The potential impacts of climate change and vegetation successionon extinctions of Blunt Nosed Leopard Lizards,

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Erosion of Lizard Diversity by Climate Change and Altered Thermal Niches

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It is predicted that climate change will cause species extinctions and distributional shifts in coming decades, but data to validate these predictions are relatively scarce. Here, we compare recent and historical surveys for 48 Mexican lizard species at 200 sites. Since 1975, 12% of local populations have gone extinct. We verified physiological models of extinction risk with observed local extinctions and extended projections worldwide. Since 1975, we estimate that 4% of local populations have gone extinct worldwide, but by 2080 local extinctions are projected to reach 39% worldwide, and species extinctions may reach 20%. Global extinction projections were validated with local extinctions observed from 1975 to 2009 for regional biotas on four other continents, suggesting that lizards have already crossed a threshold for extinctions caused by climate change.

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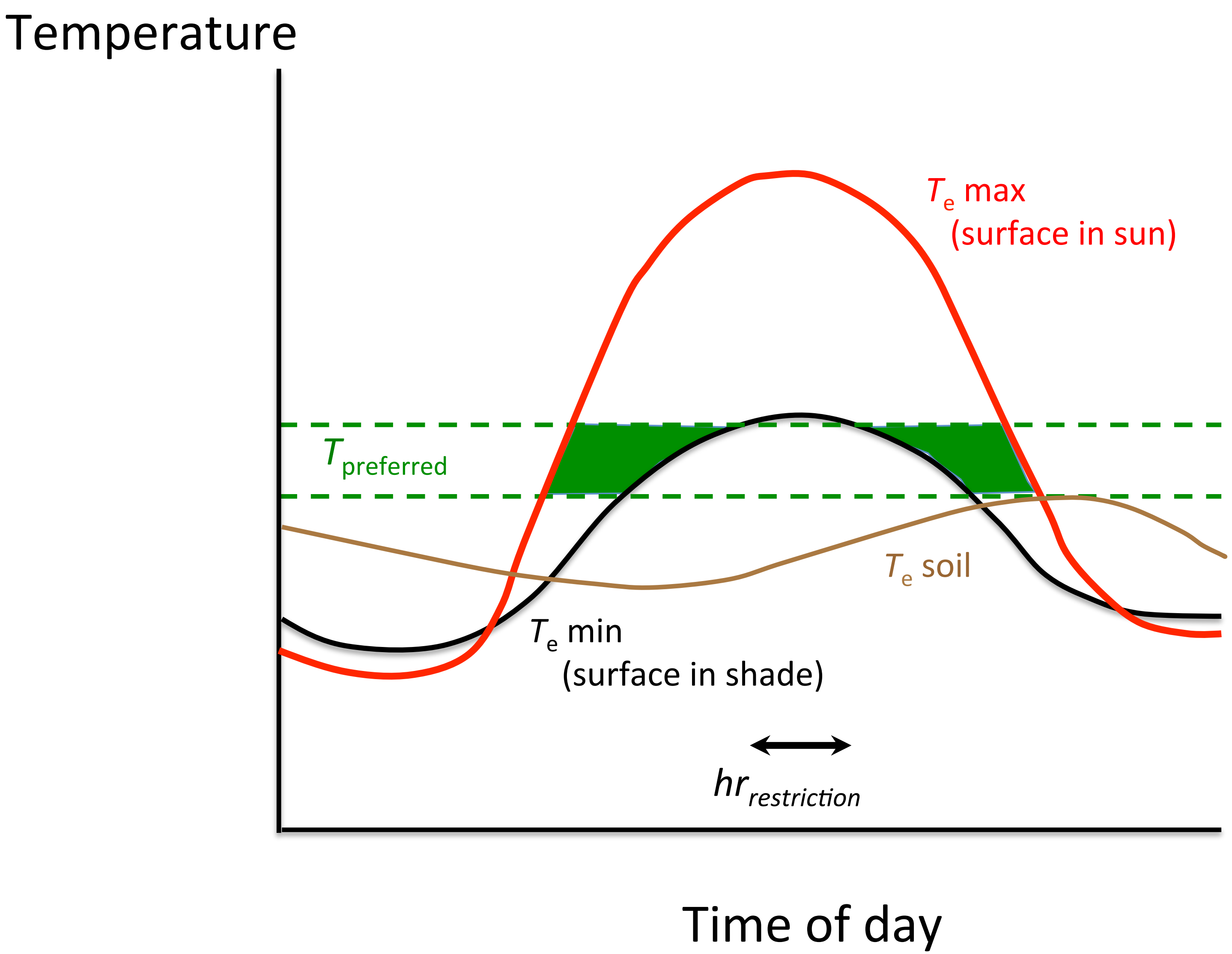
Glossary

- Tb lizard body temperature in the field
- Tp preferred lizard body temperature in lab
- Tmax – Maximum daily air temperature
- Te – Operative environmental temperature (the temperature a lizard could achieve if it were in a particular place in the environment)

Warming temperatures will restrict activity times, energy gain, and reproductive output



