

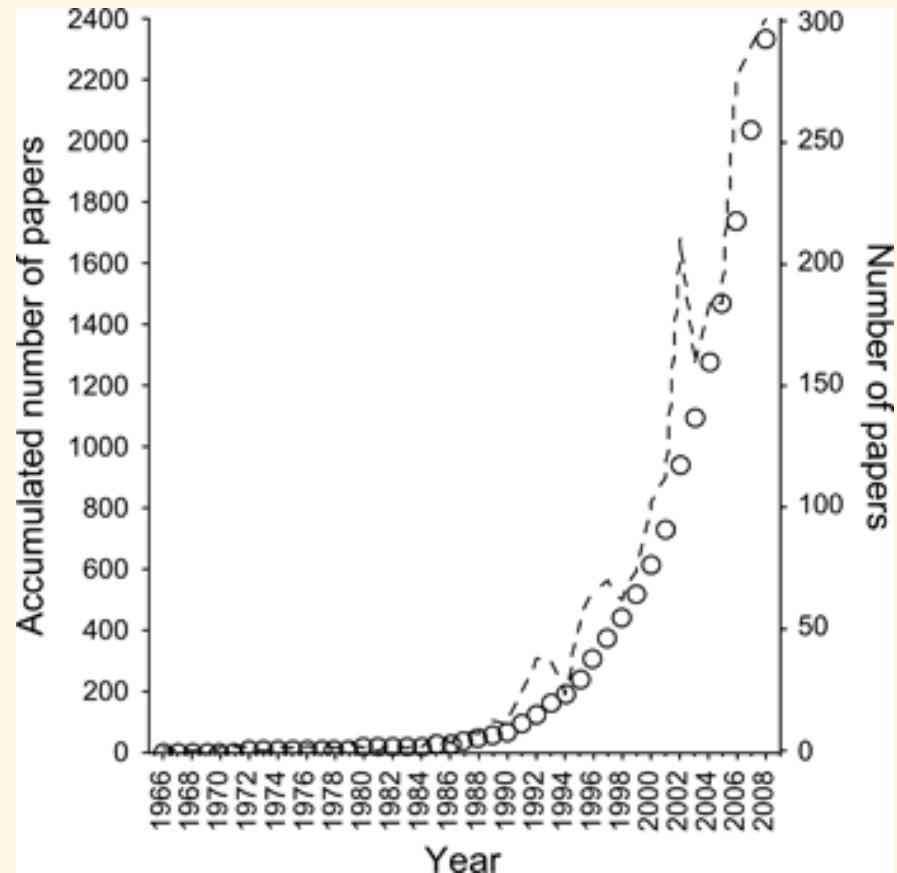
SPECIES DISTRIBUTION MODELS

DAVID ORME

OUTLINE

- Introduction
- Process overview
- Theoretical framework
- Applications
- Assessing predictive performance
- Concerns and future directions

THE UNSTOPPABLE RISE OF SDMS



Lobo et al. 2010 Ecography 33:103-114.

HOW DO I KNOW A SDM WHEN I SEE IT?



From Elith et al. 2006 Ecography 29: 129-151, Table 4

HOW DO I KNOW A SDM WHEN I SEE IT?

Many different terms:

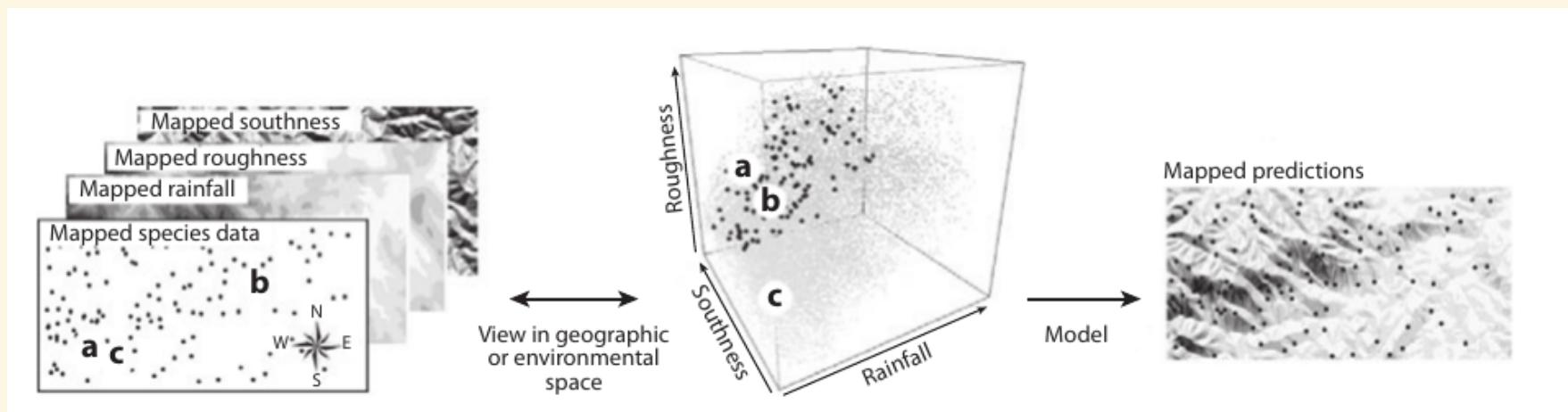
- Species Distribution Modelling
- Climate Envelope Modelling
- Bioclimate Envelope Modelling
- Habitat Distribution Modelling
- Niche Modelling

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WHAT IS SPECIES DISTRIBUTION MODELLING?

- Interpolating biological survey data in space
- Quantitative predictive models of species / environment relationships



Elith et al. 2009 Ann Rev Ecol, Evol & Syst 40:677-697.

OVERVIEW OF SDM PROCESS

- Data on species occurrence in geographical space
- Maps of environmental data
- A model to link occurrence data to the environmental variables
- A GIS with which to produce a map of predicted species occurrence
- A way to validate the predictions

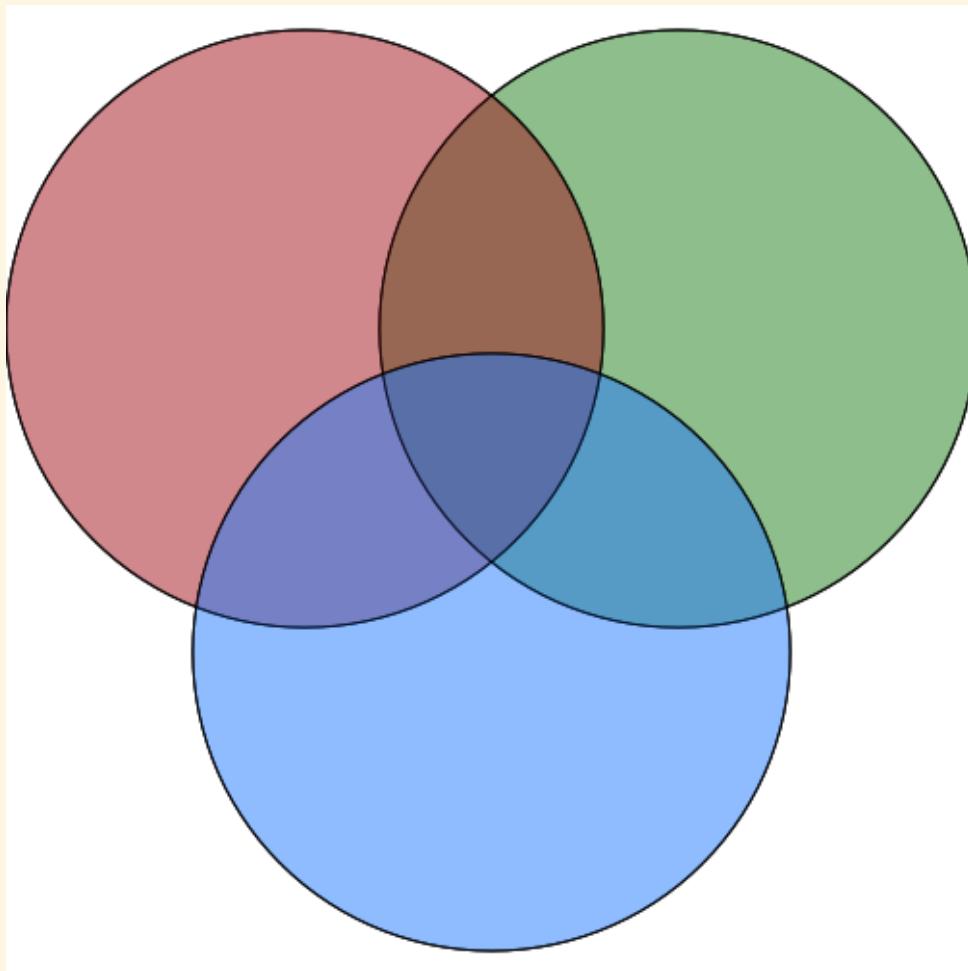
WHY?

- To understand species distributions
- To predict the occurrence of a species for locations where good survey data are lacking
 - Guide for field surveys
 - Assess climate change impacts
 - Predict invasive species spread
 - Inform reserve selection

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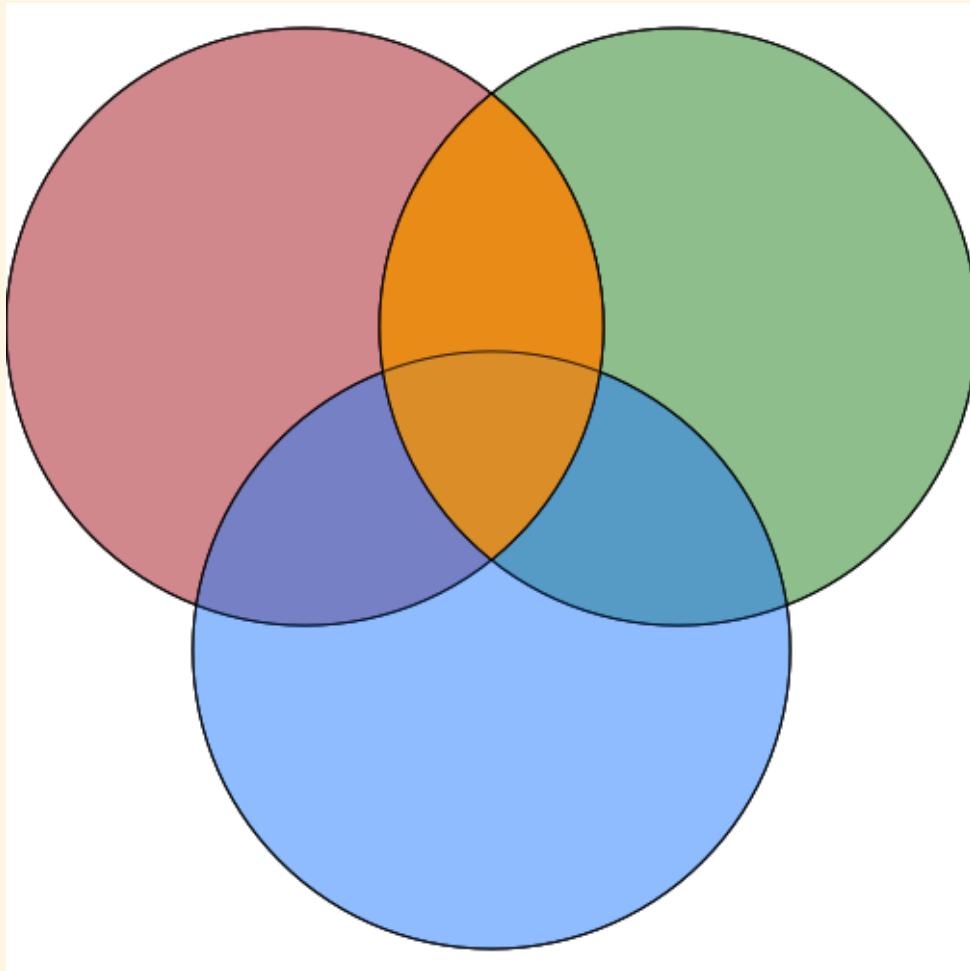
NICHE THEORY



- Abiotic
- Biotic
- Accessible area

Soberón & Peterson (2005)

