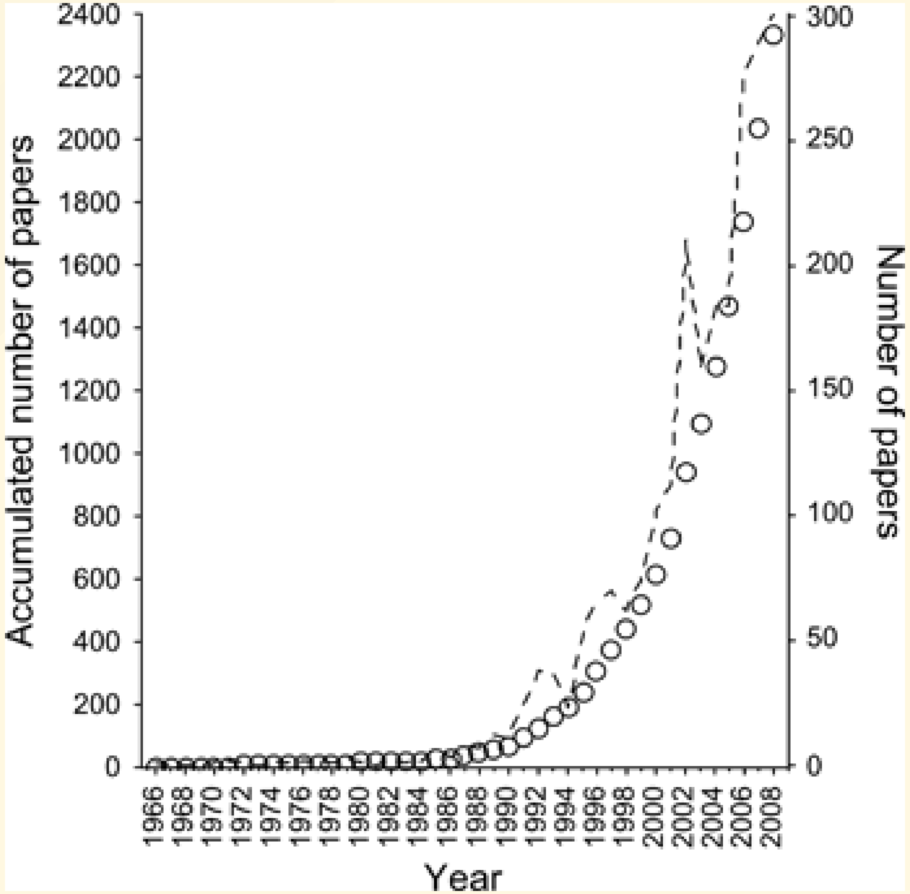
Species Distribution Models

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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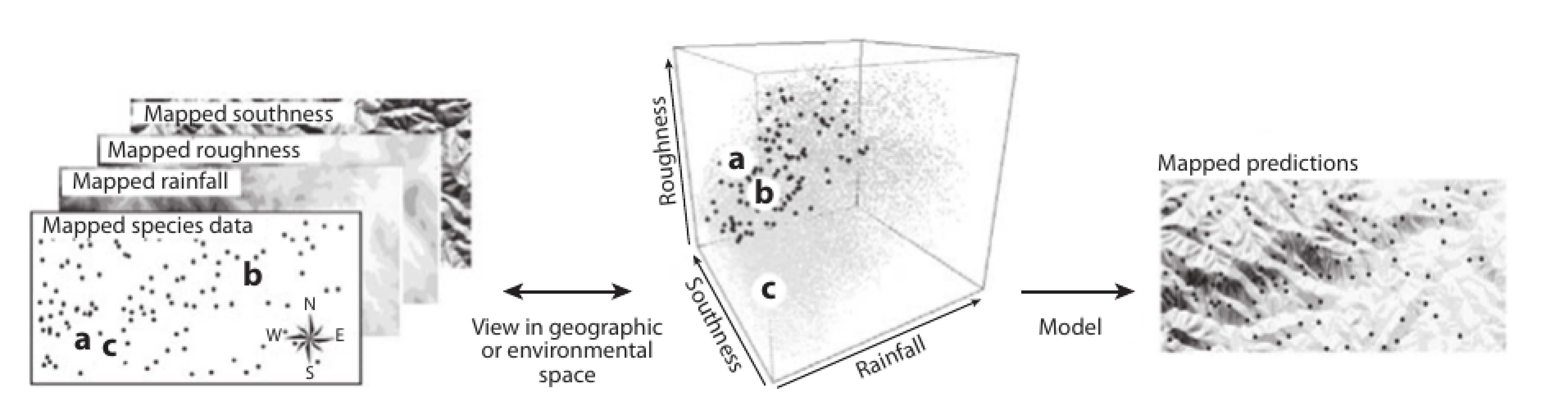
What are species distribution models?

