Climate Change Vulnerability Assessment for Rare Plants

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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
PLoS one

Climate Change and the Future of California's Endemic Flora

Scott R. Loarie[1*], Benjamin E. Carter[2,4,5], Katharine Hayhoe[3], Sean McMahon[1], Richard Moe[4], Charles A. Knight[2], David D. Ackerly[4,5]

1 Nicholas School of the Environment & Earth Sciences, Duke University, Durham, North Carolina, United States of America, 2 Department of Biological Sciences, California Polytechnic State University San Luis Obispo, San Luis Obispo, California, United States of America, 3 Department of Geosciences, Texas Tech University, Lubbock, Texas, United States of America, 4 Jepson Herbarium, University of California Berkeley, Berkeley, California, United States of America, 5 Department 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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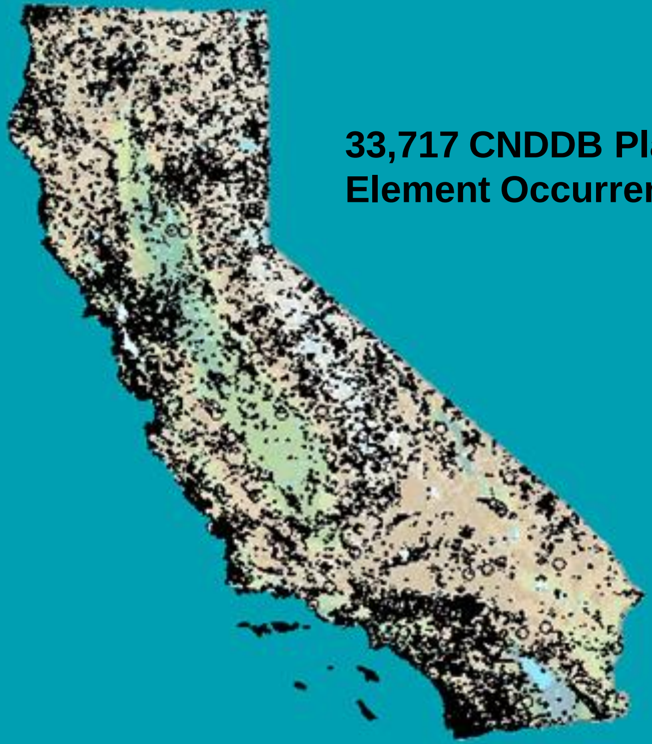
"up to 66% will experience >80% reduction in range size within a century"

California Botanical Background

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



33,717 CNDDB Plant Element Occurrences

‘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

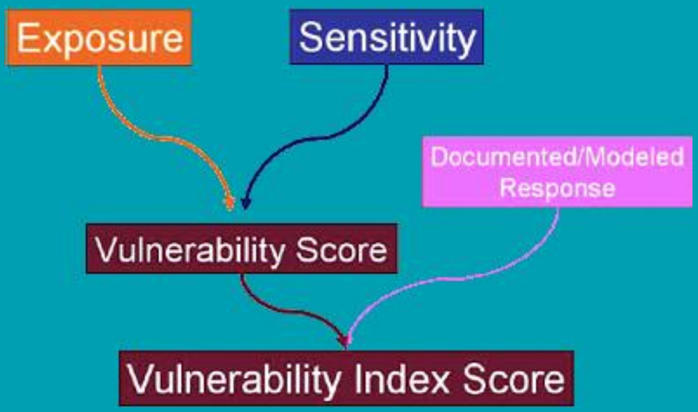
		Geographic Range			
		Large		Small	
	Somewhere Large	Common (not rare)	Locally abundant over a large range in a specific habitat type	Locally abundance in several habitats, but restricted geographically	Locally abundant in a specific habitat, but restricted geographically
Population Size					
	Everywhere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

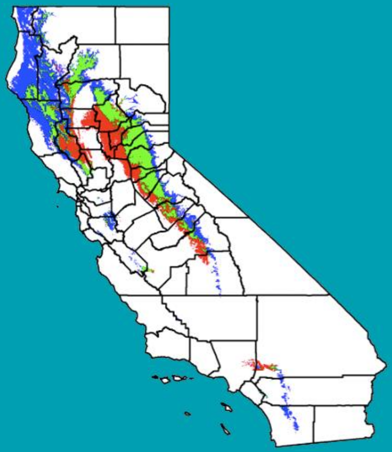
7 types of rarity (Rabinowitz 1981)

Stratification

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

Assessing Vulnerability



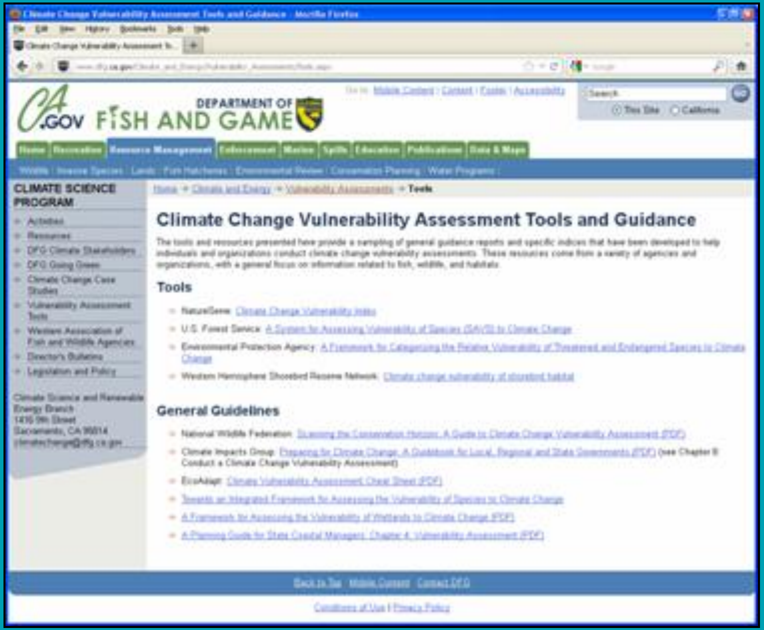


Species Attribute System

Species Distribution Models (SDM)

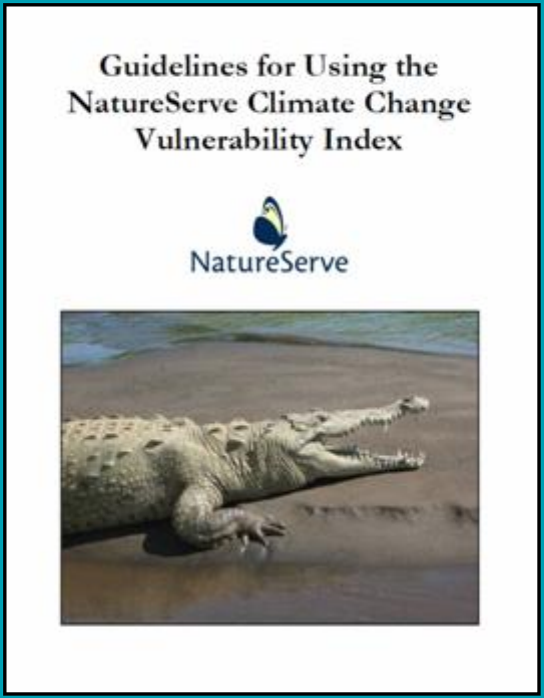
NatureServe CCVI

Why NatureServe Climate Change Vulnerability Index?