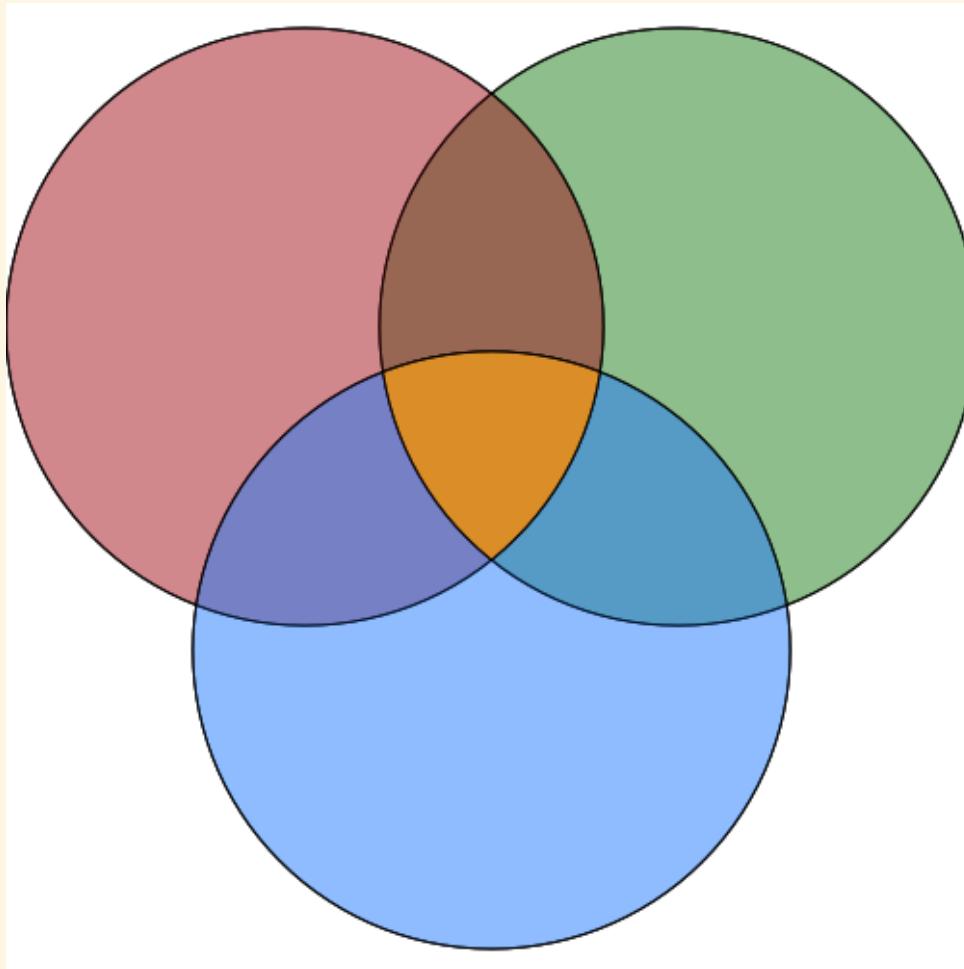
NICHE THEORY



- Abiotic
- Biotic
- Accessible area
- **Realised niche:**
both biotic and
abiotic suitability

Soberón & Peterson (2005)

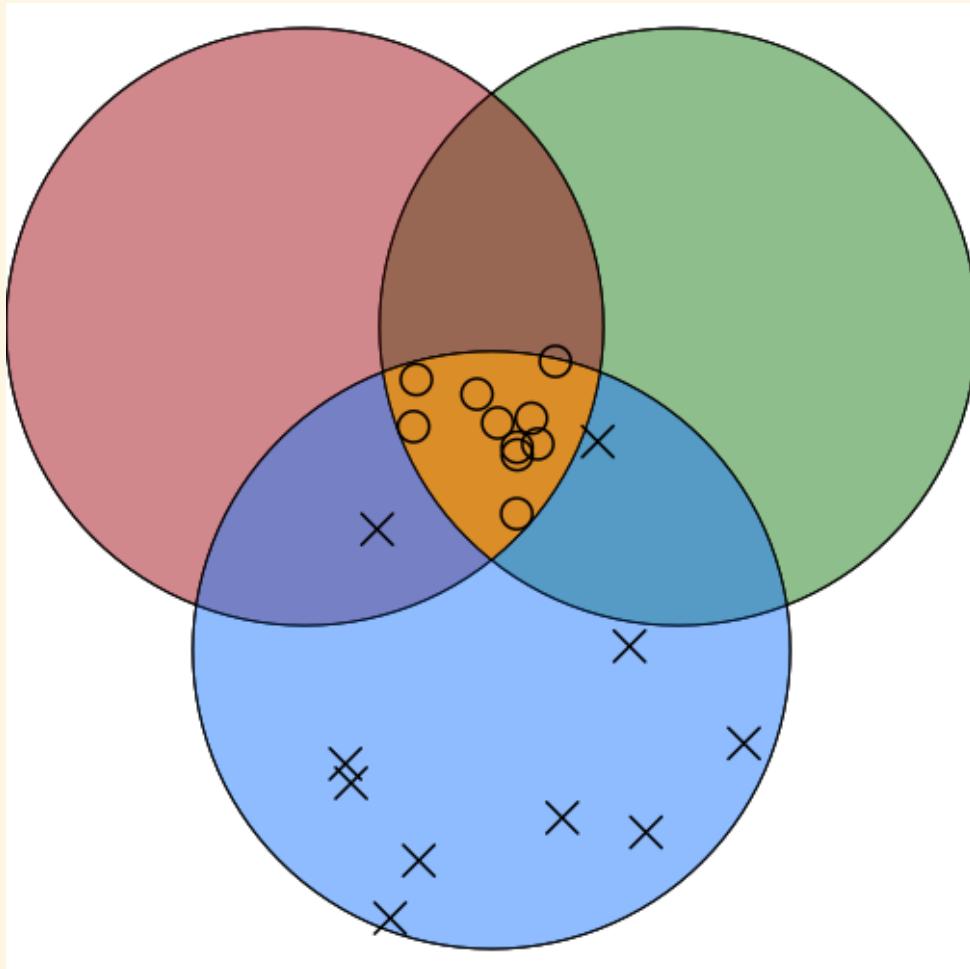
NICHE THEORY



- Abiotic
- Biotic
- Accessible area
- Range core:
accessible and in
realised niche

Soberón & Peterson (2005)

NICHE THEORY



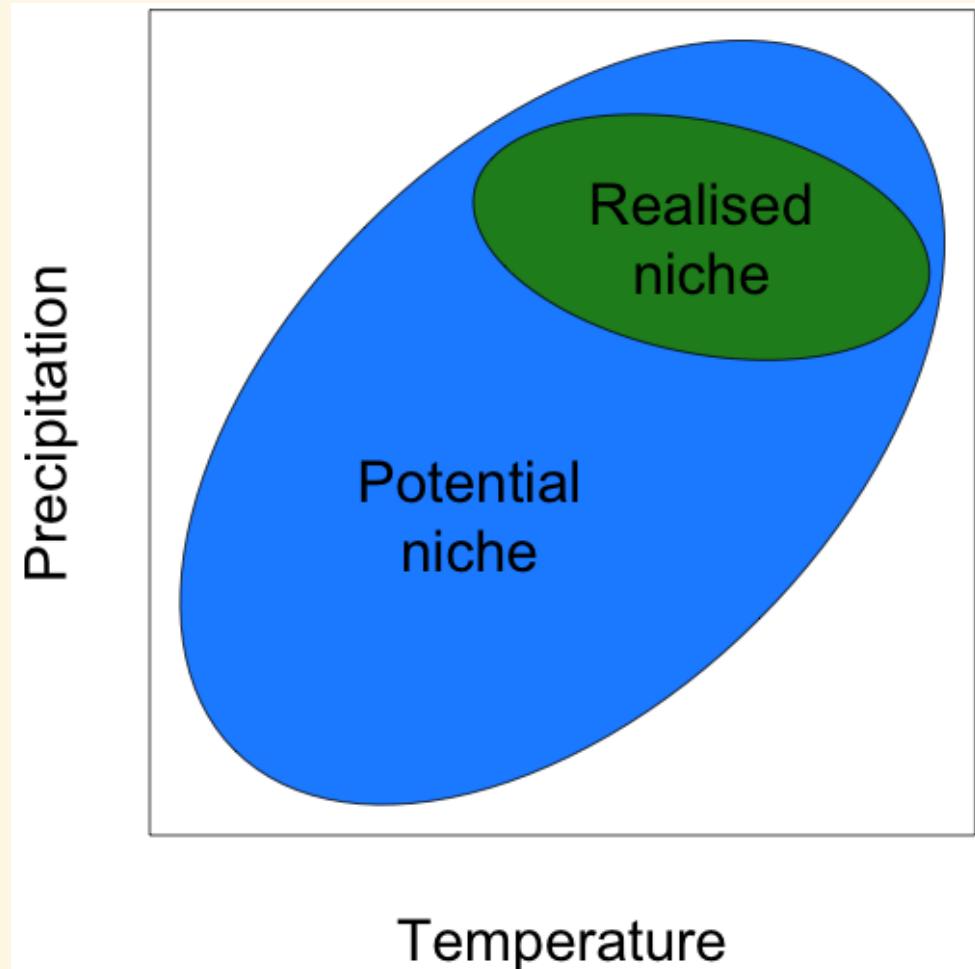
- Abiotic
- Biotic
- Accessible area
- **Populations:** can be both source (o) and sink (x)

Soberón & Peterson (2005)

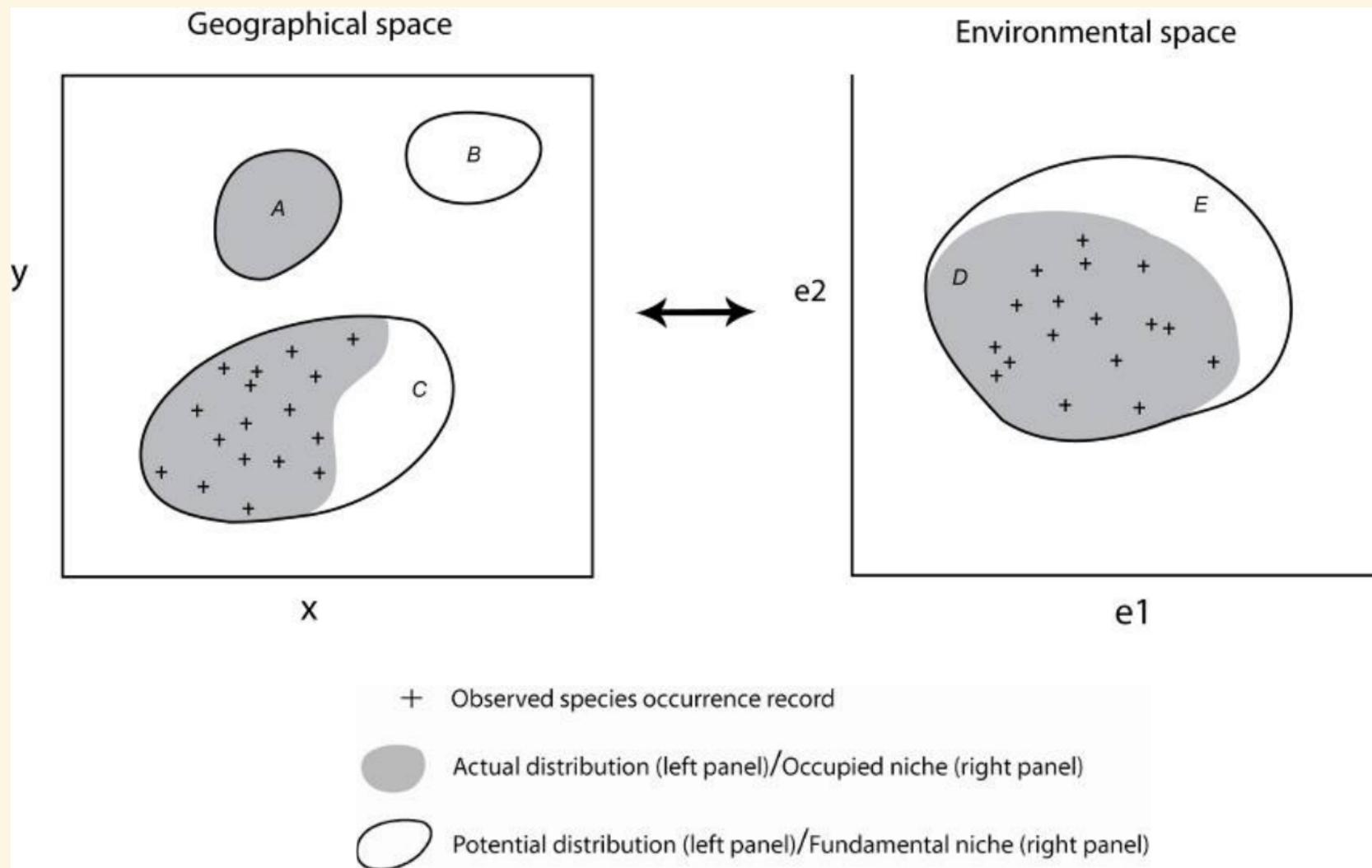
NICHE THEORY

“The n-dimensional hypervolume within which that species can survive and reproduce”

Hutchinson (1957)