- 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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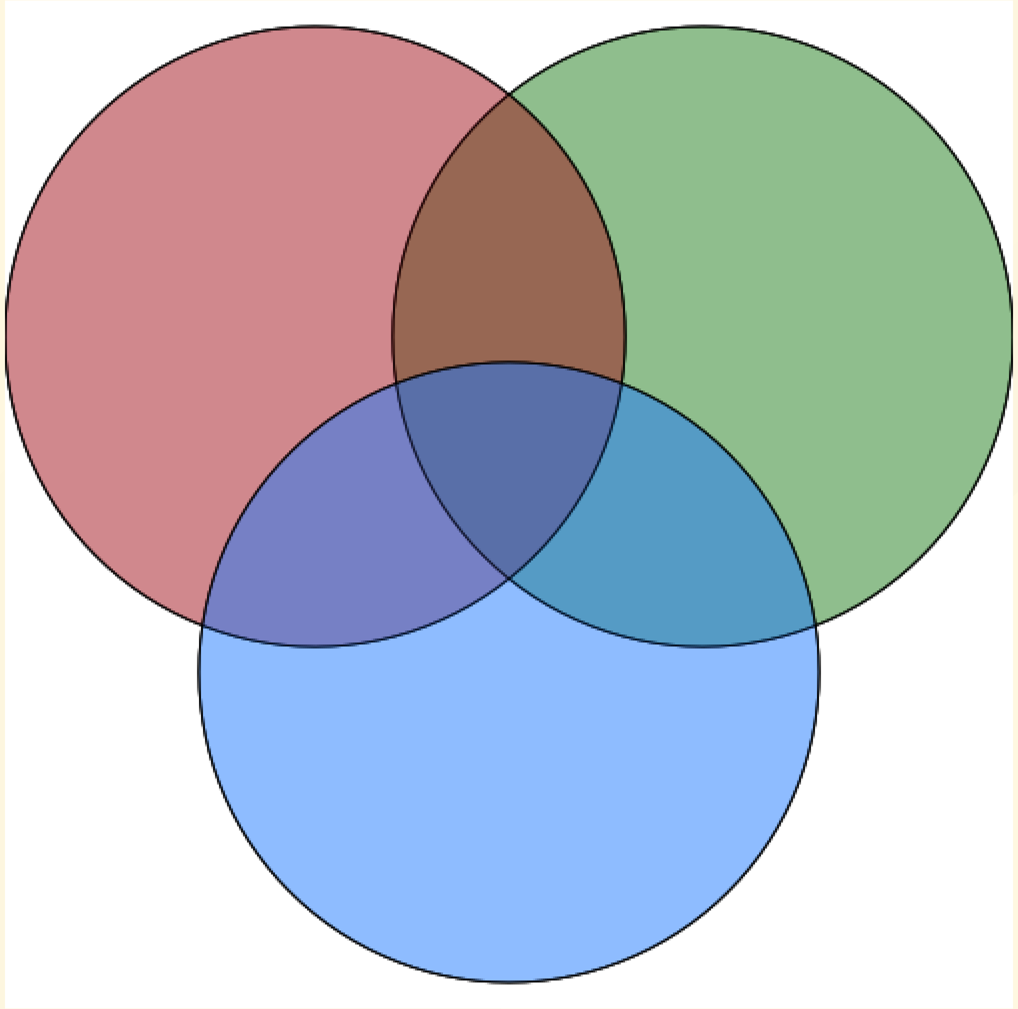
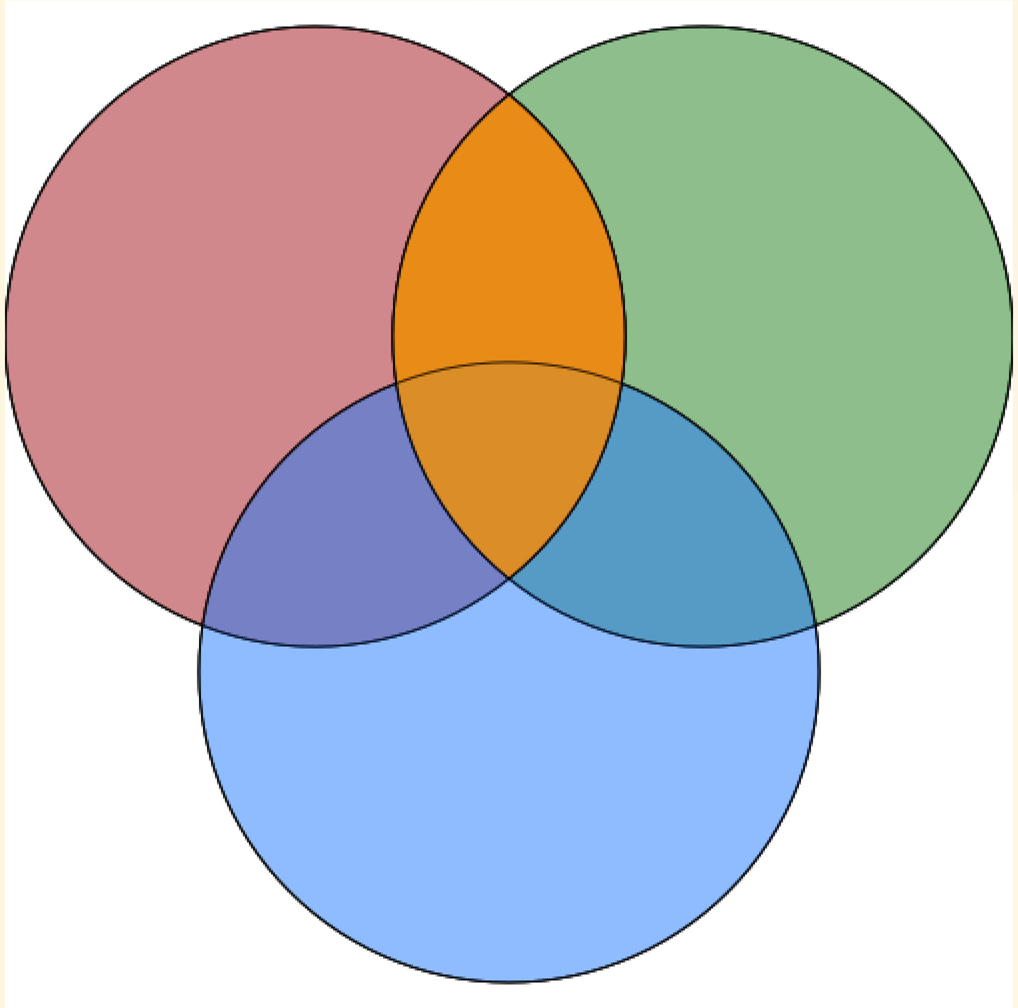
Niche theory