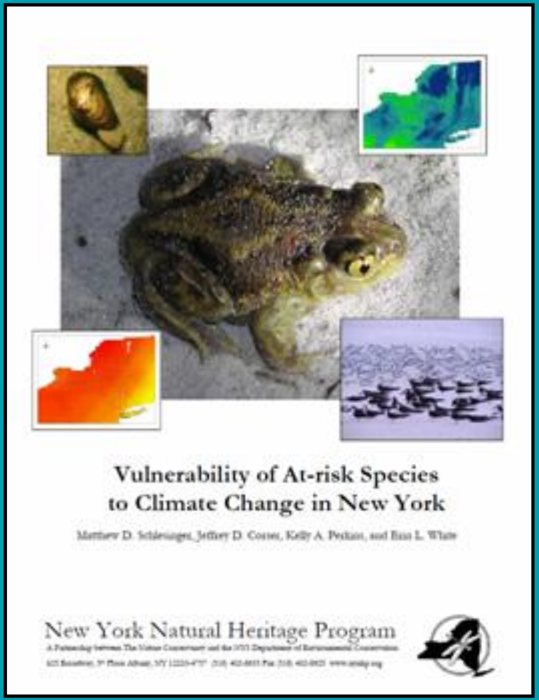


- •DFG is part of the NatureServe-coordinated natural heritage system.
- •Good to test out different methodologies (if crosswalkable).
- •Transparent, fact based, easily revised.

NatureServe CCVI



www.natureserve.org



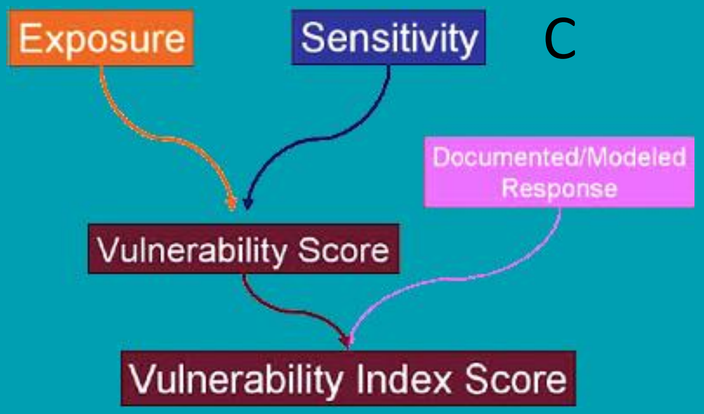
Young, B. E., K. R. Hall, E. Byers, K. Gravuer, G. Hammerson, A. Redder, and K. Szabo. 2012. **Rapid assessment of plant and animal vulnerability to climate change**. In Conserving wildlife populations in a changing climate, edited by J. Brodie, E. Post, and D. Doak. University of Chicago Press, Chicago,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

NatureServe CCVI

A & B

C

D



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

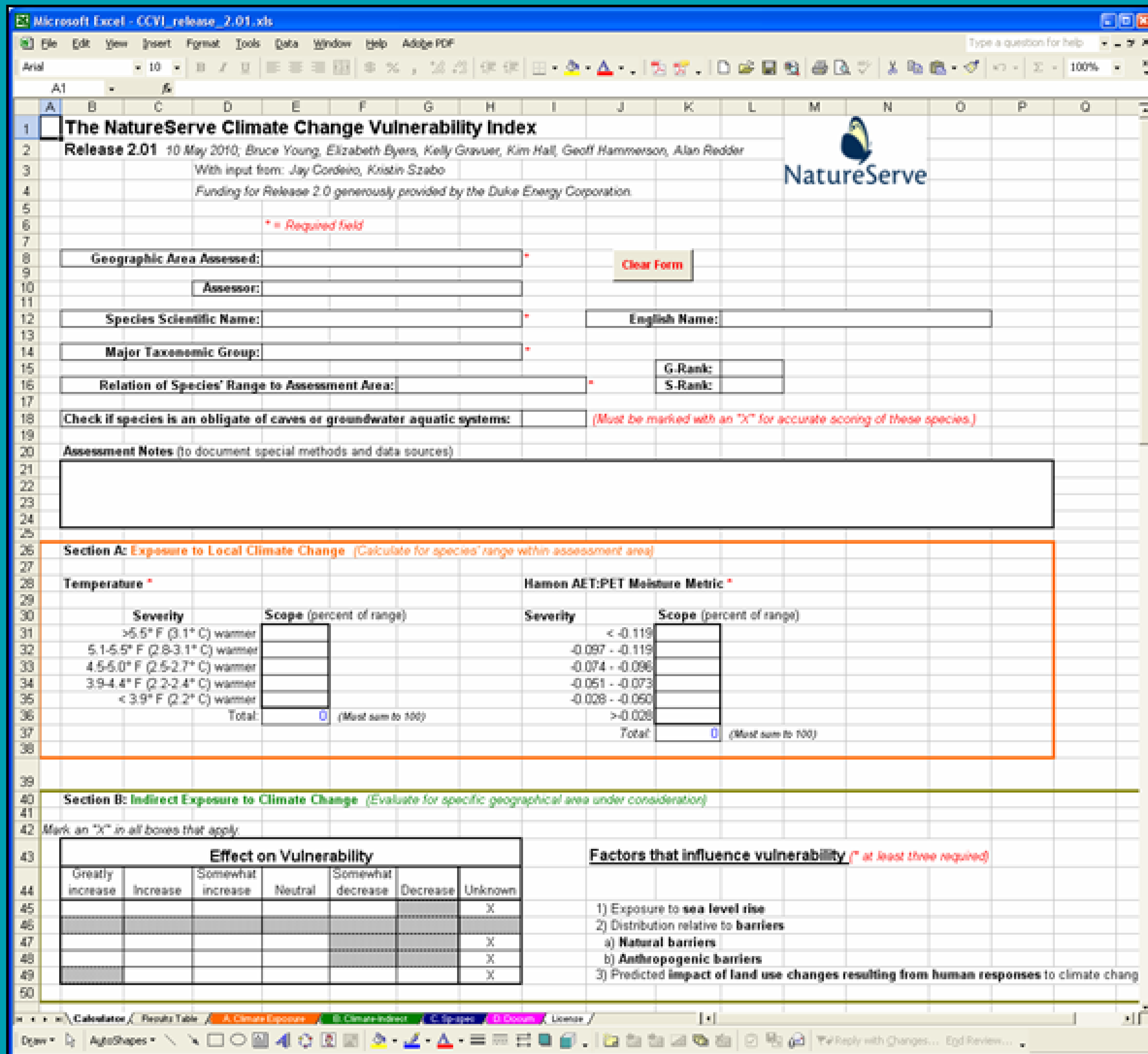
NatureServe CCVI

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: *

Clear Form

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 *

Severity	Scope (percent of range)
>5.5° F (3.1° C) warmer	
5.1-5.5° F (2.8-3.1° C) warmer	
4.5-5.0° F (2.5-2.7° C) warmer	
3.9-4.4° F (2.2-2.4° C) warmer	
< 3.9° F (2.2° C) warmer	
Total:	0 *(Must sum to 100)*

Hamon AET:PET Moisture Metric *

Severity	Scope (percent of range)
< -0.119	
-0.097 - -0.119	
-0.074 - -0.096	
-0.051 - -0.073	
-0.028 - -0.050	
>-0.028	
Total:	0 *(Must sum to 100)*

