map

High Variability in Modeled Range Change Predictions

CCVI = traits + modeled response

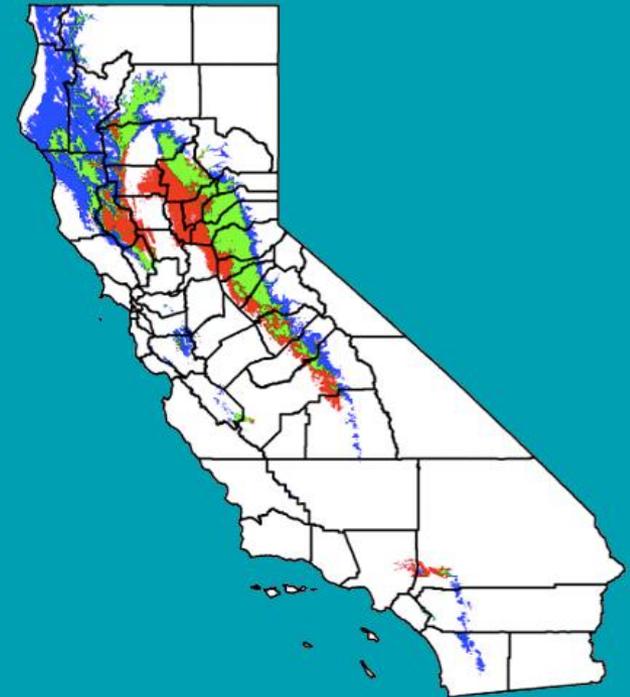
Removing modeled response can make:

Highly -> Moderately vulnerable

Increase likely -> Presumed stable

Rare species modeling paradox (Lomba et al. 2010)

“Rare species are the most in need of predictive distribution modeling but also the most difficult to model”



High Variability in Modeled Range Change Predictions

20+ models per species

4 climate variables (bioclim 1, 4, 12, 15)

