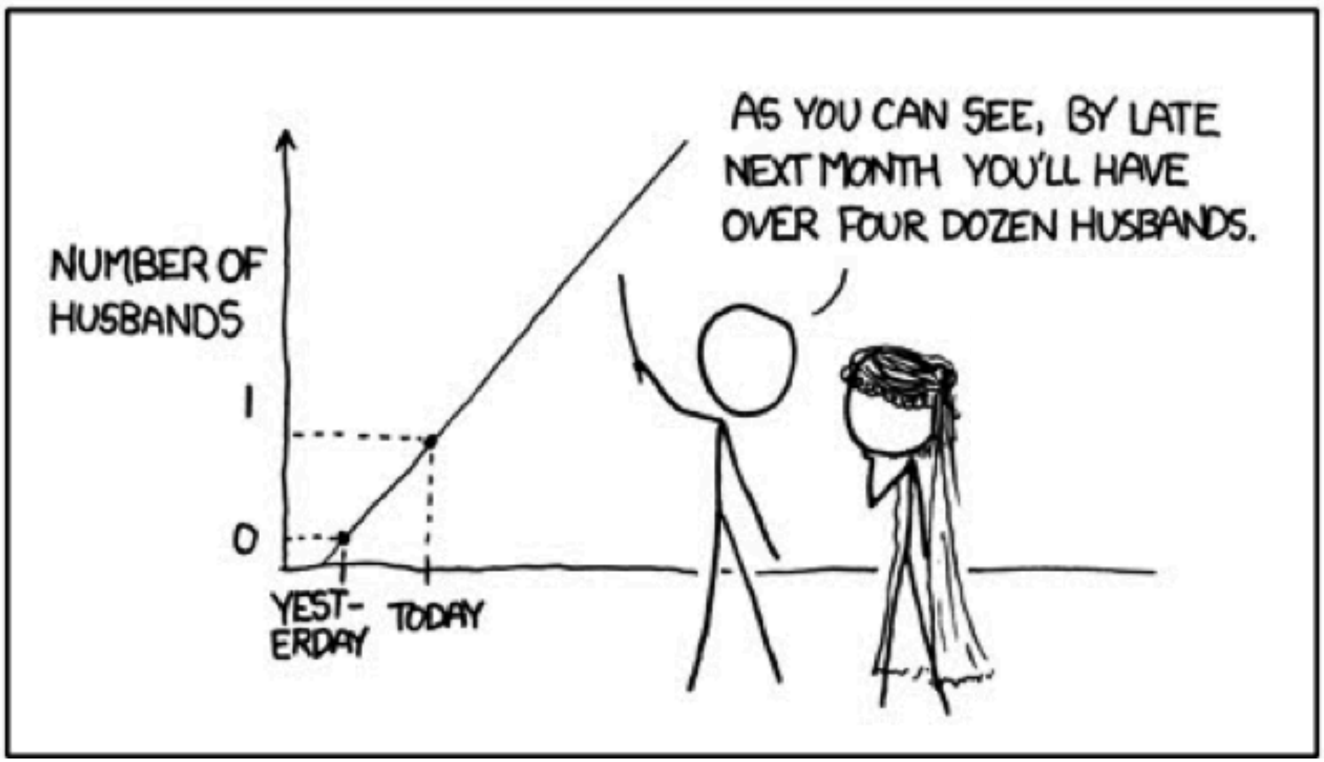
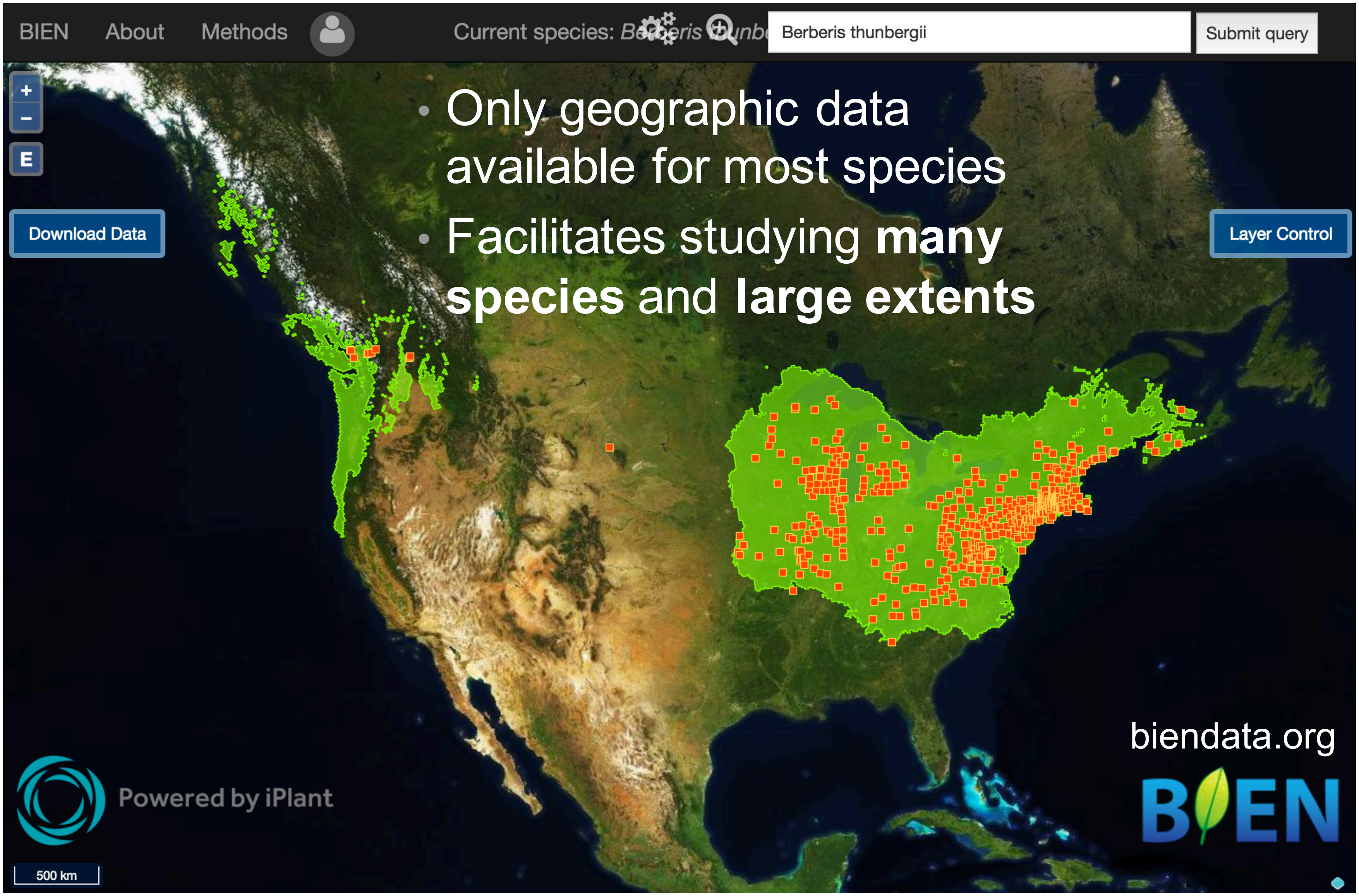
Forecasting, Extrapolation and Uncertainty

MY HOBBY: EXTRAPOLATING



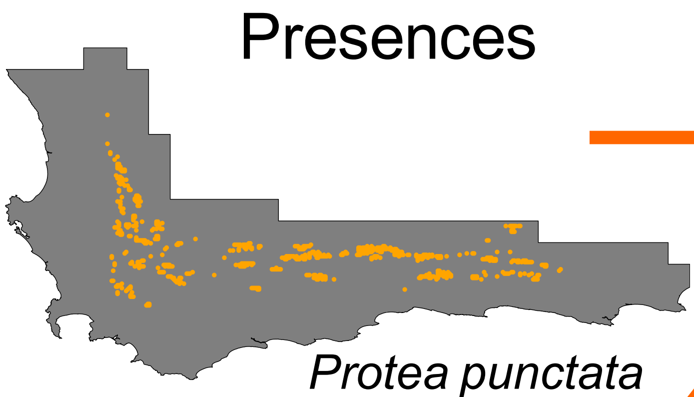
http://xkcd.com

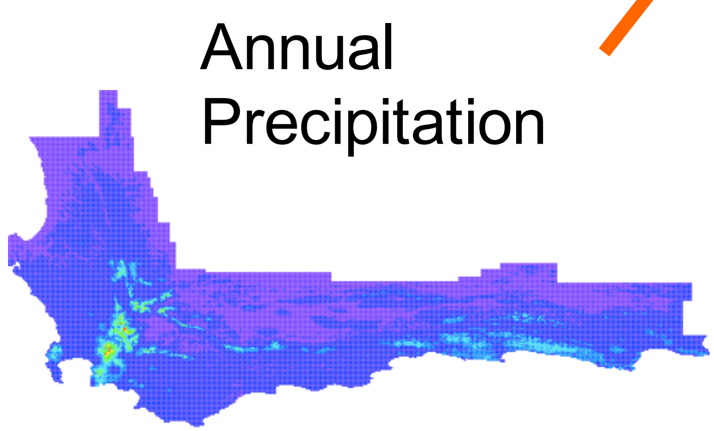
Occurrence patterns: starting point

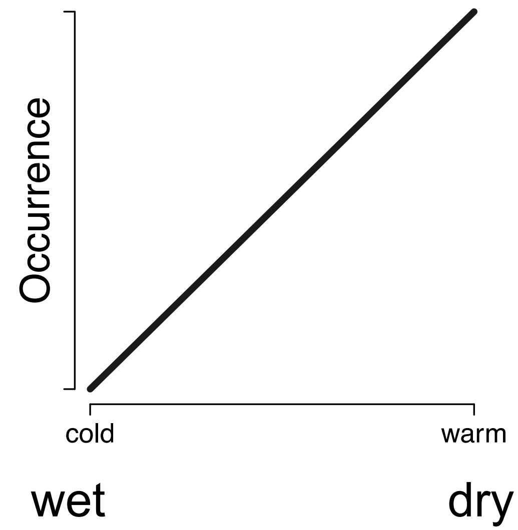


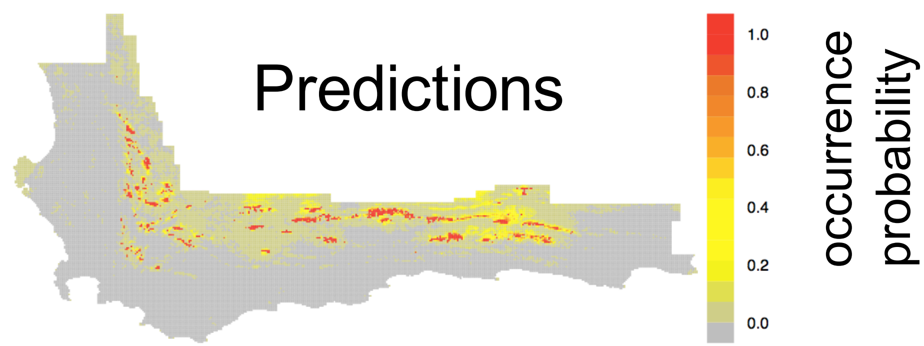
- Only geographic data available for most species
- Facilitates studying **many species** and **large extents**

Occurrence





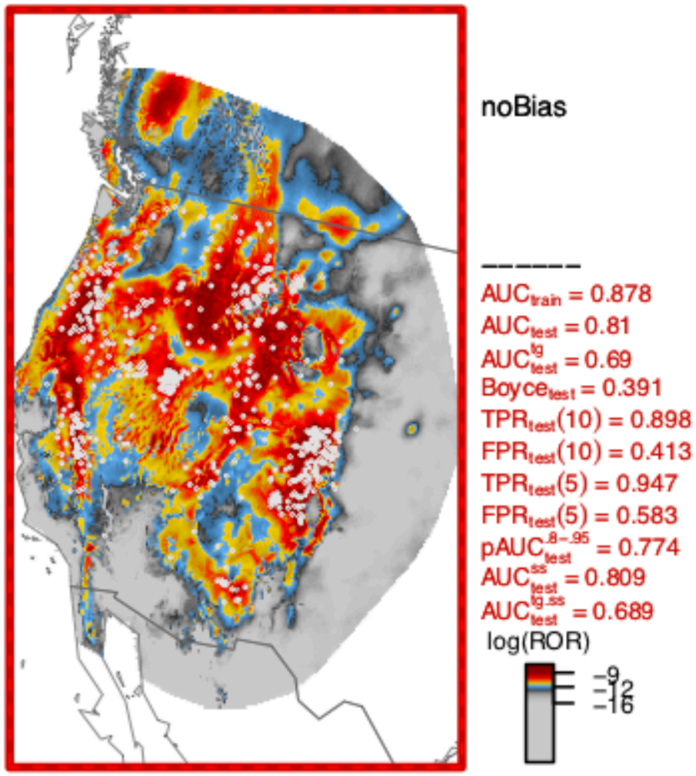




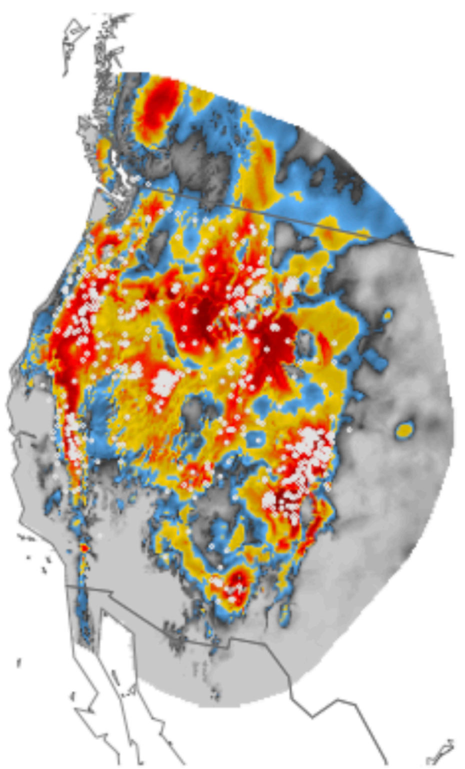
Maxent Guide: Merow et al., 2013, *Ecography*
Maxent v. Maxlike: Merow et al., 2014, *MEE*
Complexity: Merow et al., 2014, *Ecography*
Minxent: Merow et al., 2016, *GEB*
Expert Maps: Merow et al., 2017, GEB

Future Forecasts

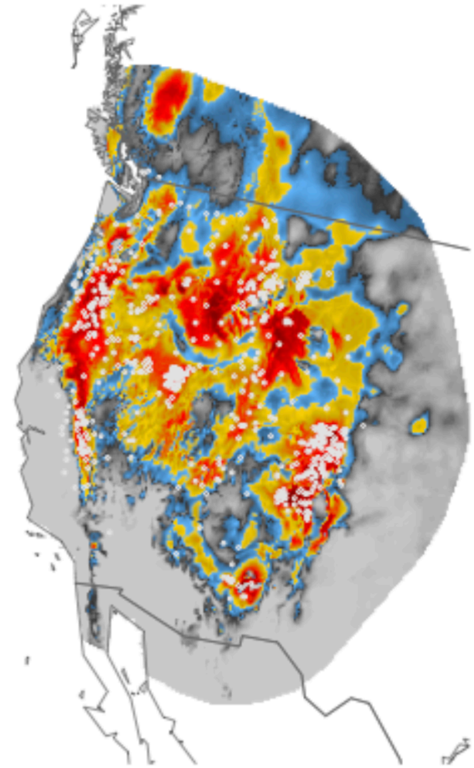
Present



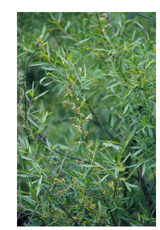
2050: RCP 8.5



2070: RCP 8.5



Salix geyeriana



Outline

Case study

Types of extrapolation

- Environment*
- Space
- Time

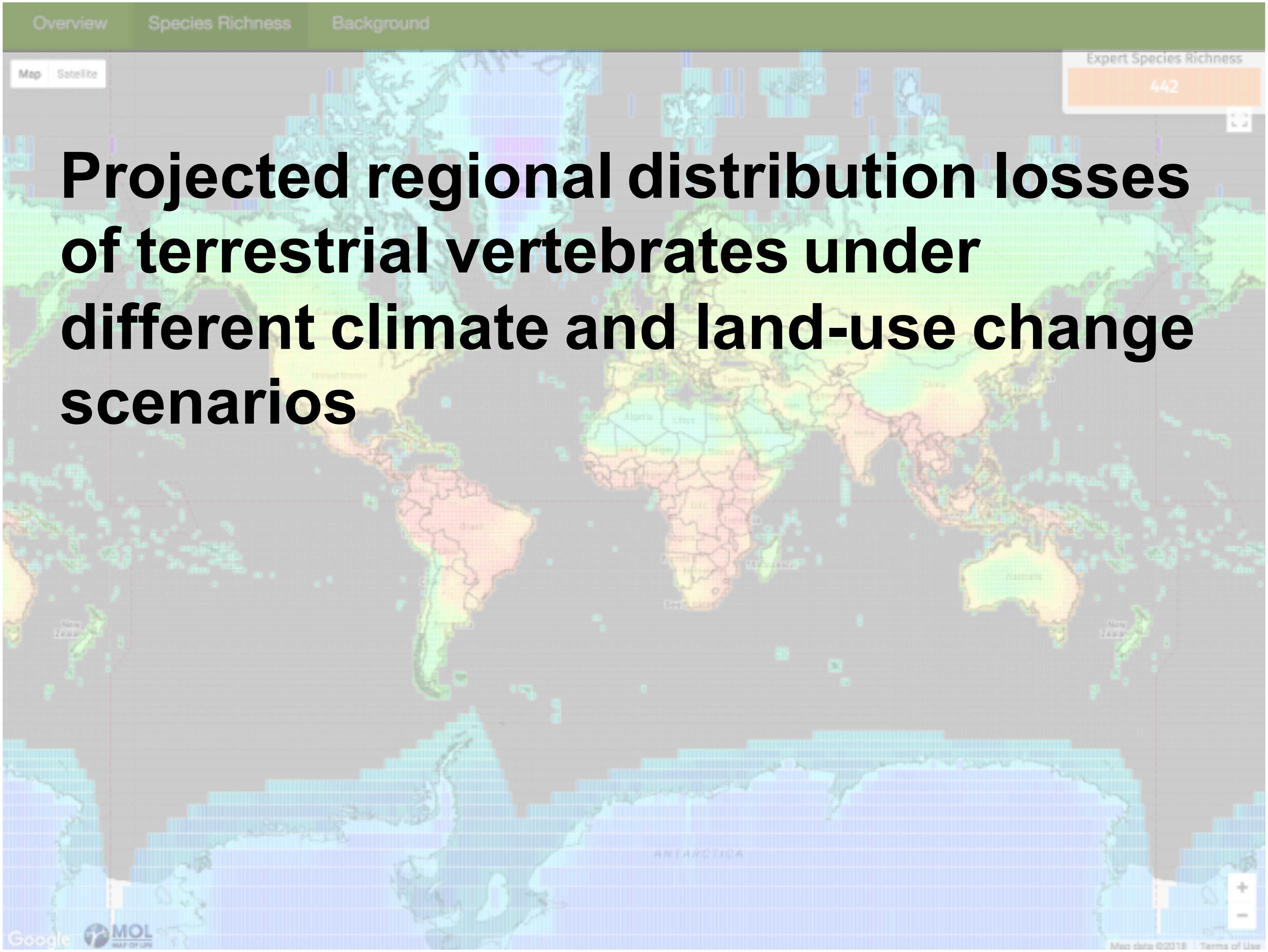
Uncertainty

- Modeling decisions
- Parameters
- Future Scenarios

Where can biology provide guidance?