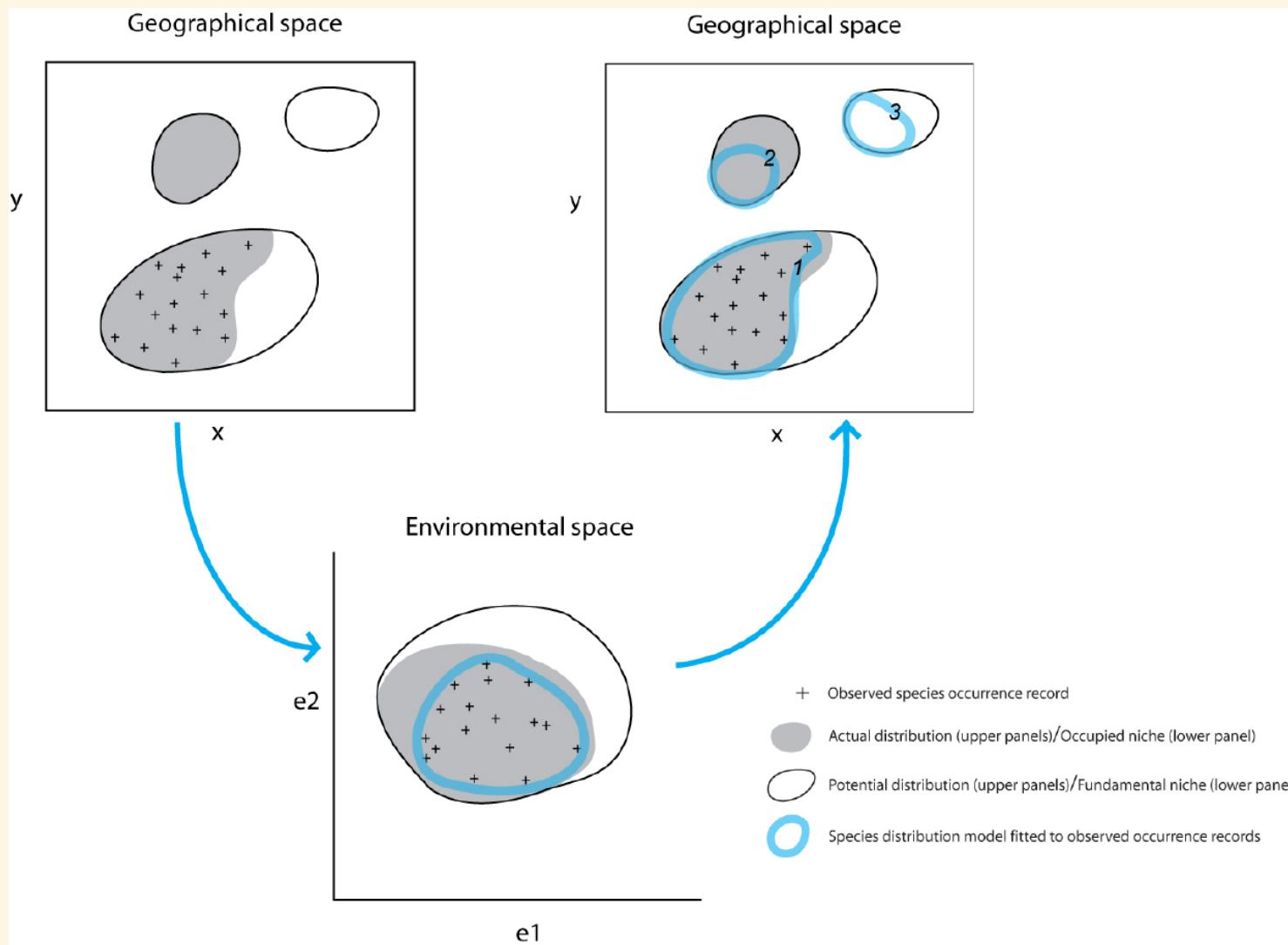


ENVIRONMENTAL AND GEOGRAPHICAL SPACE



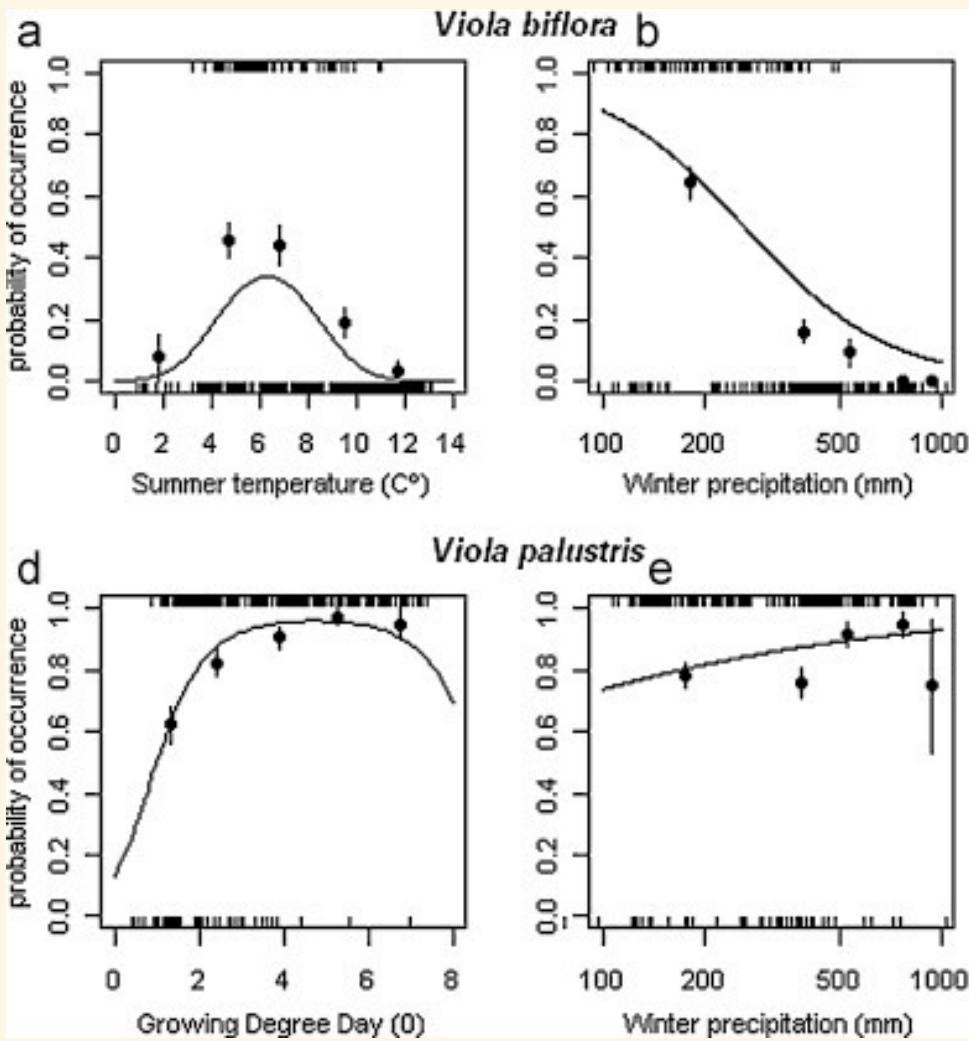
Pearson 2007., see also Peterson et al. 2011

ENVIRONMENTAL AND GEOGRAPHICAL SPACE



Pearson 2007., see also Peterson et al. 2011

MODELLLED RELATIONSHIP



MODEL ALGORITHMS

| Approach | Software |
|------------------------|------------------------------|
| Rectilinear envelope | BIOCLIM |
| ENFA | BIOMAPPER |
| Maximum Entropy | MAXENT |
| Genetic algorithm | GARP |
| Regression | e.g. R |
| Machine-learning | e.g. R |
| Classification methods | Classification Tree Analysis |

SUMMARY

Species Distribution Models:

- identify areas in a landscape,
- that have similar environments to localities,
- where the species has been observed.

That's it!

However, this information can be extremely useful in a wide range of applications.

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GUIDING FIELD STUDIES

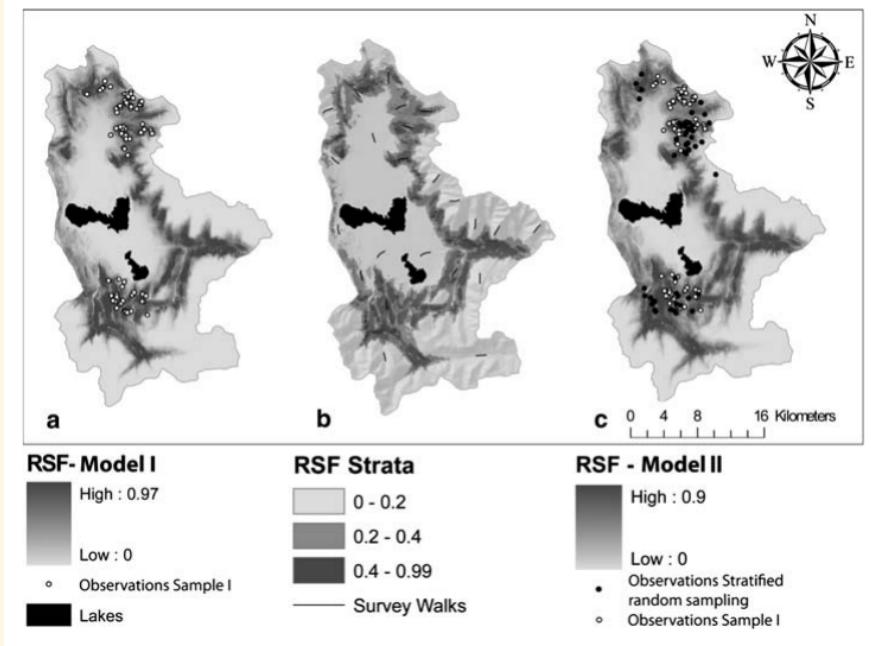
Biodivers Conserv (2009) 18:2893–2908
DOI 10.1007/s10531-009-9615-5

ORIGINAL PAPER

Using habitat suitability models to sample rare species in high-altitude ecosystems: a case study with Tibetan argali

Navinder J. Singh · Nigel G. Yoccoz · Yash Veer Bhatnagar ·
Joseph L. Fox





INFORMING OUR VIEW OF THE PAST

OPEN  ACCESS Freely available online

PLOS BIOLOGY

Climate Change, Humans, and the Extinction of the Woolly Mammoth

David Nogués-Bravo^{1*}, Jesús Rodríguez², Joaquín Hortal³, Persaram Batra⁴, Miguel B. Araújo¹

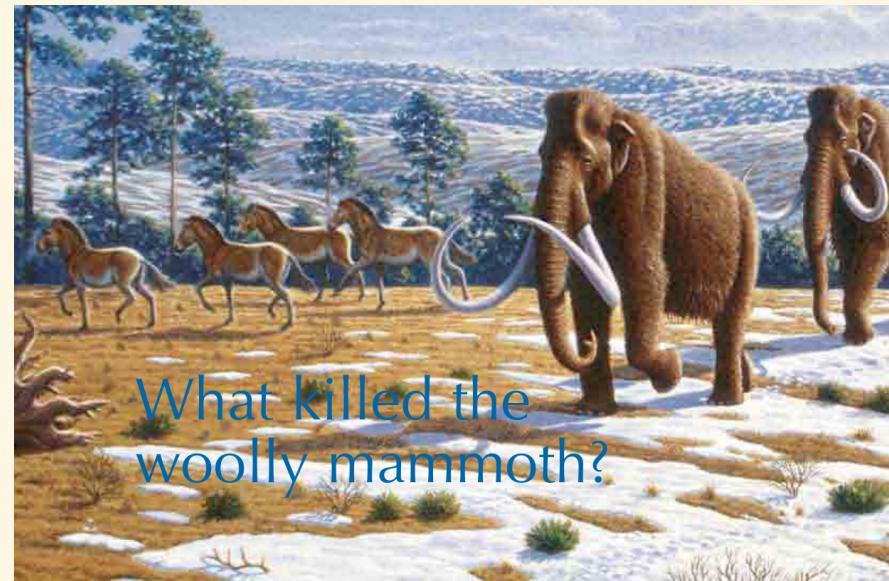
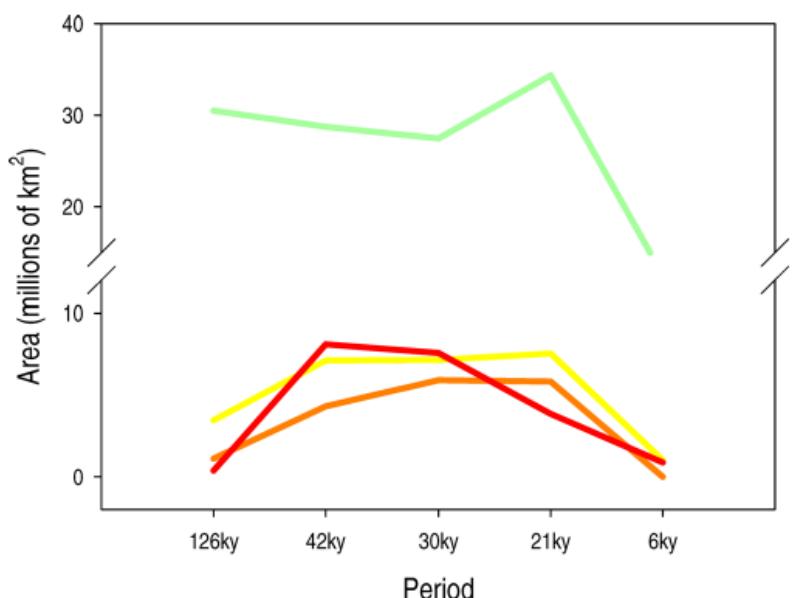
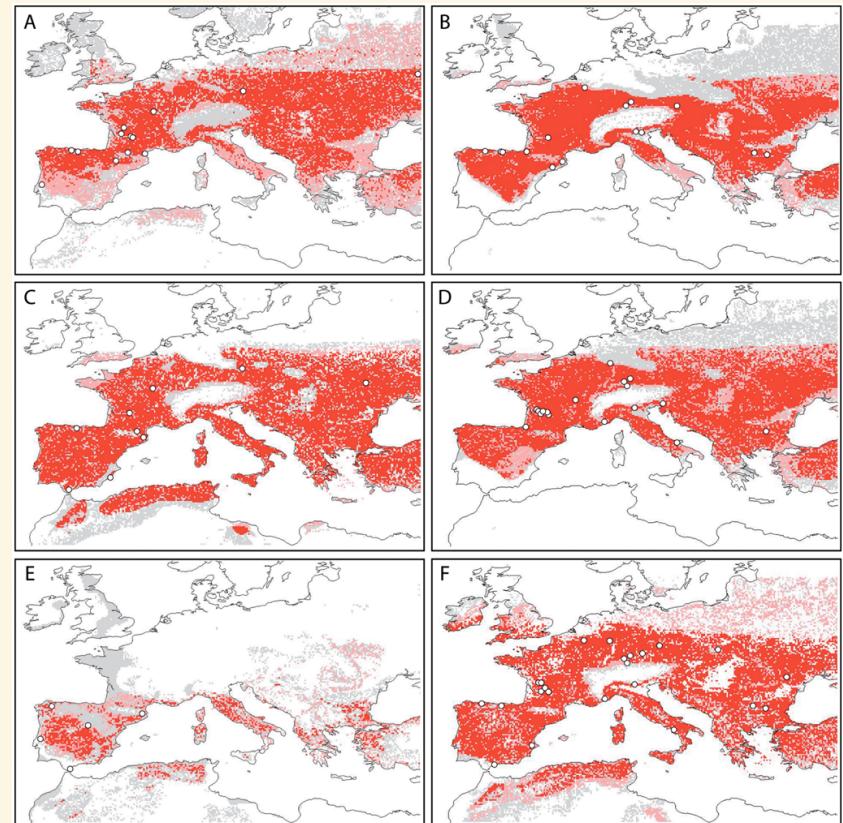