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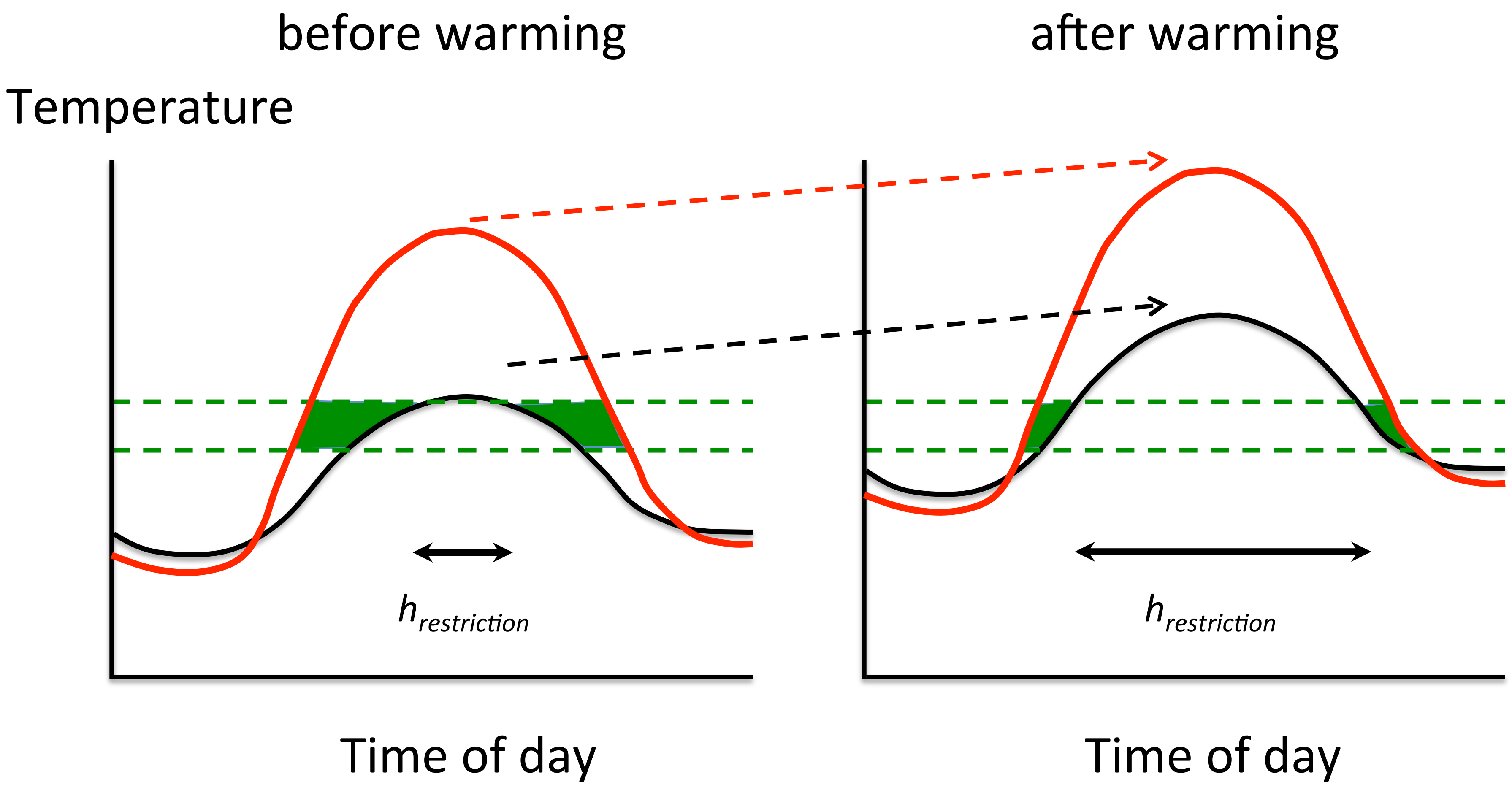
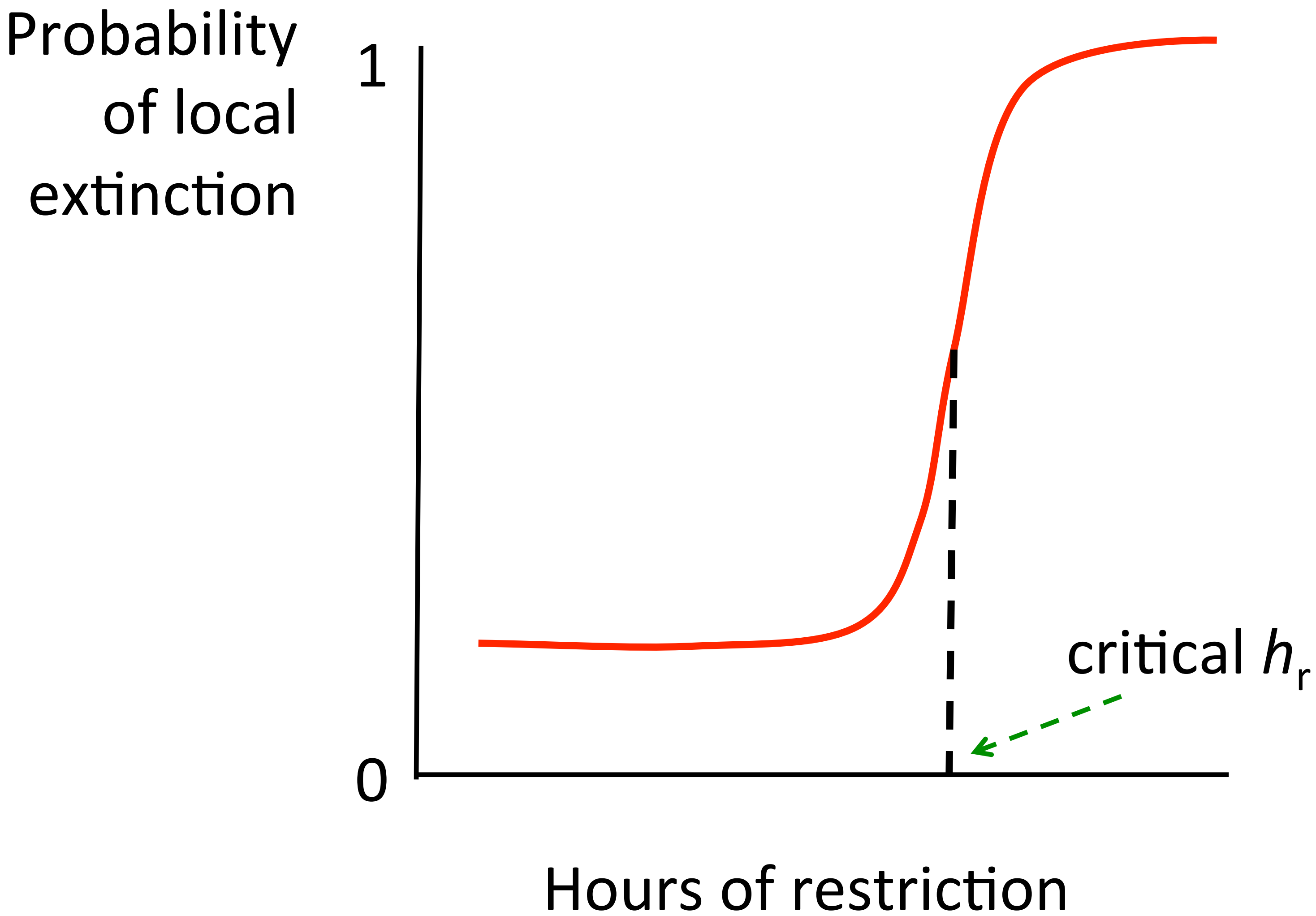
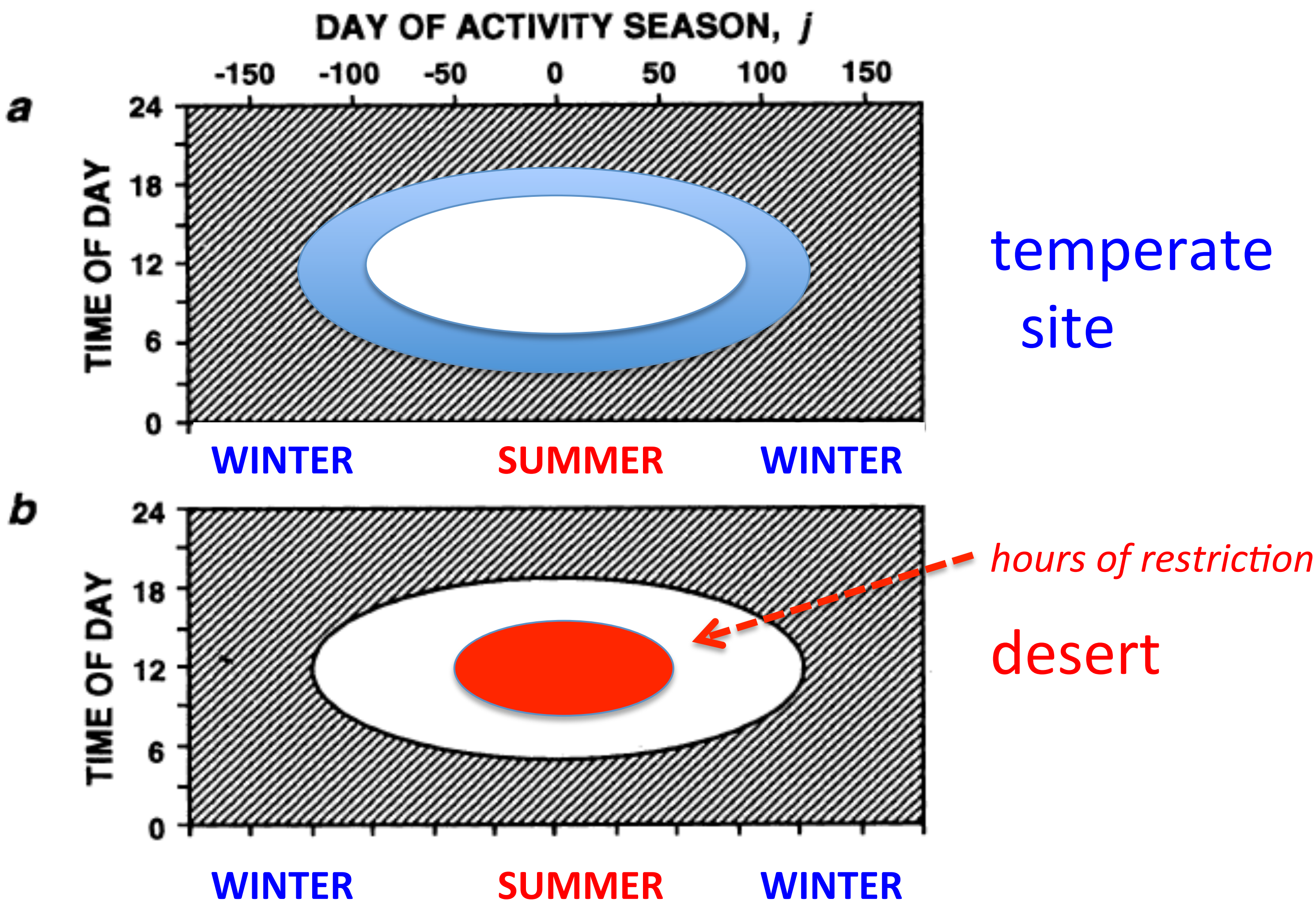
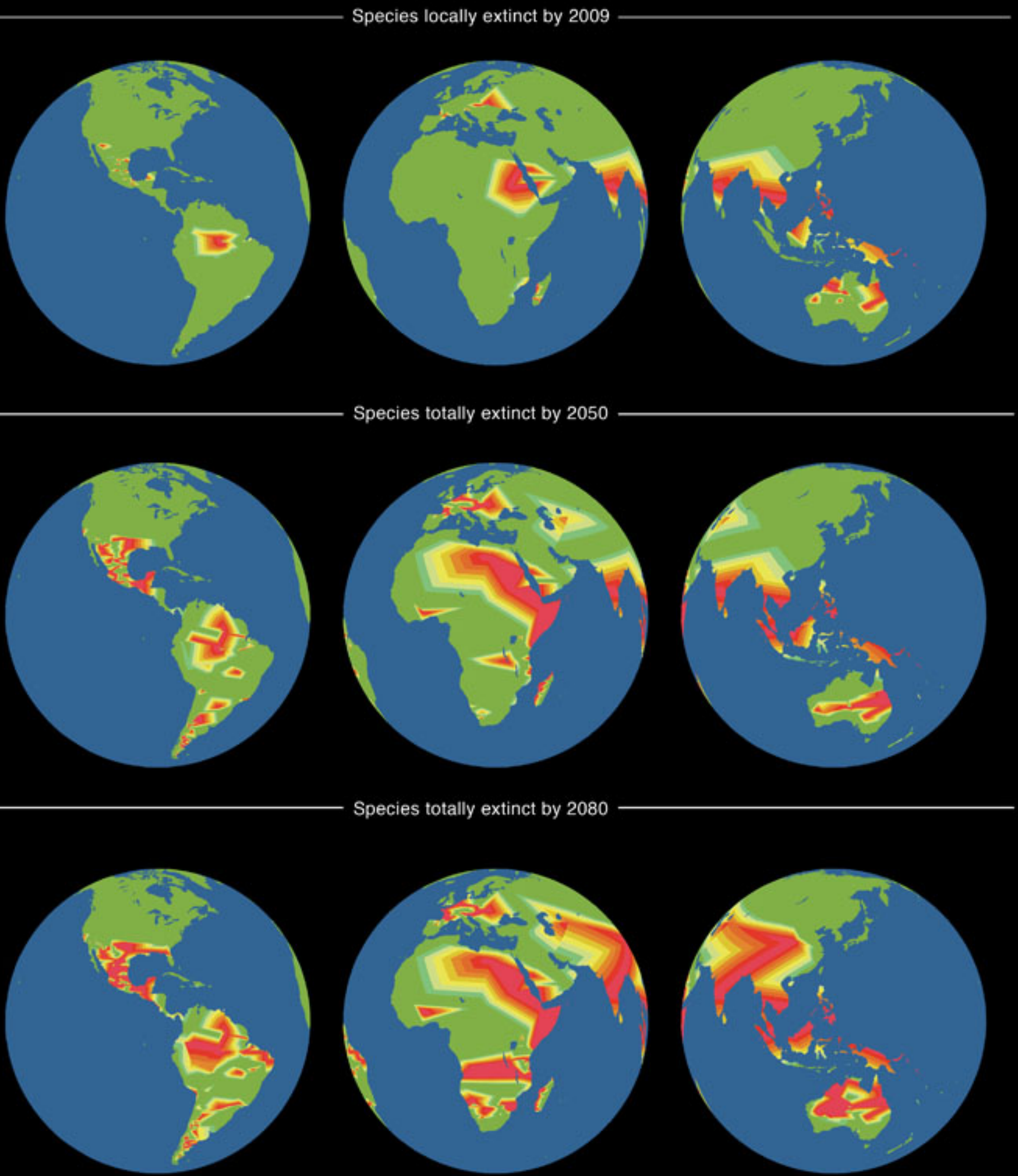


Sinervo et al. model – general pattern





Adoph & Porter 1993 Am Nat



By the numbers:

2009
- 4% local extinction
- R^2 = 0.72 in a global validation with 8 other families

2050
- 6% species extinction
- 100% in some areas

2080
- 20% species extinction
- 100% in many areas

Since Publication of Sinervo et al. 2010 New extinction validations for the Mojave Desert (and other parts of CA)

Side-blotched lizards, *Uta stansburiana*

Western Fence Lizard, *Sceloporus occidentalis*

Northern Alligator lizards, *Elgaria coerulea*

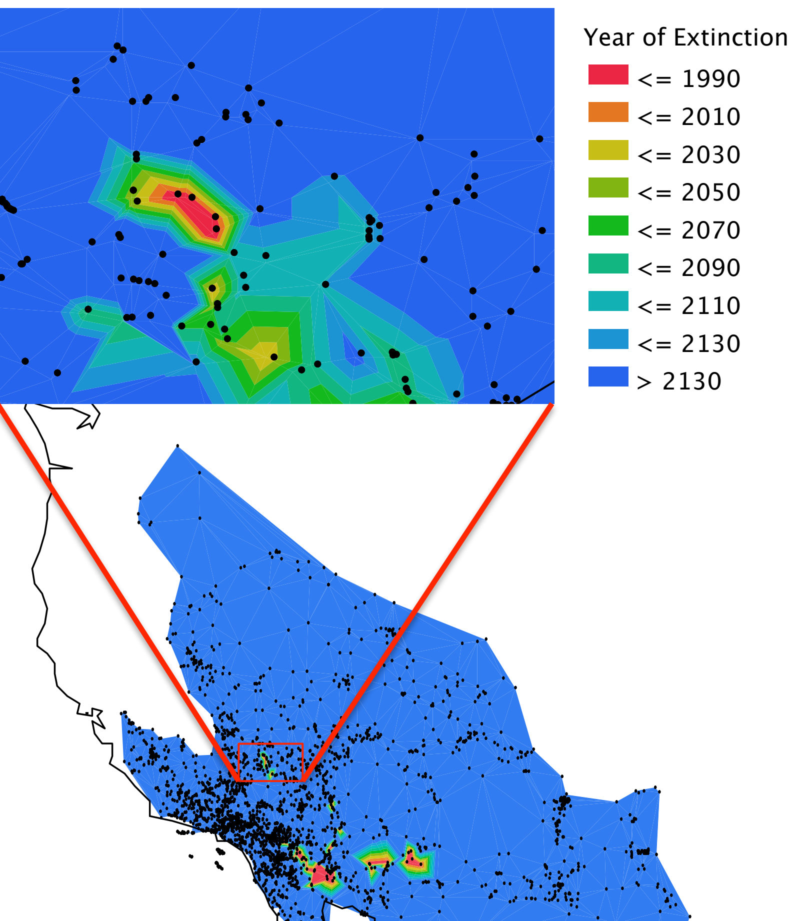
These appear driven in part by plant-die back, probably caused by warming