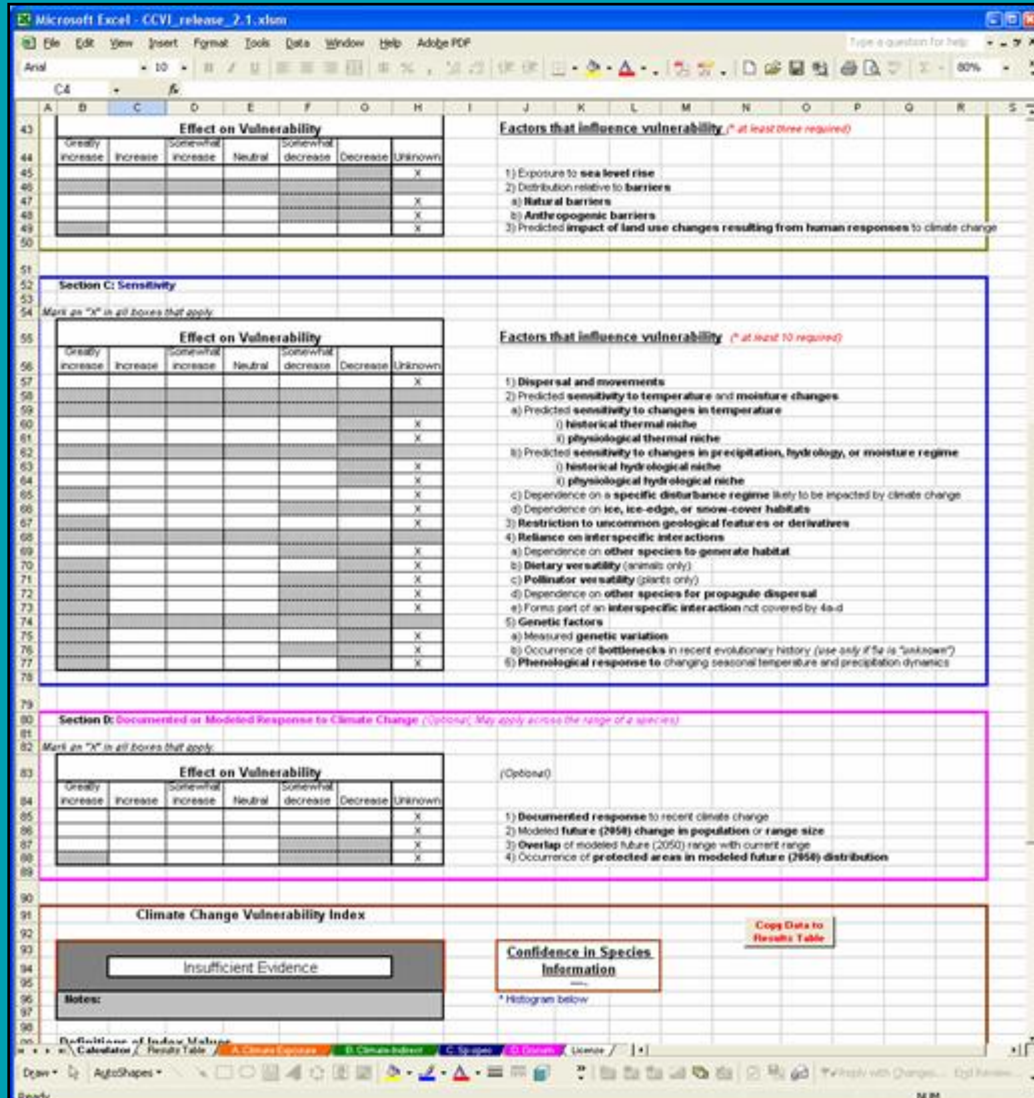
Section B: Indirect Exposure to Climate Change *(Evaluate for specific geographical area under consideration)*

Mark an "X" in all boxes that apply.

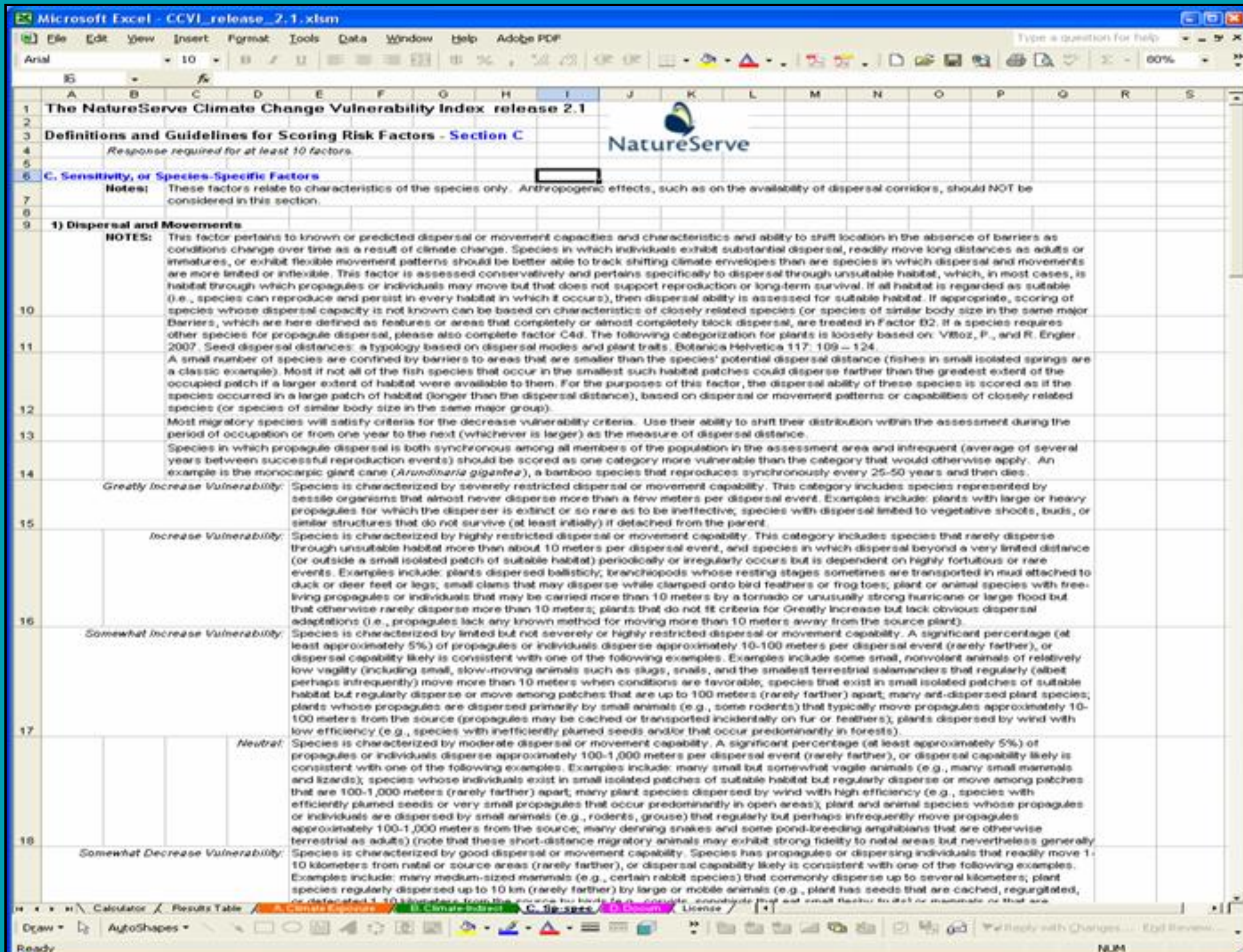
Effect on Vulnerability							
Greatly increase	Increase	Somewhat increase	Neutral	Somewhat decrease	Decrease	Unknown	**Factors that influence vulnerability** *(* at least three required)*
						X	1) Exposure to **sea level rise**
							2) Distribution relative to **barriers**
						X	a) **Natural barriers**
						X	b) **Anthropogenic barriers**
						X	3) Predicted **impact of land use changes resulting from human responses** to climate chang

Calculator / Results Table / A. Climate Exposure / B. Climate-indirect / C. Sp-spec / D. Docum / License