Figure 2. Change in the Area (%) of the Different Suitable Climatic Conditions for Woolly Mammoths

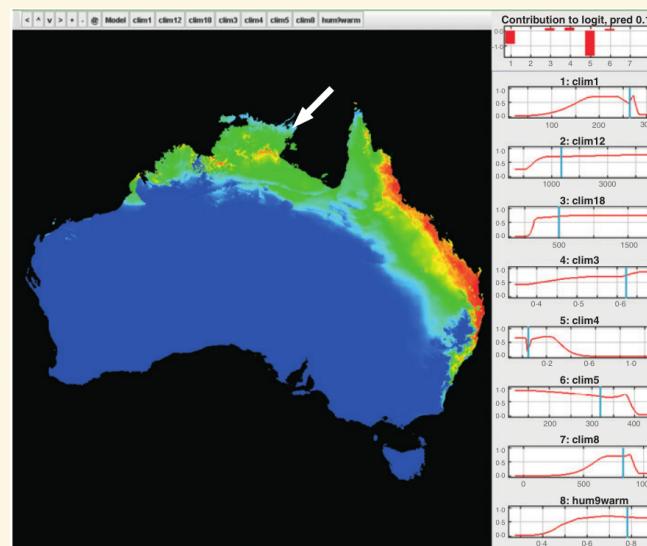
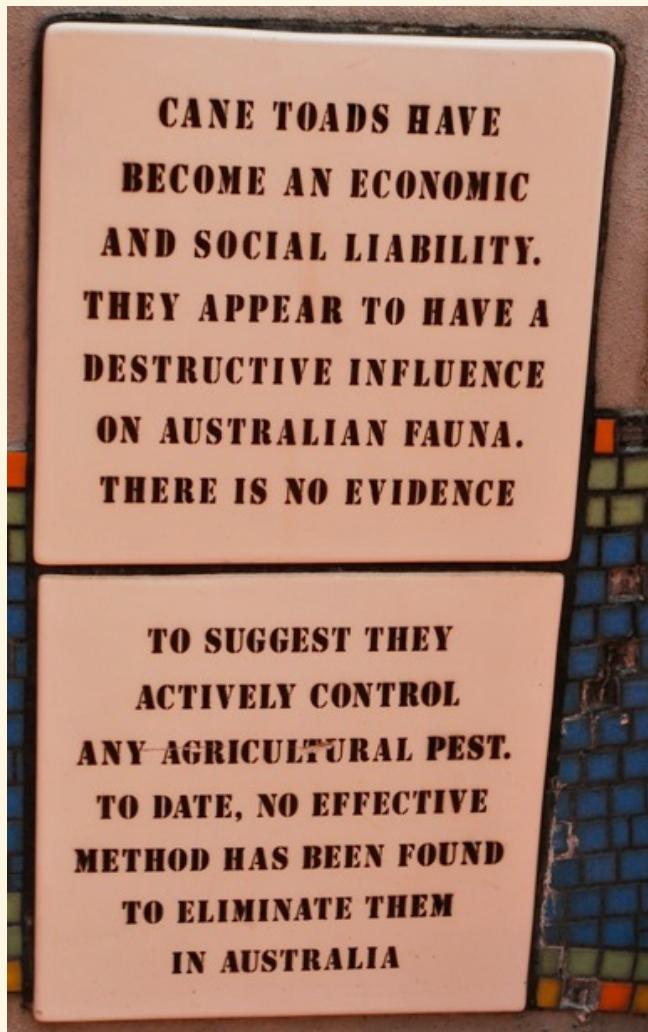
INFORMING OUR VIEW OF THE PAST

Neanderthal Extinction by Competitive Exclusion

William E. Banks^{1*}, Francesco d'Errico^{1,2}, A. Townsend Peterson³, Masa Kageyama⁴, Adriana Sima⁴, Maria-Fernanda Sánchez-Goñi⁵



SPREAD OF INVASIVE SPECIES



IMPACTS OF CLIMATE CHANGE

the guardian

News | Sport | Comment | Culture | Business | Money | Life & style

Environment > Wildlife

Climate change driving species out of habitats much faster than expected

Animals and plants have adapted to warming by moving regions up to three times faster than previously thought, report shows

Fiona Harvey, environment correspondent
The Guardian, Thursday 18 August 2011 19.00 BST



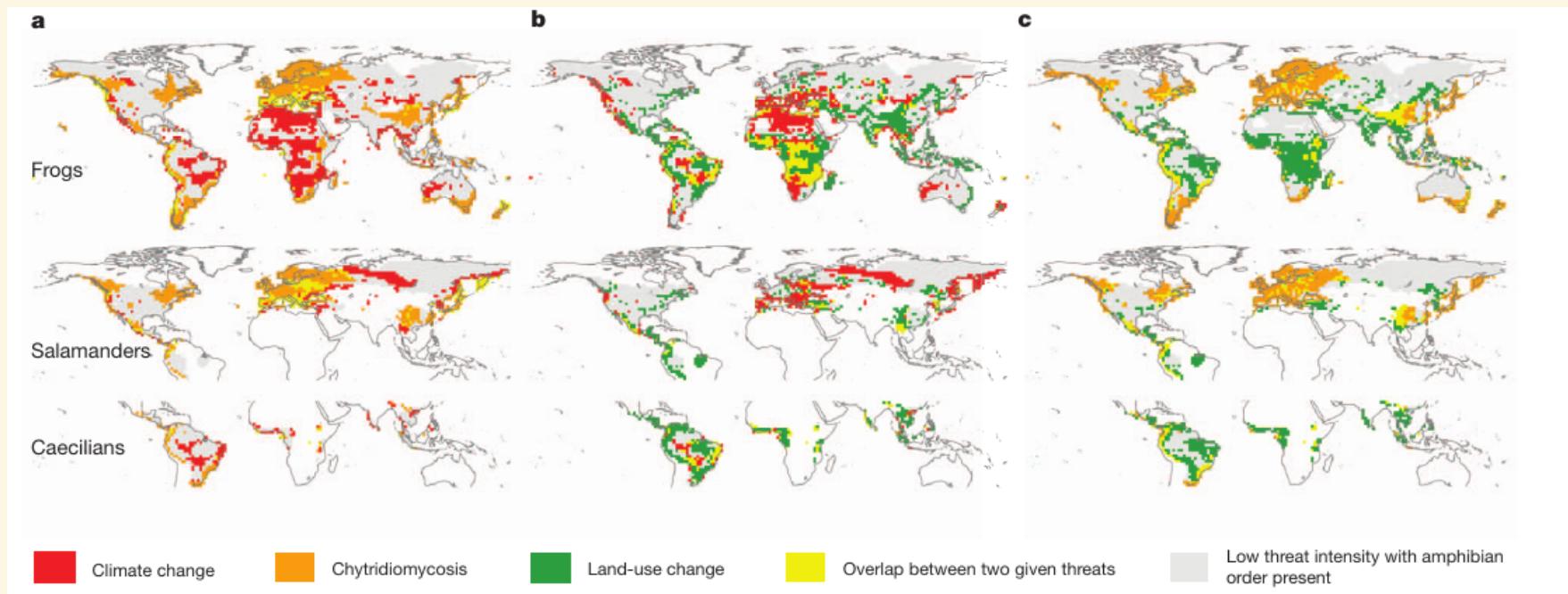
The Cetti's warbler has moved 150 km further north within the UK in the past 40 years, in response to the changing climate. Photograph: George Reszeter/Alamy

Extinction risk from climate change

Chris D. Thomas¹, Alison Cameron¹, Rhys E. Green², Michel Bakkenes³, Linda J. Beaumont⁴, Yvonne C. Collingham⁵, Barend F. N. Erasmus⁶, Martinez Ferreira de Siqueira⁷, Alan Grainger⁸, Lee Hannah⁹, Lesley Hughes⁴, Brian Huntley⁵, Albert S. van Jaarsveld¹⁰, Guy F. Midgley¹¹, Lera Miles^{8*}, Miguel A. Ortega-Huerta¹², A. Townsend Peterson¹³, Oliver L. Phillips⁸ & Stephen E. Williams¹⁴