13 GCM*ES

soil type

soil properties

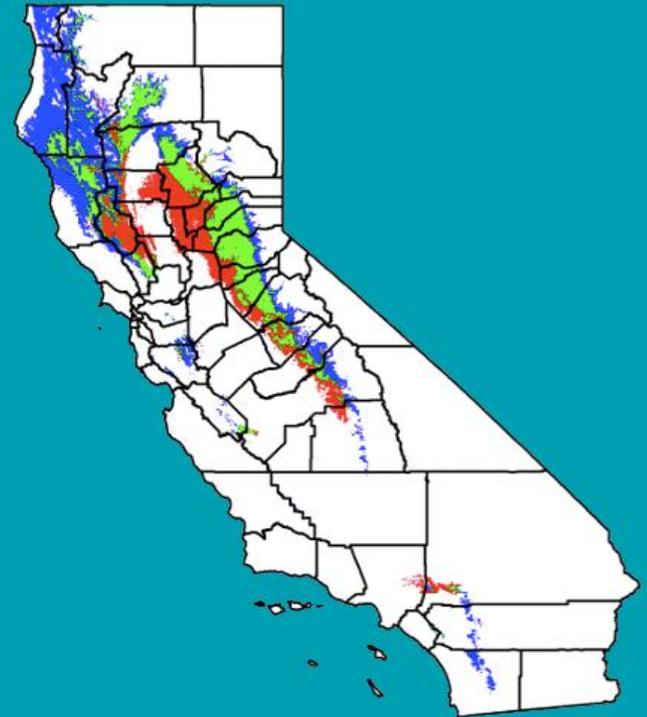
random forest

boosted regression tree

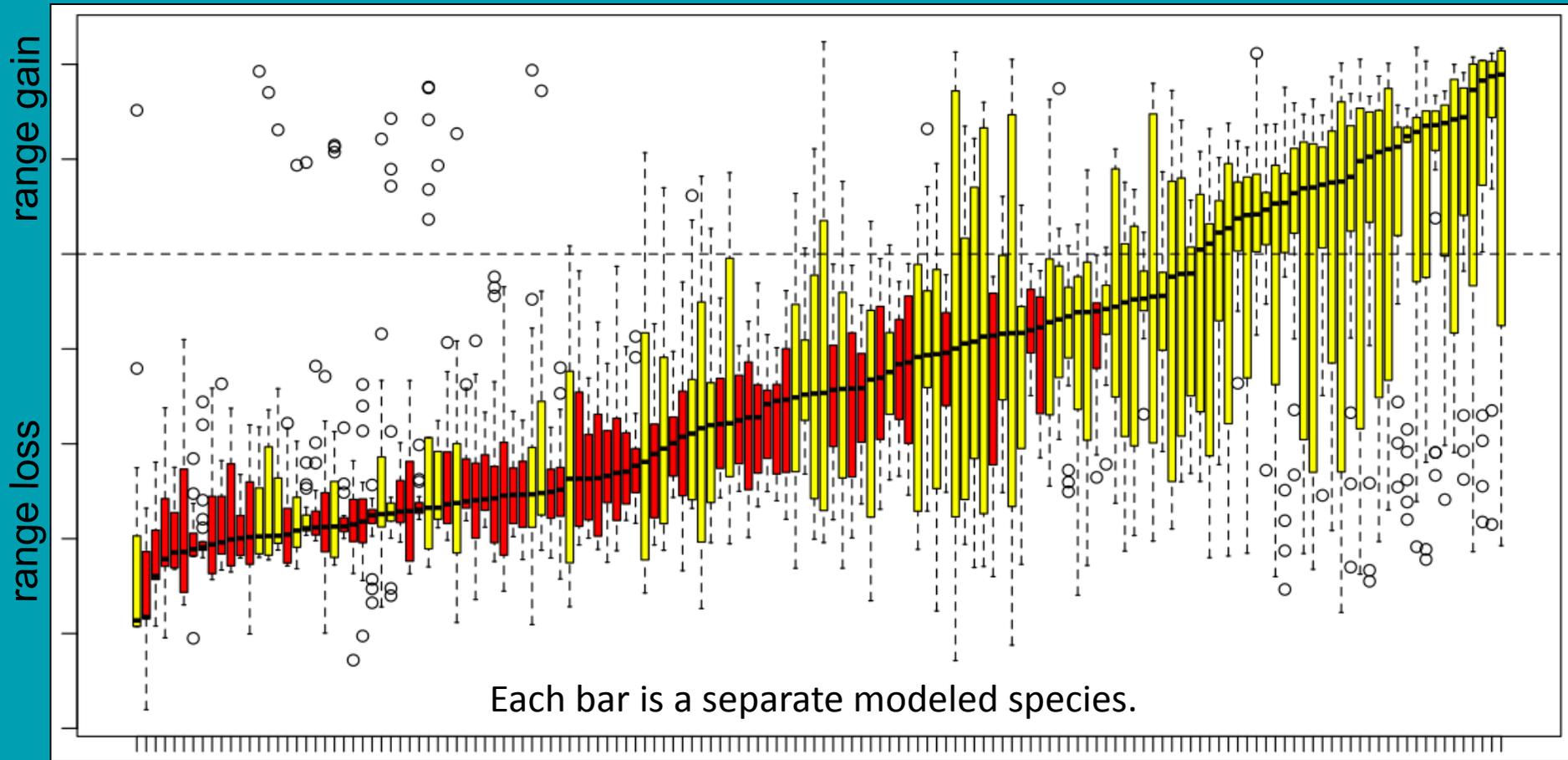
19 climate variables (bioclim 1 - 19)