Case Study

Projected regional distribution losses of terrestrial vertebrates under different climate and land-use change scenarios



Goals

Forecast potential range loss for ~20k

How do

land use change and climate change

contribute to

***EXPECTED* RANGE LOSS** this century?

Informing IPBES

International Panel on Biodiversity and Ecosystem Ser

'provides policymakers with **objective scientific assessments** about the state of knowledge regarding the planet's **biodiversity, ecosystems** and the benefits they provide to people'

Informing IPBES

THE PREPRINT SERVER FOR BIOLOGY

New Results

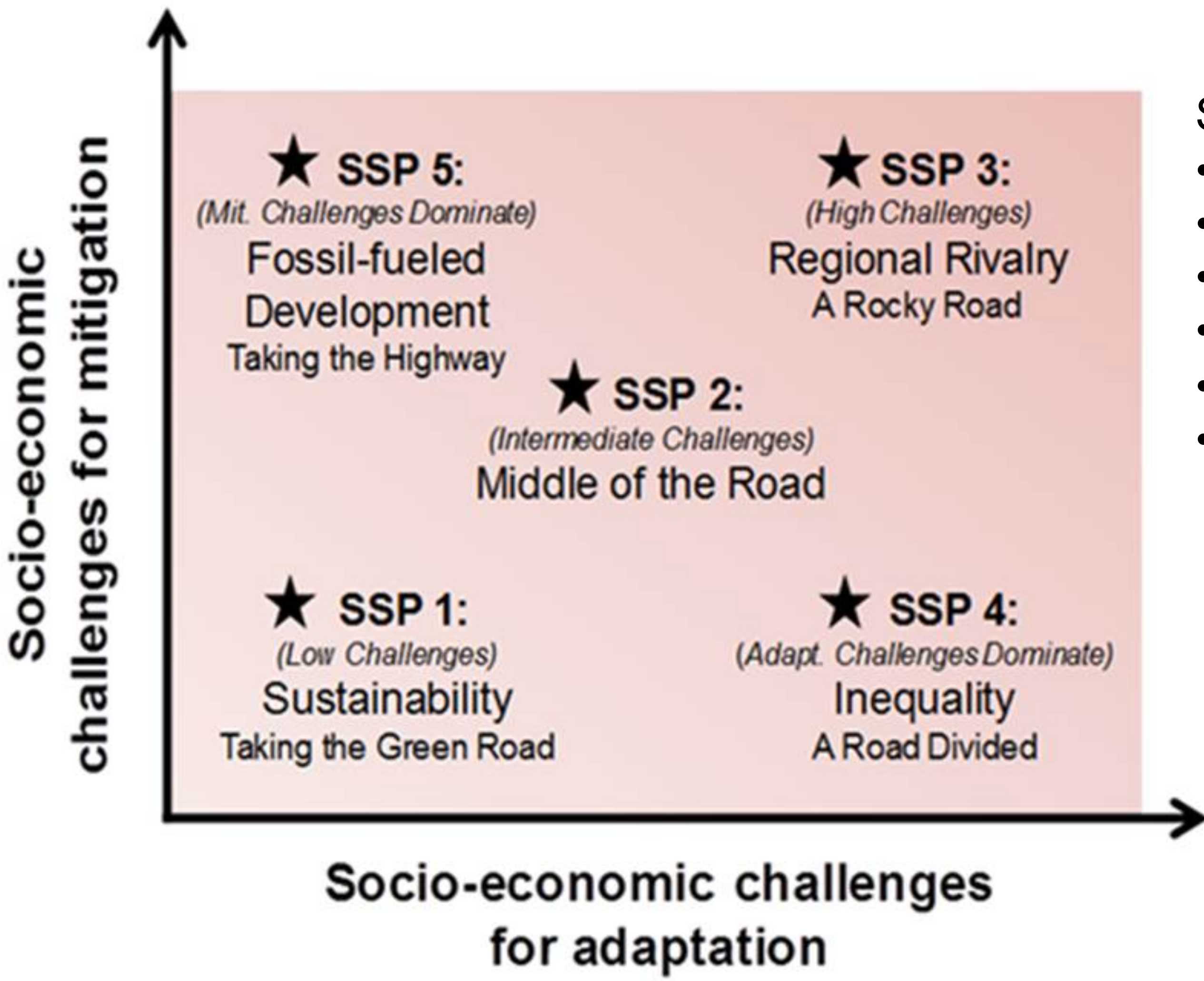
View current version of this article

A protocol for an intercomparison of biodiversity and ecosystem services models using harmonized land-use and climate scenarios

HyeJin Kim, Isabel M.D. Rosa, Rob Alkemade, Paul Leadley, George Hurtt, Alexander Popp, Detlef van Vuuren, Peter Anthoni, Almut Arneth, Daniele Baisero, Emma Caton, Rebecca Chaplin-Kramer, Louise Chini, Adriana De Palma, Fulvio Di Fulvio, Moreno Di Marco, Felipe Espinoza, Simon Ferrier, Shinichiro Fujimori, Ricardo E. Gonzalez, Maya Gueguen, Carlos Guerra, Mike Hartfoot, Thomas D. Harwood, Tomoko Hasegawa, Vanessa Haverd, Petr Havlik, Stefanie Hellweg, Samantha L.L. Hill, Akiko Hirata, Andrew J. Hoskins, Jan H. Janse, Walter Jetz, Justin A. Johnson, Andreas Krause, David Leclere, Ines S. Martins, Tetsuya Matsui, Cory Merow, Michael Obersteiner, Haruka Ohashi, Benjamin Poulter, Andy Purvis, Benjamin Quesada, Carlo Rondinini, Aafke Schipper, Richard Sharp, Kiyoshi Takahashi, Wilfried Thuiller, Nicolas Titeux, Piero Visconti, Christopher Ware, Florian Wolf, Henrique M. Pereira

doi: https://doi.org/10.1101/300632

THE SHARED SOCIO-ECONOMIC PATHWAYS (SSPs)

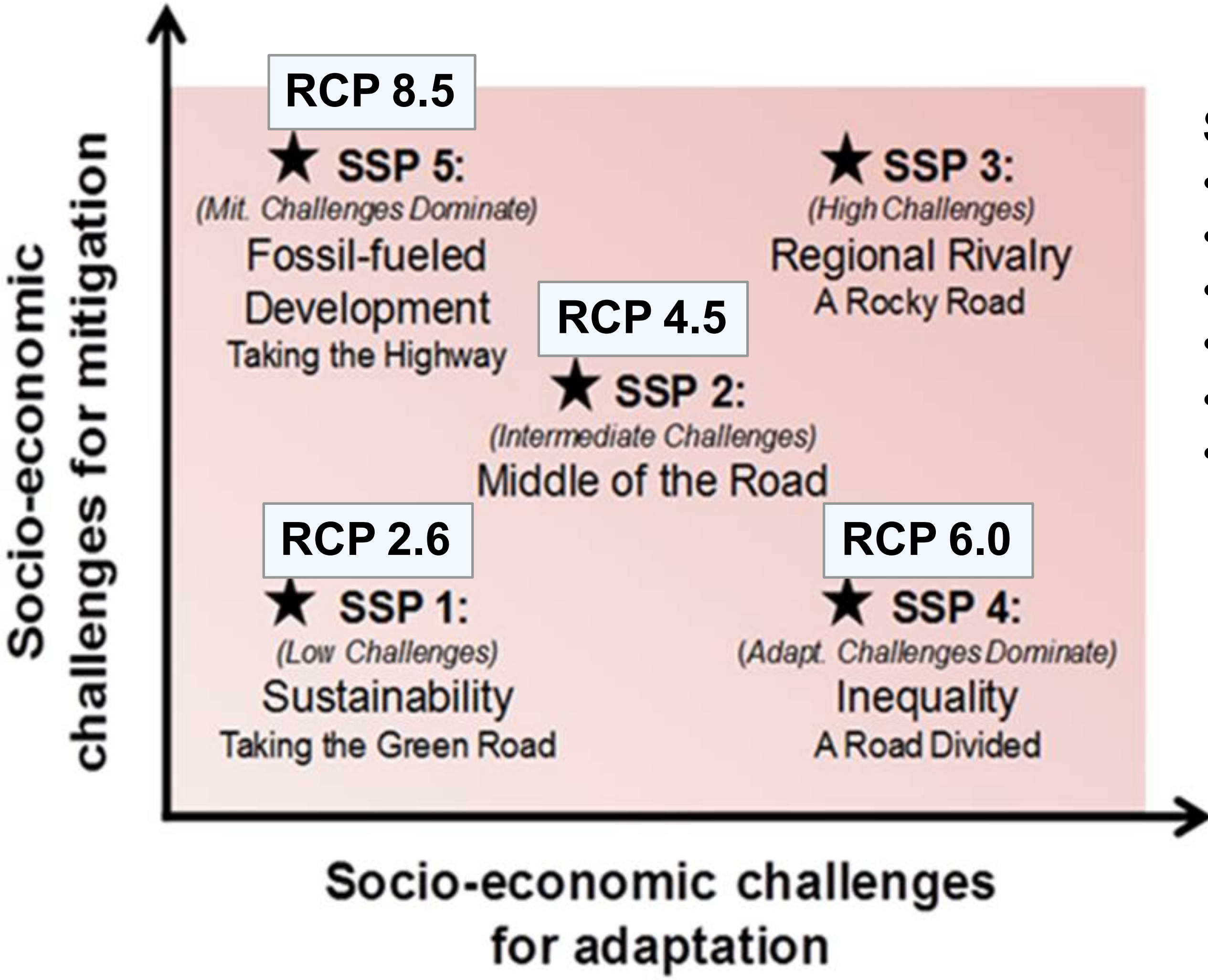


Scenarios of:
- Demographics
- Human development
- Economy and lifestyle
- Policies and institutions
- Technology
- Environment/natural resources

O'Neill et al. 2017 Glob. Env. Change

Land Use Harmonization 2 Project: luh.umd.edu

THE SHARED SOCIO-ECONOMIC PATHWAYS (SSPs)



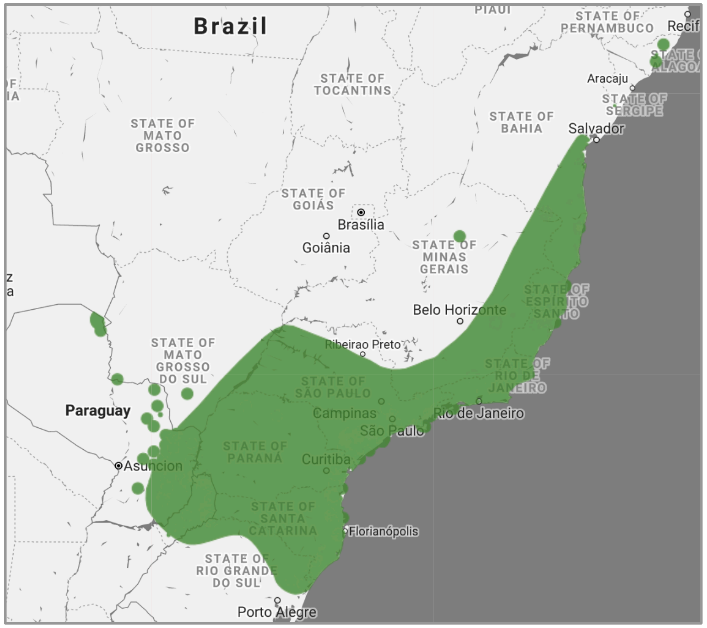
Scenarios of:

- Demographics
- Human development
- Economy and lifestyle
- Policies and institutions
- Technology
- Environment/natural resources

From O'Neill et al. 2017 Glob. Env. Change

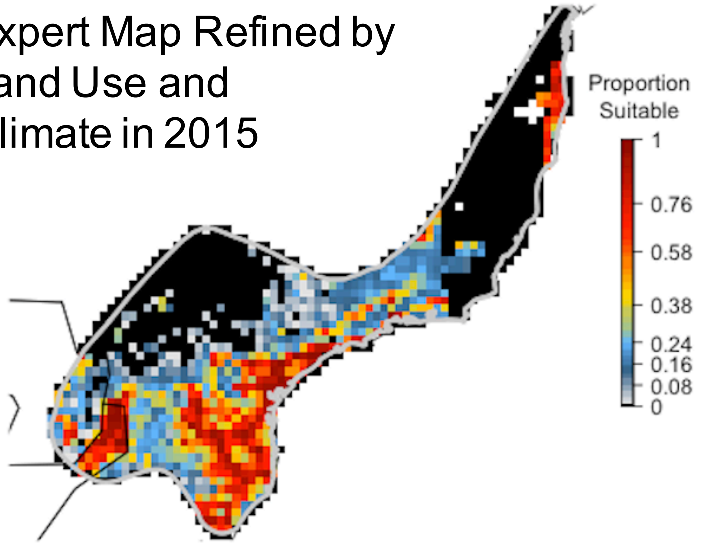
Inputs

- Expert Maps
  - ~20k amphibians, mammals and birds
- Species habitat preferences
  - forest, agriculture, urban, etc.
- Present and Future Land use maps
  - .25 degree
- Present and Future Climate
- Maxnet
- Grain of predictions: .25 degree



Partitioning land use and climate losses

Expert Map Refined by Land Use and Climate in 2015



Partitioning land use and climate losses

Expert Map Refined by
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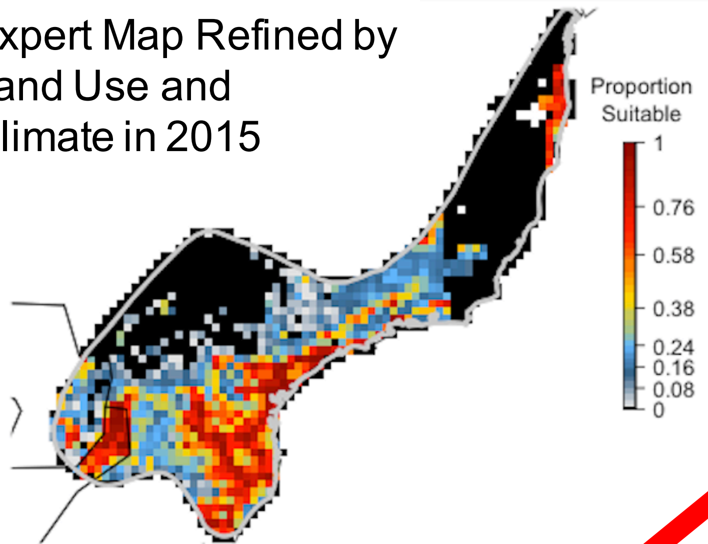
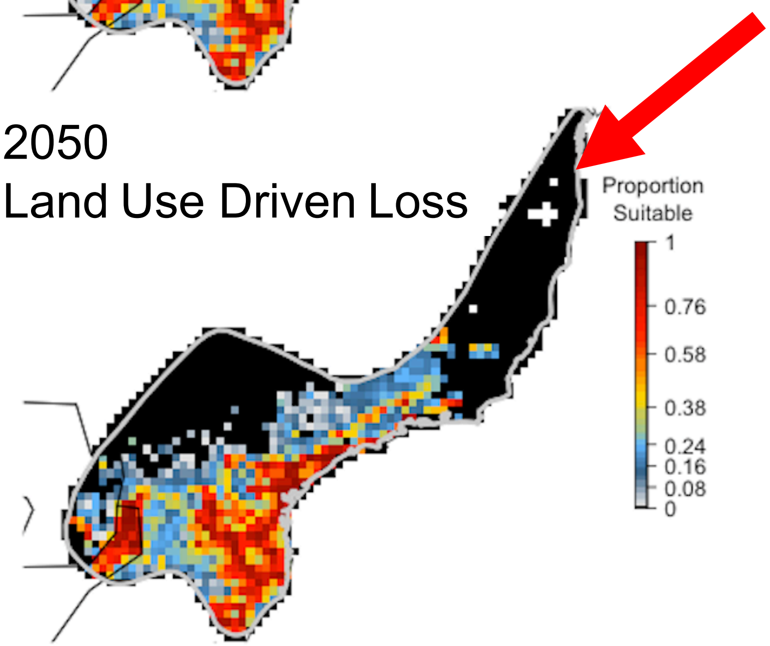
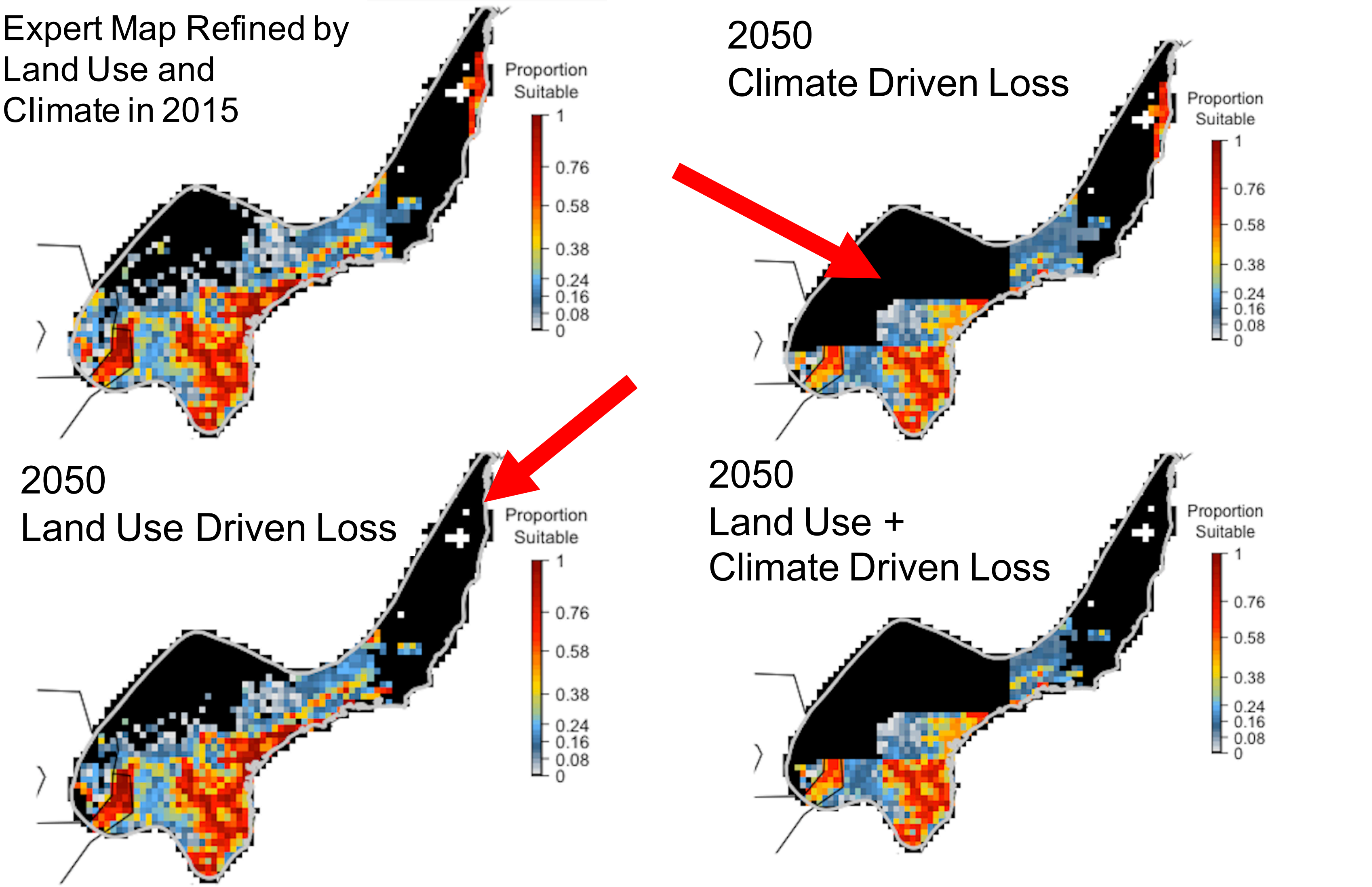