- Abiotic
- Biotic
- Accessible area

Soberón & Peterson (2005)

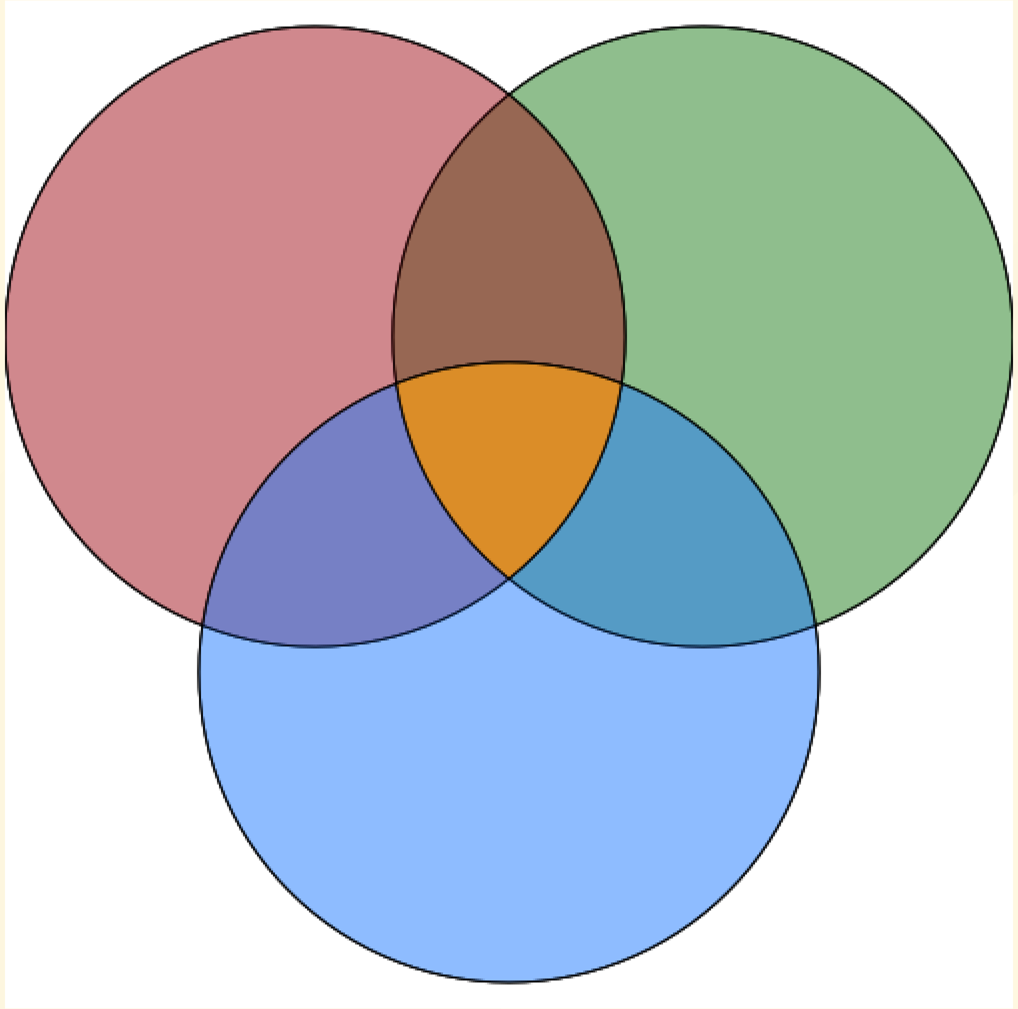
Niche theory



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

Soberón & Peterson (2005)