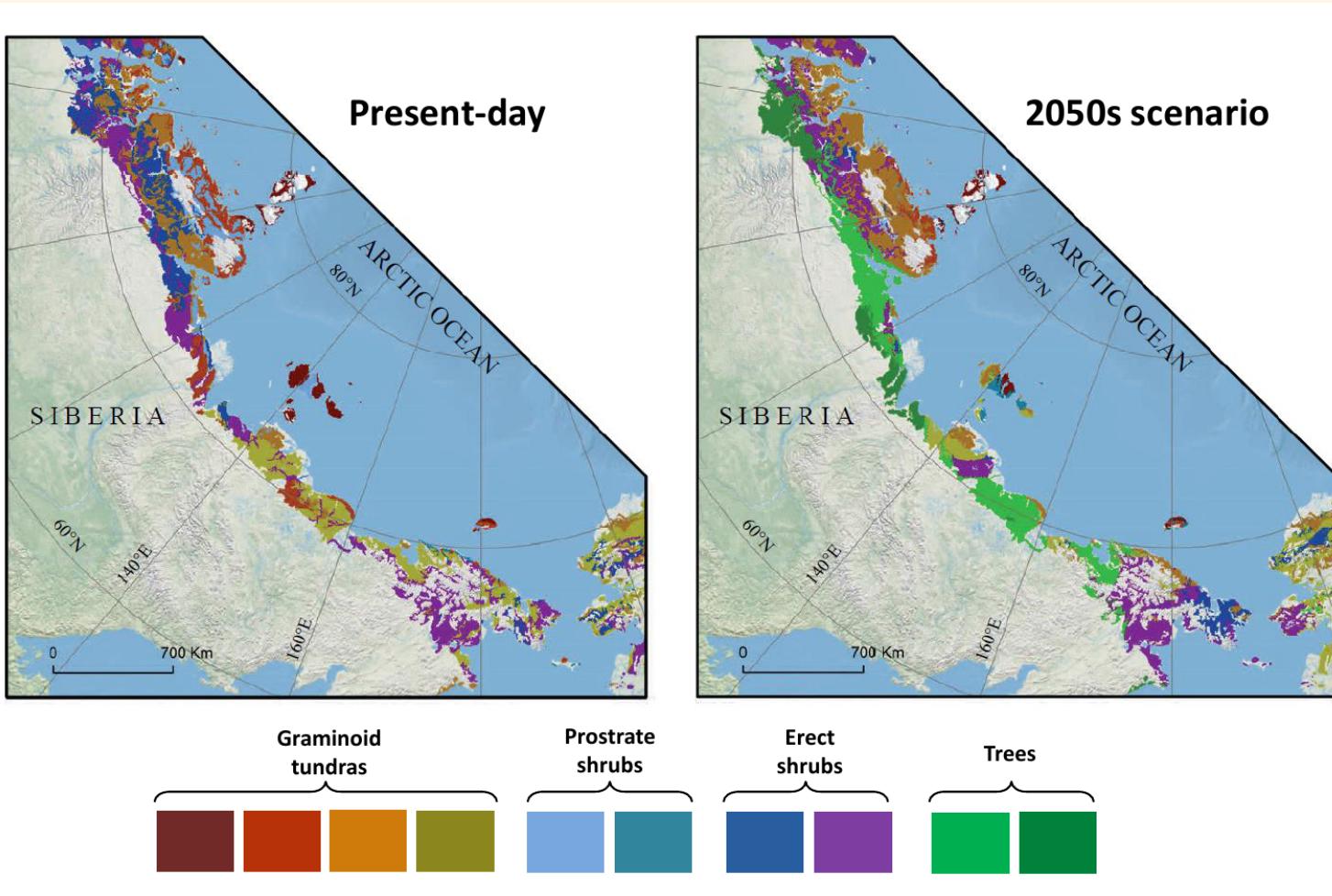


COMPARING DRIVERS



Hof et al (2011) Nature 480: 516-519

FUTURE PREDICTIONS



Pearson et al. 2013 Nature Climate Change 3:673–677

OUTLINE

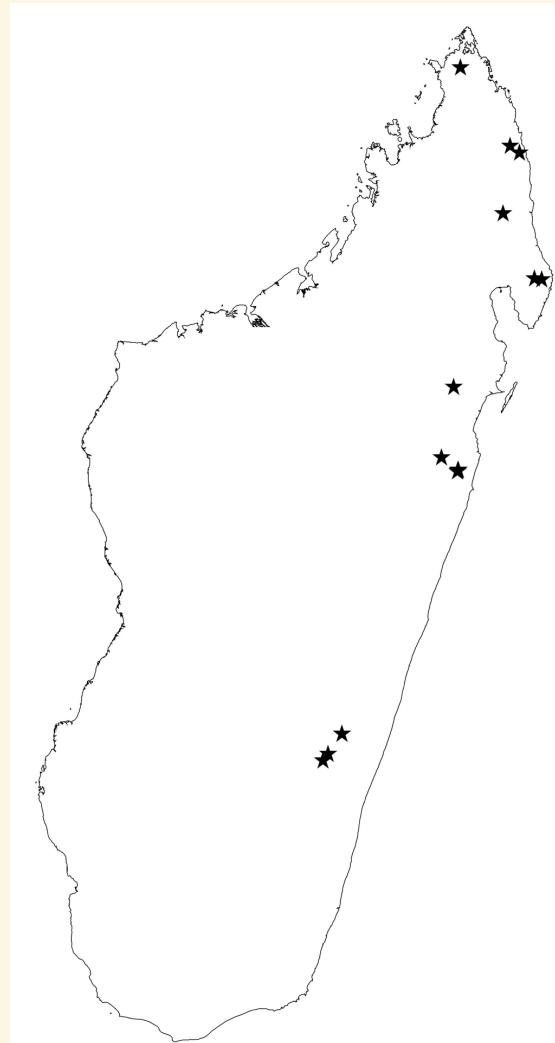
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MADAGASCAN GECKOS

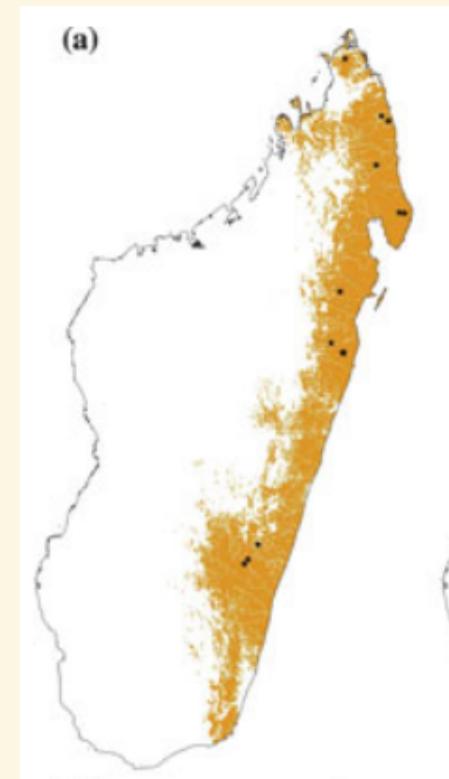
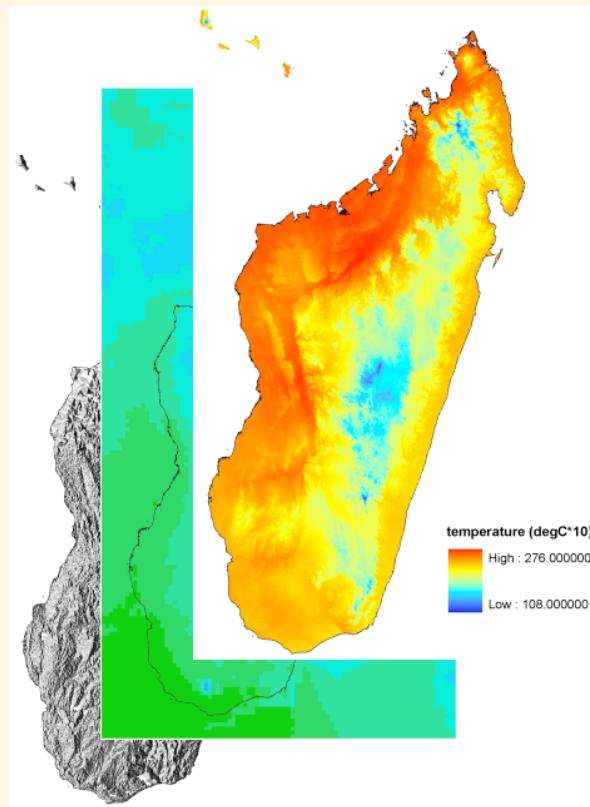
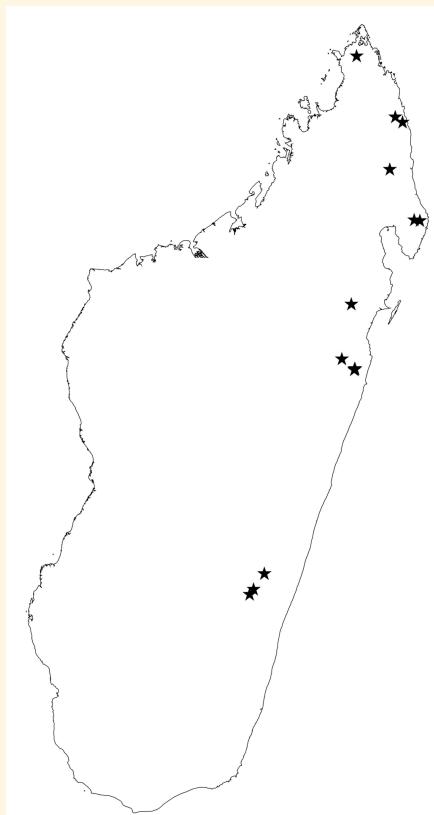


Uroplatus sp.

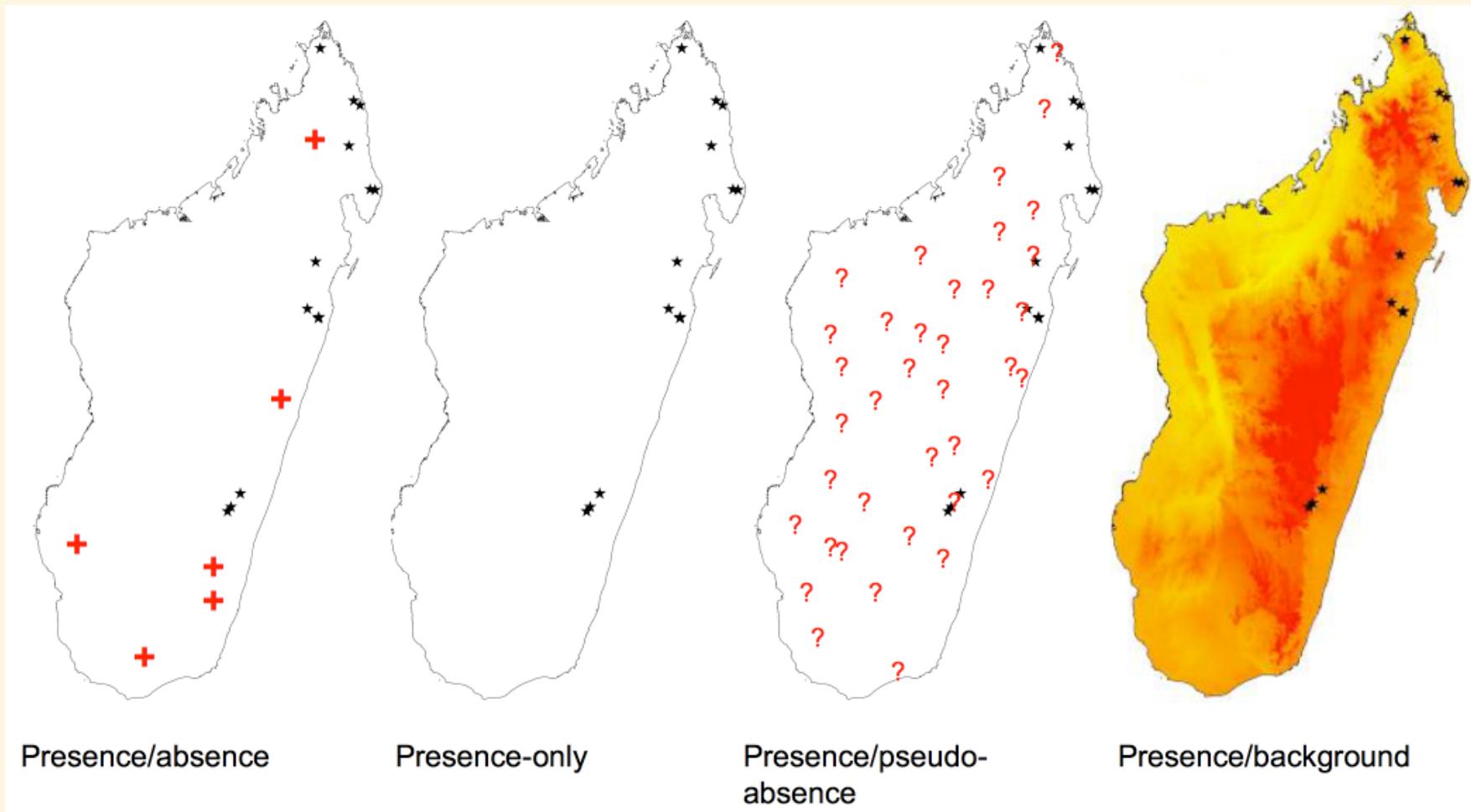
Pearson et al. (2007) J. Biogeog 34: 102-117