2050
Land Use Driven Loss

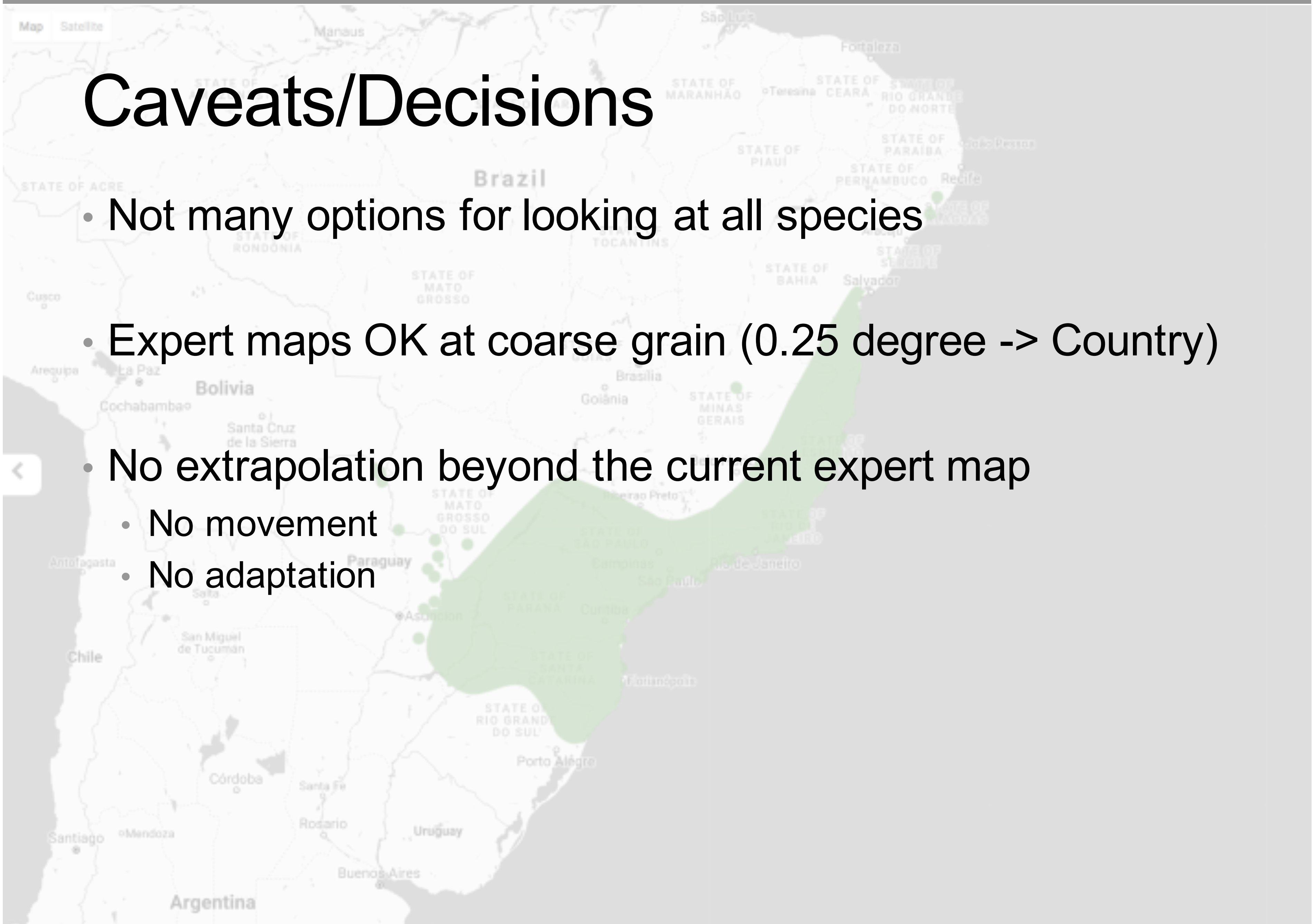


Partitioning land use and climate losses

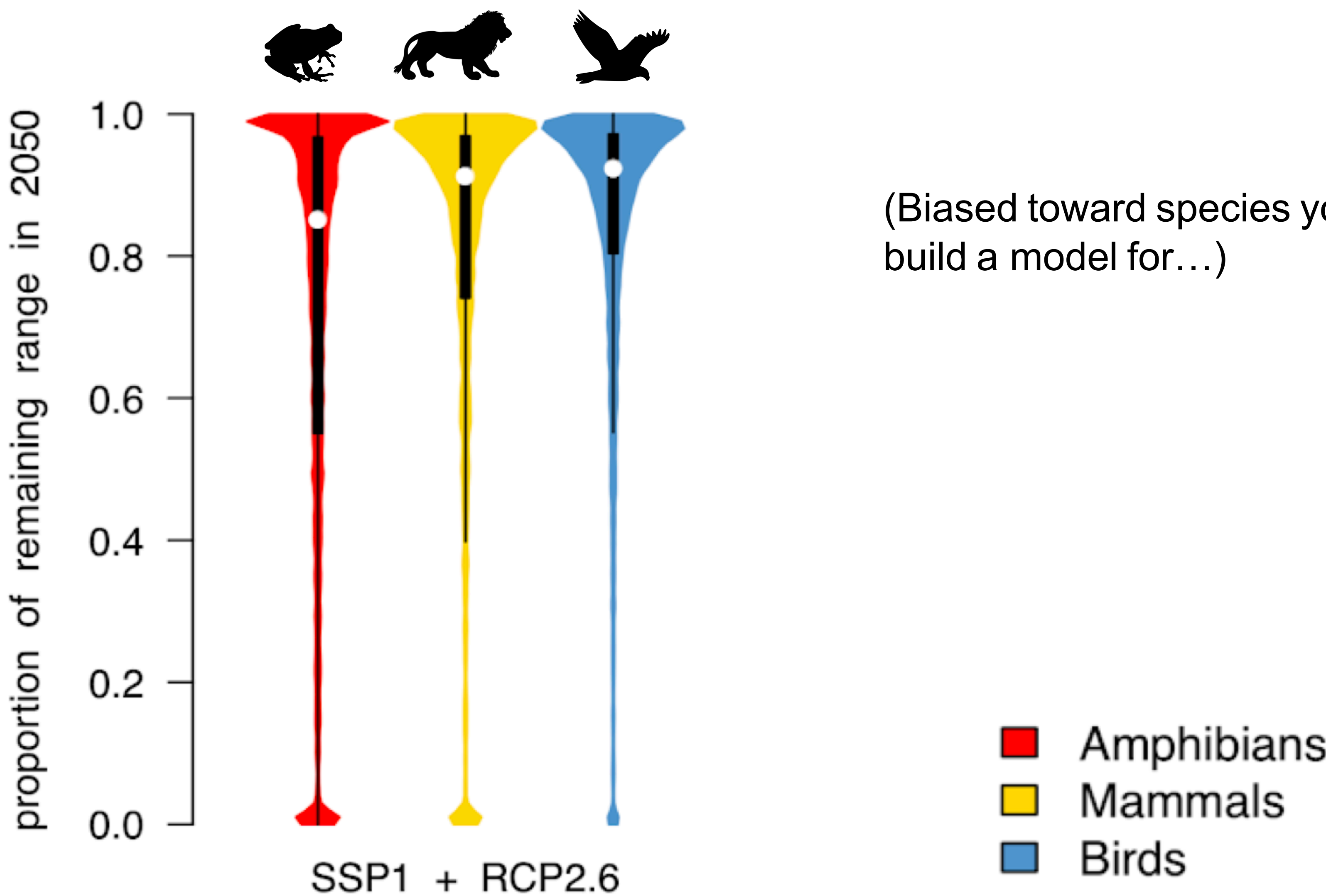


Caveats/Decisions

- Not many options for looking at all species
- Expert maps OK at coarse grain (0.25 degree -> Country)
- No extrapolation beyond the current expert map
  - No movement
  - No adaptation

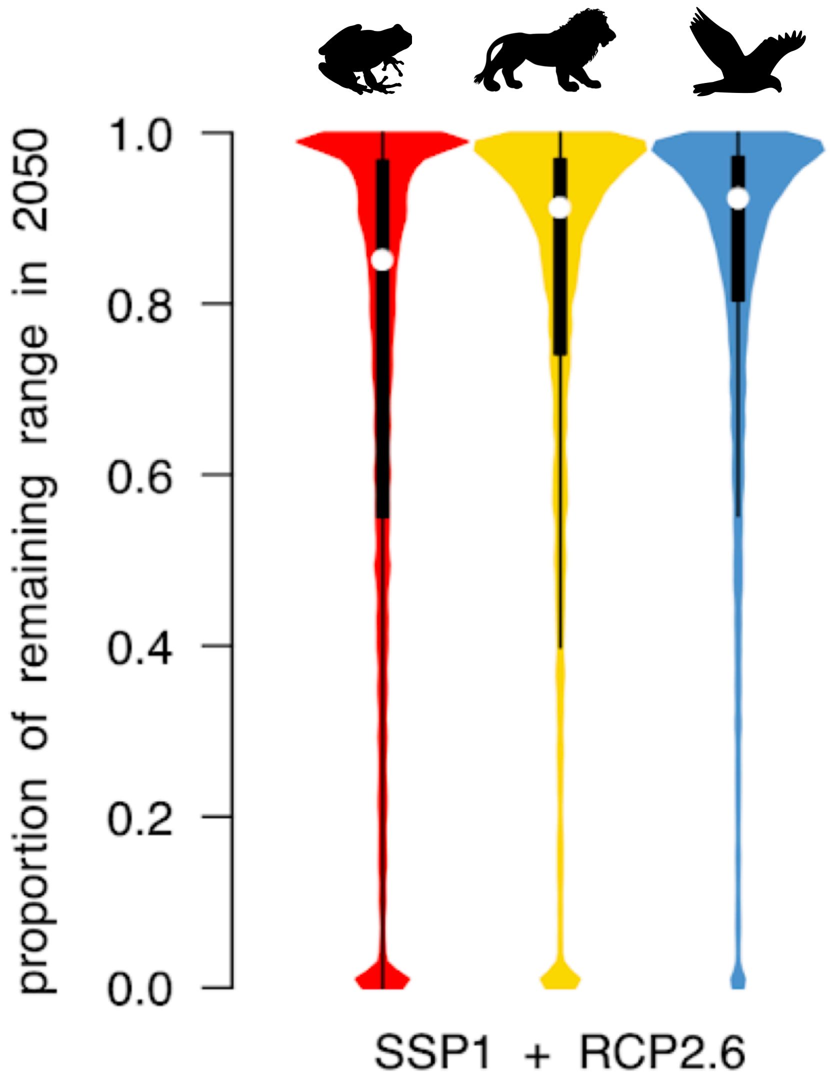


Expected losses…

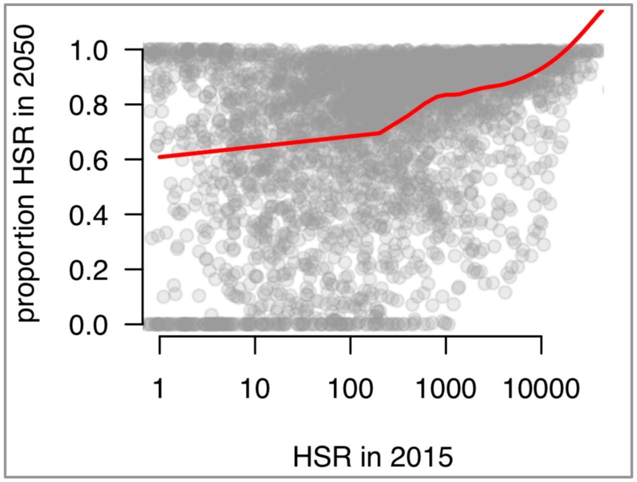


(Biased toward species you can build a model for…)

Expected losses…

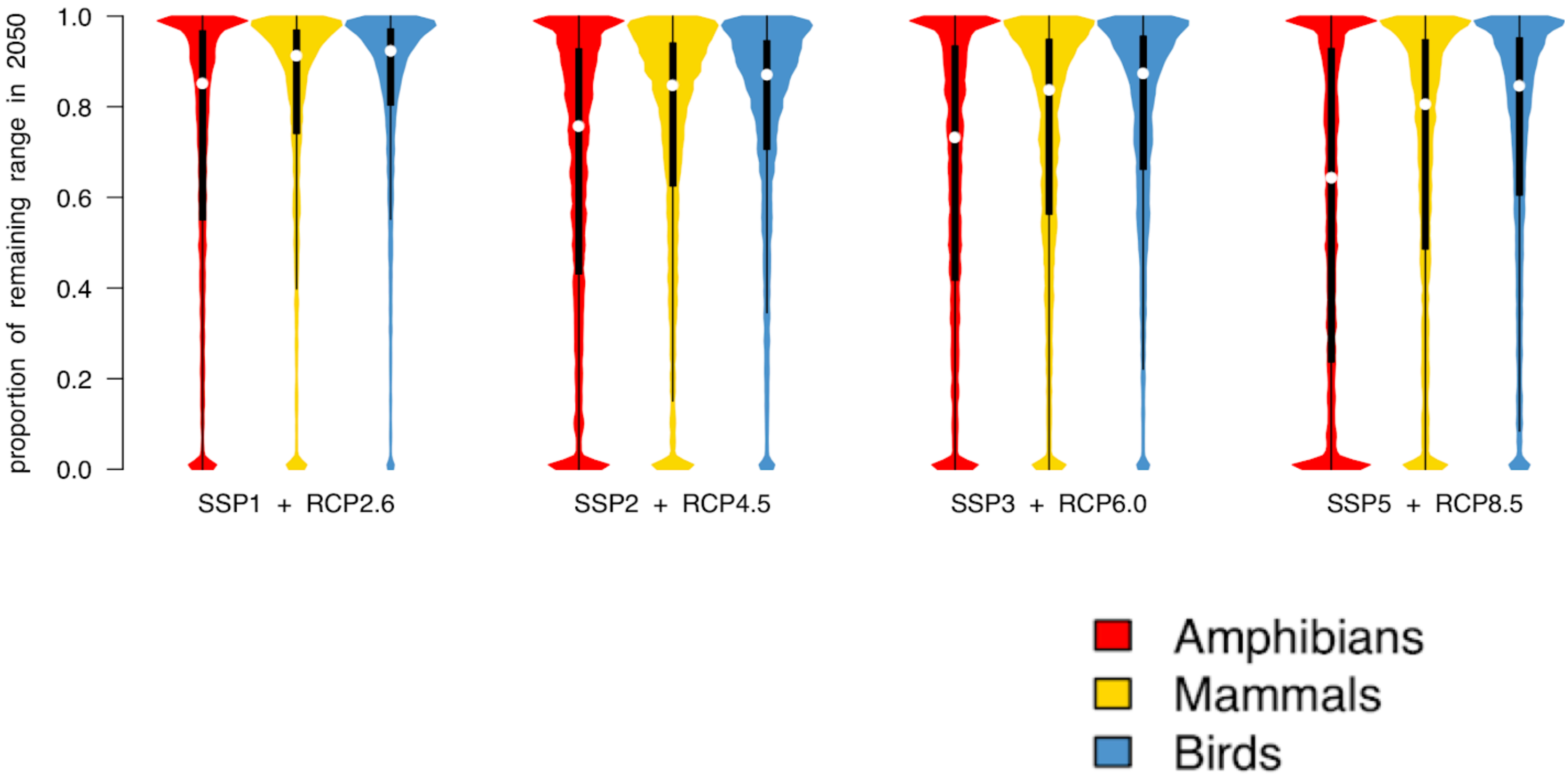


(Biased toward species you can build a model for…)