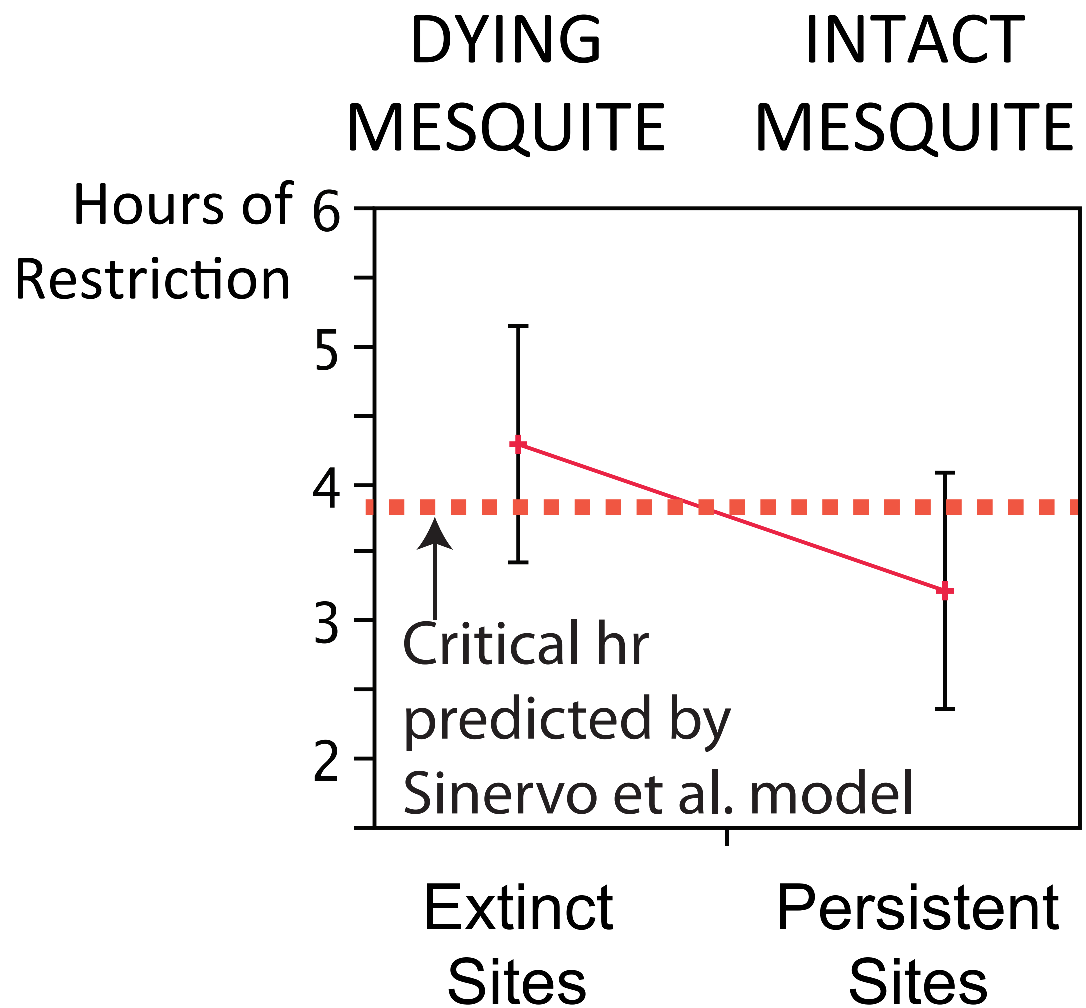
fit of Observed vs. Predicted extinctions in the new validations is R^2=0.86, remarkably good

Death Valley "Vacation"

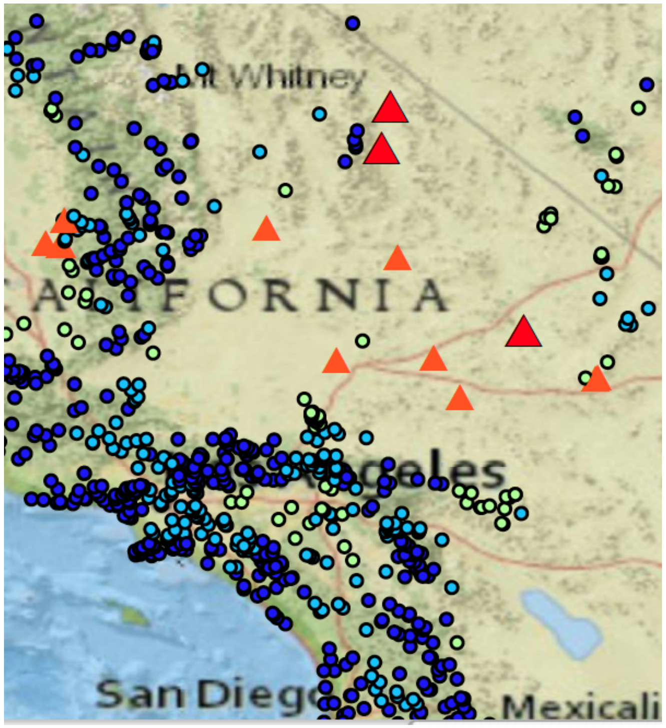
At the sites of *Uta* extinction

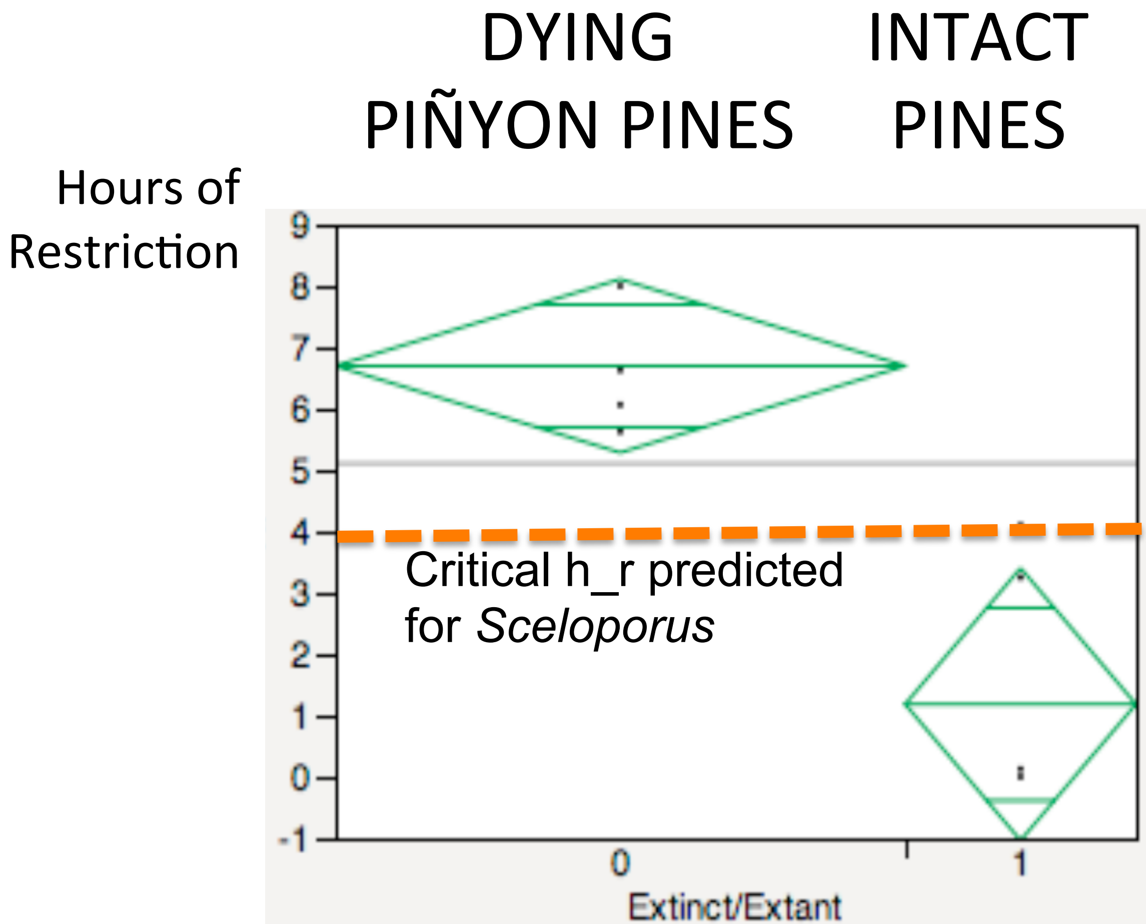
Hours of restriction of activity time is greater for extinct sites by 1 hour compared to persistent sites