MADAGASCAN GECKOS



MADAGASCAN GECKOS



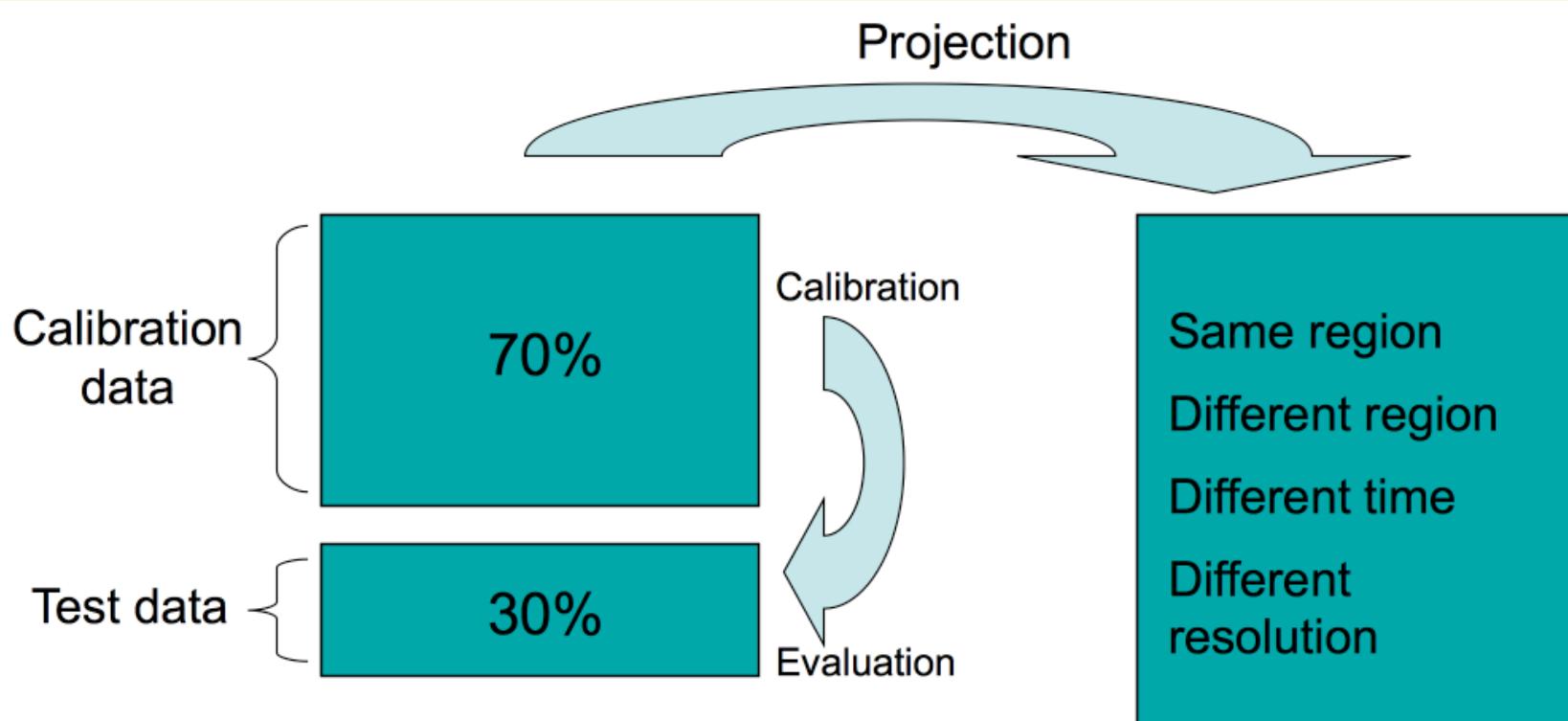
Presence/absence

Presence-only

Presence/pseudo-absence

Presence/background

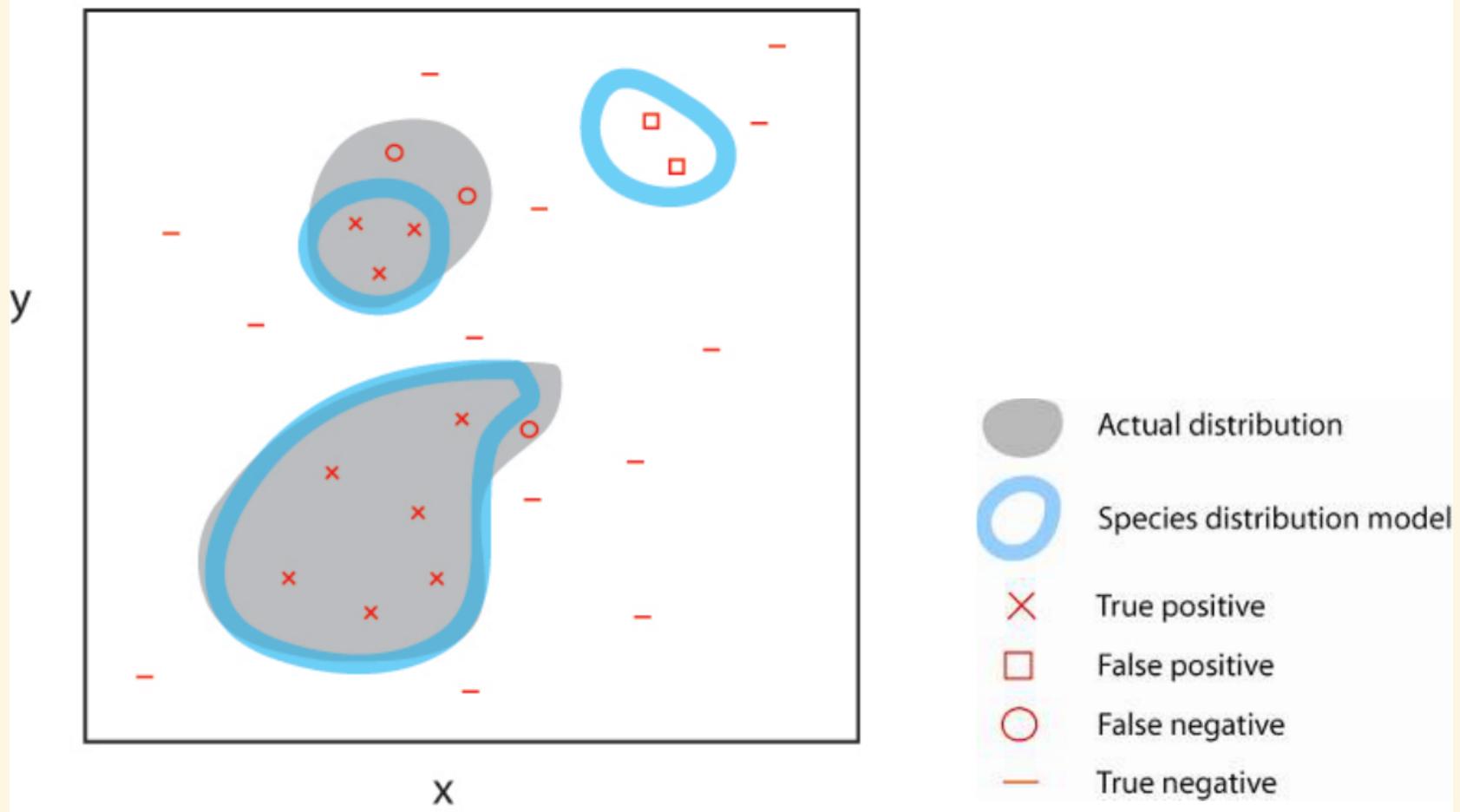
MODEL EVALUATION



(after Araújo et al. 2005 *Gl. Ch. Biol.*)

MODEL ERRORS

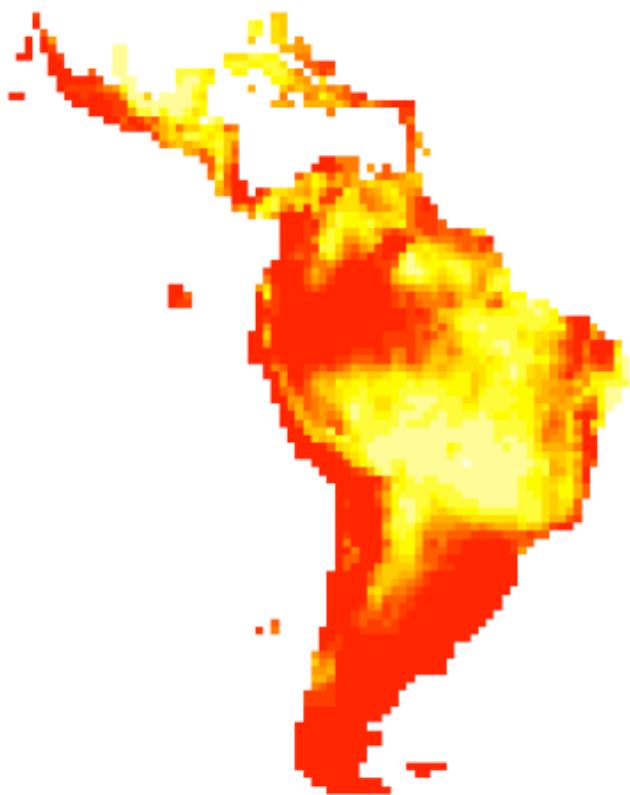
Geographical space



CONFUSION MATRIX

| | Pred. Present | Pred. Absent | Sum |
|--------------|---------------|--------------|-----|
| Obs. Present | 9 | 3 | 12 |
| Obs. Absent | 2 | 13 | 15 |
| Sum | 11 | 16 | 27 |

PROBABILITY TO PRESENCE

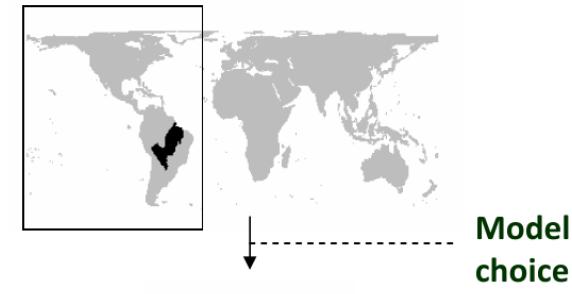


OUTLINE

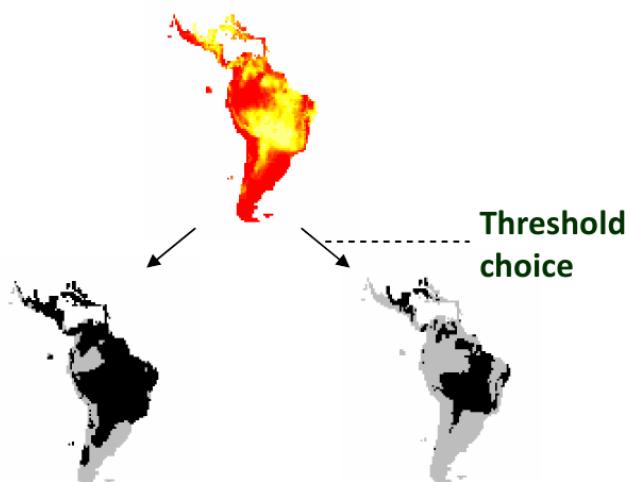
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MODEL CHOICES MATTER