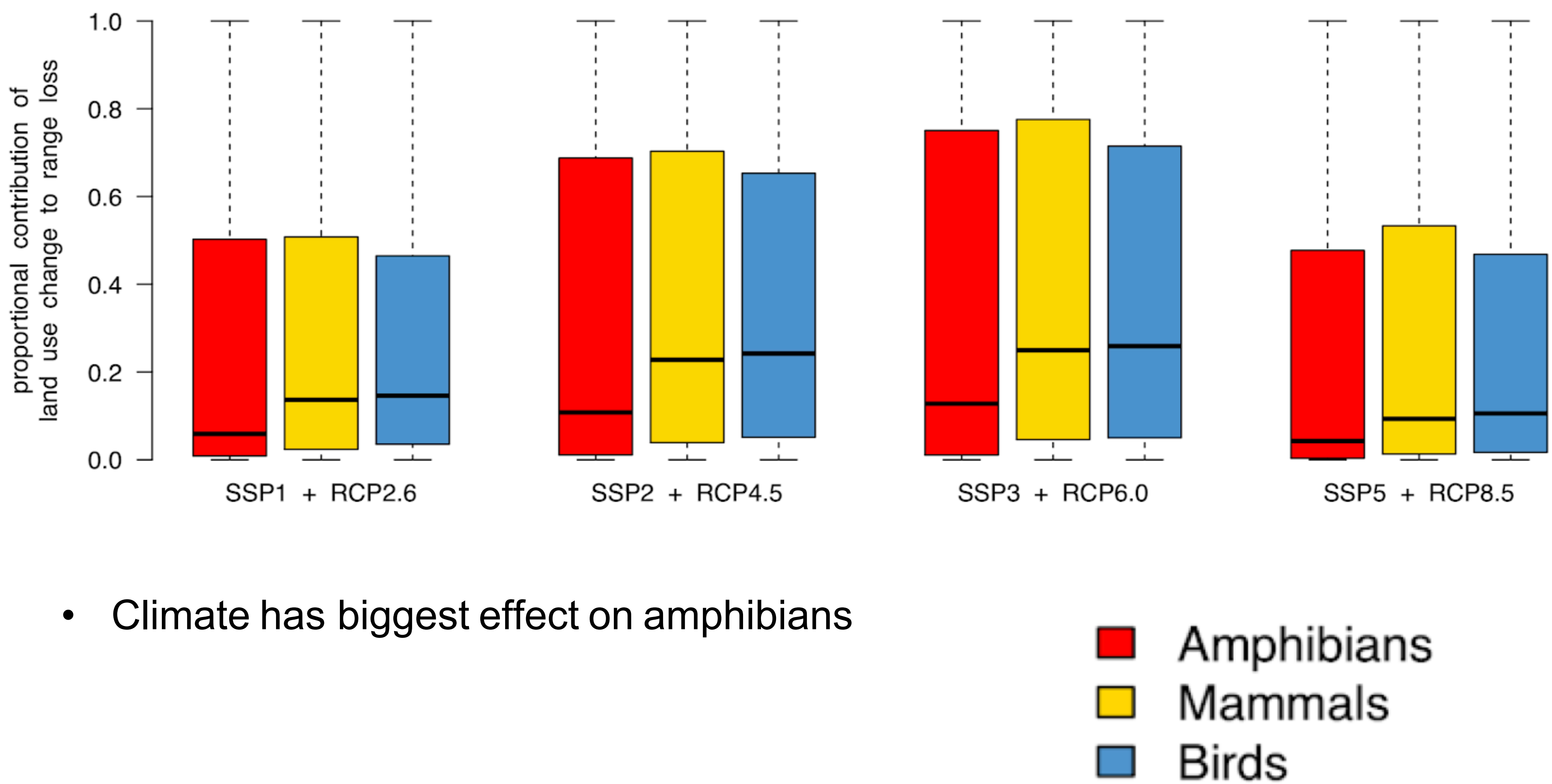


Amphibians
Mammals
Birds

Consistent trends in expected losses…

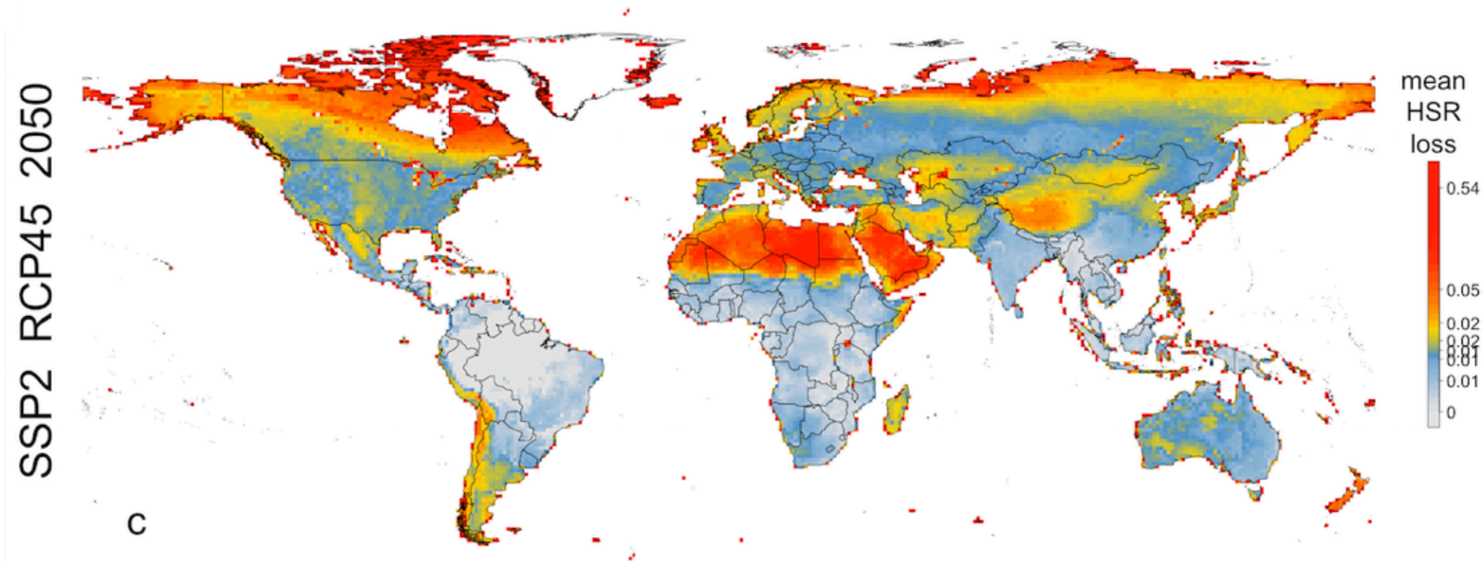


Climate >> Land Use



- Climate has biggest effect on amphibians

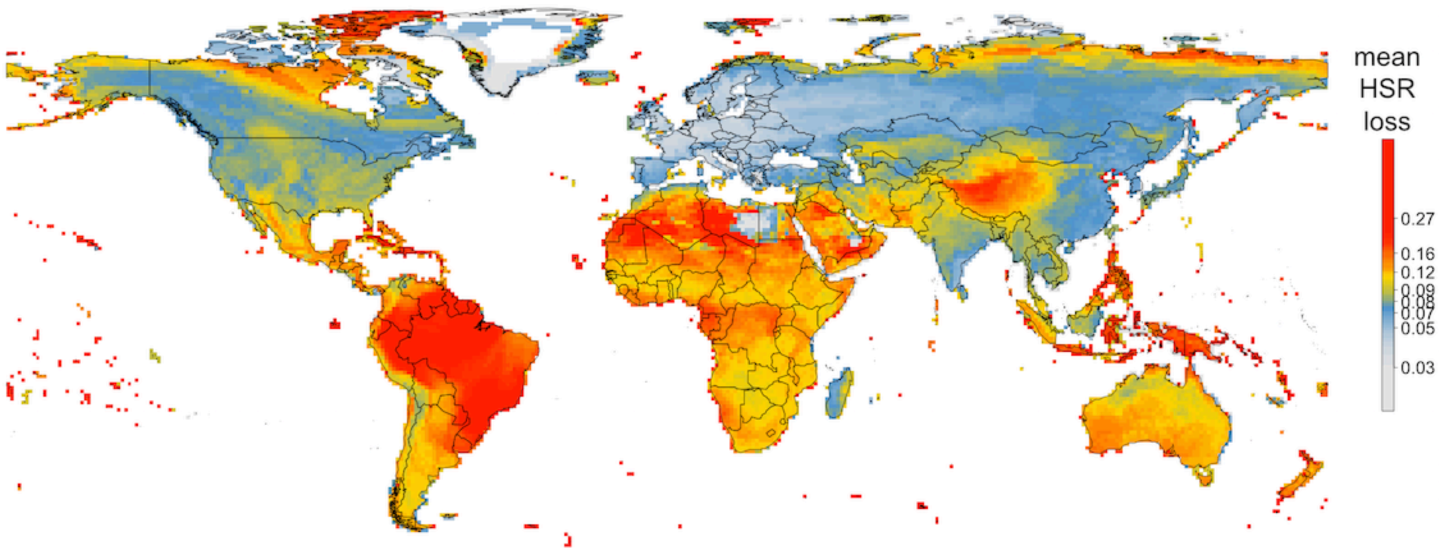
Local loss



In places that are already hot, or should be cold

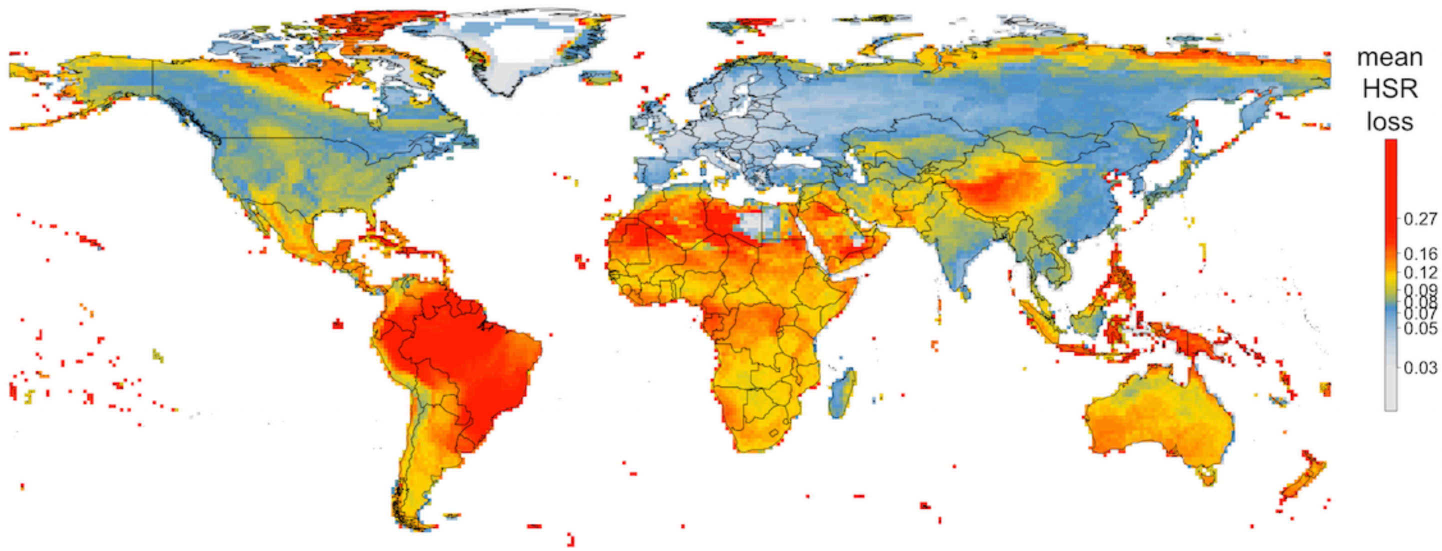
How does global loss compare to local loss?

Global loss

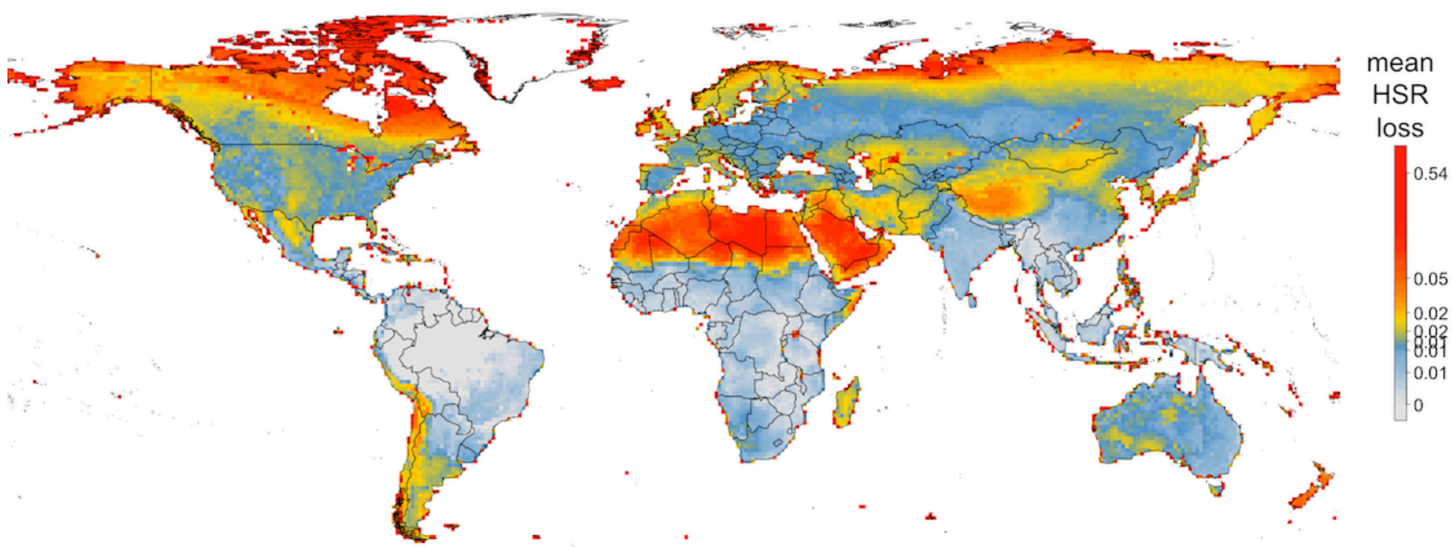


How does global loss compare to local loss?

Global loss

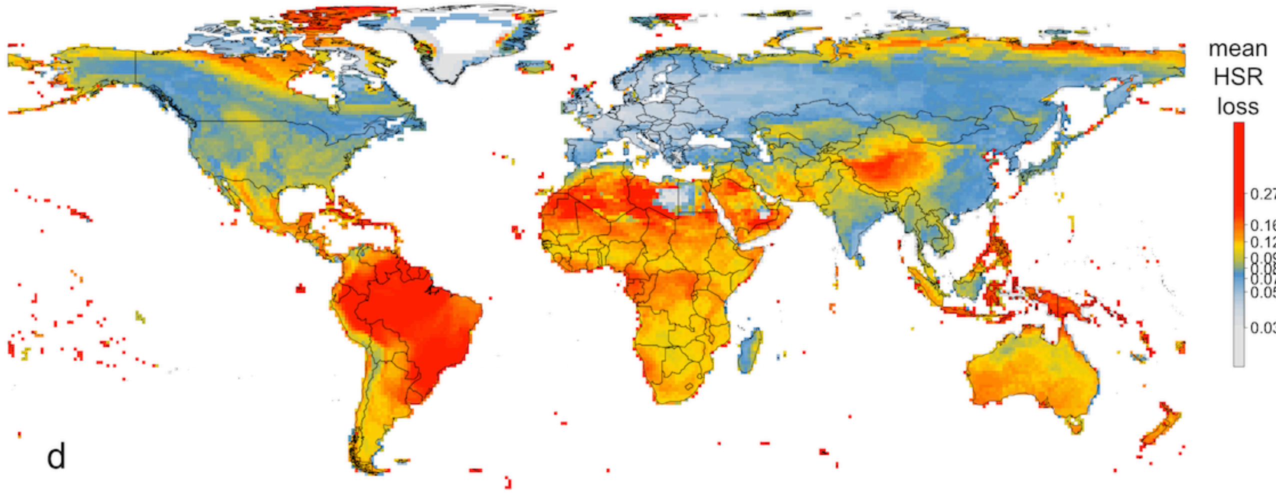


Local loss

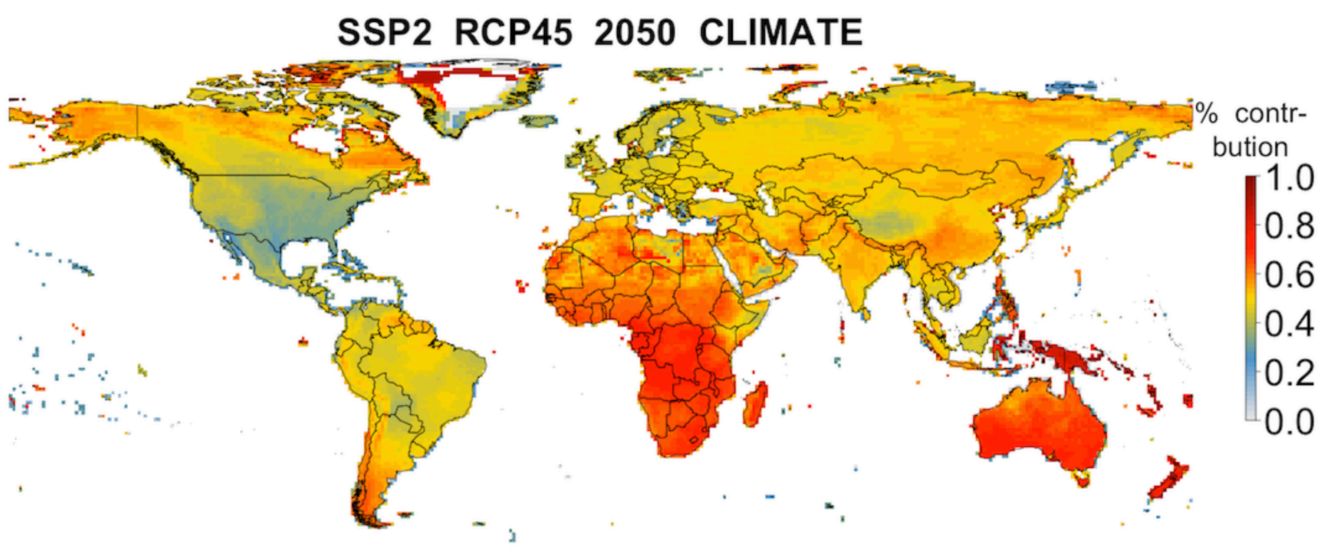


Contribution to climate

Global loss



Proportional contribution of climate



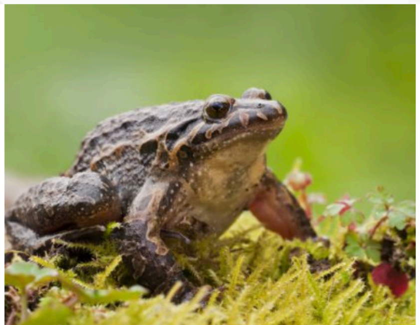
Next steps

- Targeted conservation strategies
  - Low local loss, high global loss, low climate contribution (low risk)
  - High local loss, high global loss, low climate contribution (high risk, high reward)
- Anticipate changing stewardship
- Serve to scientific community
- Serve for policy

contact us login register

MOL MAP OF LIFE

Putting biodiversity on the map

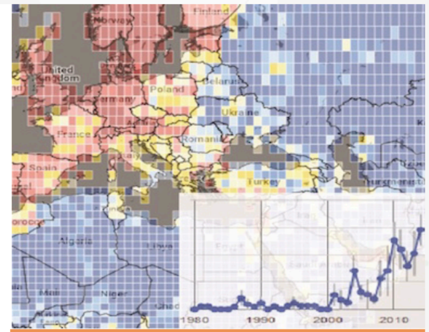


Map species

Views species range map, inventory, and occurrence data

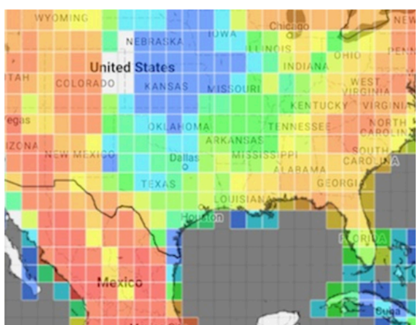
Species by location

Select a location, filter by distance or group, and view a list of species along with source data