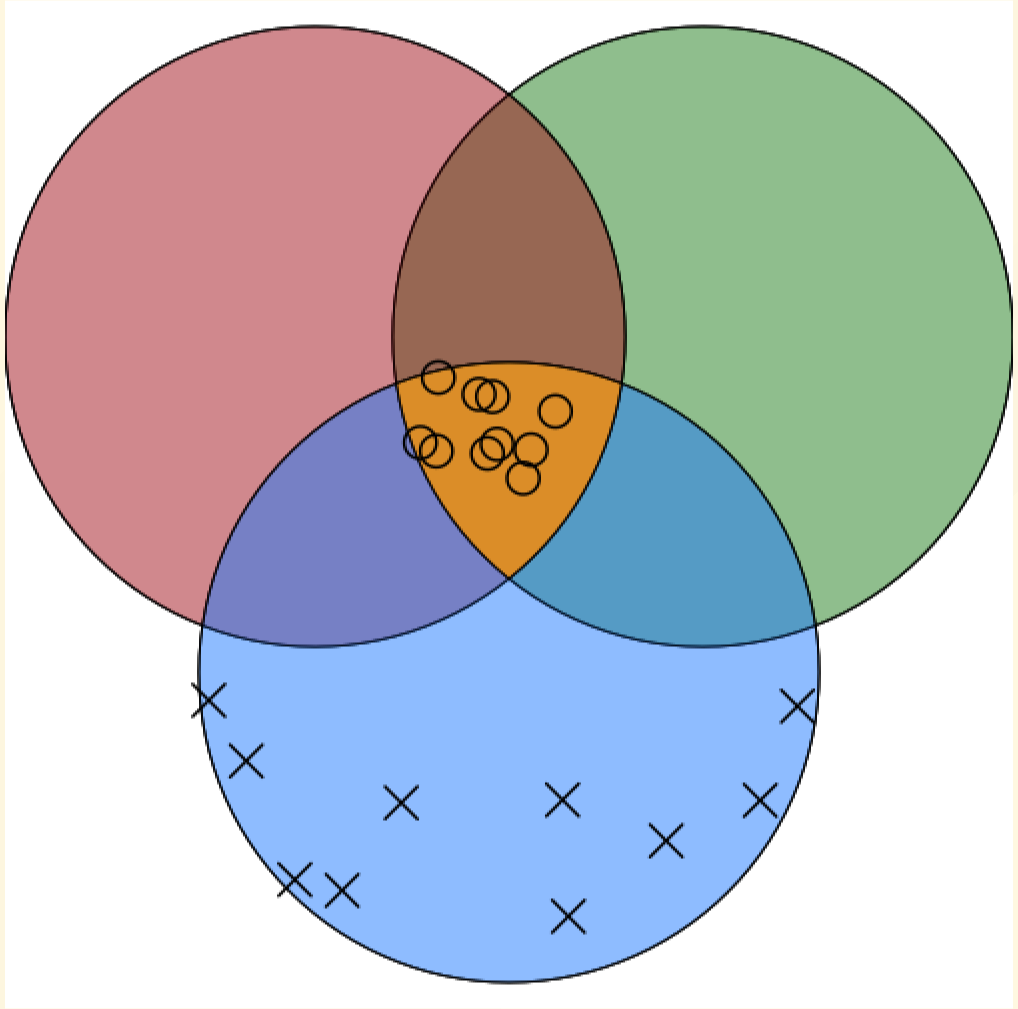
Niche theory



- Abiotic
- Biotic
- Accessible area
- **Realised niche**: accessible and in potential niche