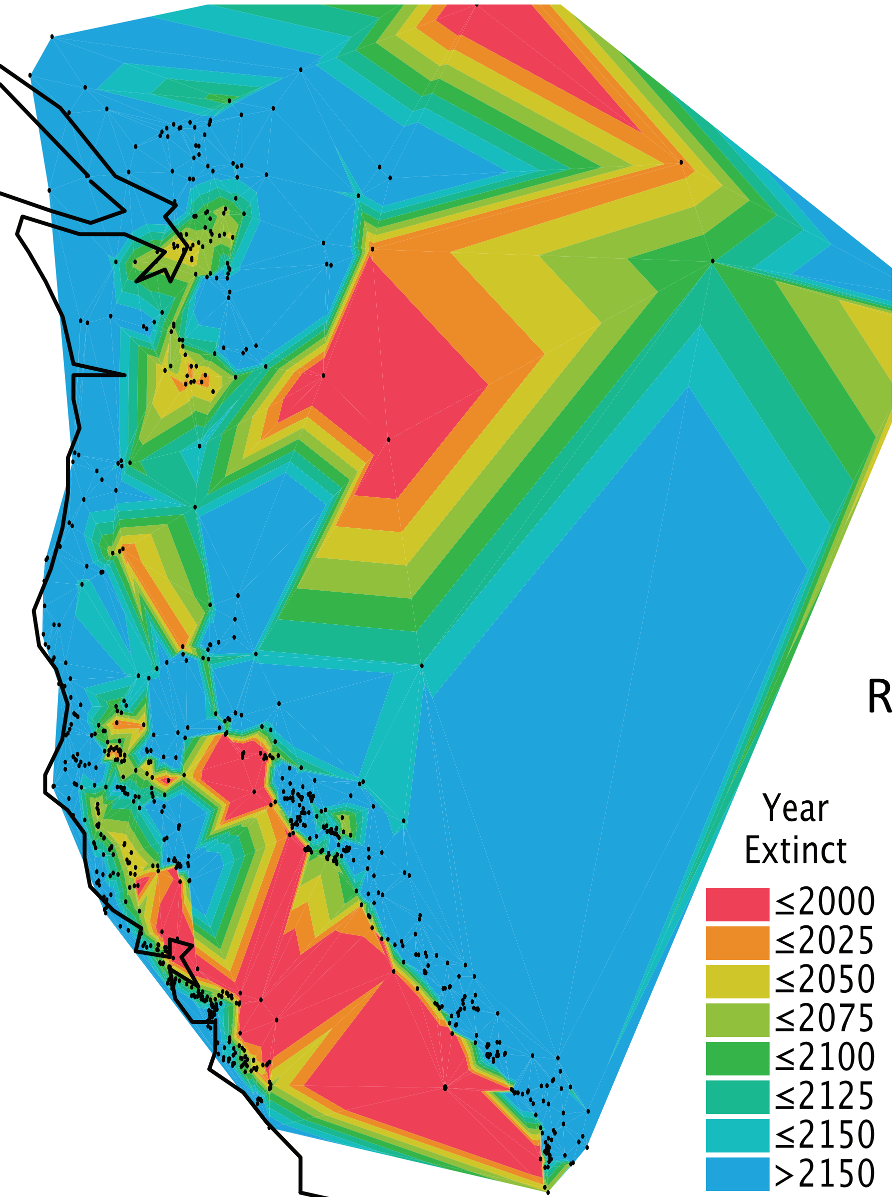


Western fence lizard validation of h_r for extinct vs persistent sites

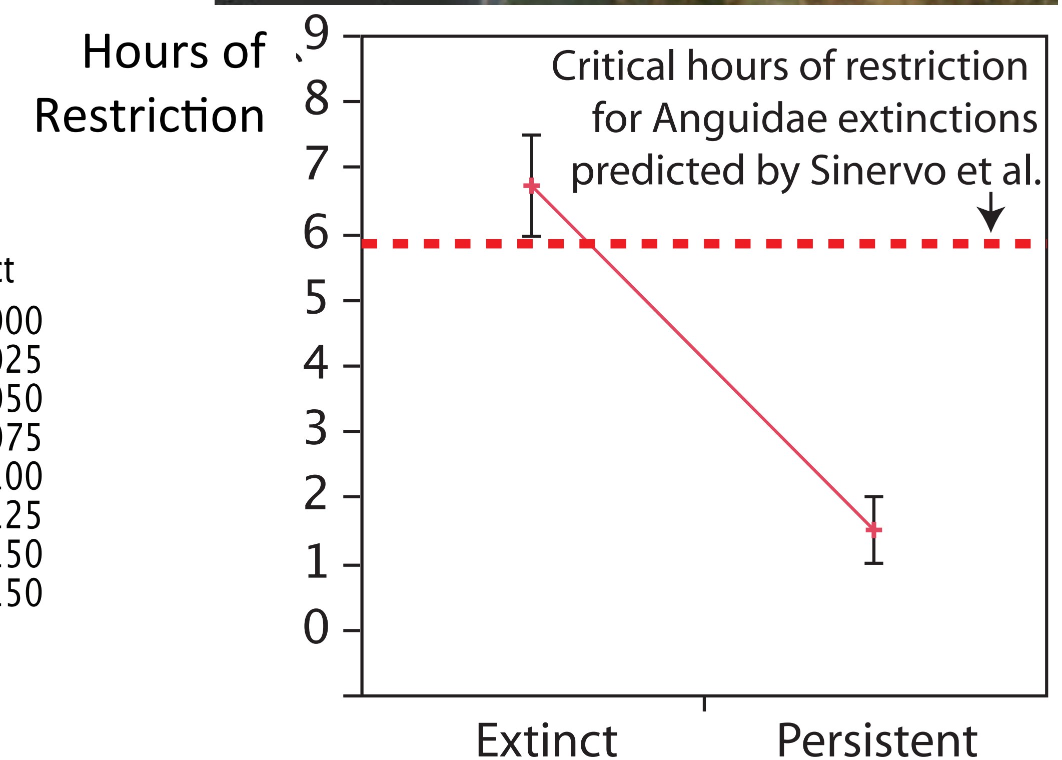




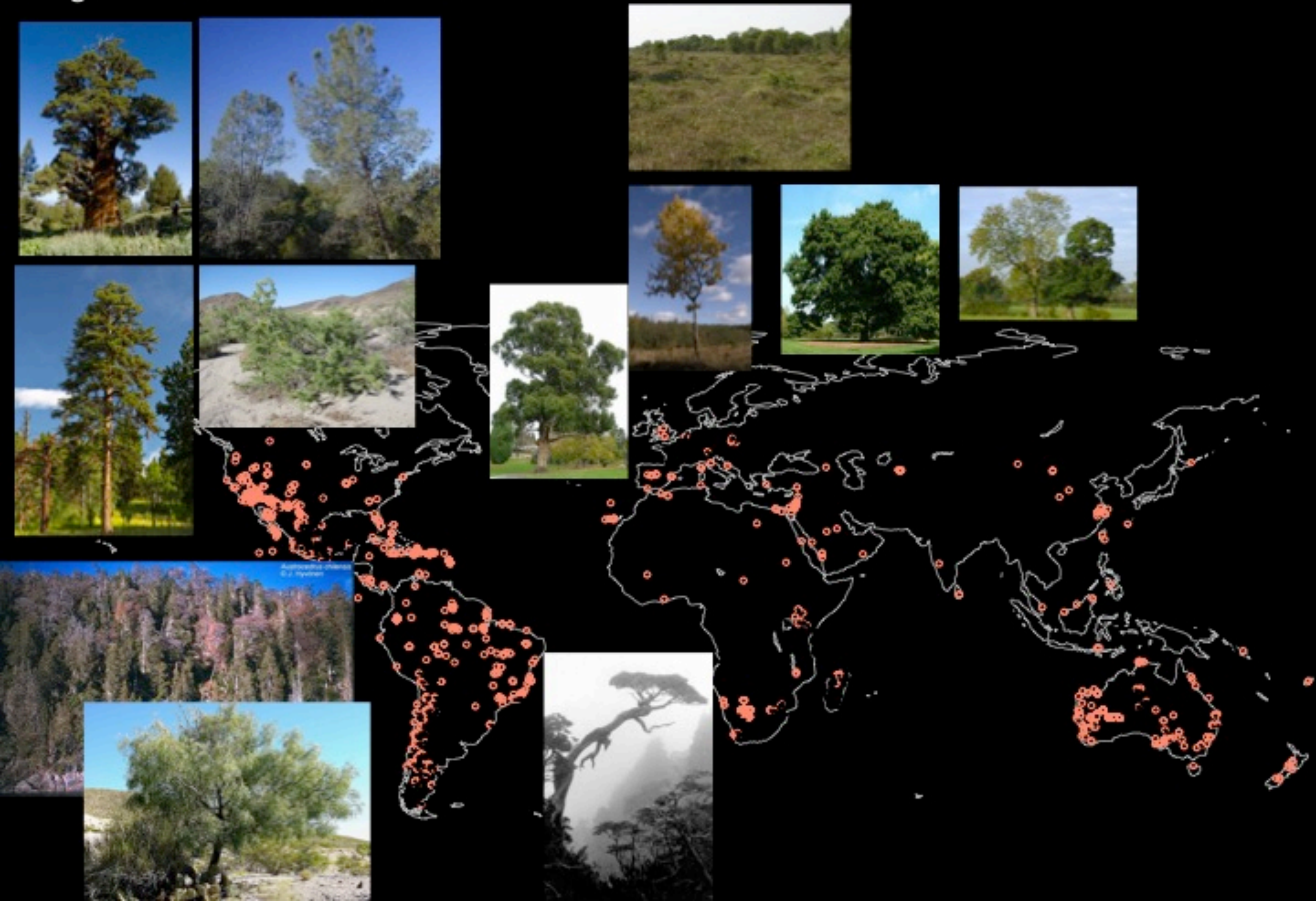
Robert B. Cooper Honors Thesis, UC Santa Cruz

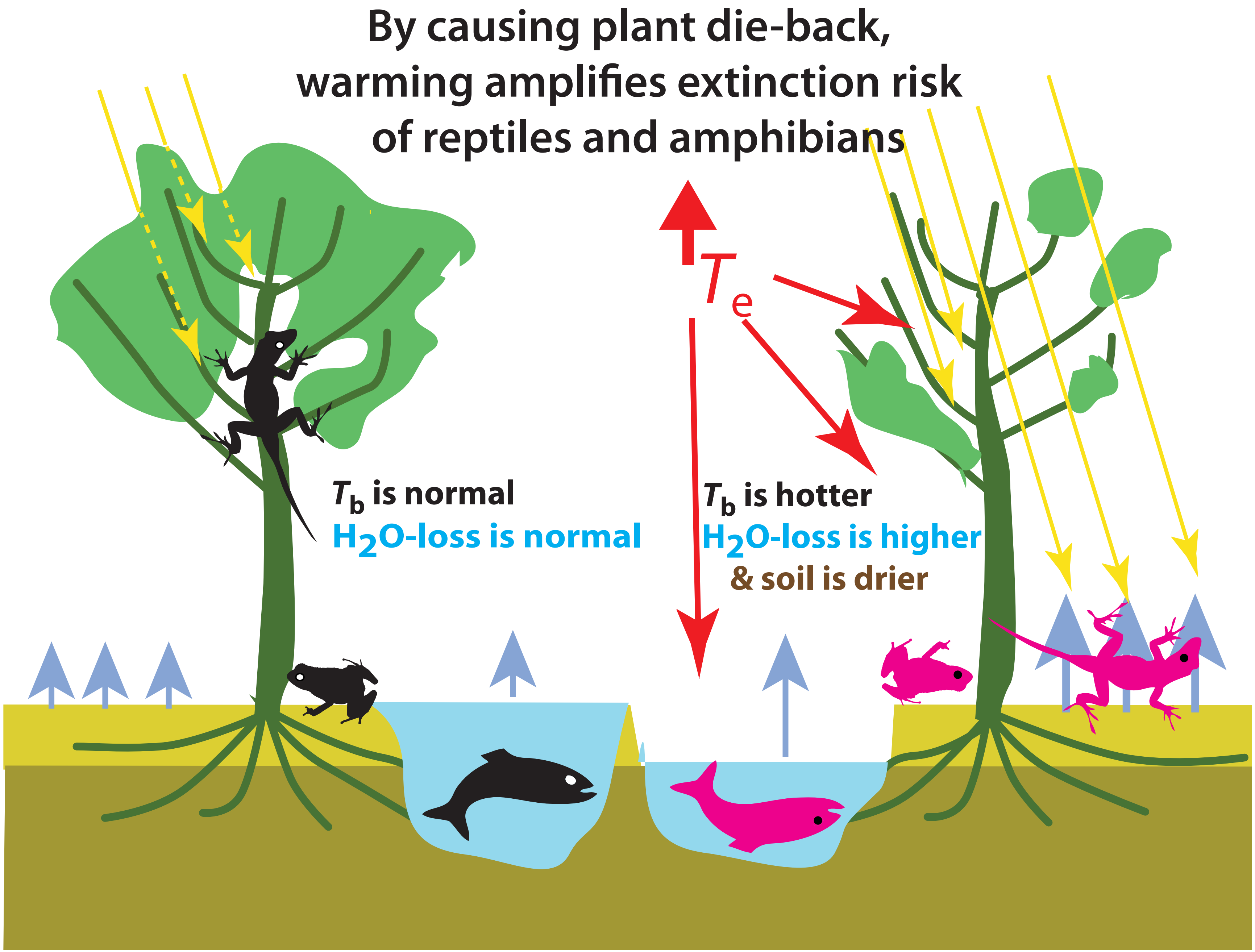

Year
Extinct
≤2000
≤2025
≤2050
≤2075
≤2100
≤2125
≤2150
>2150


San Jose
Santa Cruz
Monterey
25 km


Hours of
Restriction
9
8
7
6
5
4
3
2
1
0
Critical hours of restriction
for Anguidae extinctions
predicted by Sinervo et al.
Extinct
Persistent

Plants are dying off at all the lizard extinction sites. We are now checking for extinctions of frogs and salamanders and freshwater fish

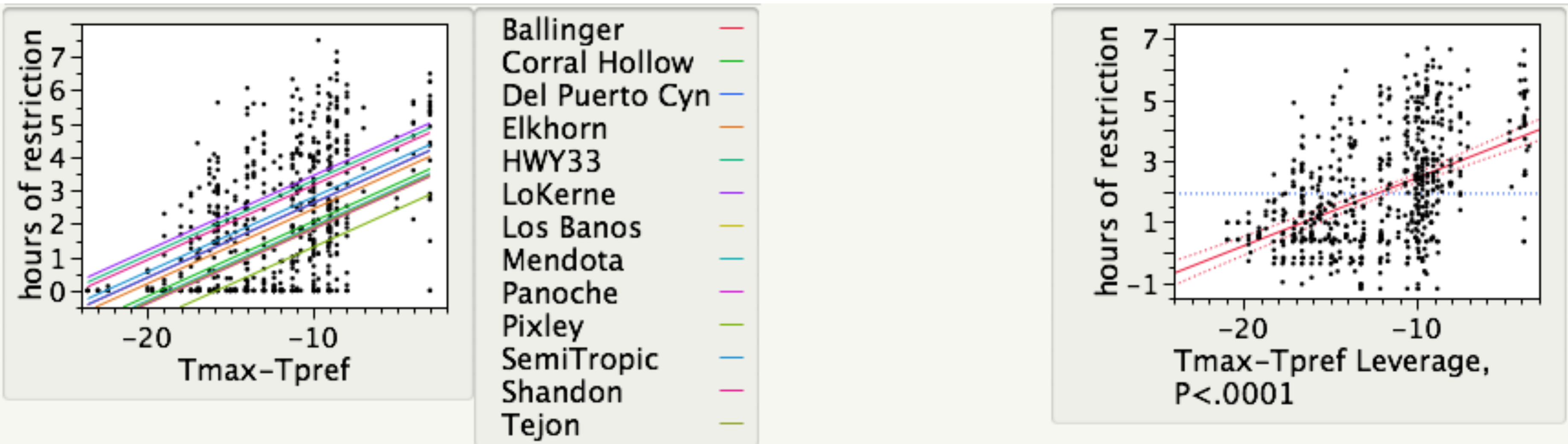



By causing plant die-back, warming amplifies extinction risk of reptiles and amphibians
T_e
T_b is normal
H_2O-loss is normal
T_b is hotter
H_2O-loss is higher
& soil is drier

BNLL Methods

- Deploy data loggers hooked up to 4 BNLL models (2 sizes: gravid female and sub-adult) at
- In vegetation, full sun, holes
- Data collected from September – November during hot to cool weather
- Download Tmax data from adjacent Weather Stations 10-20 km distant
- Regress h_r on $(T_{max} – T_b)$
- Use WorldClim.org Tmax surfaces to compute h_r at each known location (Herpnet.org)
- When $h_r > h_{r,critical}$ population assumed to go extinct

The fit for T_e across sites and pooled higher Tmax increases hours of restriction for foraging

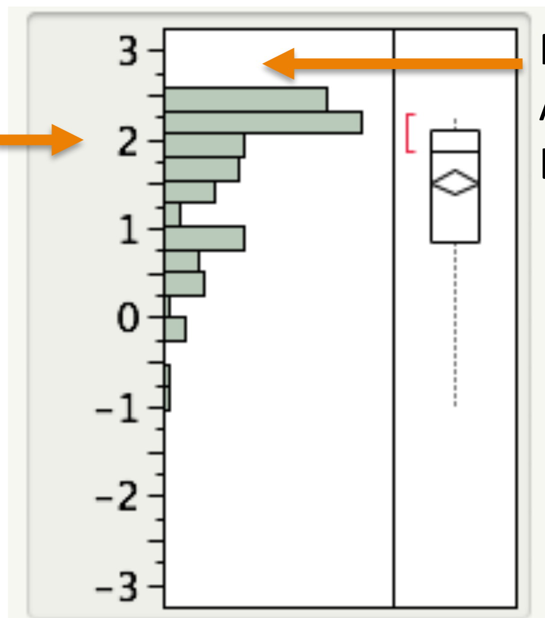


BNLL vs LNLL distributional limits defined by hours of restriction, h_r

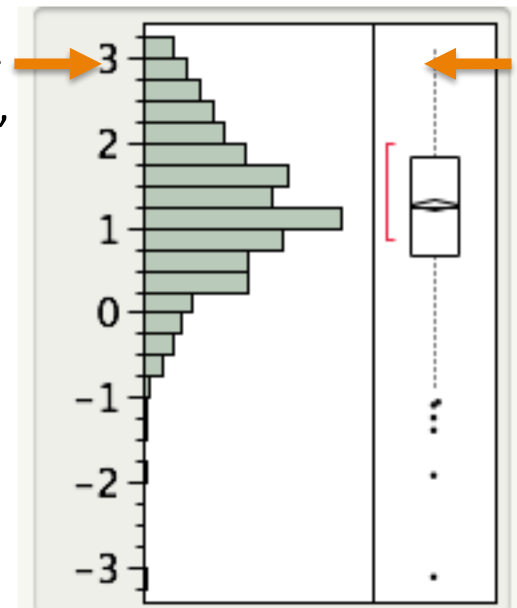
BNLL hottest site is 2.6 h

LNLL hottest site is 3.1 h

The shape of the distribution of hr for BNLL is a severe liability: many populations on the valley floor are close to climate forcing extinction limits.