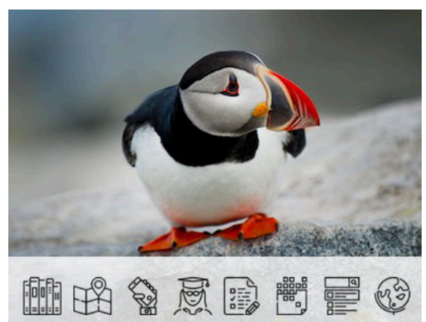
Indicators

Explore trends in biodiversity knowledge, distribution, and conservation



Patterns

Explore richness patterns and biodiversity facets



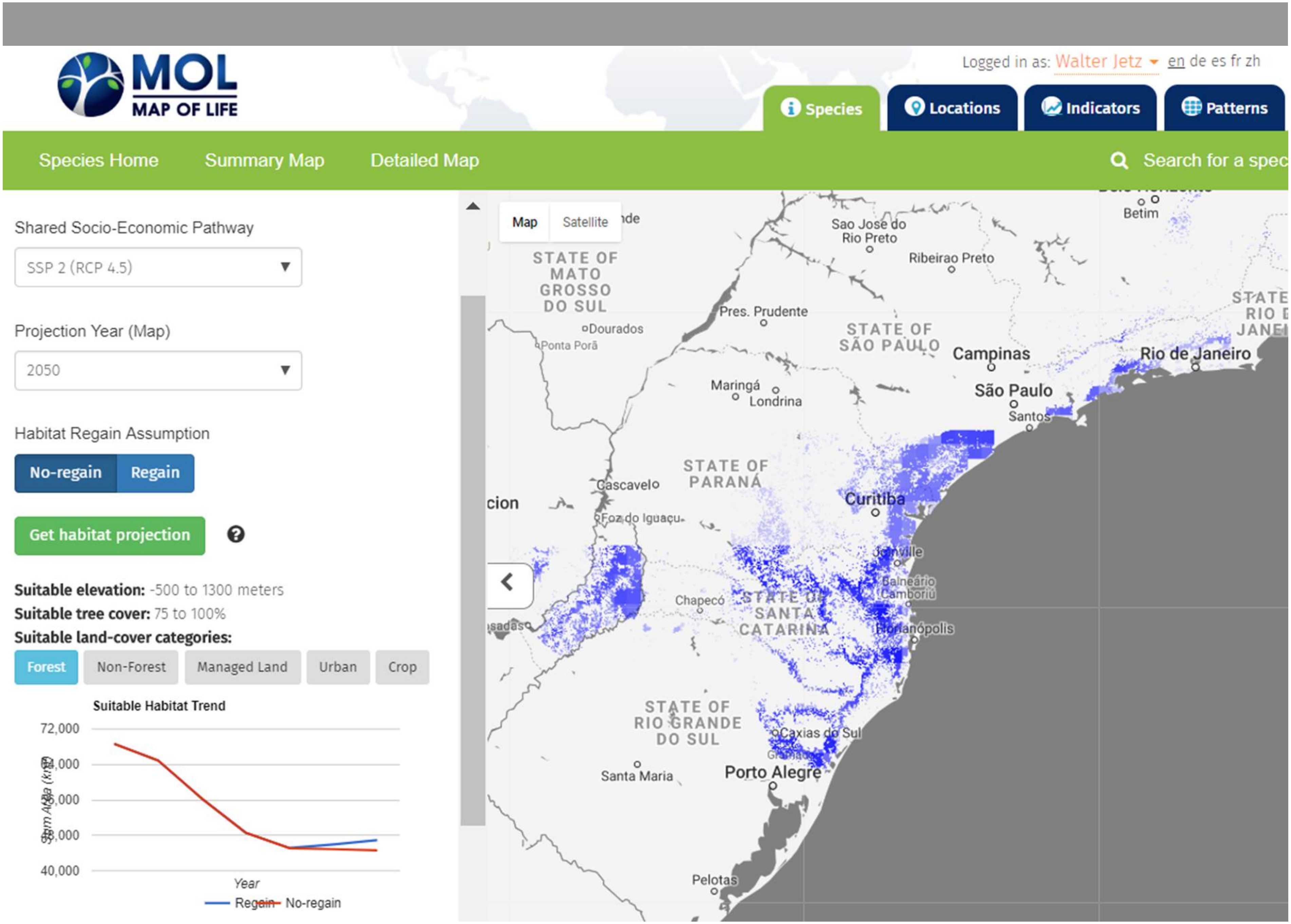
Datasets

Explore datasets used across MOL

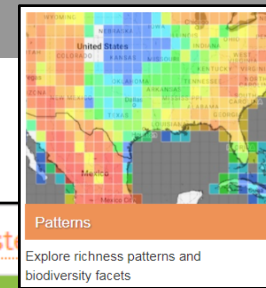
Mobile App

Discover, identify, and record biodiversity worldwide

mol.org


MOL
MAP OF LIFE
Logged in as: Walter Jetz
en de es fr zh
Species
Locations
Indicators
Patterns
Species Home
Summary Map
Detailed Map
Search for a spec
Shared Socio-Economic Pathway
SSP 2 (RCP 4.5)
Projection Year (Map)
2050
Habitat Regain Assumption
No-regain
Regain
Get habitat projection
Suitable elevation: -500 to 1300 meters
Suitable tree cover: 75 to 100%
Suitable land-cover categories:
Forest
Non-Forest
Managed Land
Urban
Crop
Suitable Habitat Trend
72,000
40,000
Year
Regain
No-regain
Map
Satellite
STATE OF MATO GROSSO DO SUL
STATE OF SÃO PAULO
STATE OF PARANÁ
STATE OF SANTA CATARINA
STATE OF RIO GRANDE DO SUL
Sao Jose do Rio Preto
Ribeirao Preto
Betim
Pres. Prudente
Dourados
Ponta Porã
Campinas
São Paulo
Santos
Rio de Janeiro
Maringá
Londrina
Cascavel
Foz do Iguaçu
Curitiba
Joinville
Balneário Camboriú
Chapecó
Florianópolis
Caxias do Sul
Santa Maria
Porto Alegre
Pelotas

Biodiversity Patterns



Conclusions

Climate >> land use

Environmental change alone doesn’t predict loss

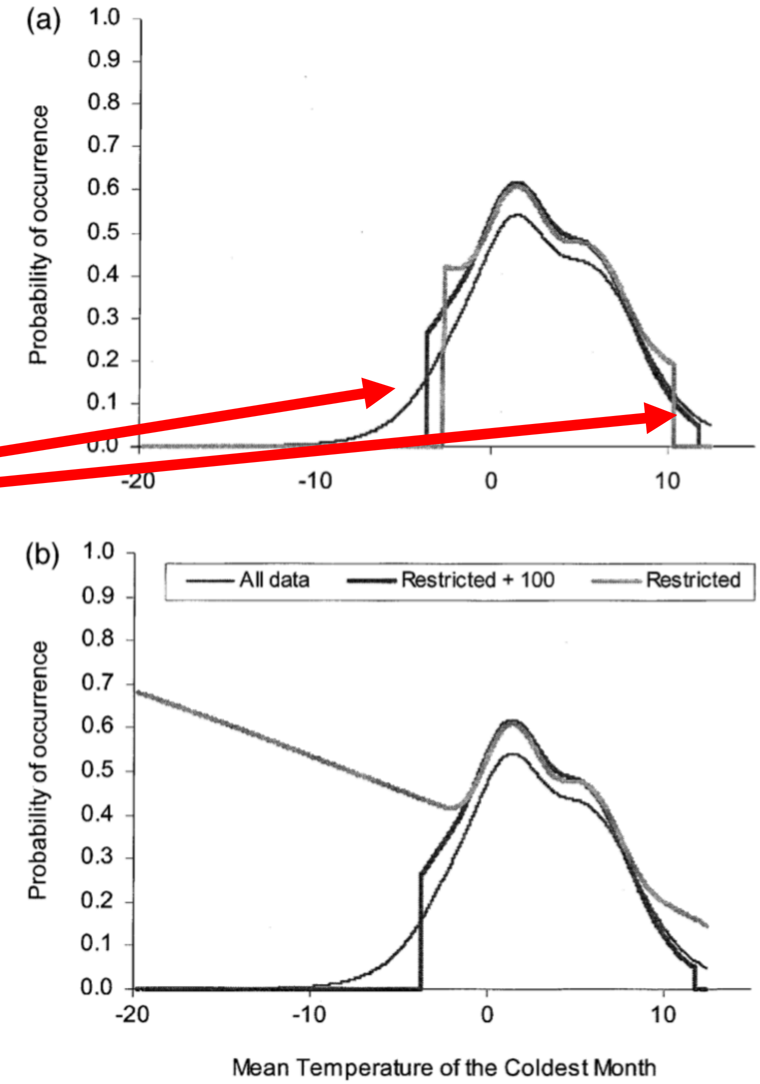
Priorities for loss

Environmental Extrapolation

What assumptions were made?

Extrapolation

clamping



oops

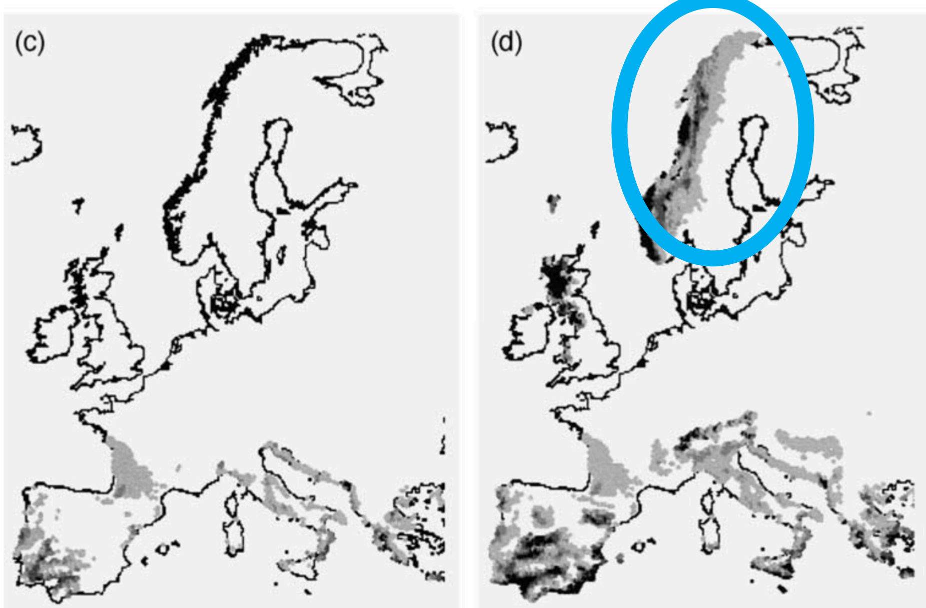
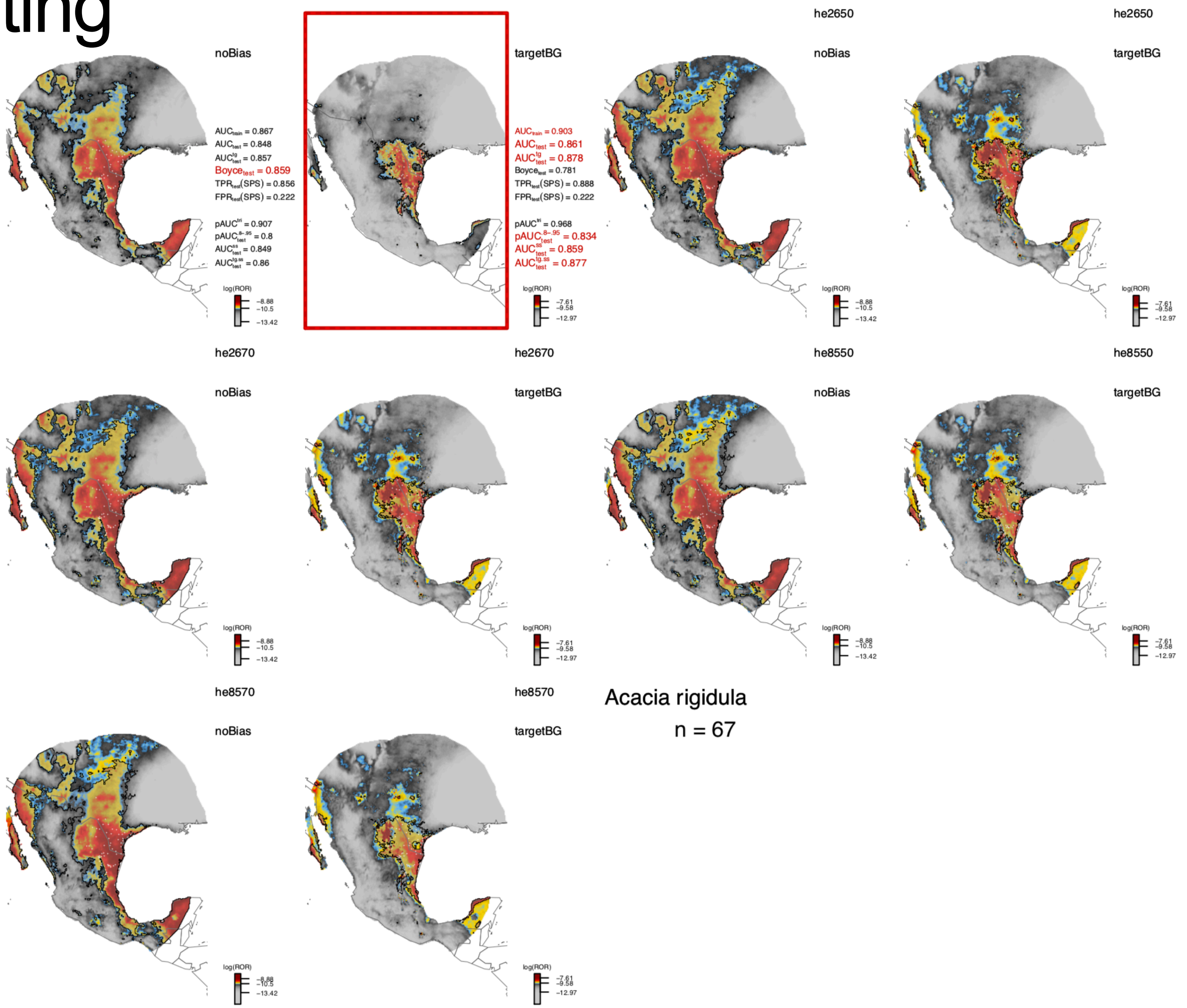


Fig. 2. Projections of response curve of *Quercus crenata* on larger spectrum of climate data at finer resolution. (a) The three models setting probability values equal to zero outside the environmental limits used to calibrate models; (b) Same as (a) but without setting probability values equal to zero outside the environmental limits used to calibrate models for the restricted model.

Thullier et al. 2004

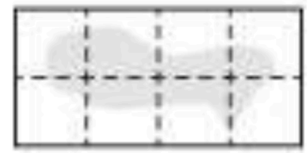
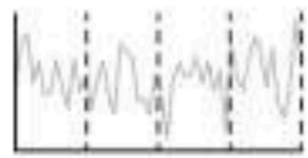
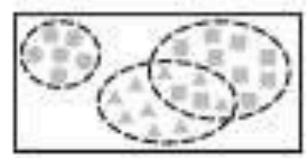
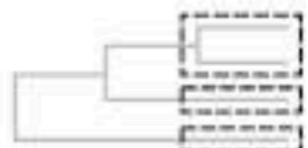
Forecasting



What can we do about it?

- Don’t do it
- Get more data in the range you want to predict
- Cross validation

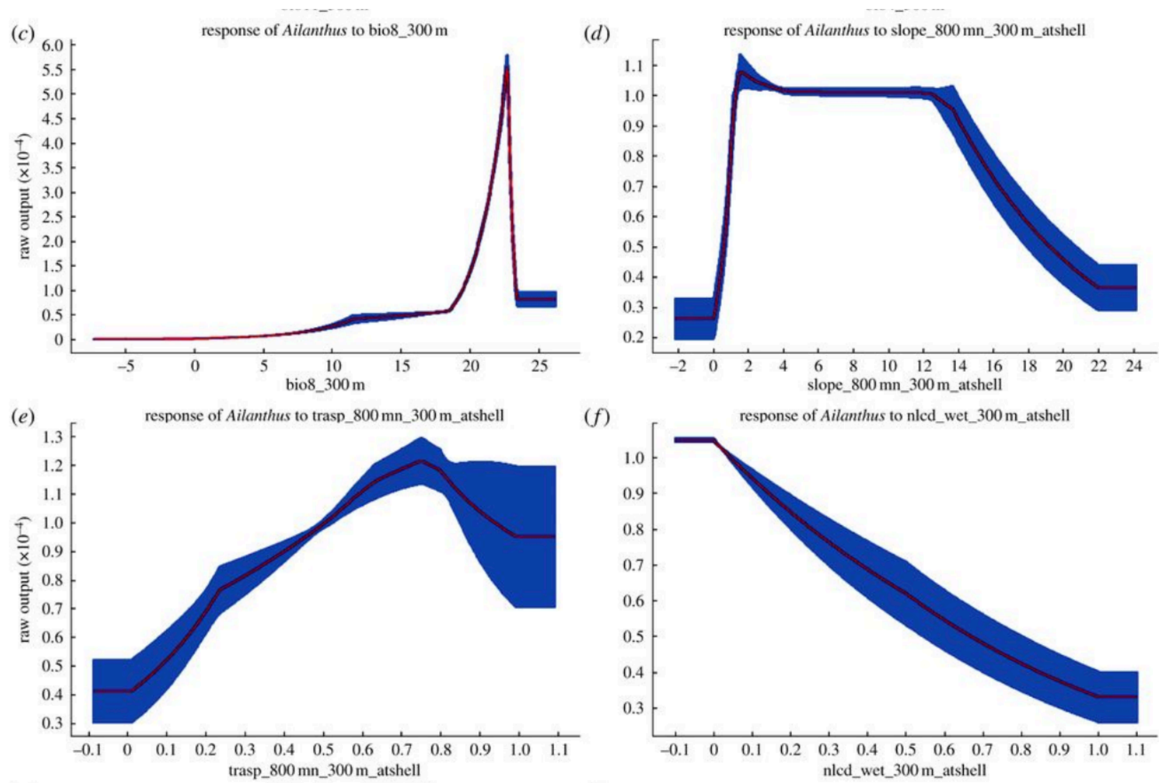
Cross Validation

Dependence structure	Parametric solution	Blocking	Blocking illustration
Spatial	Spatial models (e.g. CAR, INLA, GWR)	Spatial	
Temporal	Time-series models (e.g. ARIMA)	Temporal	
Grouping	Mixed effect models (e.g. GLMM)	Group	
Hierarchical / Phylogenetic	Phylogenetic models (e.g. PGLS)	Hierarchical	

Roberts et al. 2016, Ecography

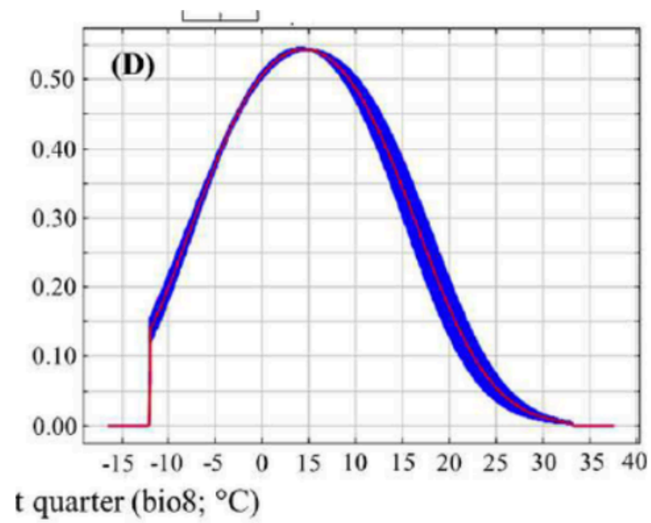
What can we do about it?

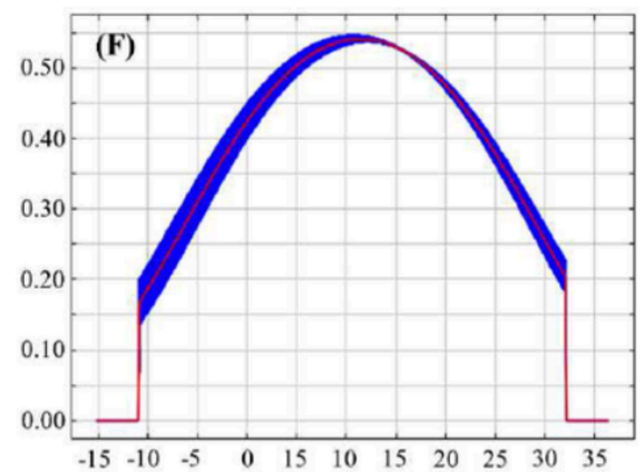
- Don't do it
- Get more data in the range you want to predict
- Cross validation
- **Constrain it**



What can we do about it?