Soberón & Peterson (2005)

Niche theory



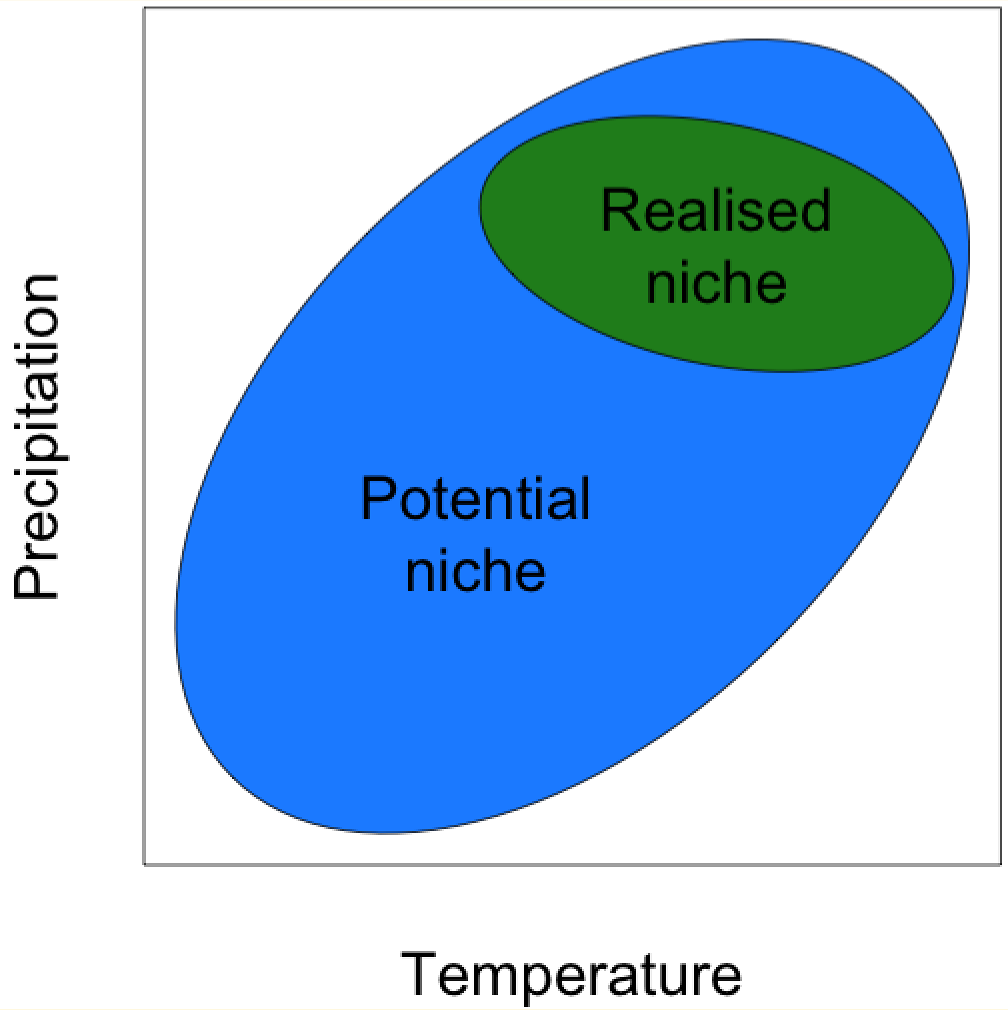
- Abiotic
- Biotic
- Accessible area
- **Populations**: can be both source (o) and sink (x)