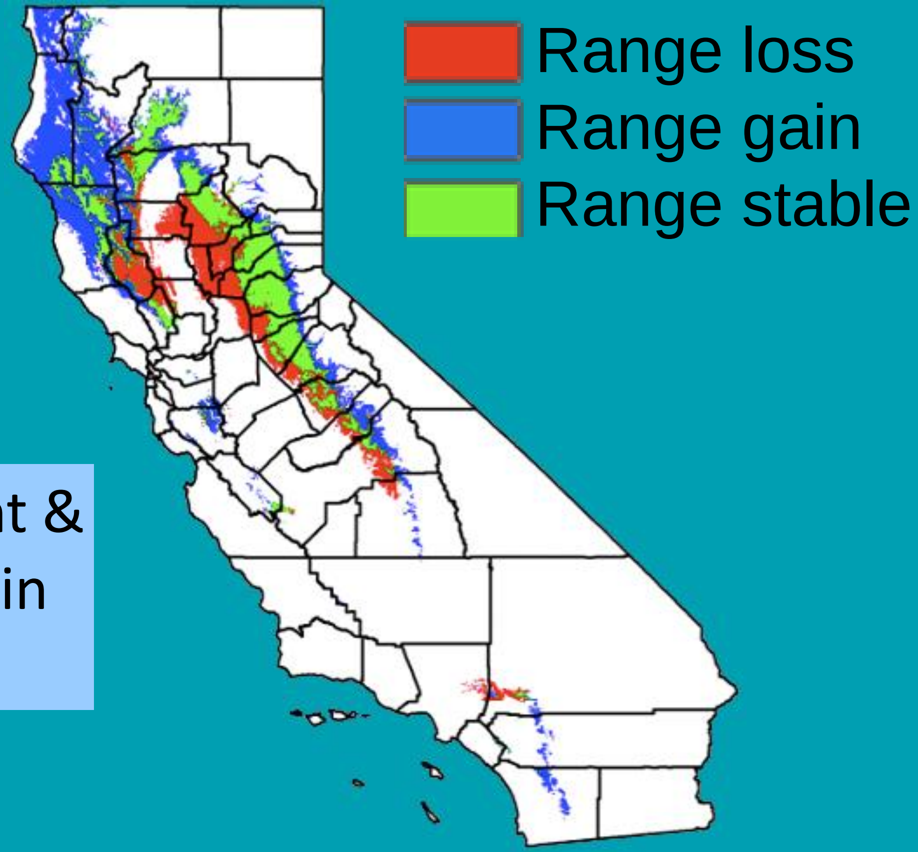
NatureServe CCVI



NatureServe CCVI



Modeled Range Change Predictions



Used Both MaxEnt & RandomForests in R script

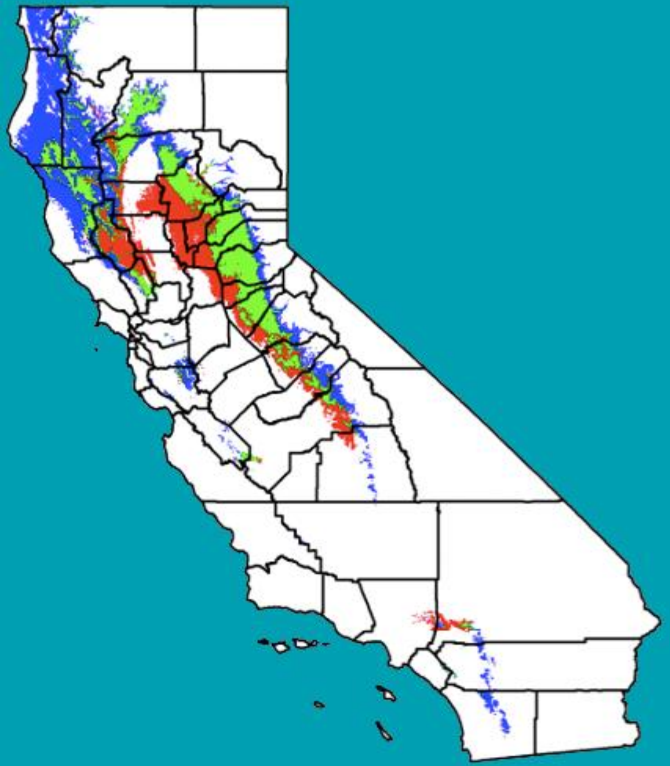
"Prediction is very difficult, especially if it's about the future."
-Niels Bohr (physicist)

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

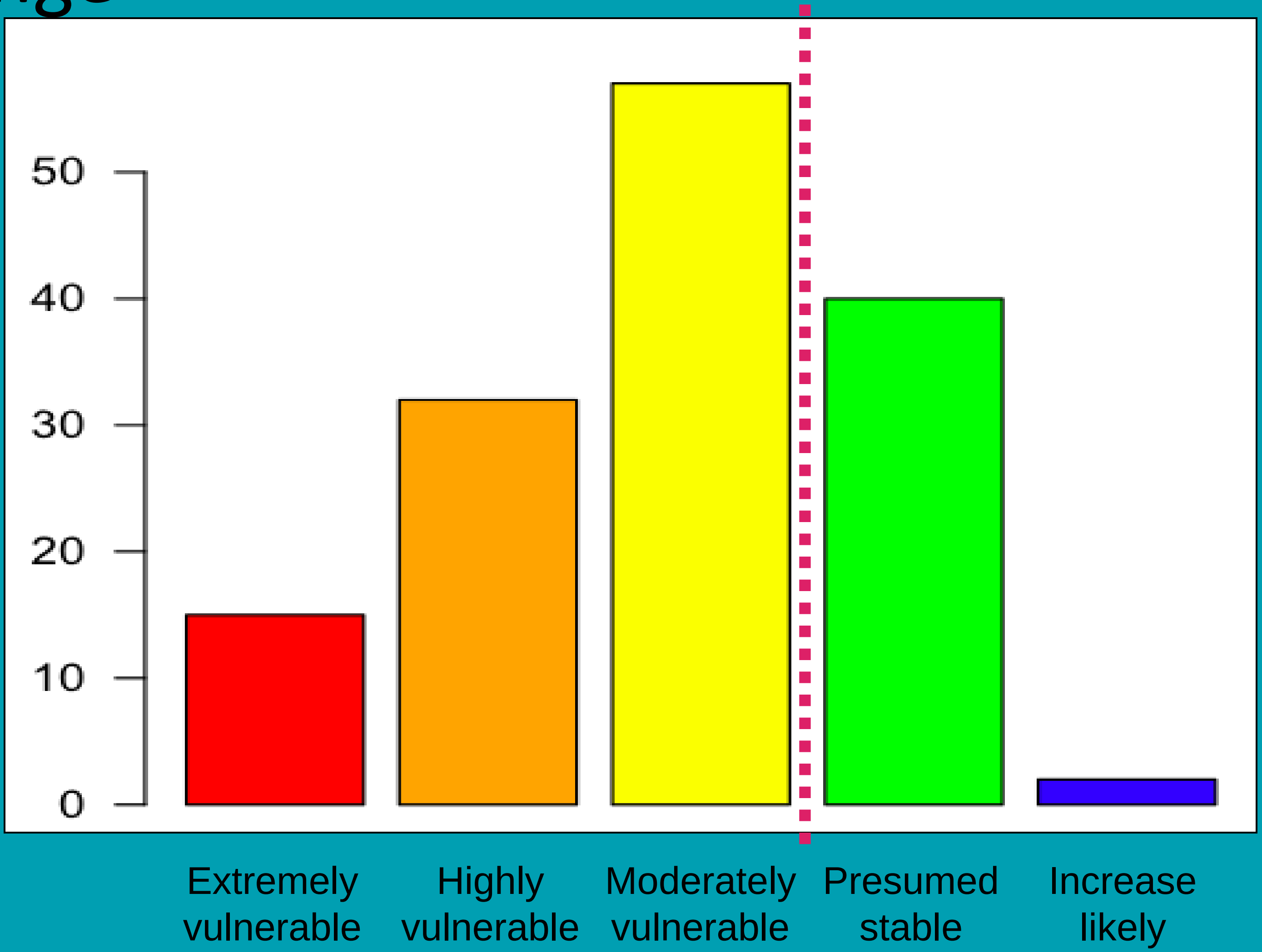
1. 99 of the 156 plants are classified as ‘vulnerable’ to climate change