- Don’t do it
- Get more data in the range you want to predict
- Cross validation
- Constrain it
- **Make a heuristic argument that its ok**



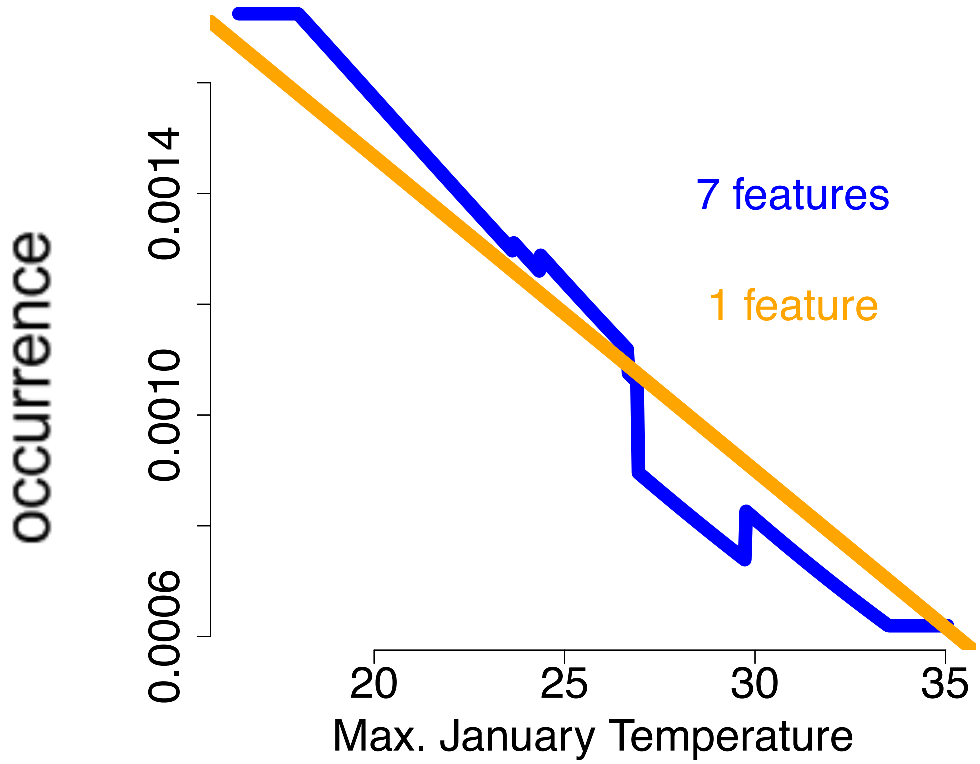


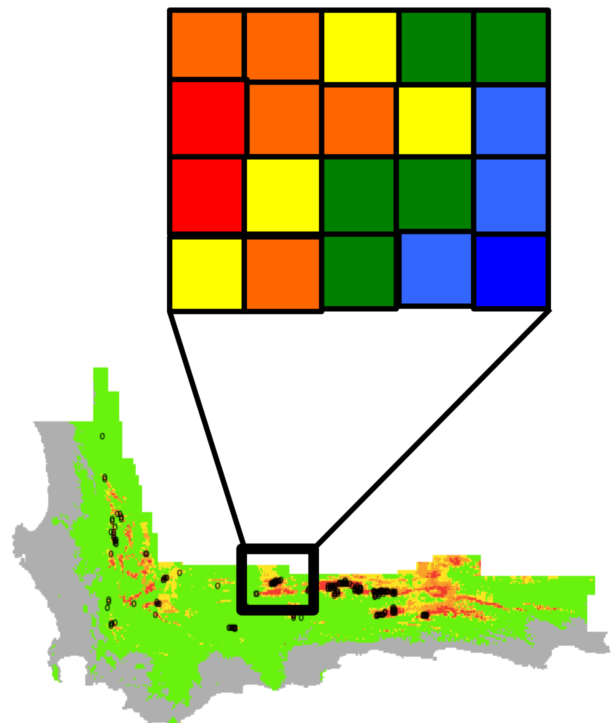
What can we do about it?

- Don’t do it
- Get more data in the range you want to predict
- Cross validation
- Constrain it
- Make a heuristic argument that its ok
- **Make a mechanistic model**
- **Predict another emergent pattern to validate the extrapolation with a different type of data**