Soberón & Peterson (2005)

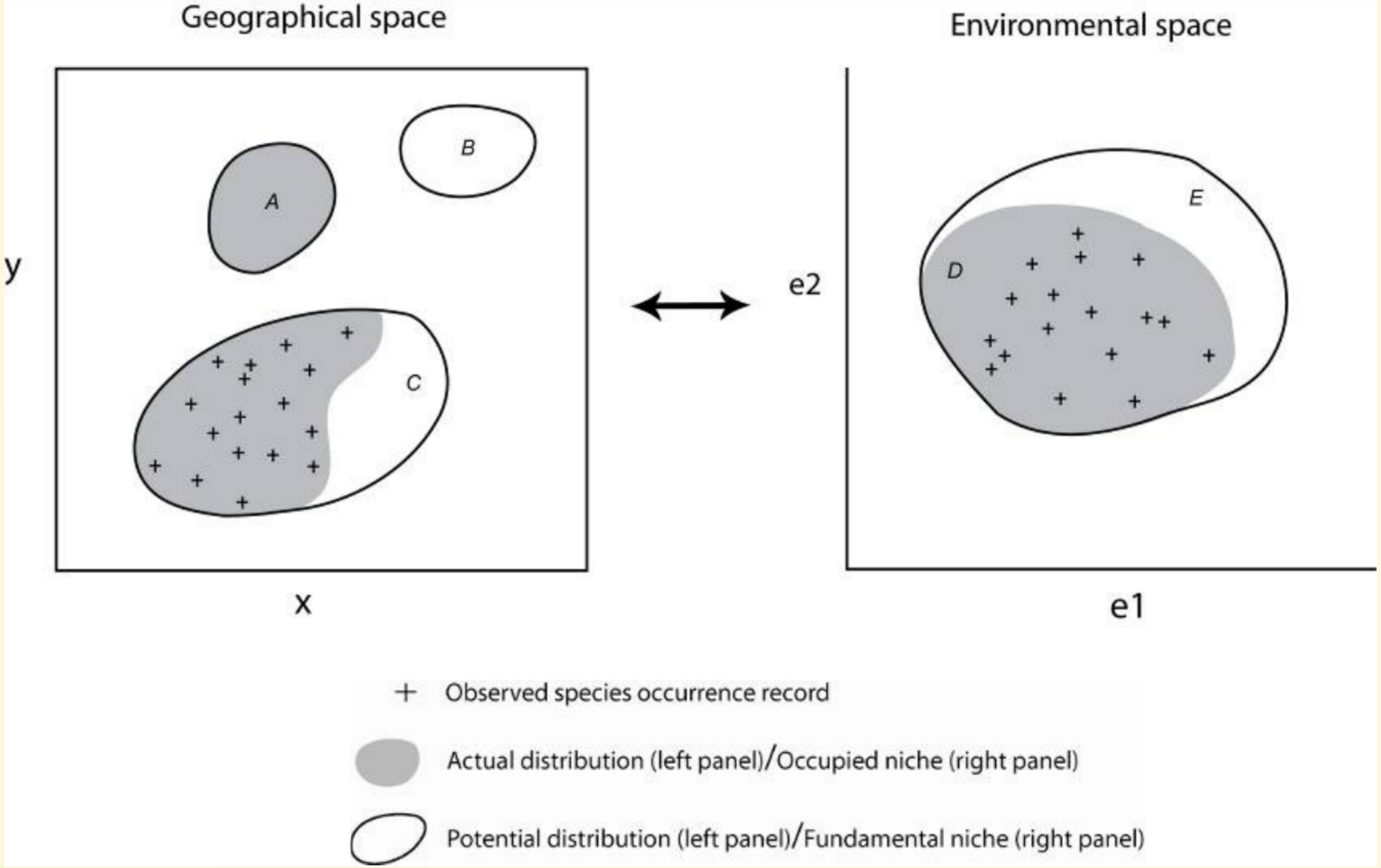
Niche theory

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

Hutchinson (1957)