soil type

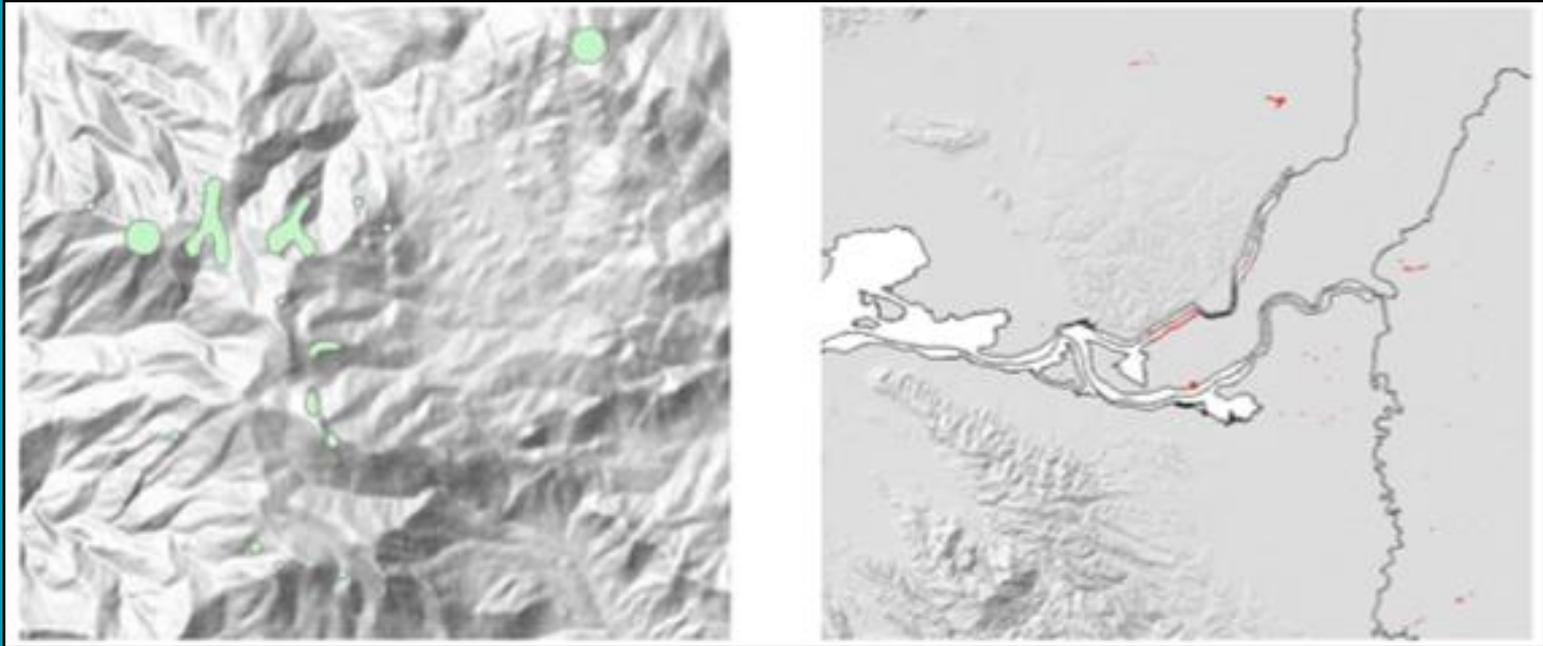
soil properties



High Variability in Modeled Range Change Predictions



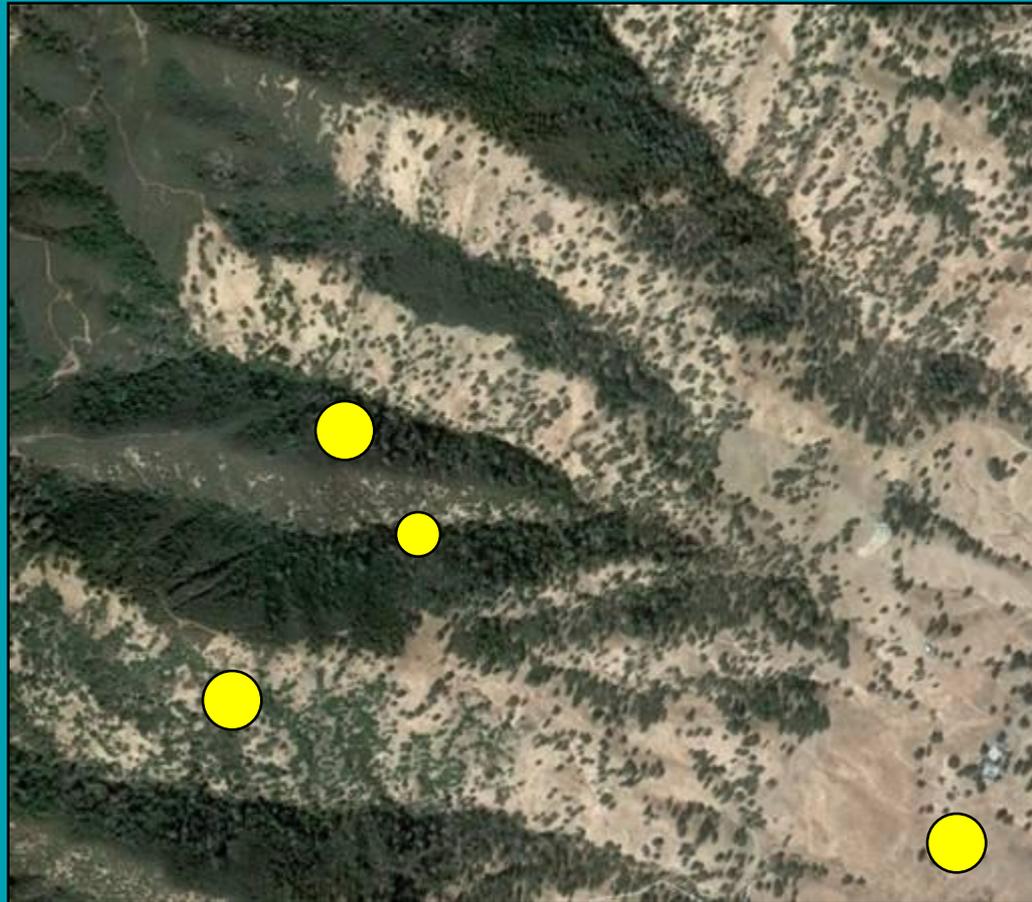
Can Topographic Complexity Reduce Vulnerability?