Spatial Extrapolation

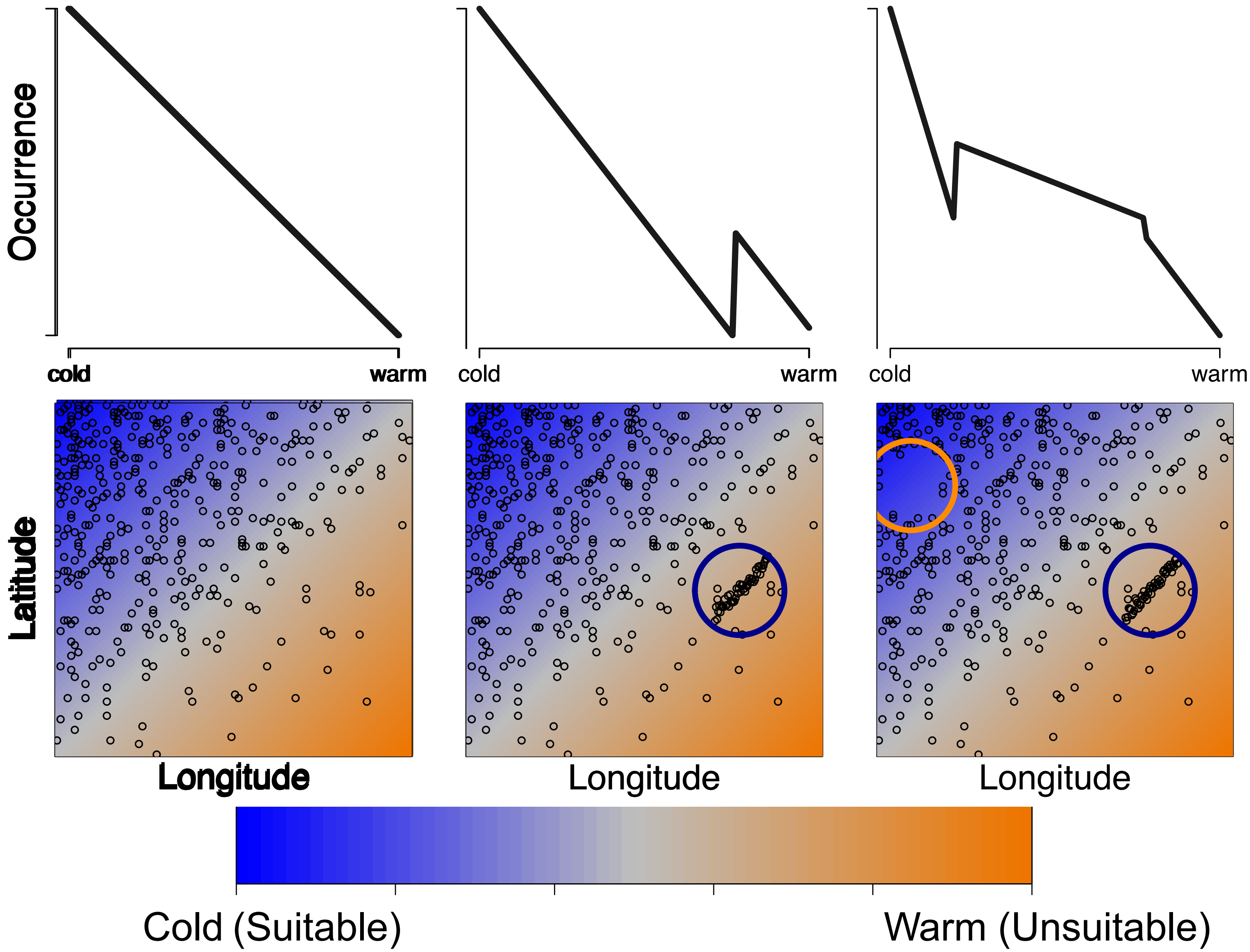
Two cultures of SDMing



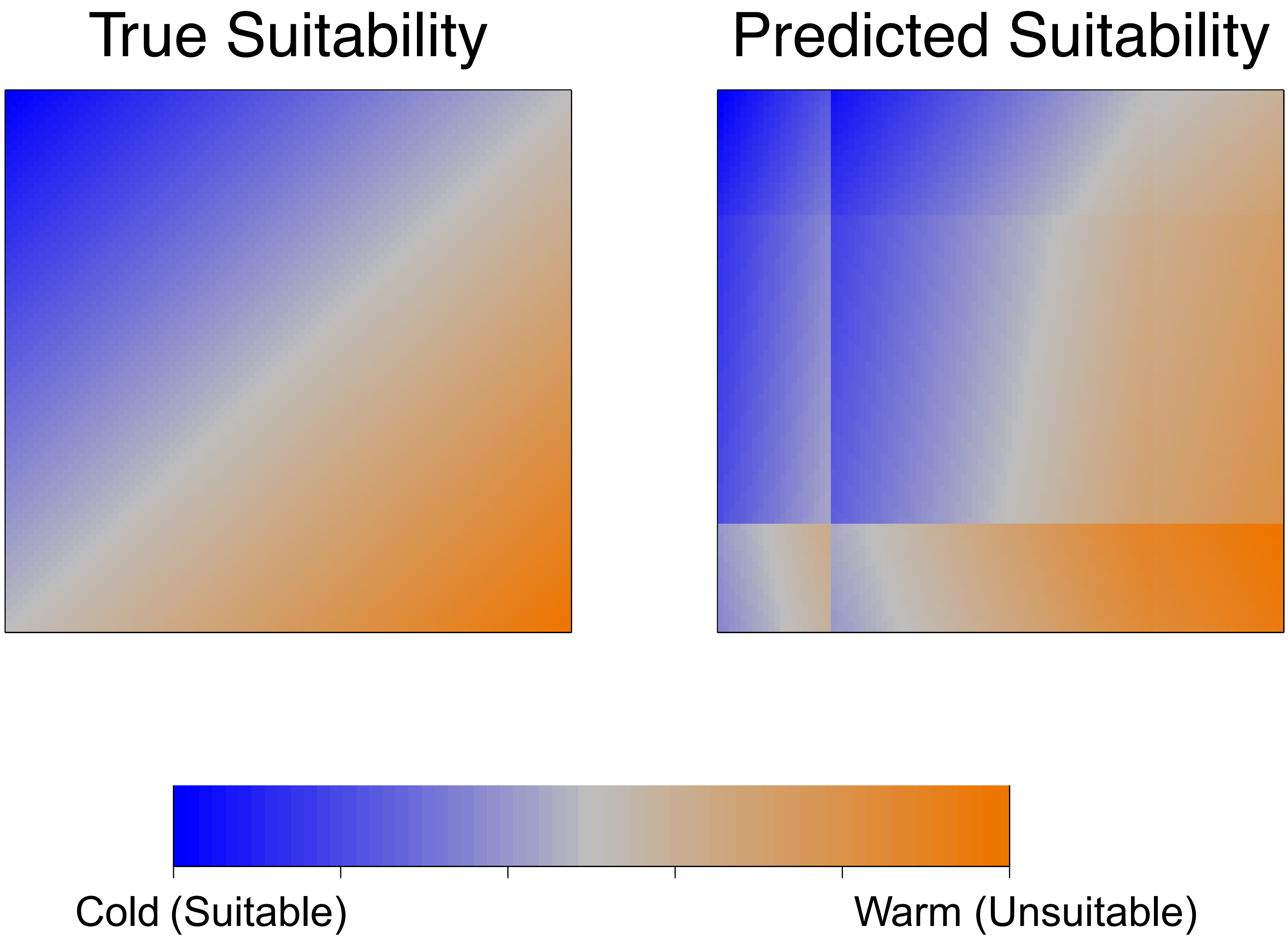


Bumps attributed to environmental response actually arise in geographic space

Spatial Aggregation and Overfitting



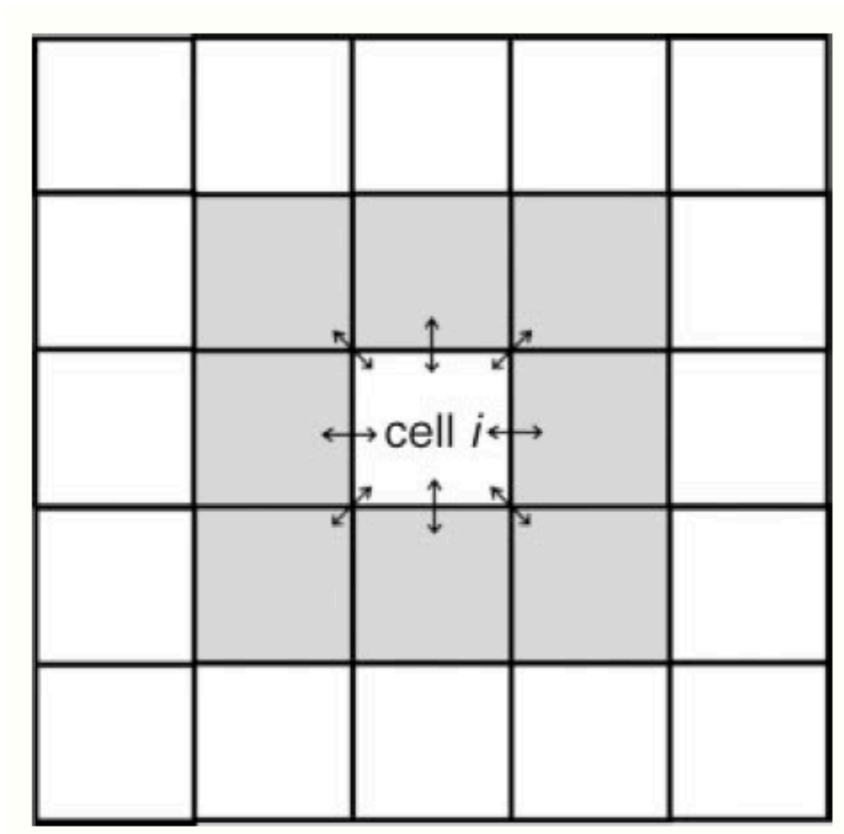
Overfitting



Bayesian Spatial models

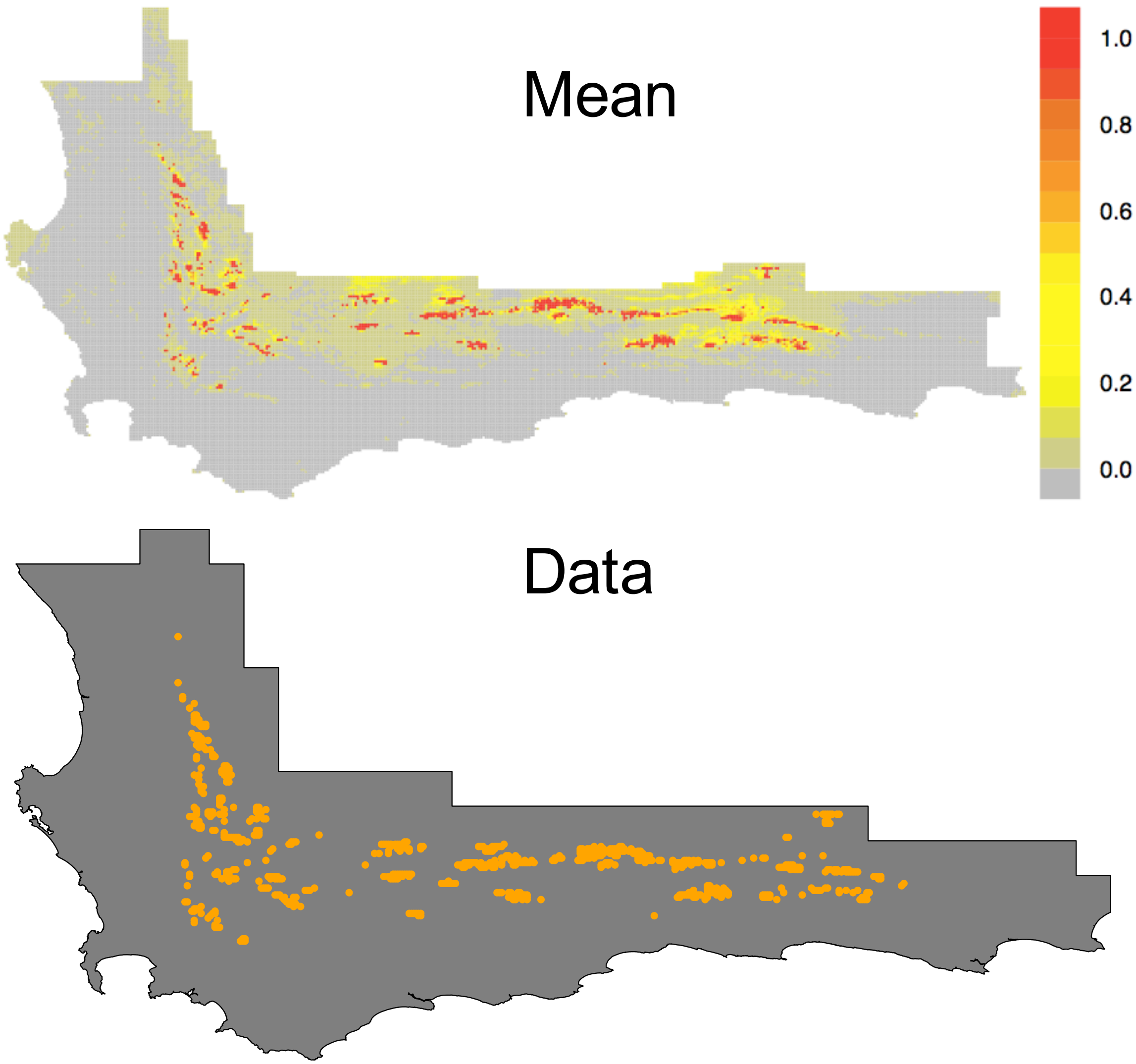
$$\text{logit}(p_i) = X_i\beta + w_i$$

Spatial random intercepts

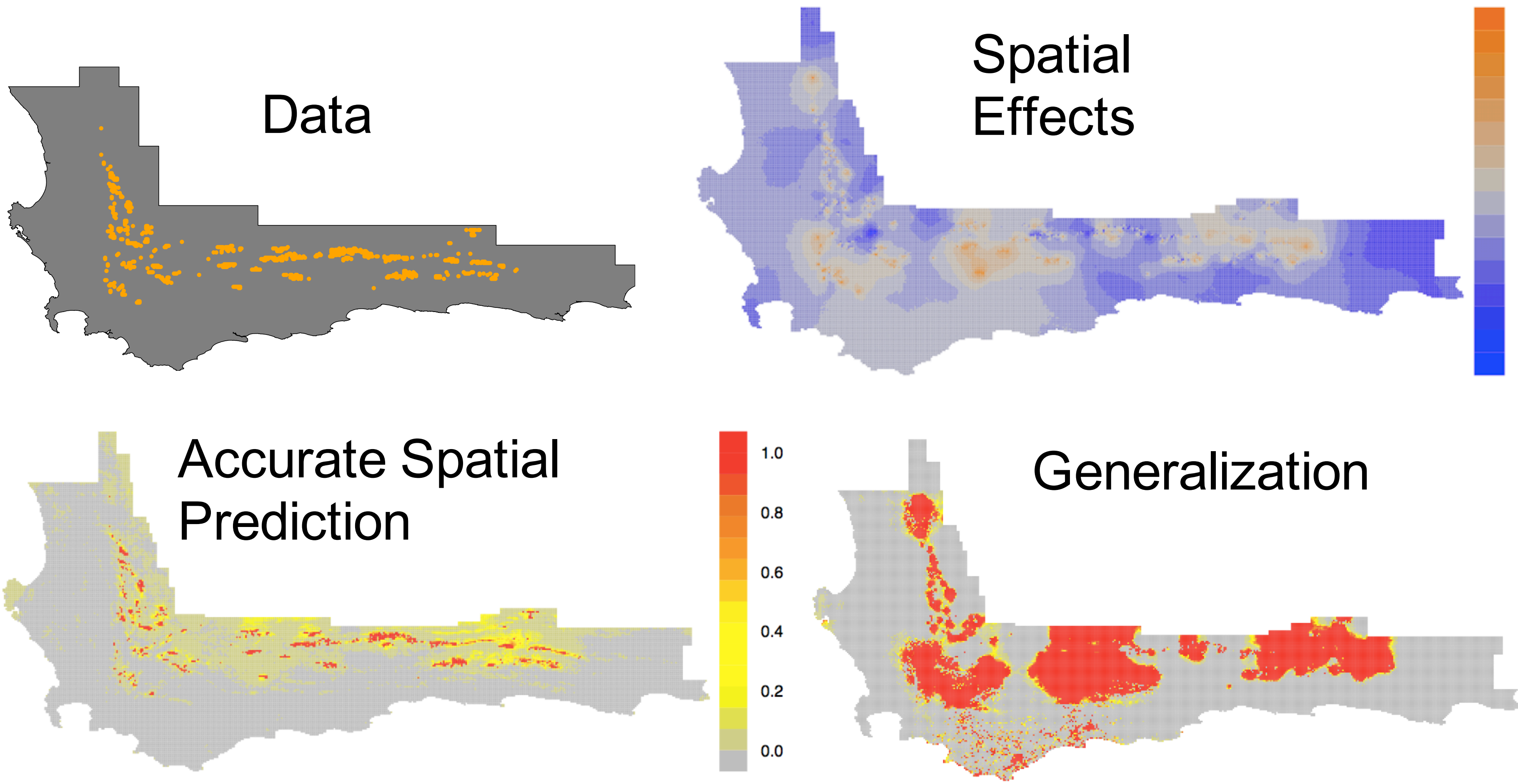


R package: hSDM

Spatial prediction

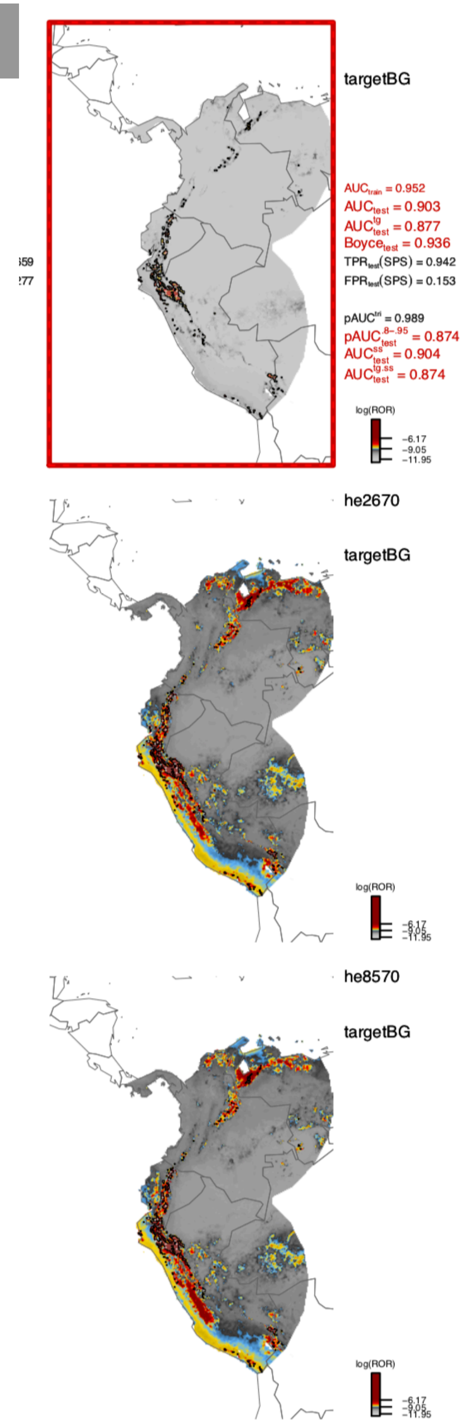


Spatial prediction



Temporal Extrapolation

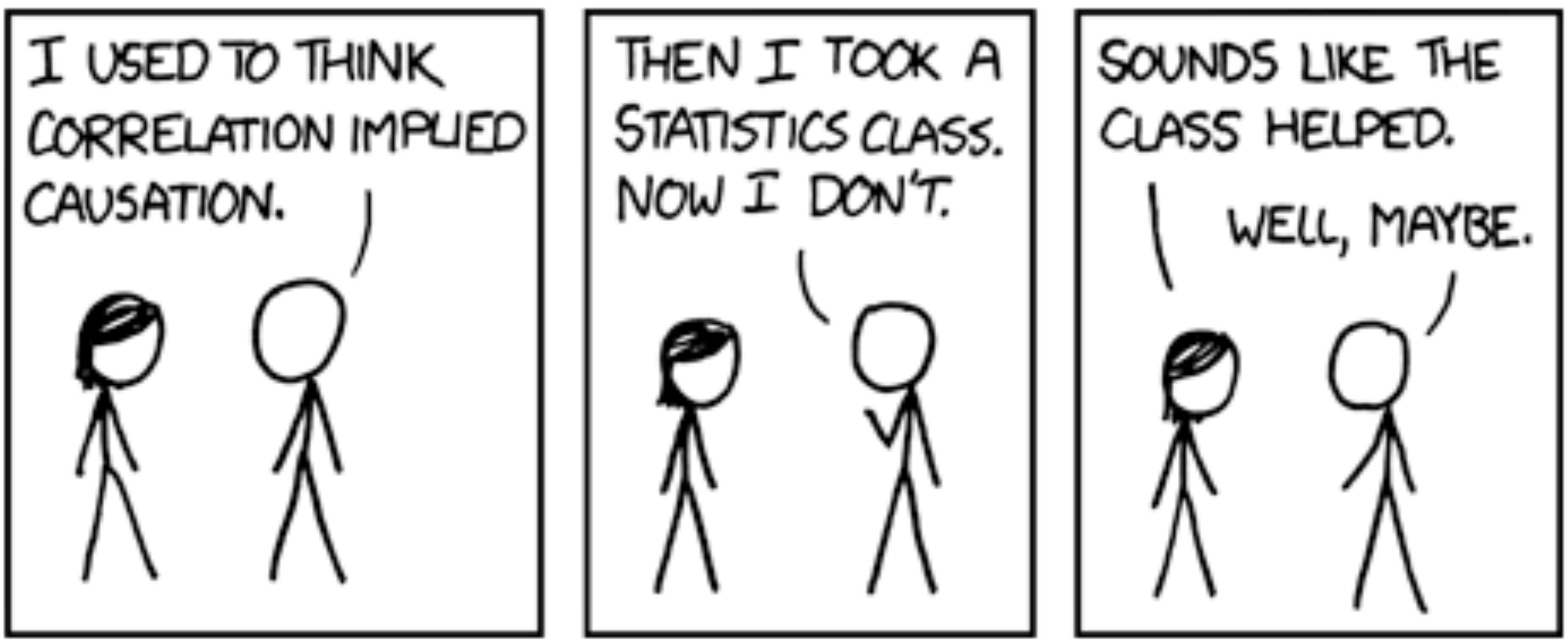
Temporal extrapolation



Correlative models can only take you so far….

Forecasting

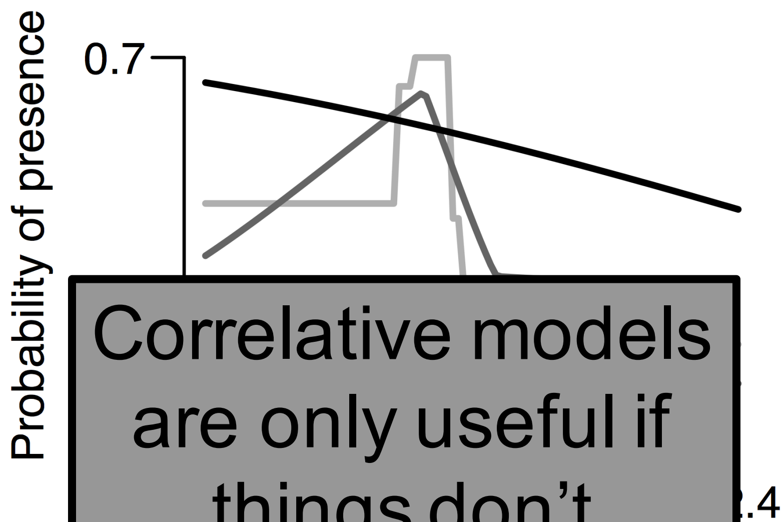
And the need for mechanism…



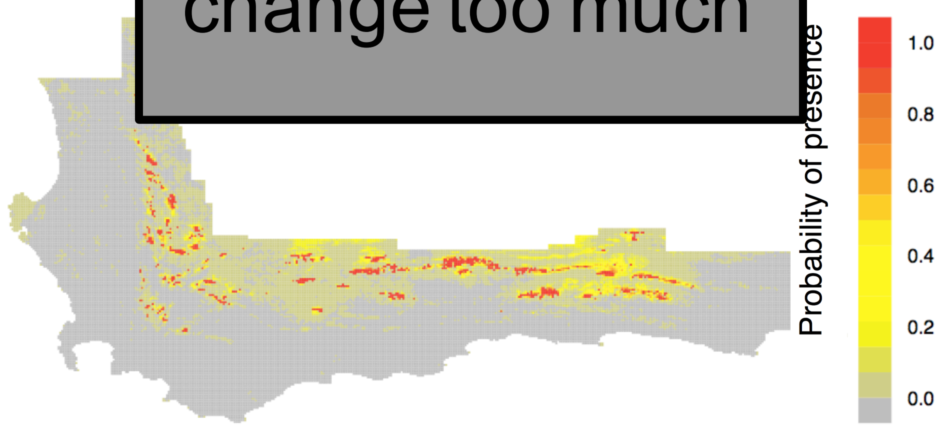
http://xkcd.com

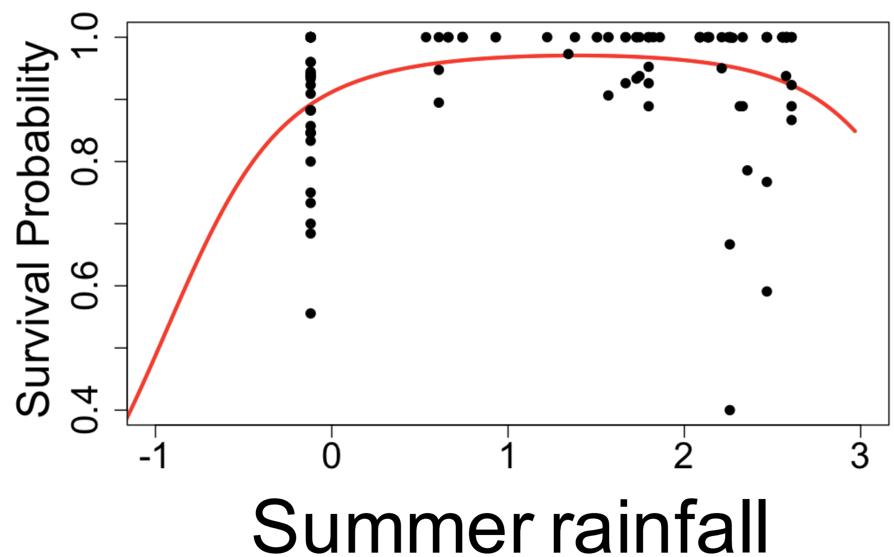
Correlative

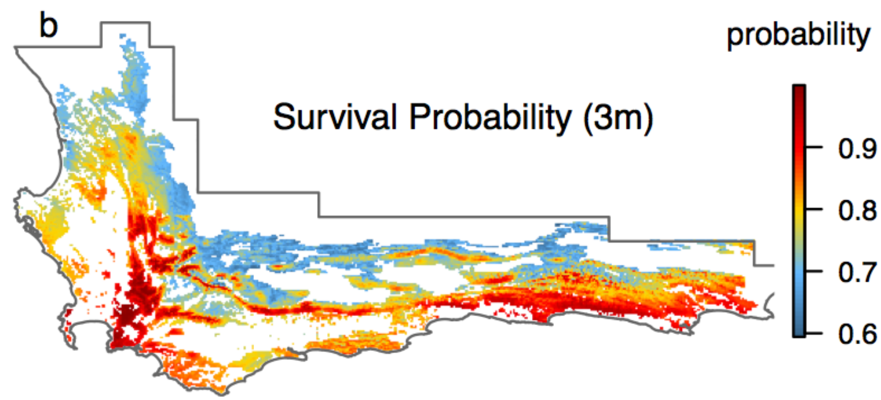
Mechanistic



Correlative models are only useful if things don't change too much



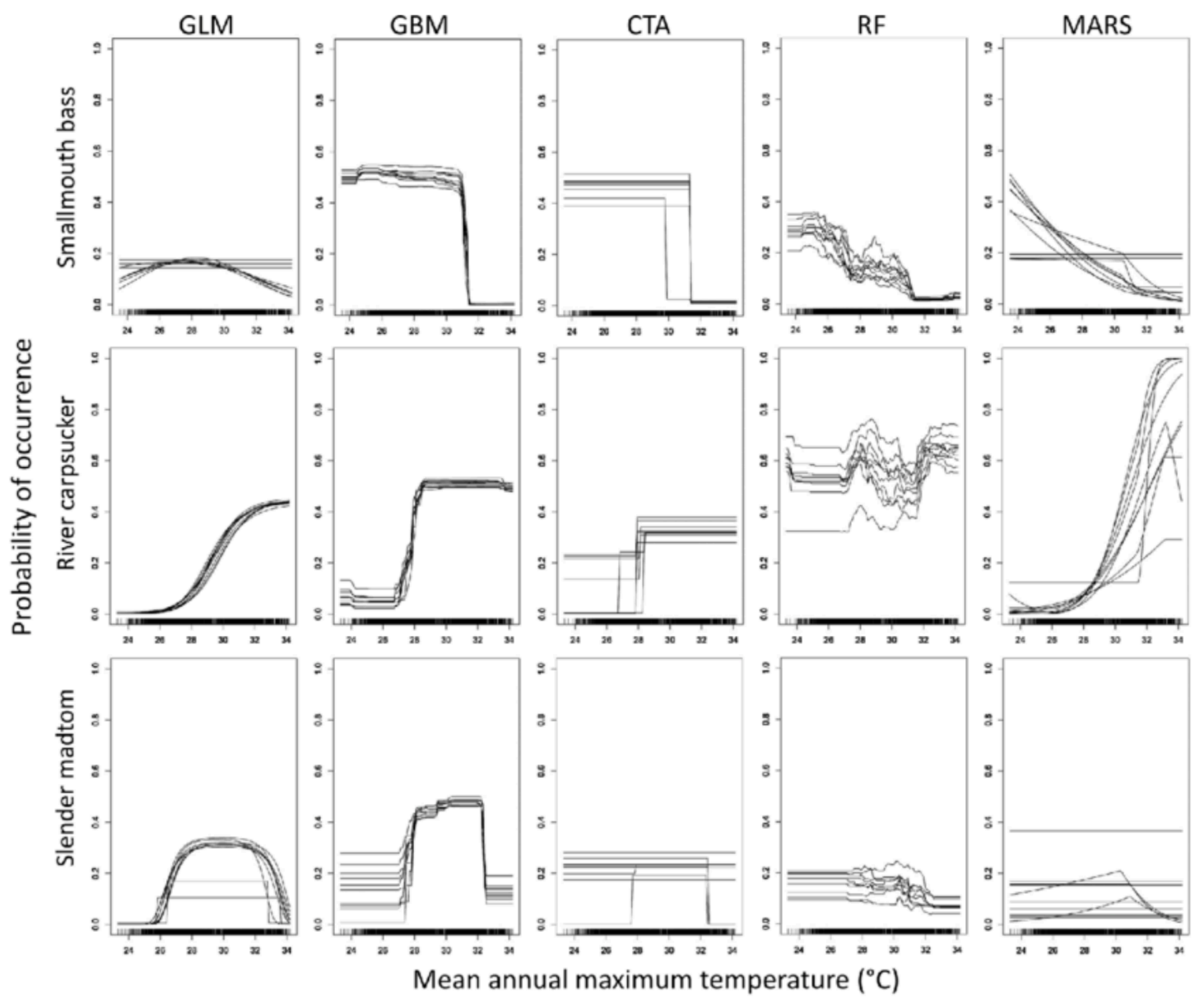




Uncertainty

- Modeling decisions
- Parameters
- Future Scenarios

Modeling decisions: algorithms



Modeling decisions: ensembles

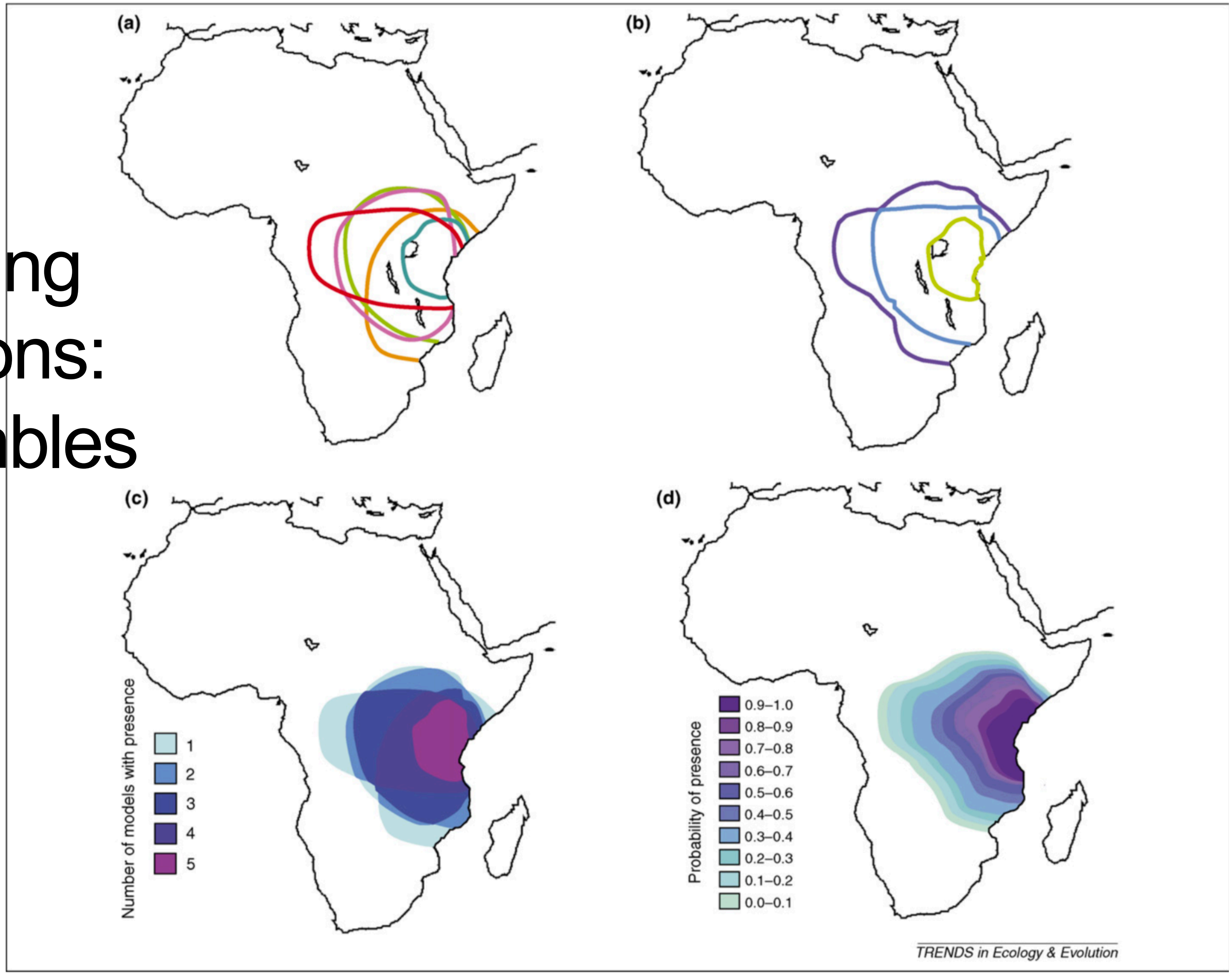
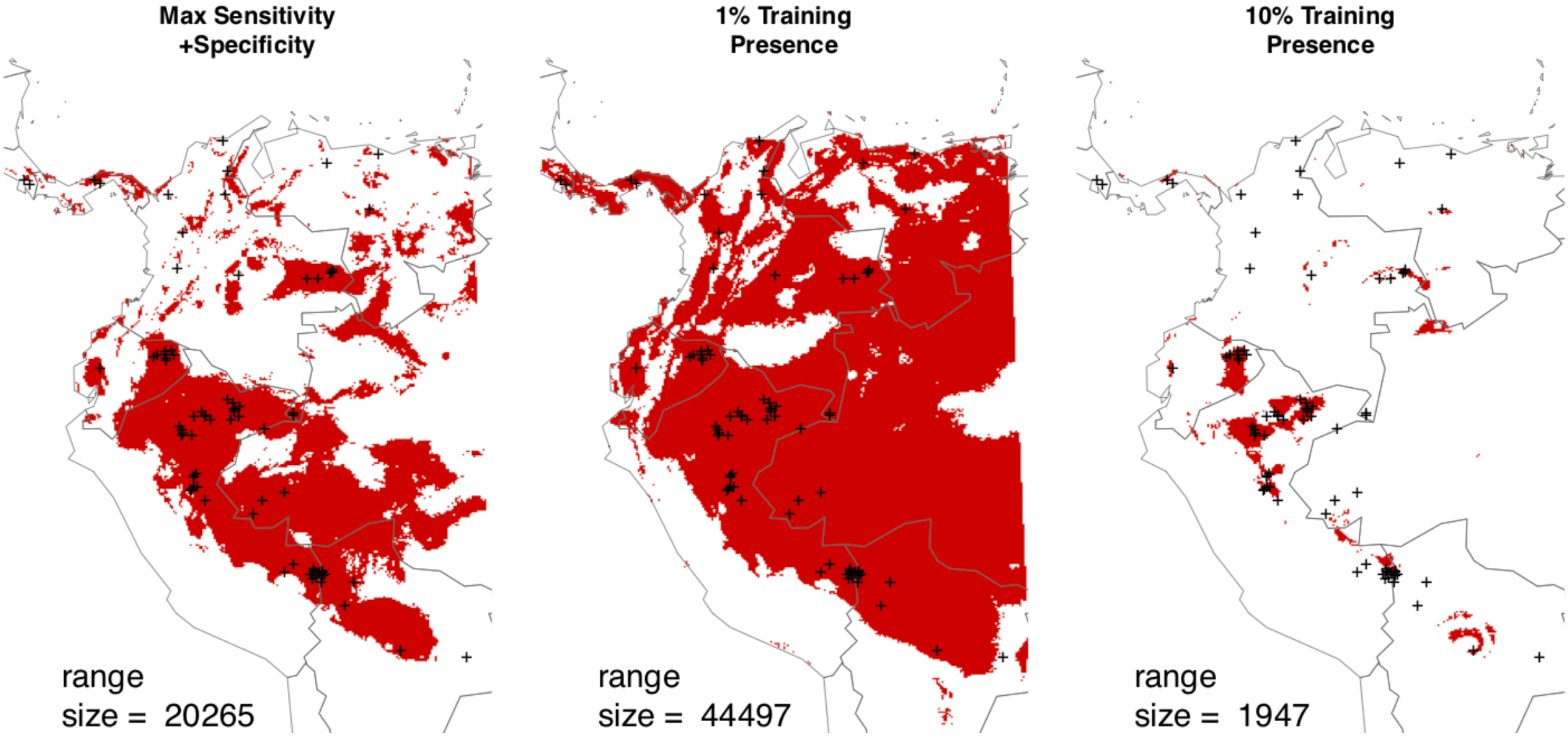