Room for BNLL Adaptation c.f., LNLL h_r limits?



Only a small fraction of LNLL are near the upper limit so few are at risk of extinction.

The ancestral LNLL Tolerates hotter spots than the BNLL and the LNLL has a higher Tb in the field: 38.9 for LNLL vs 39 C for BNLL

We ran two physiological scenarios

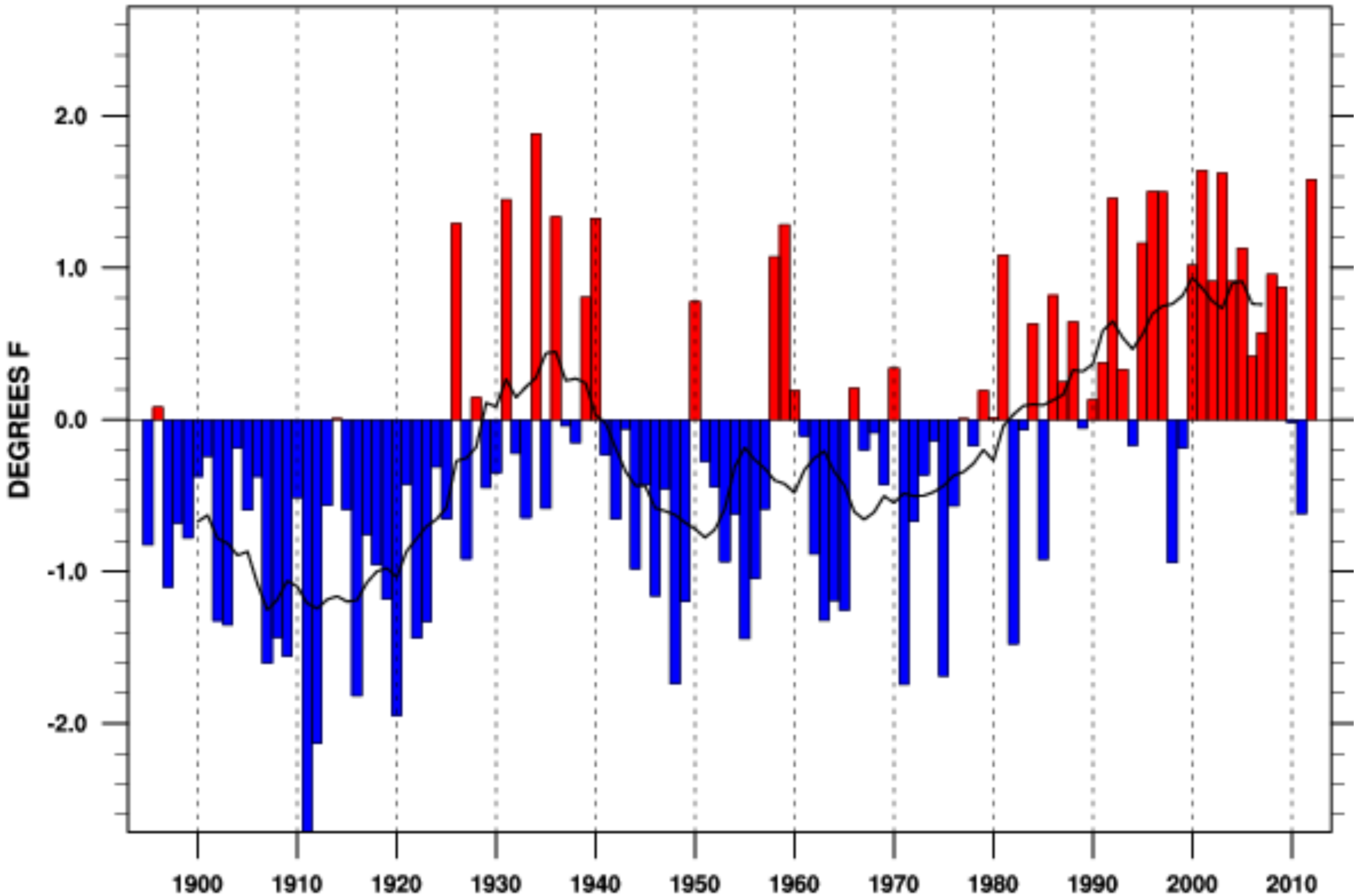
- The BNLL shows regional Tb adaptation:

T_b = 38.0 C and hours of restriction (h_r) in the hottest site in the central valley is the current limit ($h_{r,critical}$=2.6)

- The BNLL could potentially achieve limits seen in the LNLL (which is found at hotter sites)

T_b = 38.9 C and hours of restriction (h_r) in the hottest site of the LNLL also sets the current limit for BNLL (e.g., assume BNLL $h_{r,critical}$=3.1)

San Joaquin Valley Region
Mean Temperature Departure Jan-Dec



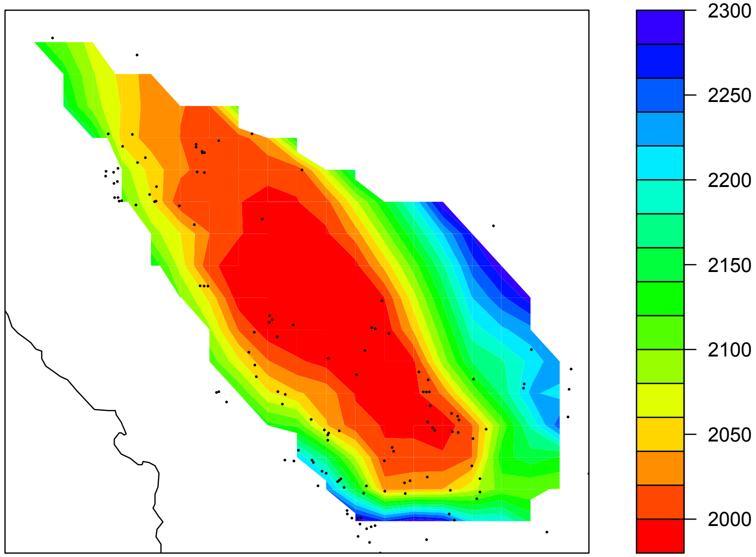
Black Line Denotes 11 -year Running Mean
Departures from 1949-2005 Base Period

Western Regional Climate Center

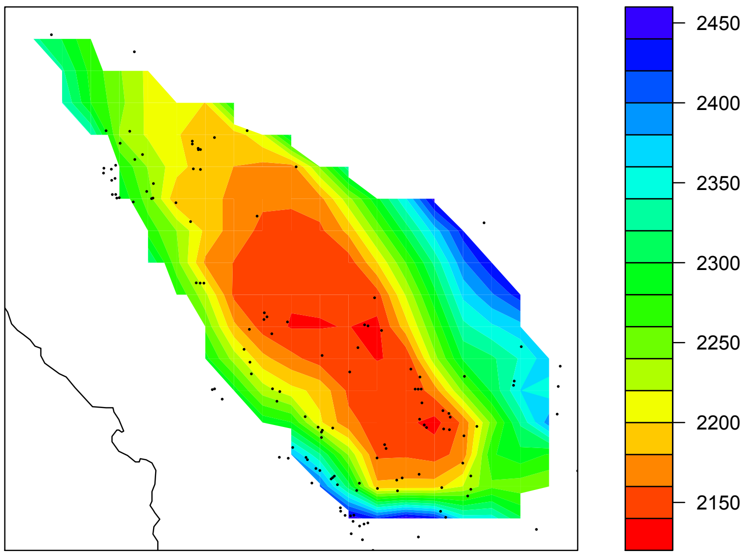
Linear Trend 1895-present + 1.37 ± 0.45 °F/100yr

Linear Trend 1949-present + 2.56 ± 1.05 °F/100yr

Scenario 1: BNLL has no plasticity in Behavioral Thermoregulation



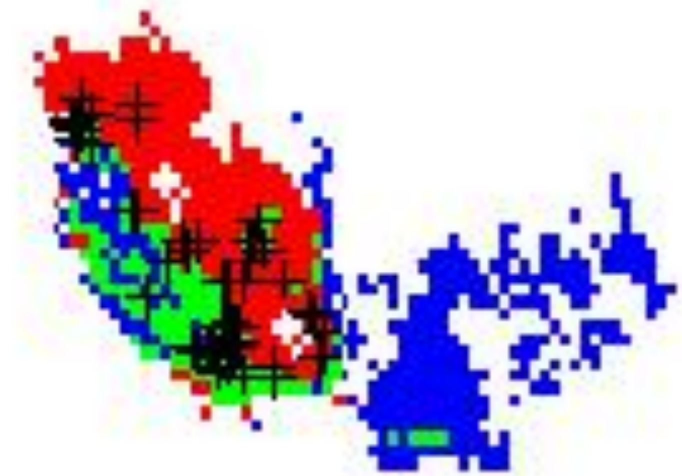
Scenario 1: BNLL can achieve ancestral thermal adaptation seen in LNLL