“The velocity of temperature change is lowest in mountainous biomes” – Loarie 2009 Nature



Can Topographic Complexity Reduce Vulnerability?



1 mile



Can Topographic Complexity Reduce Vulnerability?



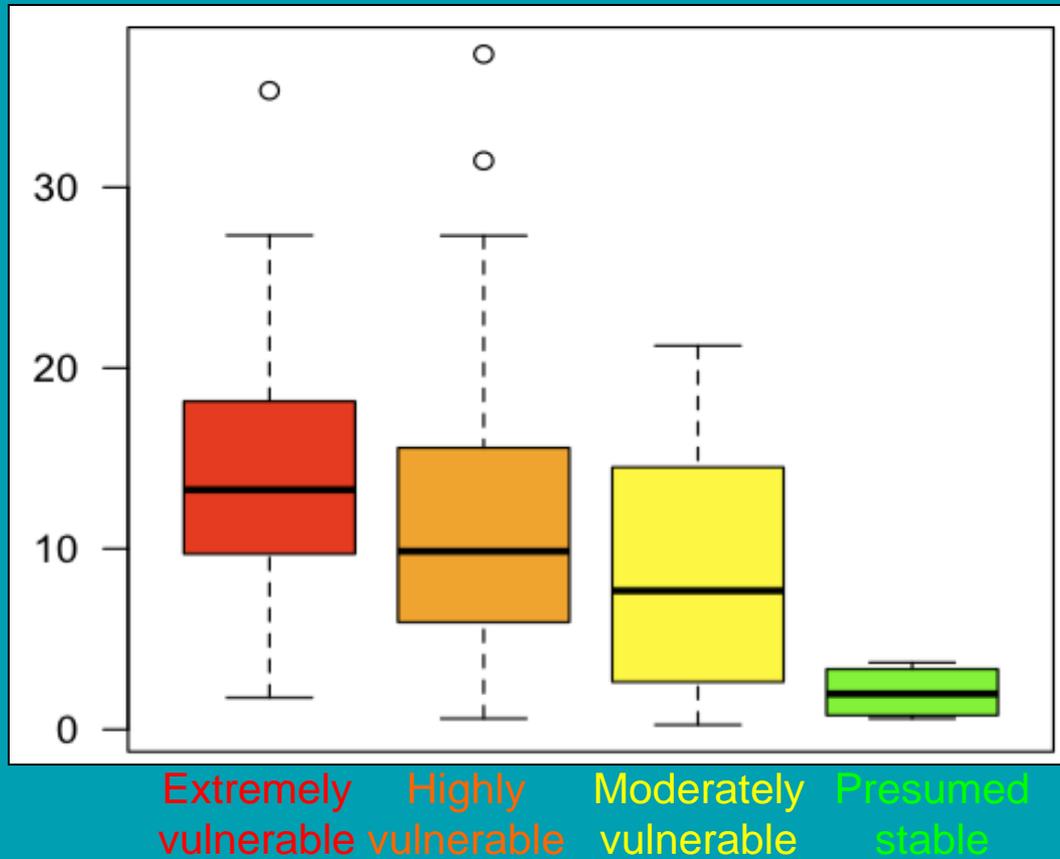
Spatial variability in climate can be nested into:

- macroclimate 100+ km – climate models
- mesoclimate - 1–100 km regional models
- topoclimate - 0.01–1 km downscaling
- microclimate (<10 m) – land facet, veg maps

Geiger & Aron, 2003, Ackerly, et al. 2010

Can Topographic Complexity Reduce Vulnerability?