Figure 1. Examples of alternative approaches to analysing ensemble forecasts using artificial data projected onto the map of Africa: **(a)** Individual results from five hypothetical bioclimatic models (shown by coloured lines) predicting the area occupied by a key species under a climate change scenario (no combination of the ensemble forecast is performed); **(b)** a bounding box showing the area where at least one (purple) or all models (green) predict species presence in the future, and a consensus forecast (blue) showing the area where at least half the models (the median) forecast species presence; **(c)** a frequency histogram, showing the number of models (1–5) forecasting the presence of the species at any point; and **(d)** a probability density function showing the likelihood of species presence estimated from a large ensemble

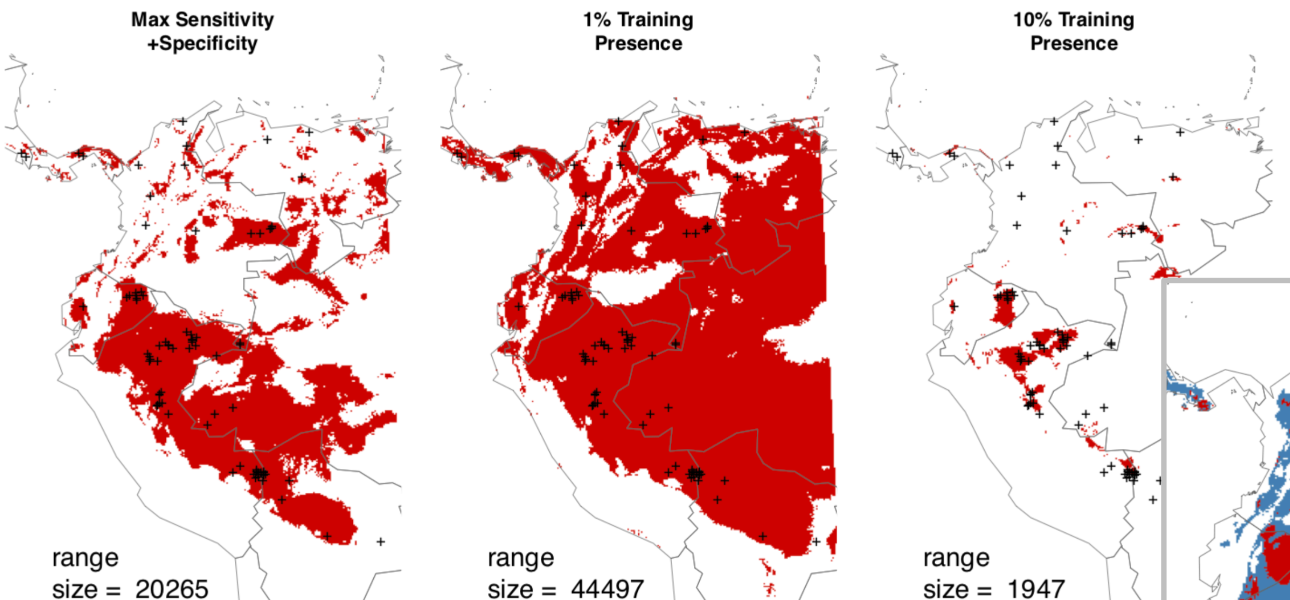
Modeling Decisions: Binary Maps

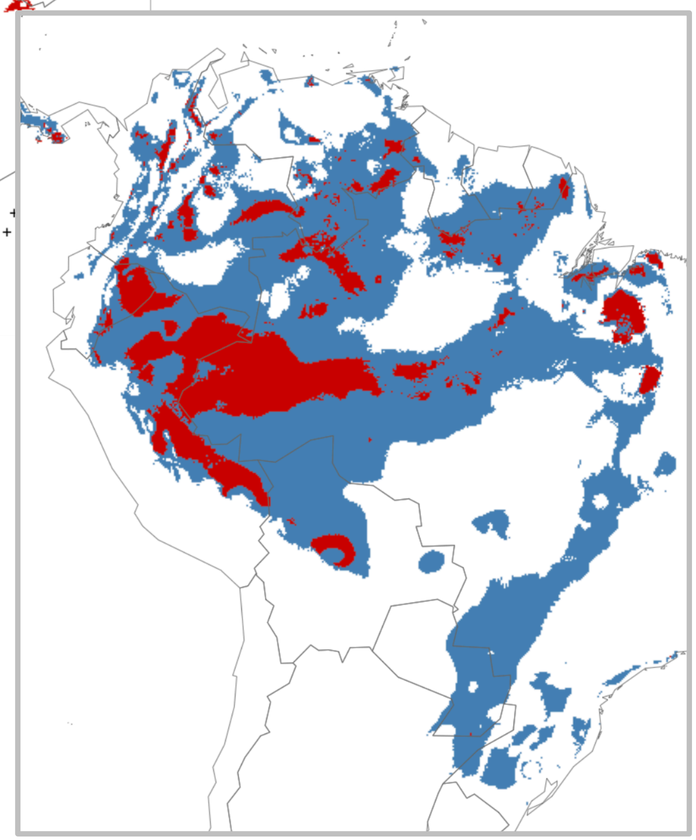


Determining the right threshold is dodgy with **presence – only** data

Merow et al, pretty soon

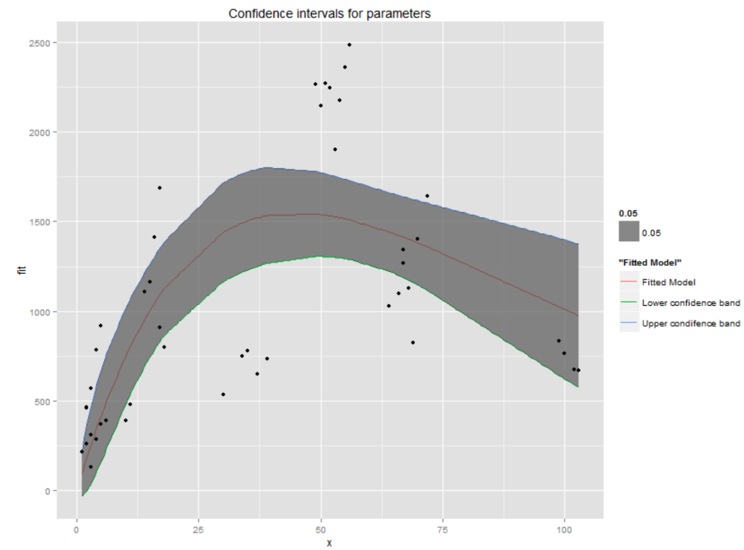
Modeling Decisions: Binary vs. **Trinary** Maps

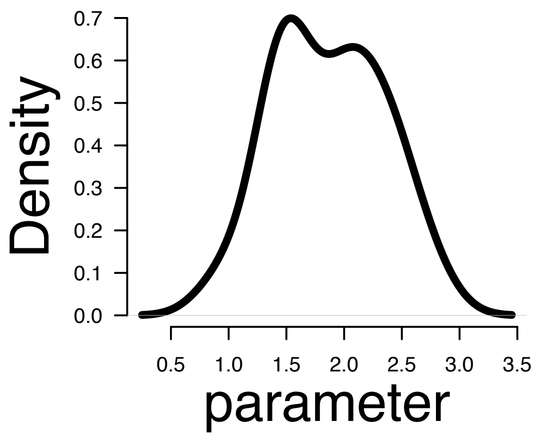


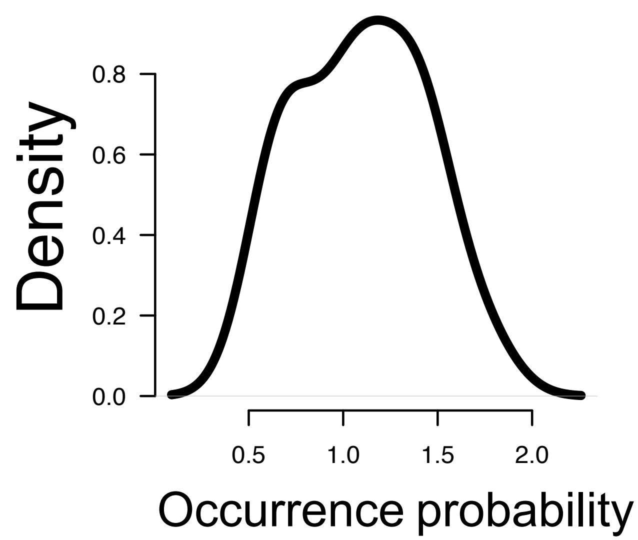


Merow et al, pretty soon

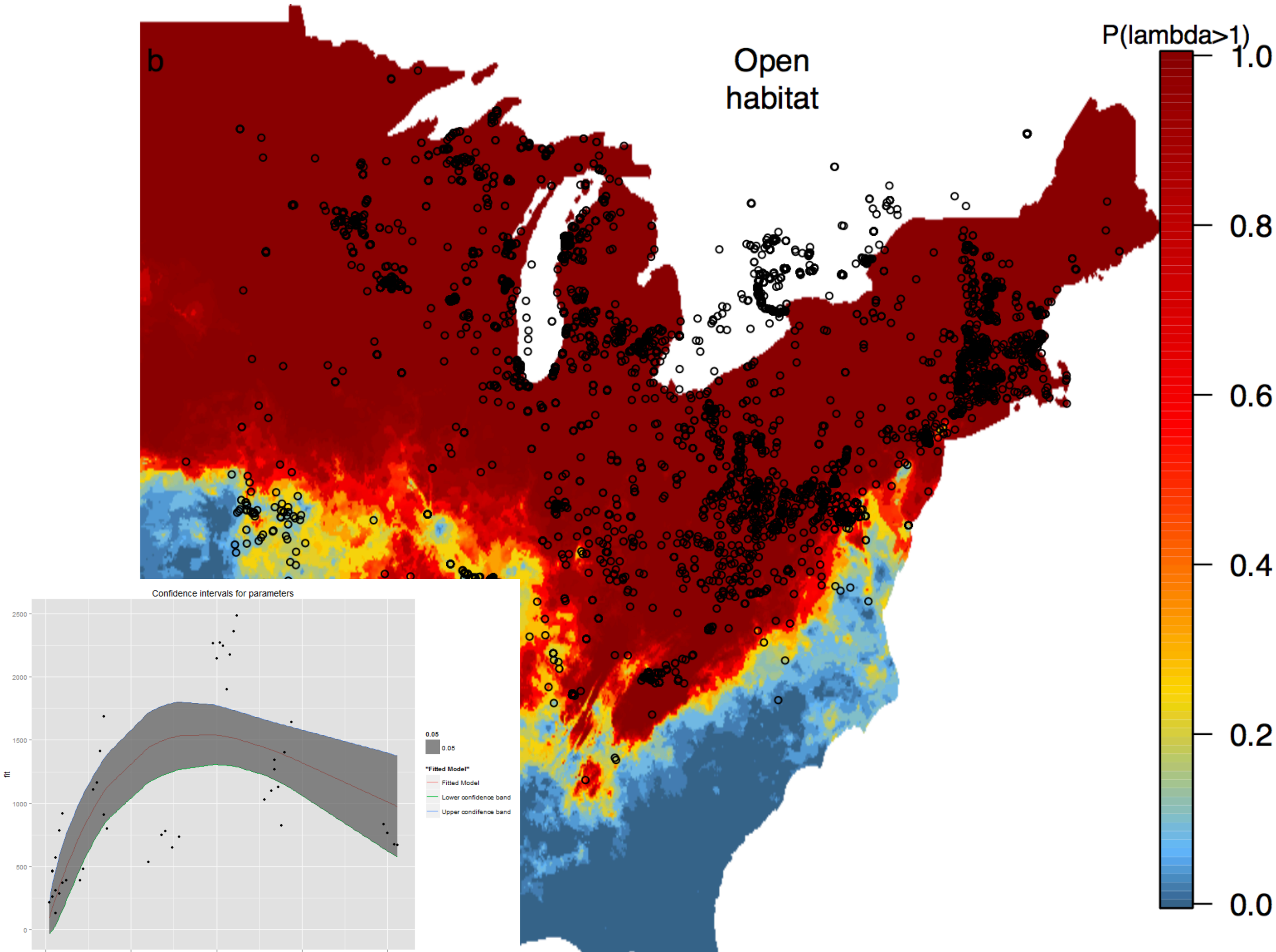
Parameter Uncertainty







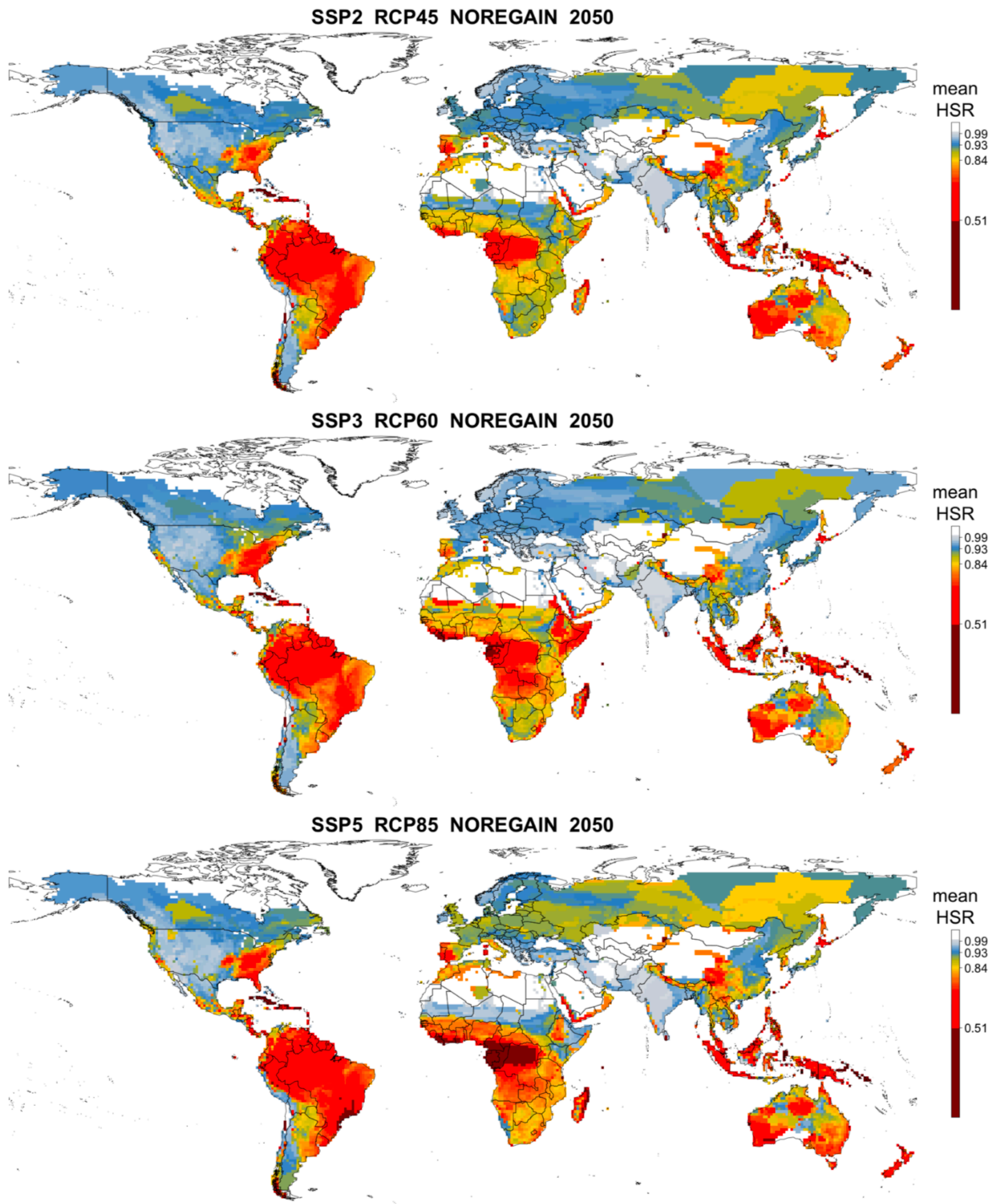
Parameter Uncertainty



Merow, et al. 2017, PNAS

Future scenarios

Weather
Climate
Land Use
Disperal



Concluding thoughts

Types of extrapolation

- Environment
- Space
- Time

Uncertainty

- Modeling decisions
- Parameters
- Future Scenarios

Identify the type

Reduce, report