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

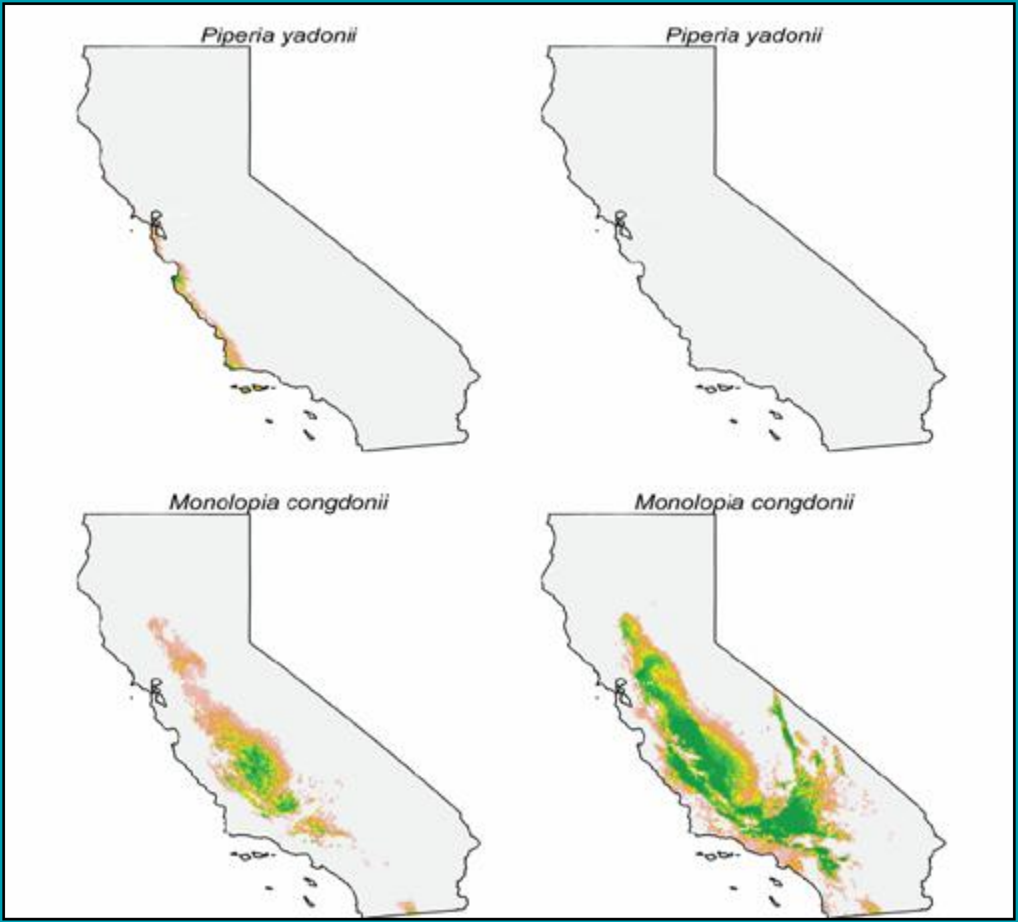
Change



99 of 156 are 'Vulnerable' to Climate Change

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

99 of 156 are ‘Vulnerable’ to Climate Change



Current Predicted   Future Predicted

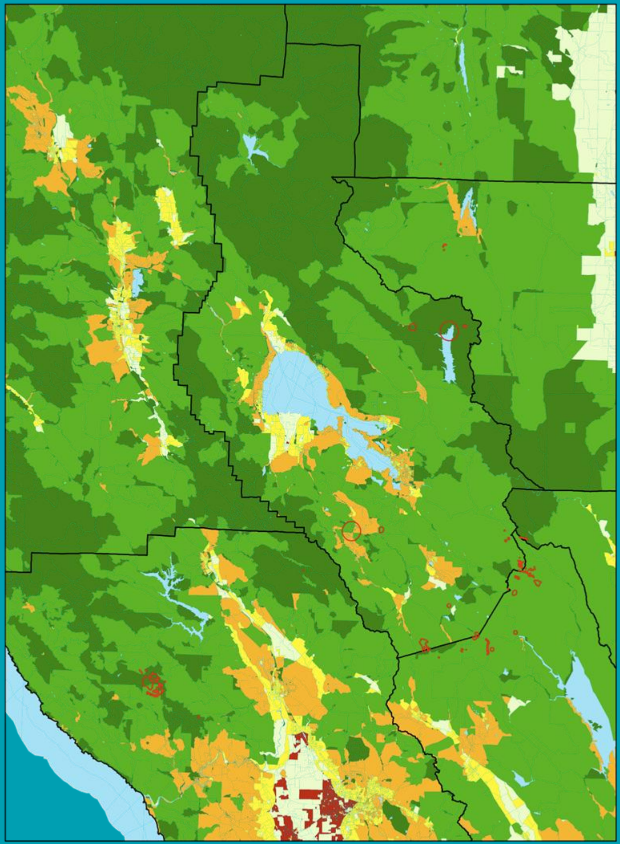
99 of 156 are ‘Vulnerable’ to Climate Change

Important factors

• anthropogenic barriers (99 taxa)

• renewable energy development (80 taxa)

• historical temperature exposure (80 taxa)



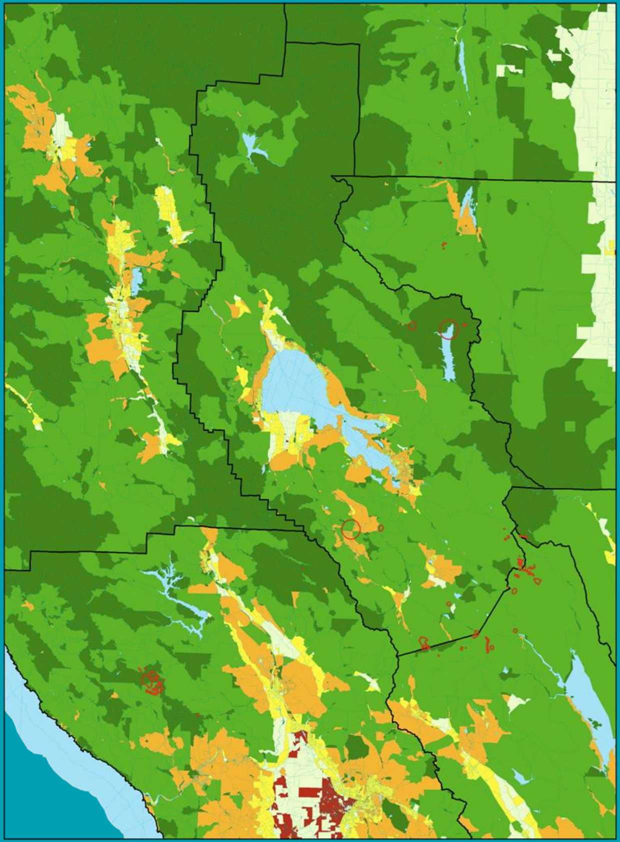
Land Use Map

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

<u>CCVI = traits + modeled response</u>

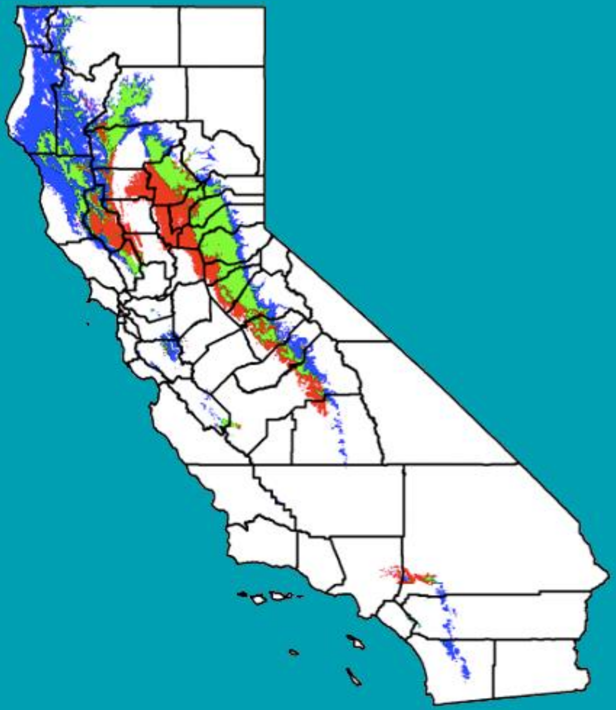
Removing modeled response can make:

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

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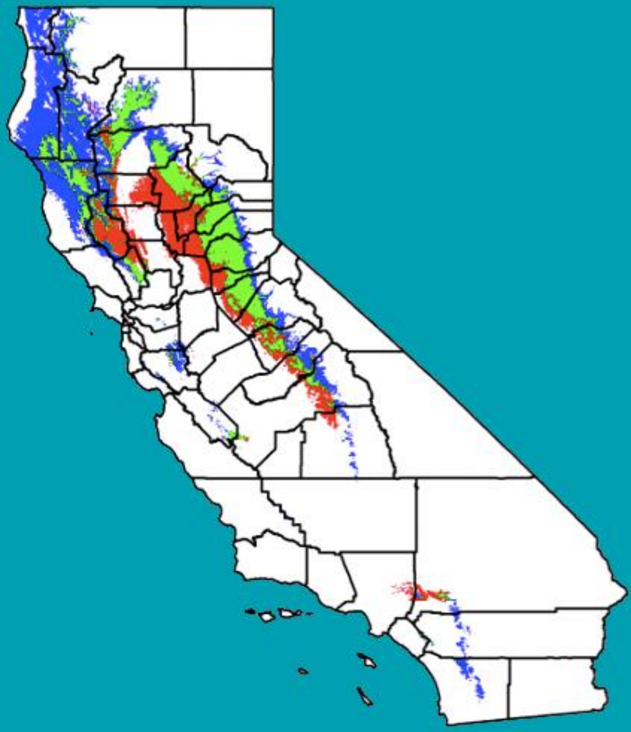
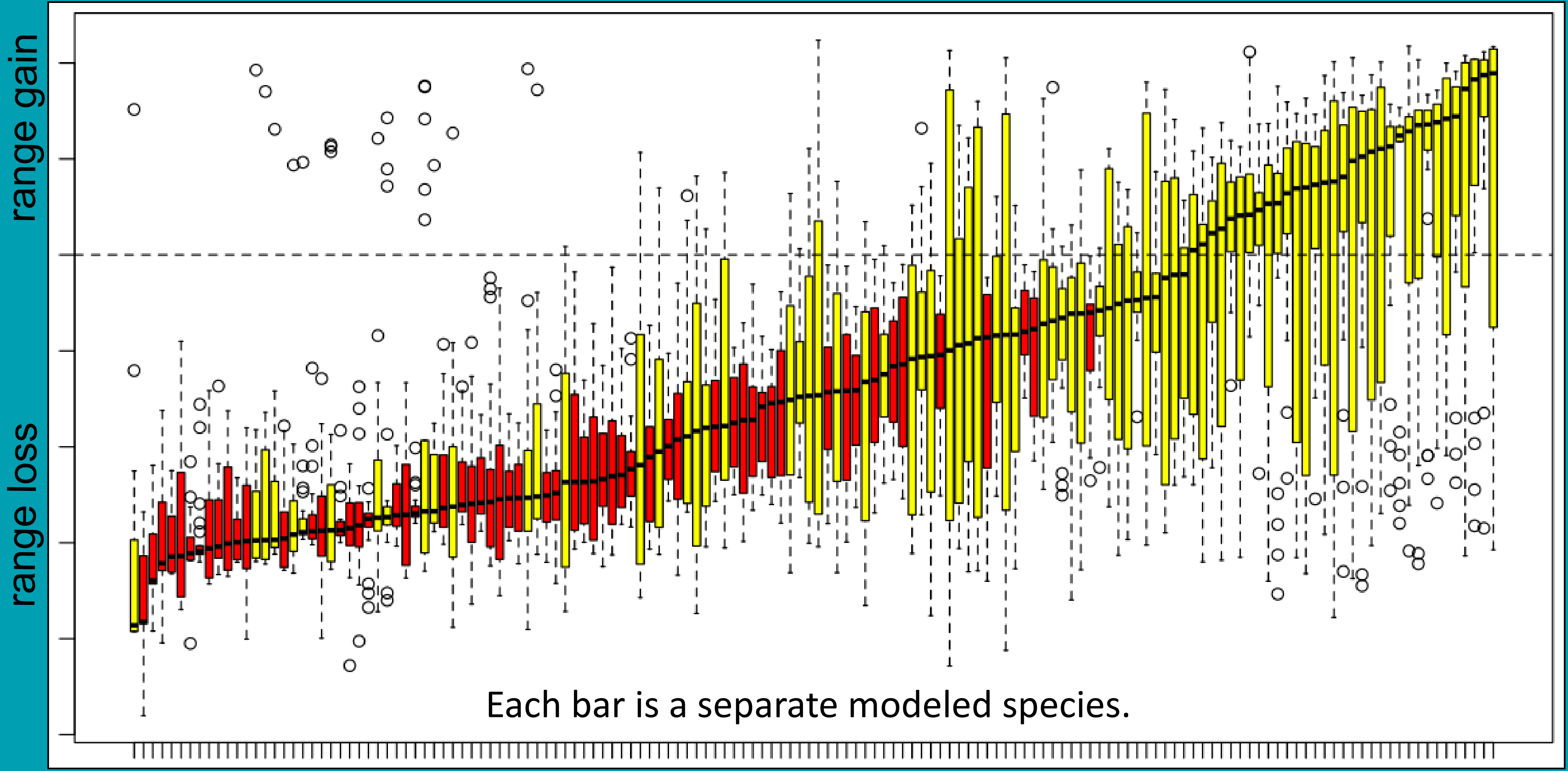
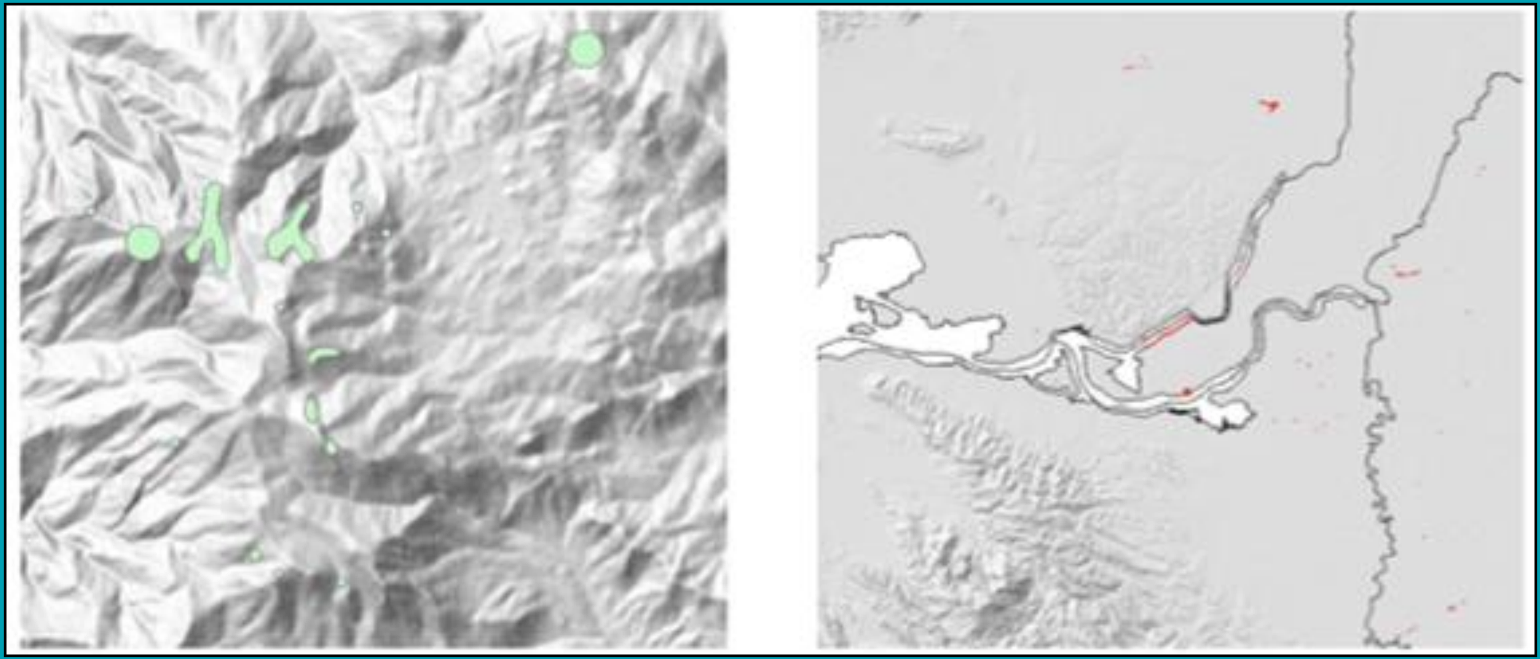