Topographic complexity



What Do The Results mean for Planning Management, and Regulation

BIOLOGICAL CONSERVATION 142 (2009) 14–32

available at www.sciencedirect.com

 ScienceDirect

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

Review

Biodiversity management in the face of climate change: A review of 22 years of recommendations

Nicole E. Heller^a, Erika S. Zavaleta

Environmental Studies Department, University of California, Santa Cruz, Santa Cruz, CA 95066, United States

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ABSTRACT

Climate change creates new challenges for biodiversity conservation. Species ranges ecological dynamics are already responding to recent climate shifts, and current research will not continue to support all species they were designed to protect. These problems are exacerbated by other global changes. Scholarly articles recommending measures to adapt conservation to climate change have proliferated over the last 22 years. We systematically reviewed this literature to explore what potential solutions it has identified

REVIEWS REVIEWS REVIEWS

Resource management in a changing and uncertain climate

Joshua J Lawler^{a*}, Timothy H Tear^a, Chris Pyke^b, M Rebecca Shaw^a, Patrick Gonzalez^a, Peter Kareiva^a, Lara Hansen^a, Lee Hannah^a, Kirk Klausmeyer^a, Allison Aldous¹⁰, Craig Biern¹¹, and Sam Pearsall¹²

Climate change is altering ecological systems throughout the world. Managing these systems in a way that ignores climate change will likely fail to meet management objectives. The uncertainty in projected climate-change impacts is one of the greatest challenges facing managers attempting to address global change. In order to select successful management strategies, managers need to understand the uncertainty inherent in projected climate impacts and how these uncertainties affect the outcomes of management activities. Perhaps the most important tool for managing ecological systems in the face of climate change is active adaptive management, in which systems are closely monitored and management strategies are altered to address expected and ongoing changes. Here, we discuss the uncertainty inherent in different types of data on potential climate impacts and explore climate projections and potential management responses at three sites in North America. The Central Valley of California, the headwaters of the Klamath River in Oregon, and the barrier islands and sounds of North Carolina each face a different set of challenges with respect to climate change. Using these three sites, we provide specific examples of how managers are already beginning to address the threat of climate change in the face of varying levels of uncertainty.

Front Ecol Environ 2009; 7, doi:10.1890/070146

Climate change has already had important effects on ecological systems (Parmesan 2006; Root and Schneider 2006; IPCC 2007a; Rosenzweig *et al.* 2008). Projected changes in climate for the coming century are all greater than the climatic changes the Earth has experienced in the past 100 years (IPCC 2007b). Consequently, future changes in climate are likely to

continue to shift species distributions, and substantial changes in ecosystem processes (IPCC 2007a). Changes in hydrologic and fire regimes will fundamentally alter ecological systems. Sea-level rise, in particular, will have dramatic effects on coastal systems (Watson *et al.* 1996). Changes in phenology will affect the delicate relationships between pollinators and

Heller and Zavaleta 2009

Lawler, Tear, Pyke, et al. 2009

What Do The Results mean for Planning Management, and Regulation

Planning Issues

- Given the uncertainty of predictions plans must address many scenarios and be adaptive.
- Changes the targets for land acquisitions, bigger may be even better.
- Corridors and connectivity are needed to facilitate natural migration and population viability.
- Maintenance, restoration and enhancement may be reprioritized based on range shifts. Invest these activities in areas that will harbor species over time.



What Do The Results mean for Planning Management, and Regulation

Management Issues

- Most current threats are exacerbated in less suitable range (especially invasives, fire, development in cool areas). Prevention measures even more important.
- Adaptive management more important than before.
- May need to “assist” migration
- Monitoring of vulnerable species especially at warmest part of their range just beyond the cooler end.



What Do The Results mean for Planning Management, and Regulation

Regulatory Issues

- Conservation status i.e. ranking and listing now must look at CC vulnerability.
- Mitigation must deal with long term predictions of viability.
- Does T&E critical habitat need to include ‘future habitat’?