MAXENT confirms extinction risk

Current

Lost – Red, Persist – Green
Colinization -- Blue

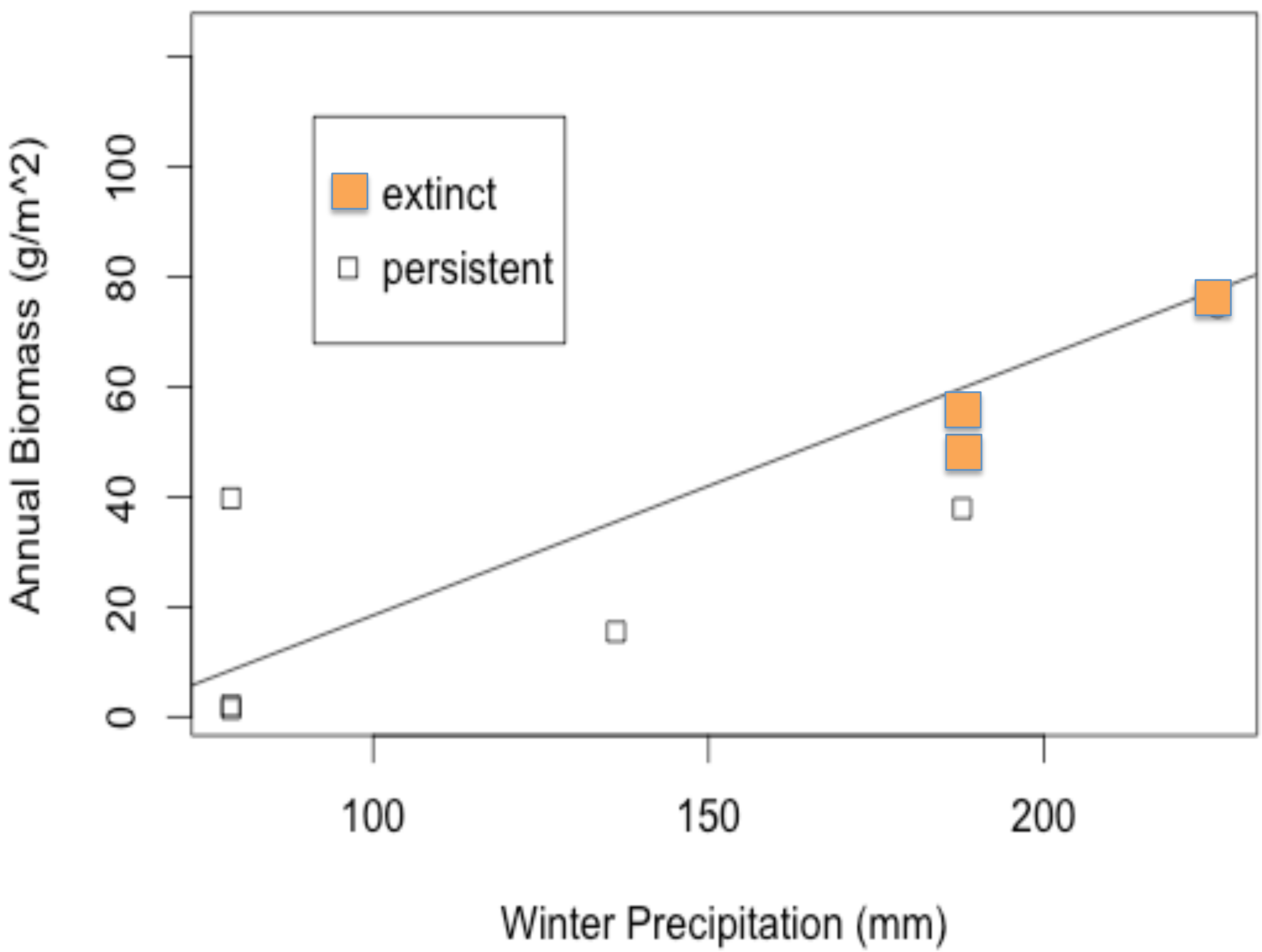


The BNLL cannot expand to blue
Because the LNLL is there

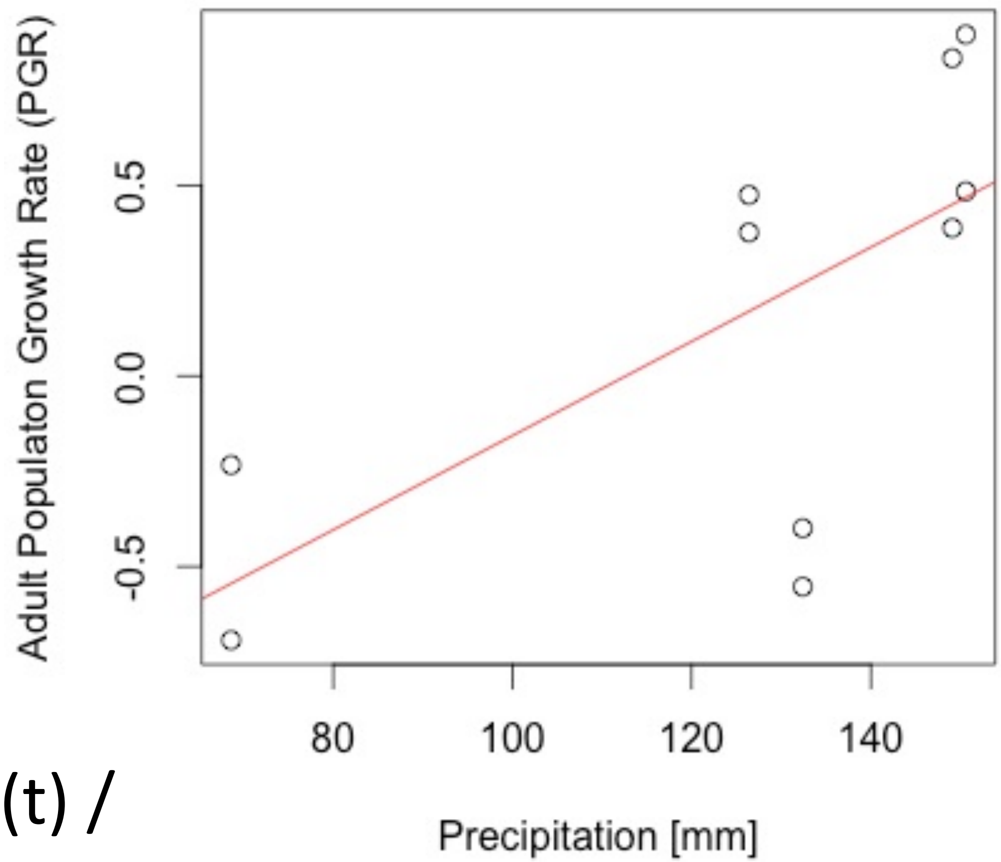
Conclusions

- The populations on the floor of the Central Valley are at grave risk of extinction in the next 100 years
- This leaves the Carrizo, and to a lesser extent the Panoche, as the only long-term refuges from climate change (and Tejon Ranch)

Effects of Winter Precipitation and Biomass on Population Status

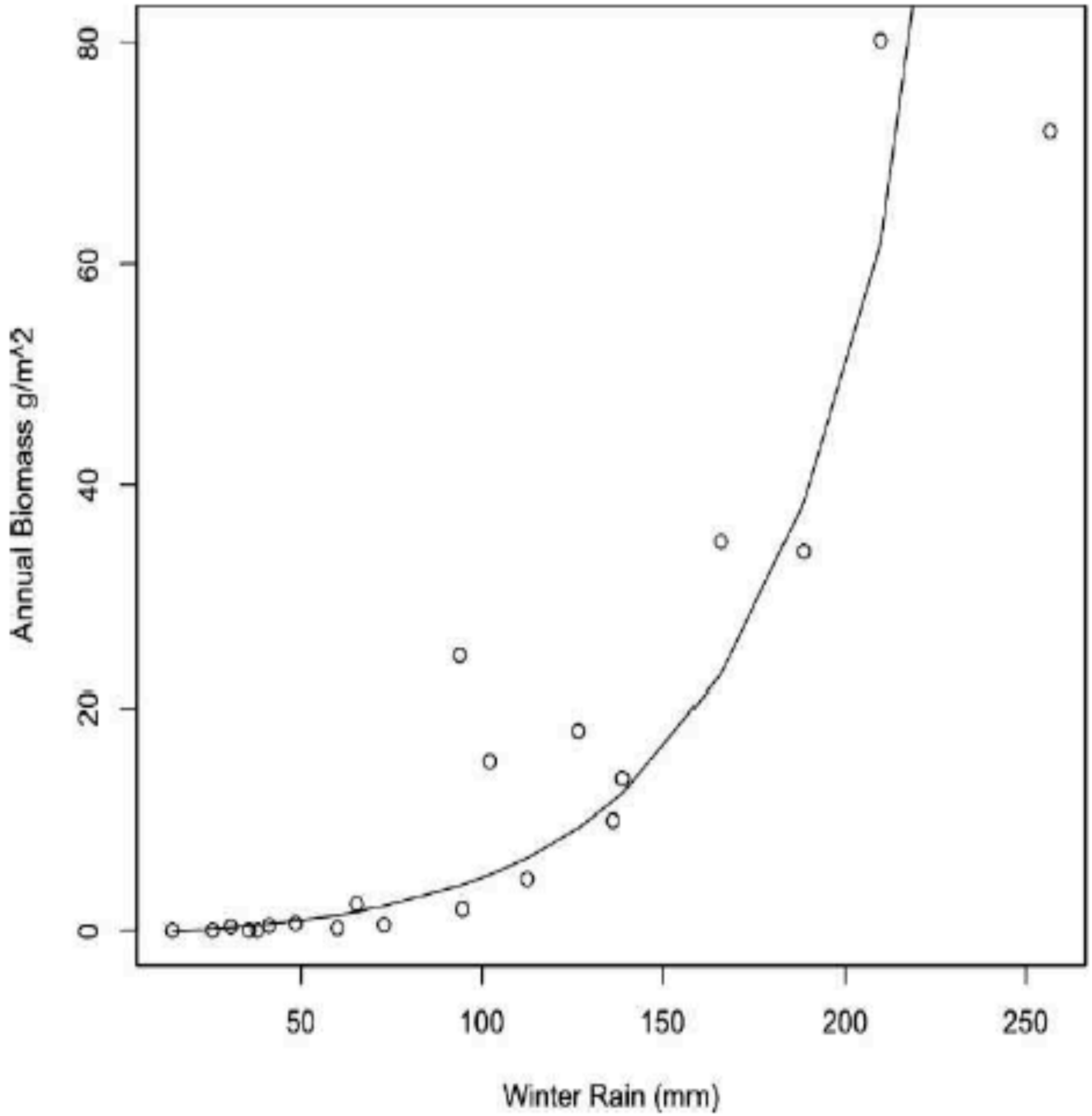


Precipitation impacts recruitment! So extended droughts can drive rapid future extinctions

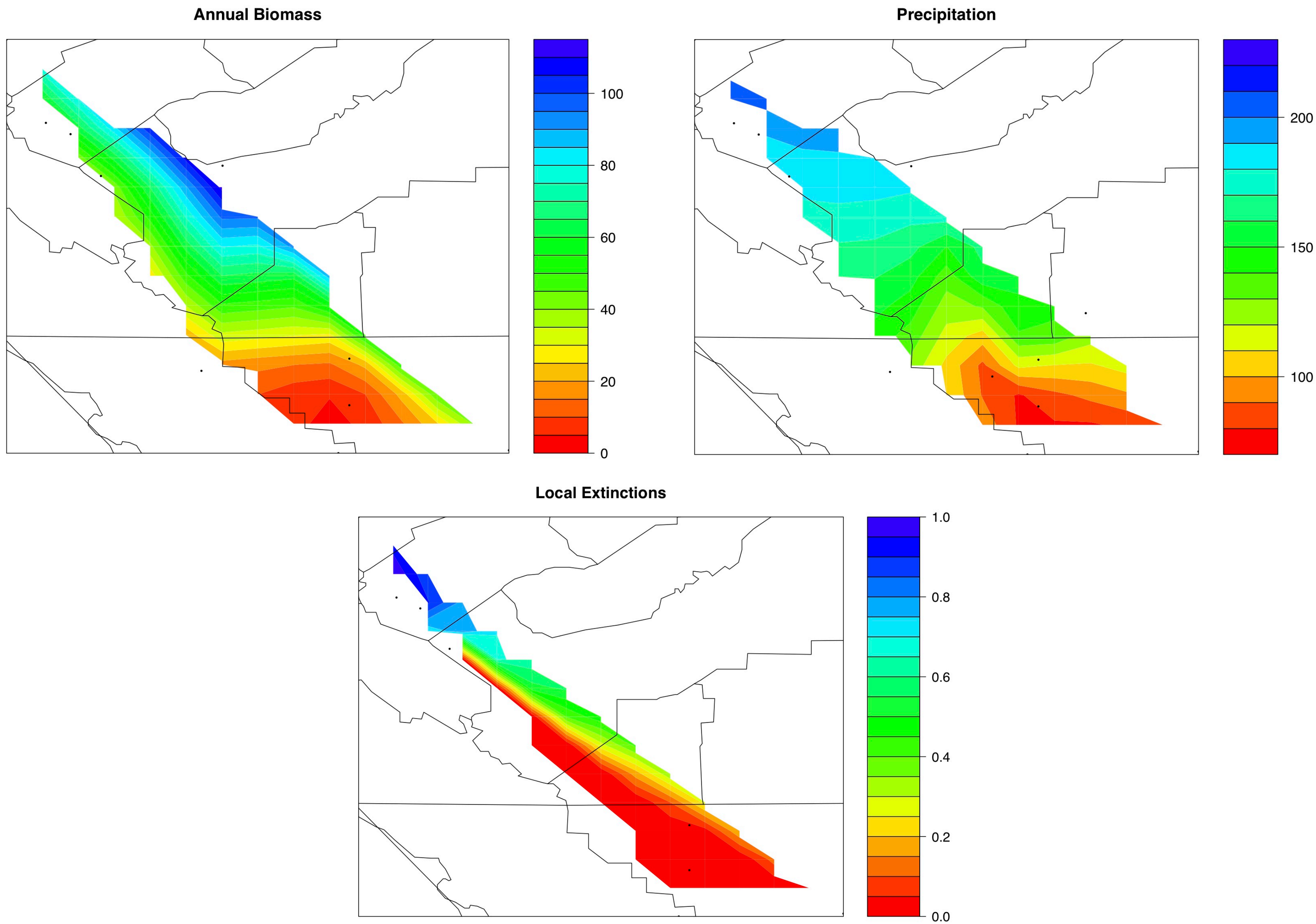


PGR = ln(Num_Adults(t) / Num_Adults(t-1))