High Variability in Modeled Range Change Predictions

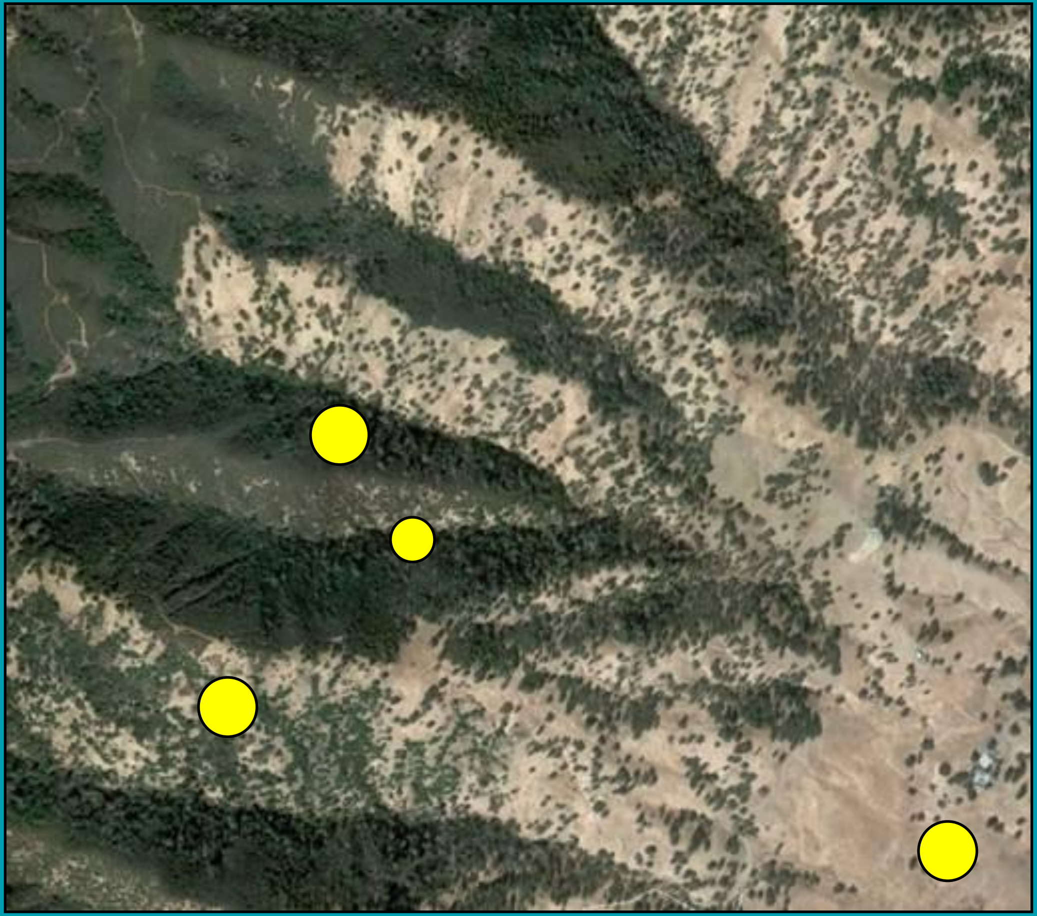


Can Topographic Complexity Reduce Vulnerability?



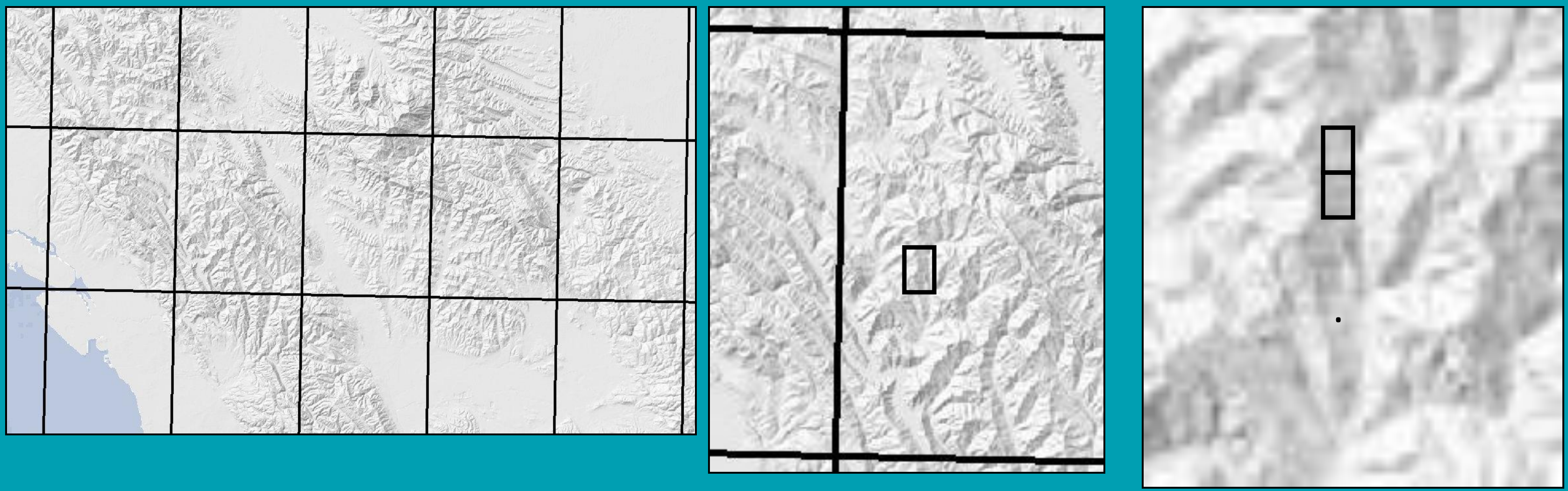
"The velocity of temperature change is lowest in mountainous biomes" – Loarie 2009 Nature

Can Topographic Complexity Reduce Vulnerability?



1 mile

Can Topographic Complexity Reduce Vulnerability?