Occupied realm projection

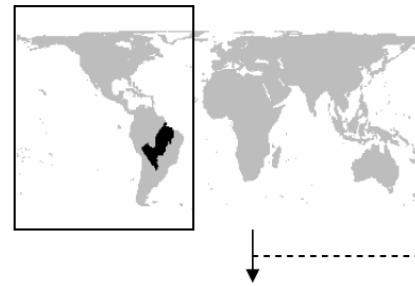


Model
choice

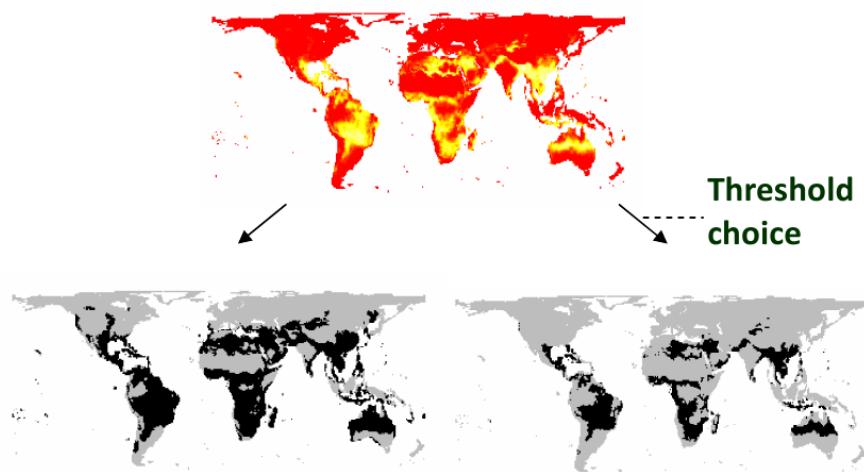


Threshold
choice

Whole world projection



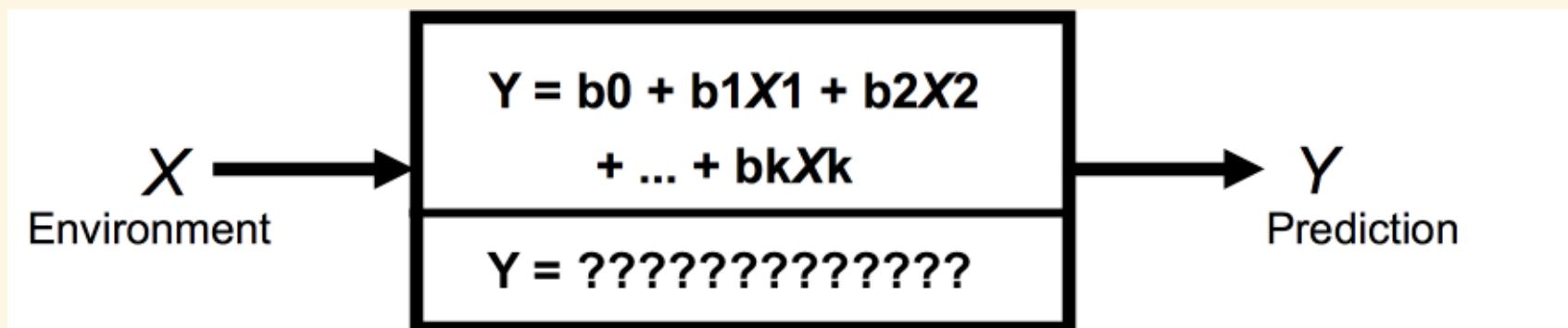
Model
choice



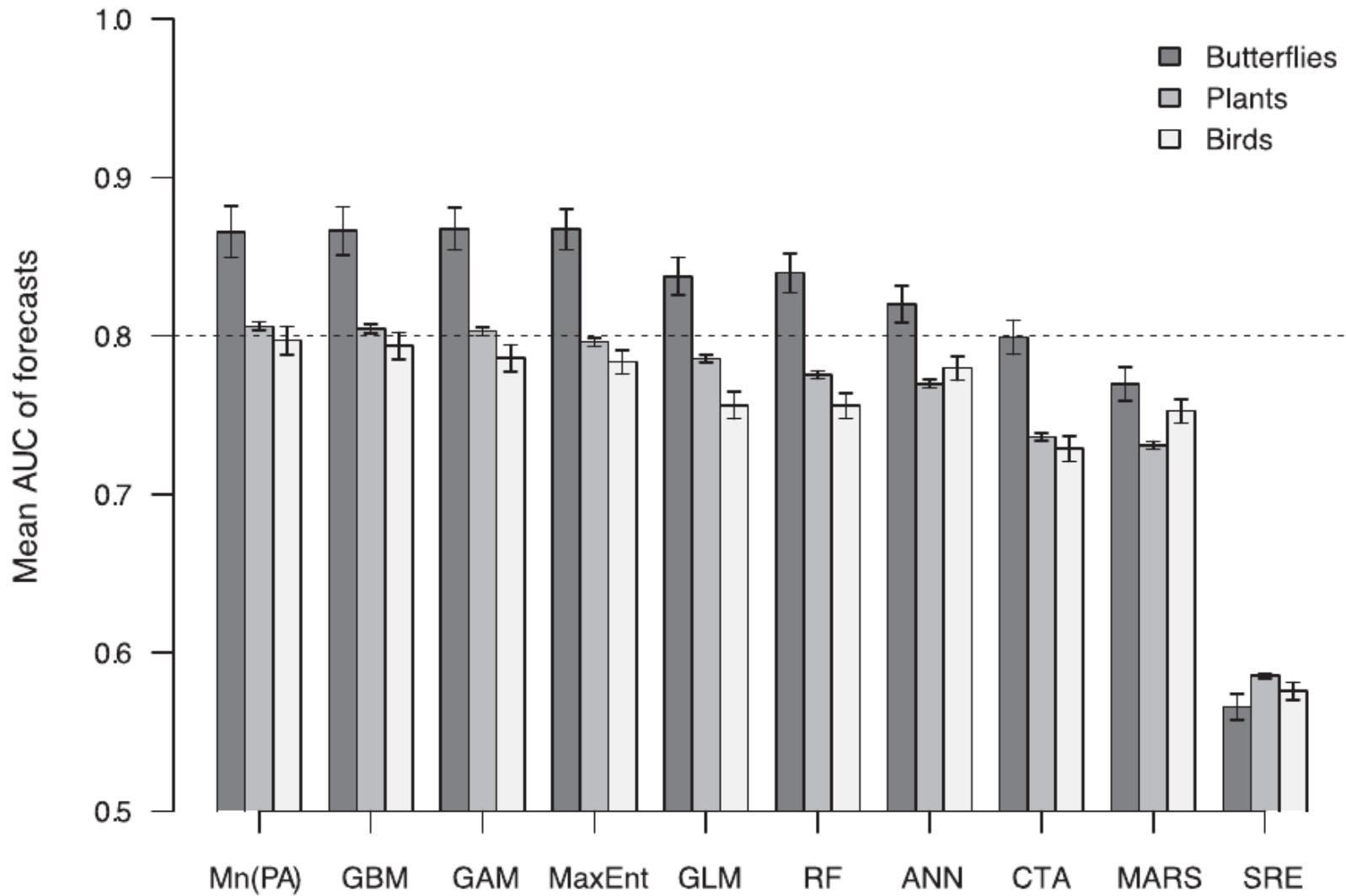
Threshold
choice

EXPLAIN VS. PREDICT

- Occam's razor: prefer a simple good explanation (model simplification)
- Prediction: prefer the best explanation even if elements are minor or unclear. Unavoidable with some methods.

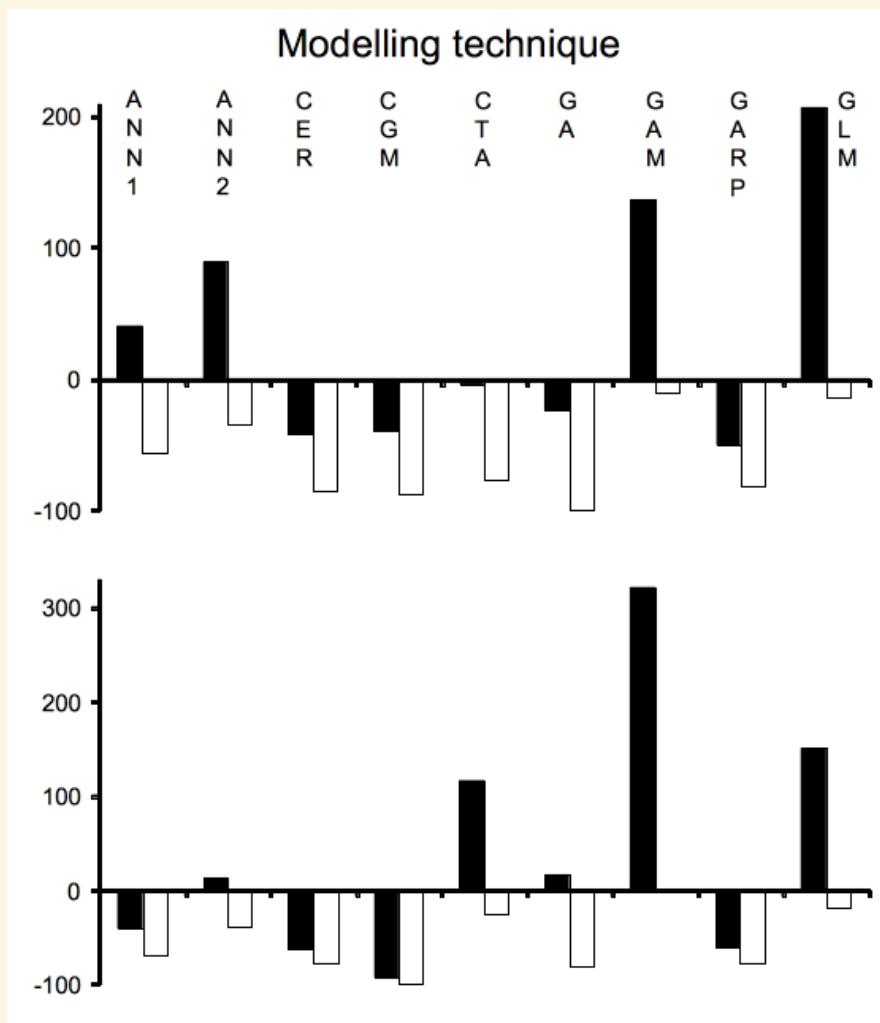


MODEL PERFORMANCE



Rapacciulo et al 2012 PLoS One (7) 7 e40212

MODEL UNCERTAINTY



Diastella divaricata



*Leucospermum
hypophyllocarpodendrum*



from Pearson et al., Biogeography. 2006, Blackwell Publishing

ENSEMBLE FORECASTING

Ensemble forecasting and uncertainty analysis in BIOMOD

Initial conditions
State of the system



Model classes
Different types of models



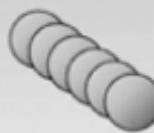
Model parameters
Range of values for key parameters



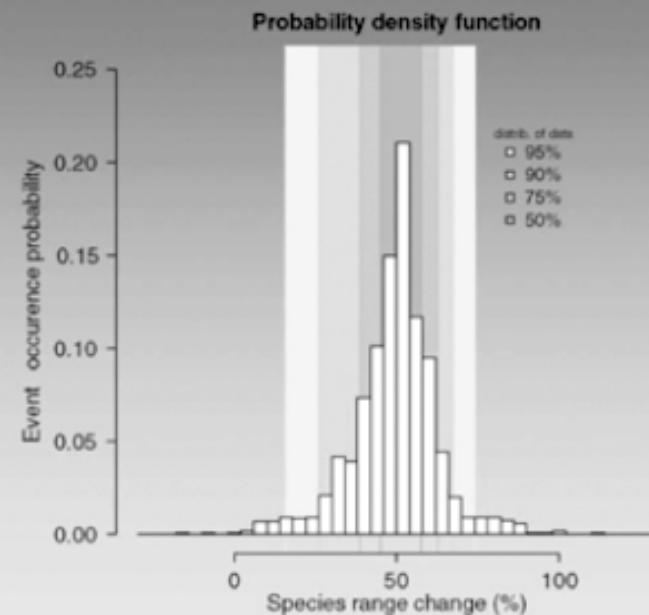
Climatic scenarios
Ensemble of climatic projections



Ensemble of species/
biodiversity projections



Probability density function



Thuiller et al (2009) Ecography 32: 369 - 373

DANGER, WILL ROBINSON

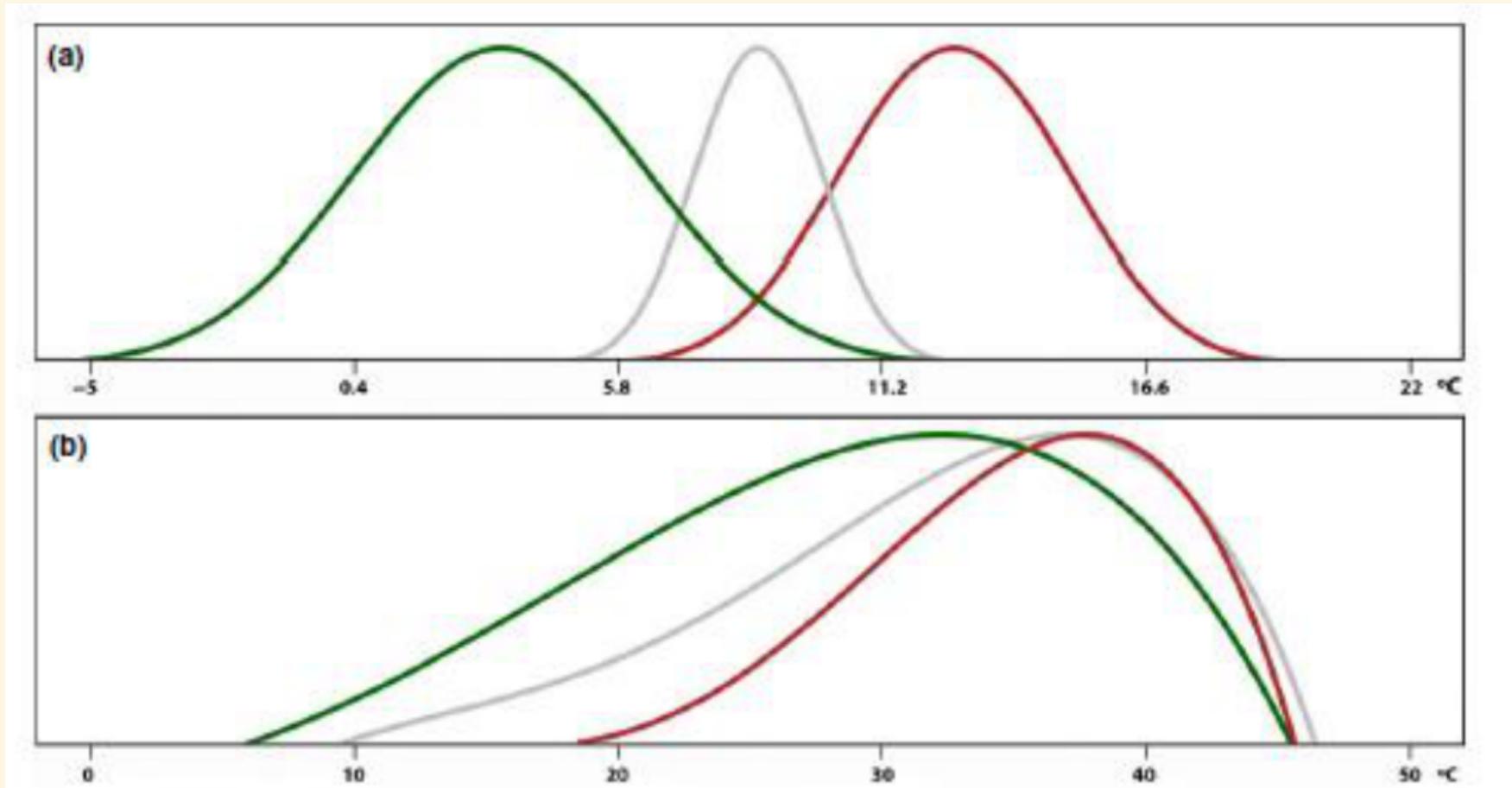
Assumptions

- Appropriate data exist at a relevant scale
- Species are at equilibrium with their environment...