Data from Germano and Williams 2005



Data from the Mojave



Annual Biomass
0
20
40
60
80
100
Precipitation
100
150
200
Local Extinctions
0.0
0.2
0.4
0.6
0.8
1.0

European Jeweled Lizard (*Timon lepidus*) – also going extinct from Land use change – Lapse of agriculture allowing Forests to grow back

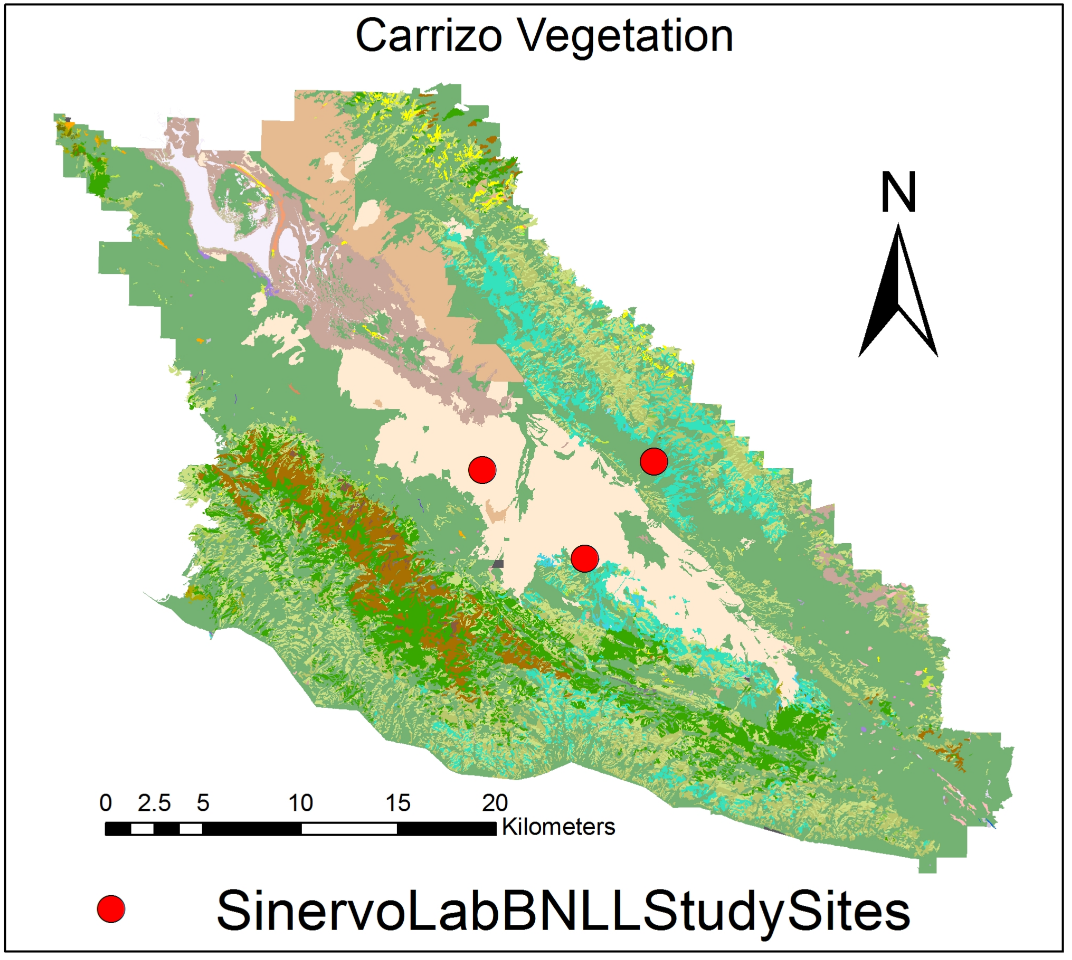
Future models and refinements

- In collaboration with Cam Barrows (UCR) use Habitat Niche models that factor in vegetation
- In collaboration with Dave Germano (CSU Bakersfield) use data on demography to develop a Population Viability Model, coupled to temperature and precipitation changes.
- Use Regional Climate Models developed for CA by Lisa Sloan (UCSC) and also refined estimates by Bruno Sanso that remove the biases of current IPCC climate surfaces (e.g., for CA, IPCC poorly predicts observed decreases to summer monsoon rains and winter rains). This may explain extinctions in the center of BNLL range

Vegetation and BNLL

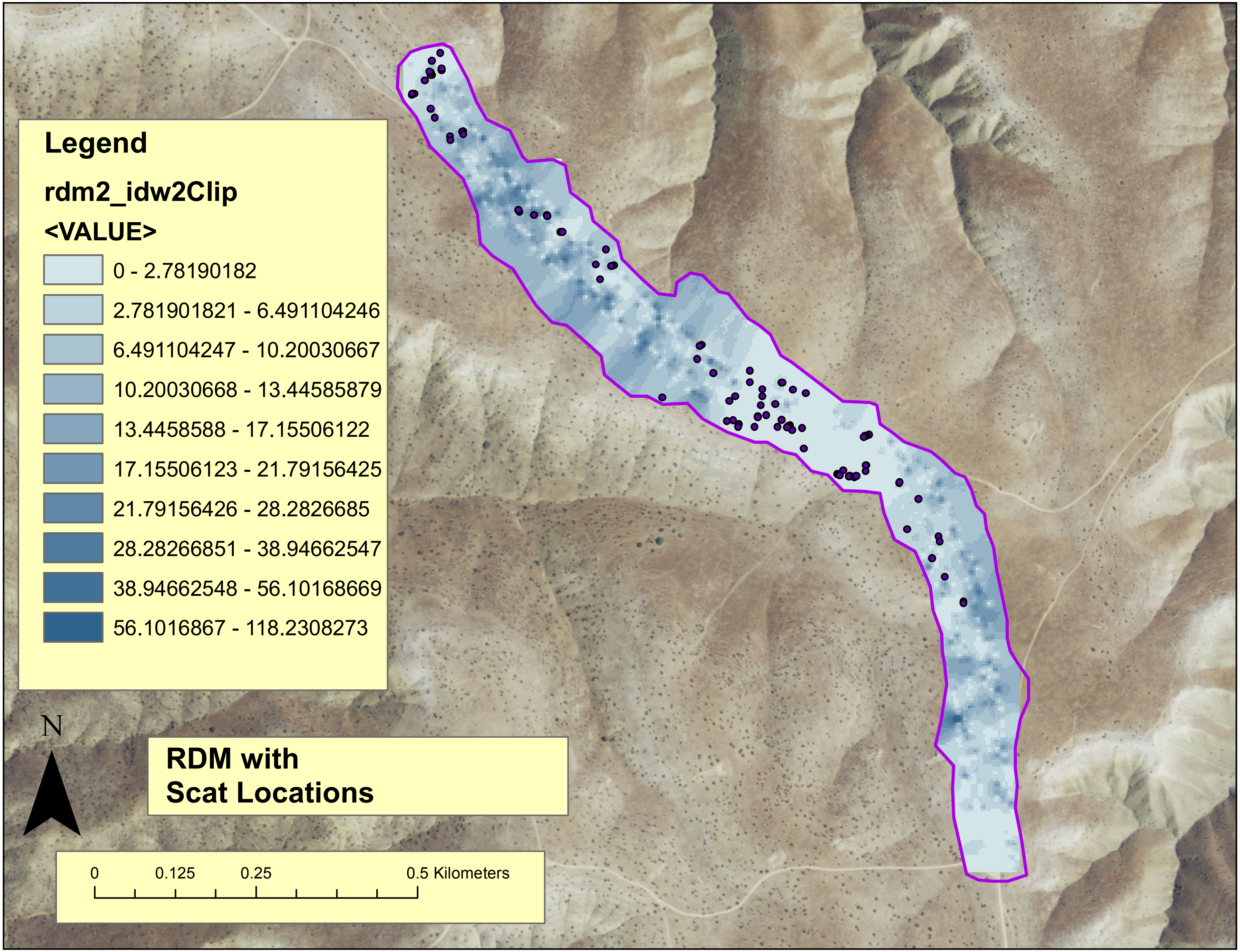
Integrating:

- Residual Dry Mass
- NDVI
- CNPS Veg Maps
- Climate Forecasts



Microhabitat (from the Panoche)

- Measure RDN every 5 m over a 1 km transect
- Measure BNLL use of bushes with Dogs trained to sniff BNLL poop (Dogs for Conservation)
- Association of RDM and BNLL habitat use



Legend
rdm2_idw2Clip
<VALUE>
0 - 2.78190182
2.781901821 - 6.491104246
6.491104247 - 10.20030667
10.20030668 - 13.44585879
13.4458588 - 17.15506122
17.15506123 - 21.79156425
21.79156426 - 28.2826685
28.28266851 - 38.94662547
38.94662548 - 56.10168669
56.1016867 - 118.2308273
N
RDM with
Scat Locations
0
0.125
0.25
0.5 Kilometers

Contemporary climate-forced reptile extinctions in the Mojave Desert and accelerated extinctions due to proposed Solar Plant Projects: Desert Tortoise

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University of California, Santa Cruz

With:

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Robert B. Cooper, UCSC

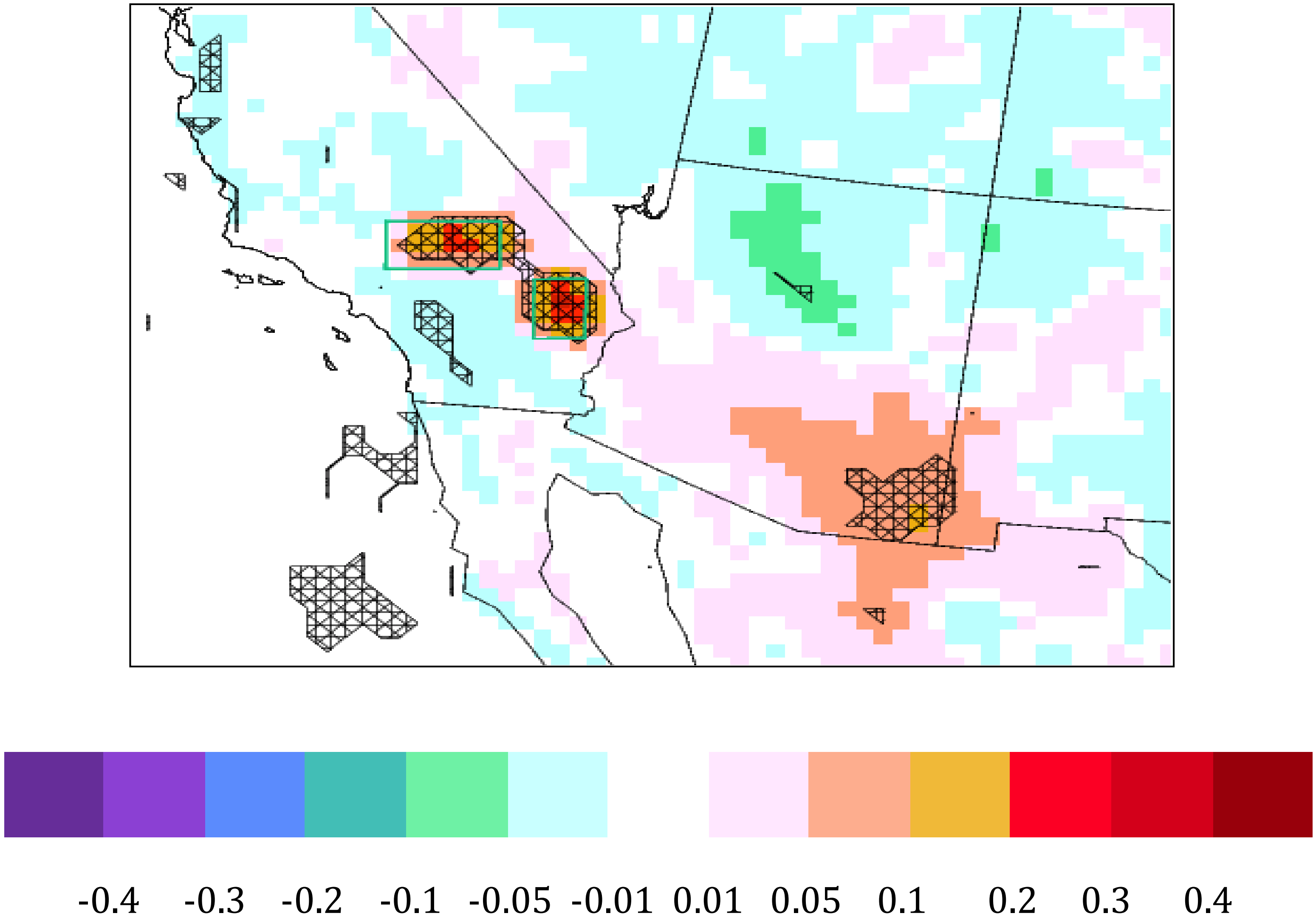
Amy Patten, Humbolt University

Ray Huey, UW

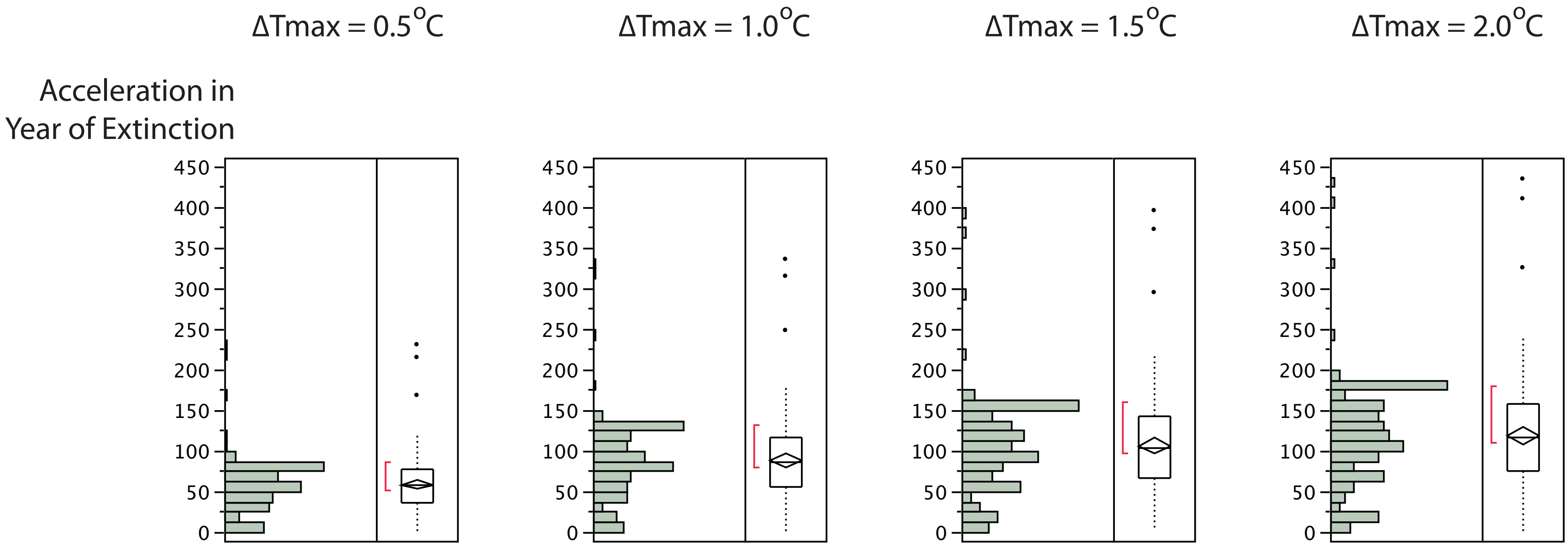
Jeff Lovich and Josh Ennen, USGS

and many more …….

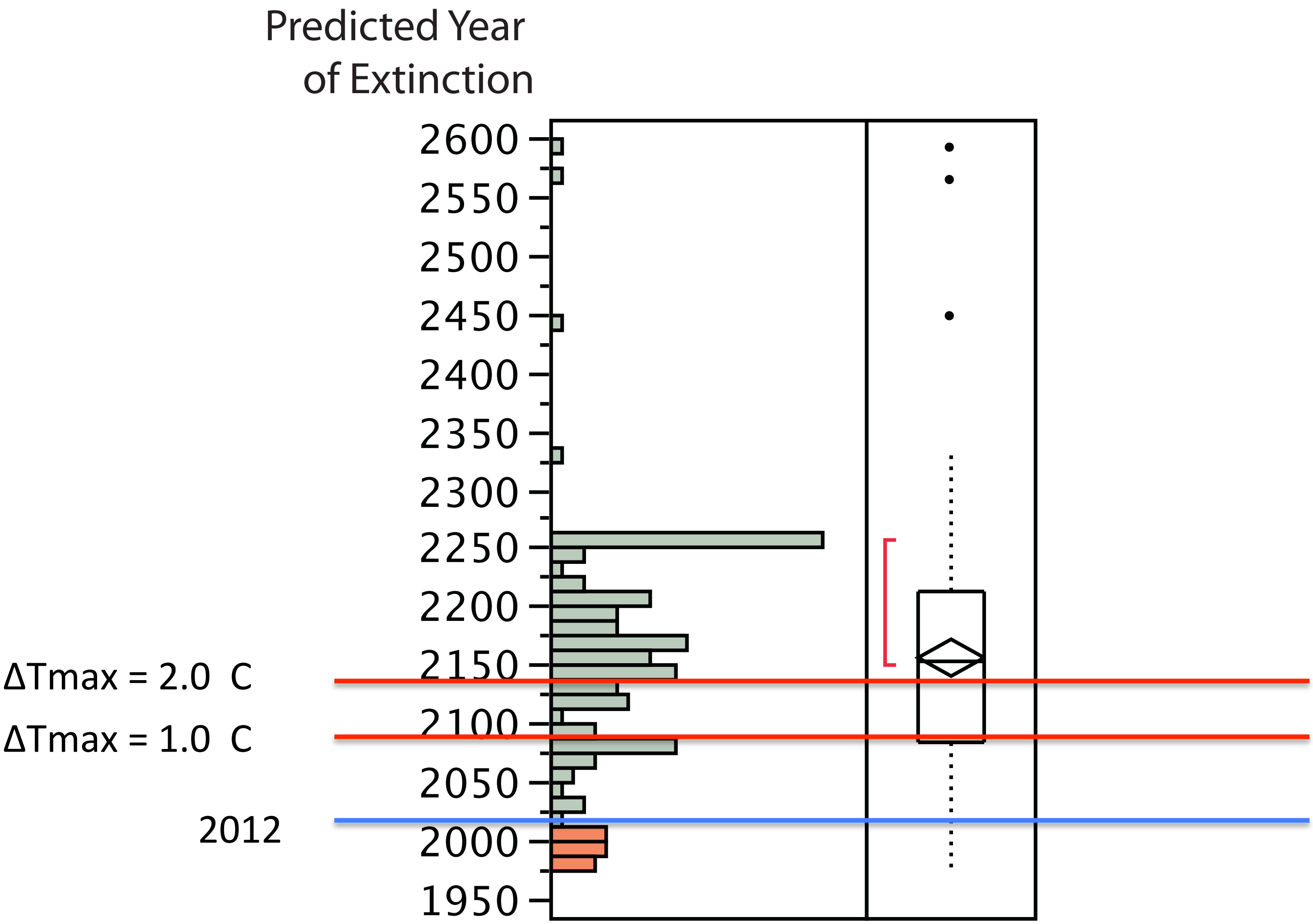
Millstein & Menton (2011) Env. Res. Letters
Solar Farms as Urban Heat Islands

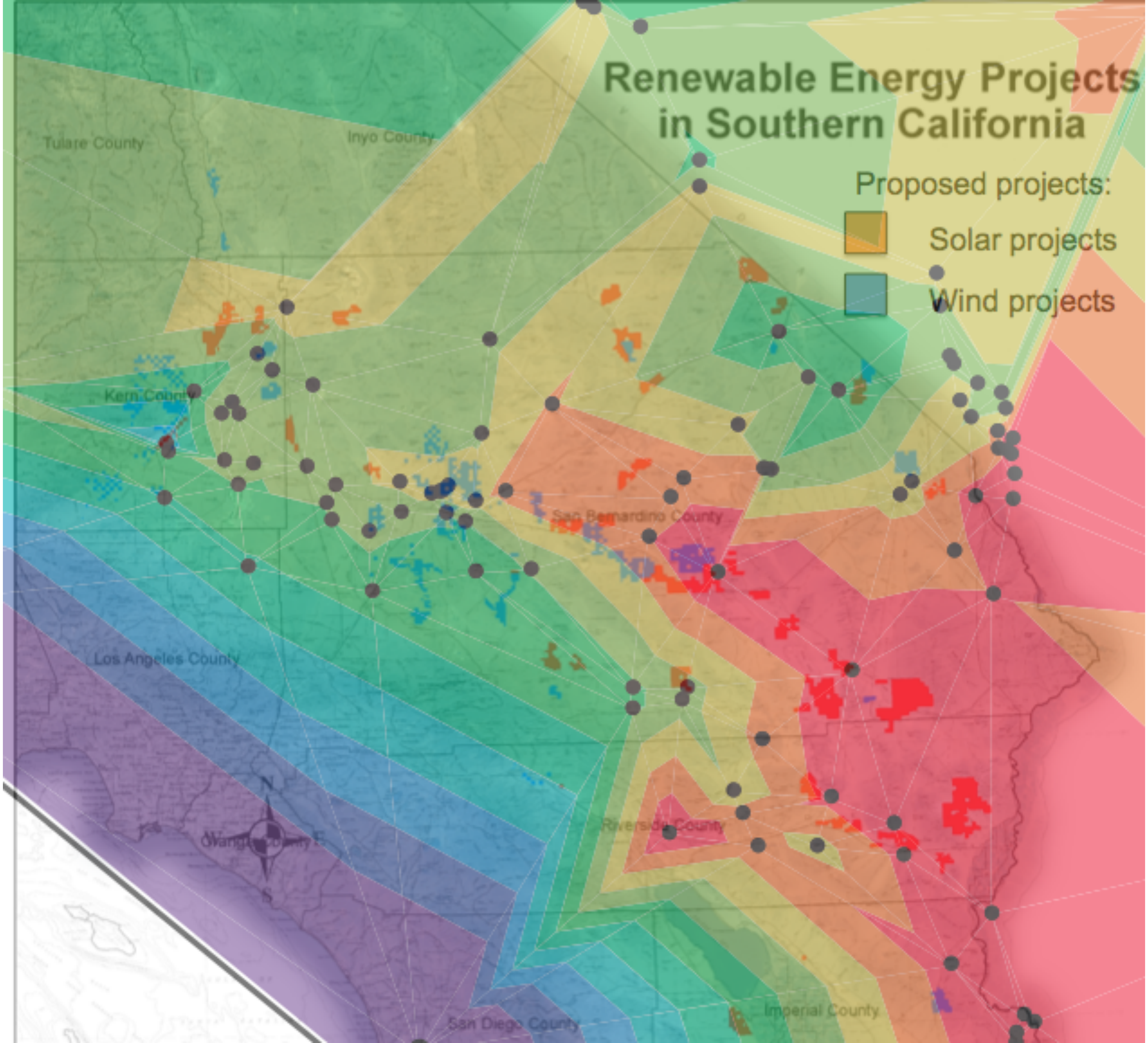


Hypothetical acceleration in onset of extinction from solar plants if they elevate T_{max} in nearby habitat



Year of climate-forced extinction




Renewable Energy Projects
in Southern California
Proposed projects:
Solar projects
Wind projects
Tulare County
Inyo County
Kern County
San Bernardino County
Los Angeles County
Orange County
Riverside County
San Diego County
Imperial County

Funding

- Thanks to the BLM and TNC for funding
- And to NSF Macrosystems

New Solar

- Panels that have low impact
- Clear, and only filter out usable solar leaving vegetation intact
- Sue Carter, UCSC