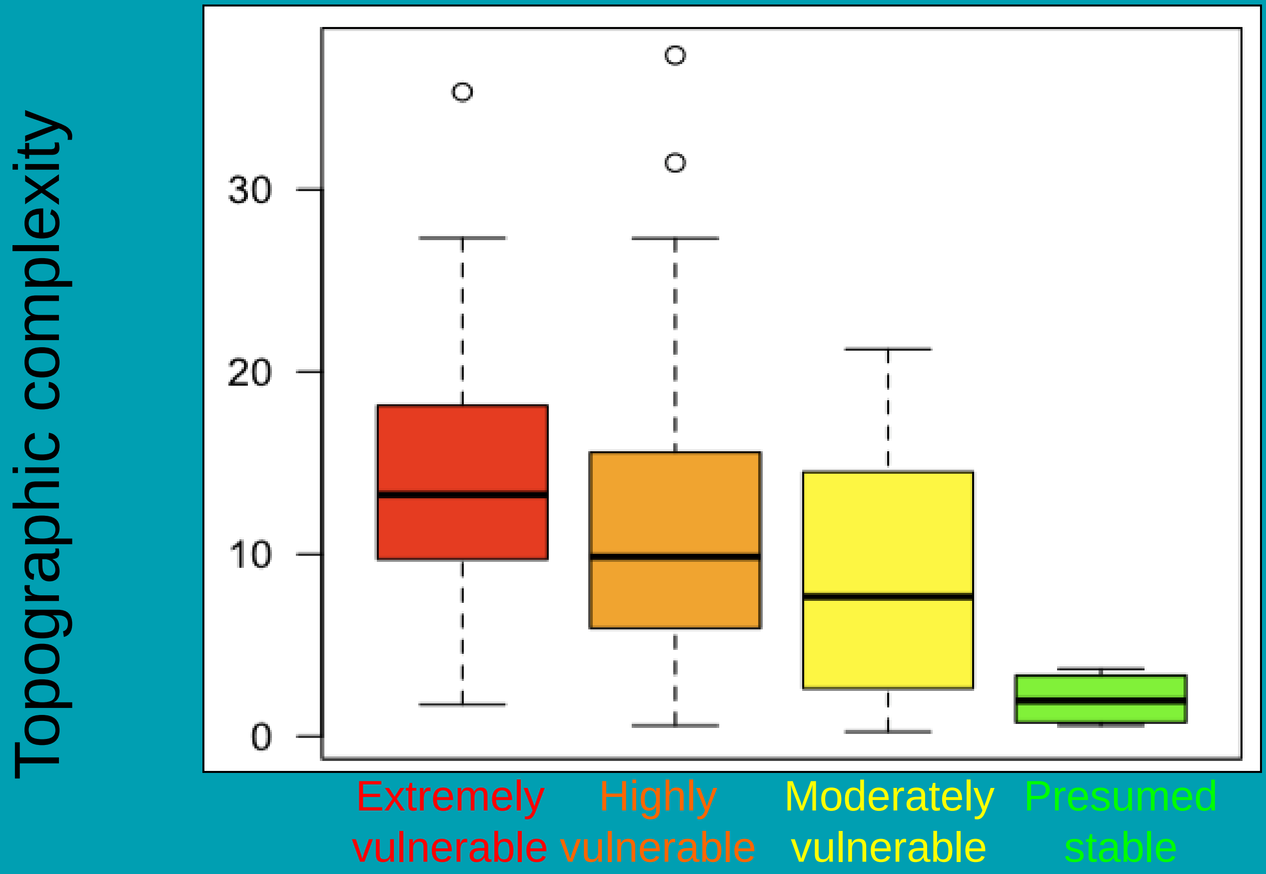


Spatial variability in climate can be nested into:

- 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?



What Do The Results mean for Planning Management, and Regulation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available at www.sciencedirect.com
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journal homepage: www.elsevier.com/locate/biocon

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Review

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

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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 rese will not continue to support all species they were designed to protect. These probl are exacerbated by other global changes. Scholarly articles recommending measure adapt conservation to climate change have proliferated over the last 22 years. We syst atically reviewed this literature to explore what potential solutions it has identified

Heller and Zavaleta 2009


REVIEWS REVIEWS REVIEWS

Resource management in a changing and uncertain climate

Joshua J Lawler[1*], Timothy H Tear[2], Chris Pyke[3], M Rebecca Shaw[4], Patrick Gonzalez[5], Peter Kareiva[6], Lara Hansen[7], Lee Hannah[8], Kirk Klausmeyer[9], Allison Aldous[10], Craig Bienz[11], and Sam Pearsall[12]

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 corals), continued shifts in 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

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

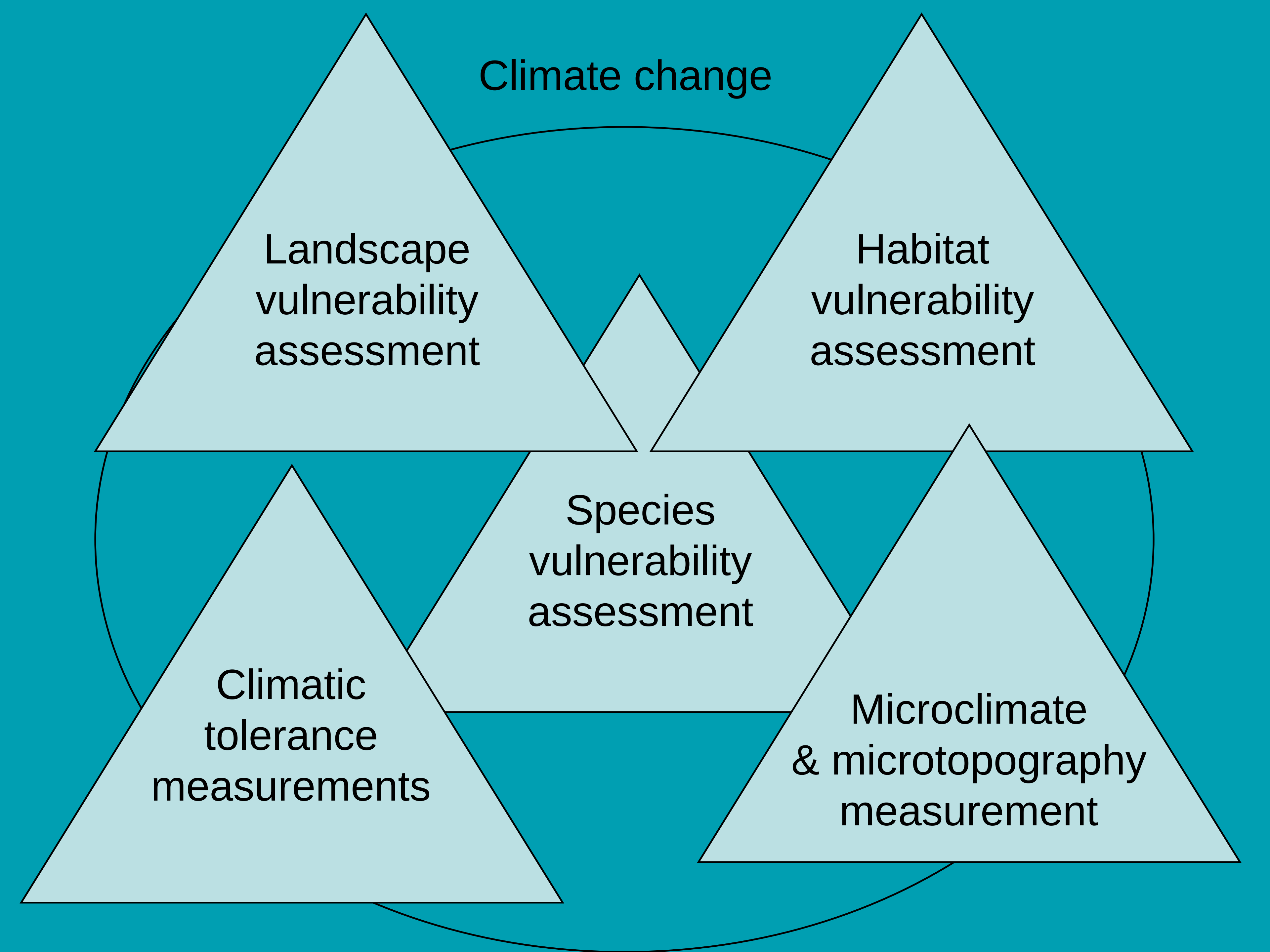
Management Issues

- 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

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

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