Climate change

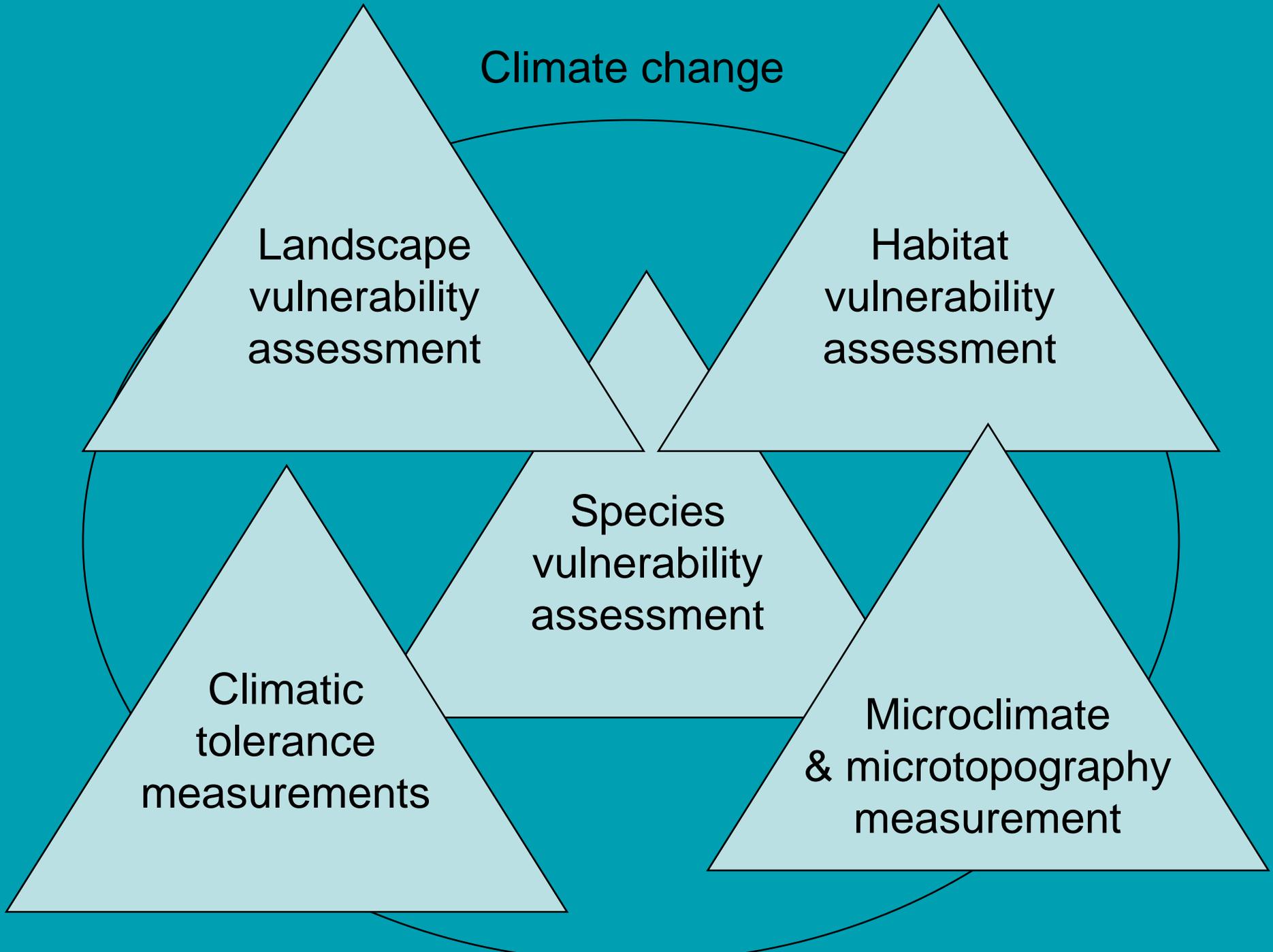
Landscape
vulnerability
assessment

Habitat
vulnerability
assessment

Species
vulnerability
assessment

Climatic
tolerance
measurements

Microclimate
& microtopography
measurement



Next Steps

- Communicate our results for the species deemed most vulnerable.
- Enhanced monitoring and surveys.
- Do another vulnerability assessment for the next 150 taxa – the most ‘threatened’ or imperiled.
- Look at common plants and plant communities that wildlife depend on.
- Incorporate local topographic complexity into spatial modeling.

Acknowledgements

- Funding provided by the California Landscape Conservation Cooperative



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Species data:

Mike Vasey, Julie Nelson, Vern Yadon, Betsy Landis, Dale McNeal, Graciela Hinshaw, and Christina Sloop.

sschoenig@dfg.ca.gov

www.dfg.ca.gov/bdb