Warnings

- Garbage in, garbage out
- Model extrapolation in time or space (transferability)
- The lure of complicated technology

LAB DATA

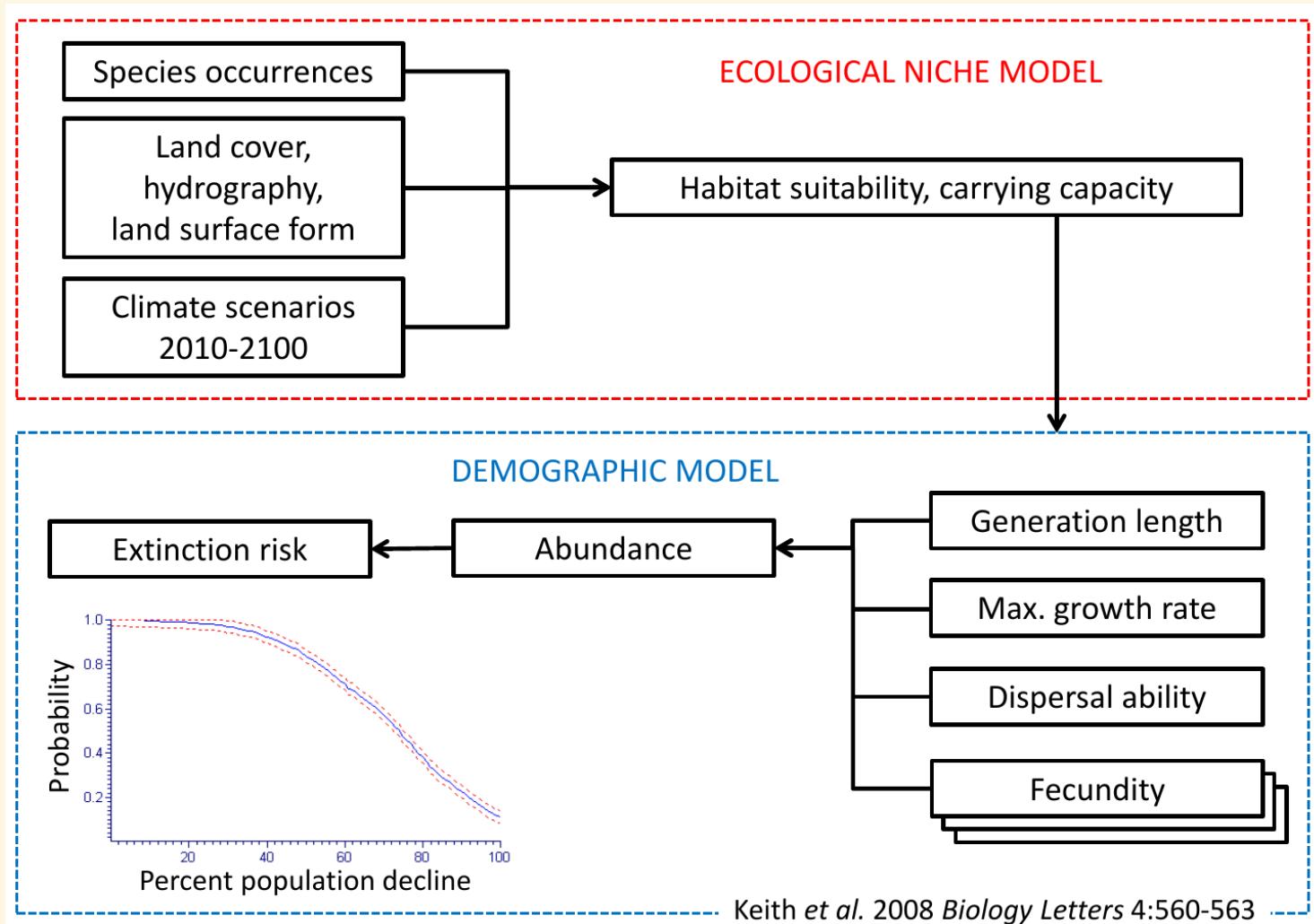


Araujo et al (2013) Ecology Letters 16: 1206 - 1209

FUTURE DIRECTIONS

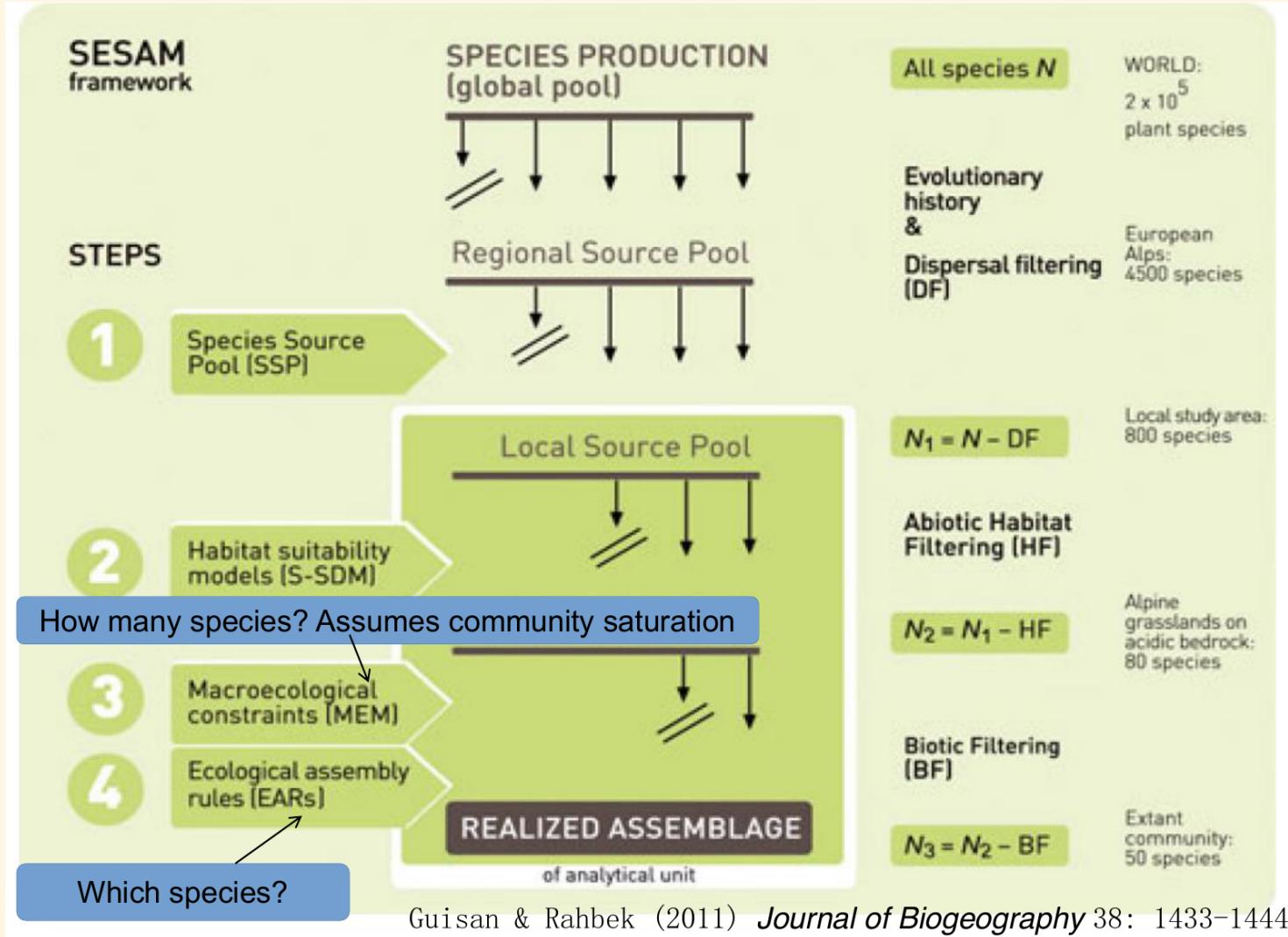
- Incorporating dispersal
- Incorporating biotic interactions
- More mechanistic models

CONNECT TO DEMOGRAPHY

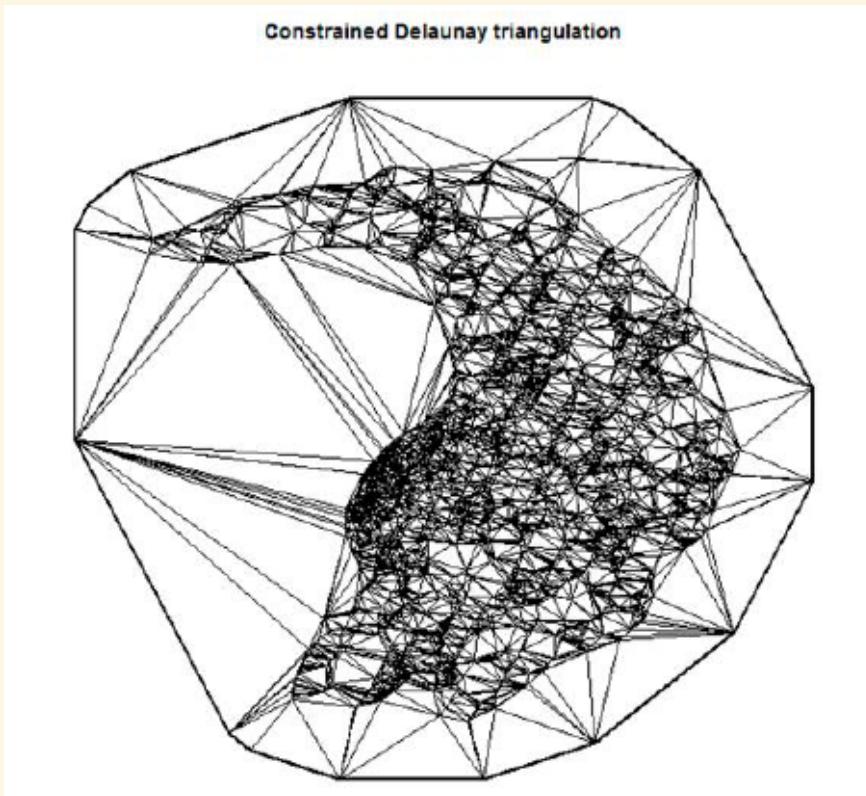


Keith et al. 2008 *Biology Letters* 4:560-563

COMMUNITY ASSEMBLY



BAYES AND SPATIAL AUTOCORRELATION



Blangiardo et al 2013
Spatial and spatio-temporal
models with R-INLA. *Spatial
and Spatio-temporal
Epidemiology* 4:33-49

GENERAL READING

- Franklin, J. (2009) Mapping species distributions: spatial inference and prediction. Cambridge, Cambridge University Press.
- Guisan, A., and N. E. Zimmermann. (2000) Predictive habitat distribution models in ecology. Ecological Modelling, 135:147-186.
- Elith J, Graham CH: (2009) Do they? How do they? WHY do they differ? On finding reasons for differing performances of species distribution models. Ecography, 32:66-77.
- Beale, C.M. and Lennon, J.K. (2012) Incorporating uncertainty in predictive distribution modelling. Phil Trans R. Soc. B 367:247-258

APPLIED EXAMPLES

- Singh, N.J., Yoccoz, N.G., Bhatnagar, Y.V., Fox, J.L. (2009) Using habitat suitability models to sample rare species in high-altitude ecosystems: A case study with Tibetan argali. *Biodiversity and Conservation*, 18: 2893-2908.
- Nogués-Bravo D., Rodríguez J., Hortal J., Batra P., Araújo M. B. (2008) Climate change, humans, and the extinction of the woolly mammoth. *PLoS Biol*, 6, e79.
- Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus et al. (2004.) Extinction risk from climate change. *Nature* 427:145-148.
- Smolik, M. G., S. Dullinger, F. Essl, I. Kleinbauer, M. Leitner, J. Peterseil, L.-M. Stadler et al. (2009). Integrating species distribution models and interacting particle systems to predict the spread of an invasive alien plant. *Journal of Biogeography* 37:411-422.
- Raxworthy, C.J., Martinez-Meyer, E., Horning, N., Nussbaum, R.A., Schneider, G.E., Ortega-Huerta, A., and Peterson, A.T. (2003). Predicting distributions of known and unknown reptiles species in Madagascar. *Nature*. 426: 837-841.

METHODS BACKGROUND

- Guisan, A., T. C. Edwards, and T. Hastie. 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling* 157:89-100
- Thuiller, W., B. Lafaucade, R. Engler, and M. B. Araújo. 2009. BIOMOD - a platform for ensemble forecasting of species distributions. *Ecography* 32:369 - 373.
- Elith, J., J. R. Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. *Journal of Animal Ecology* 77:802-813.
- Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190:231-259.