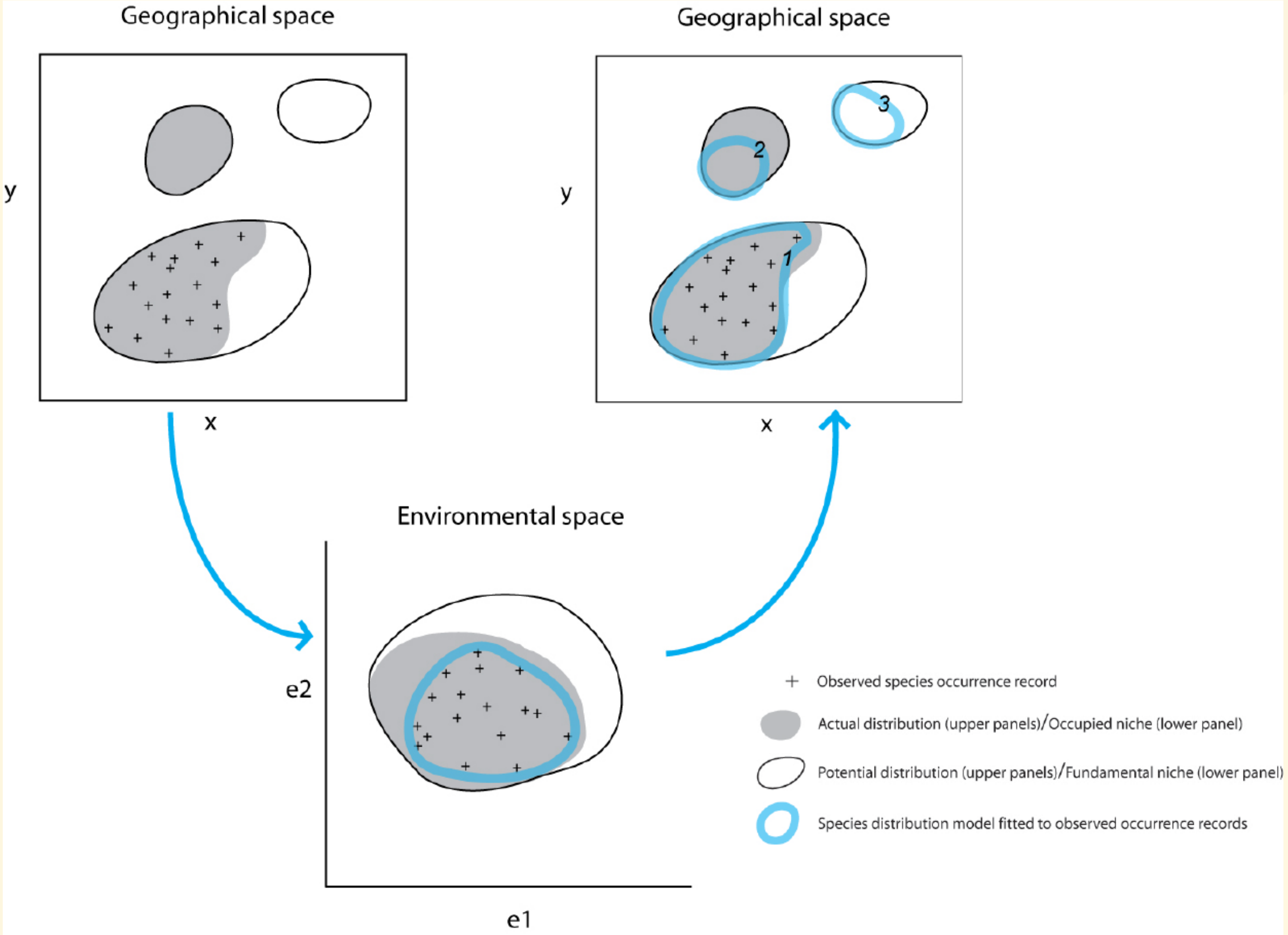


Environmental & geographical space



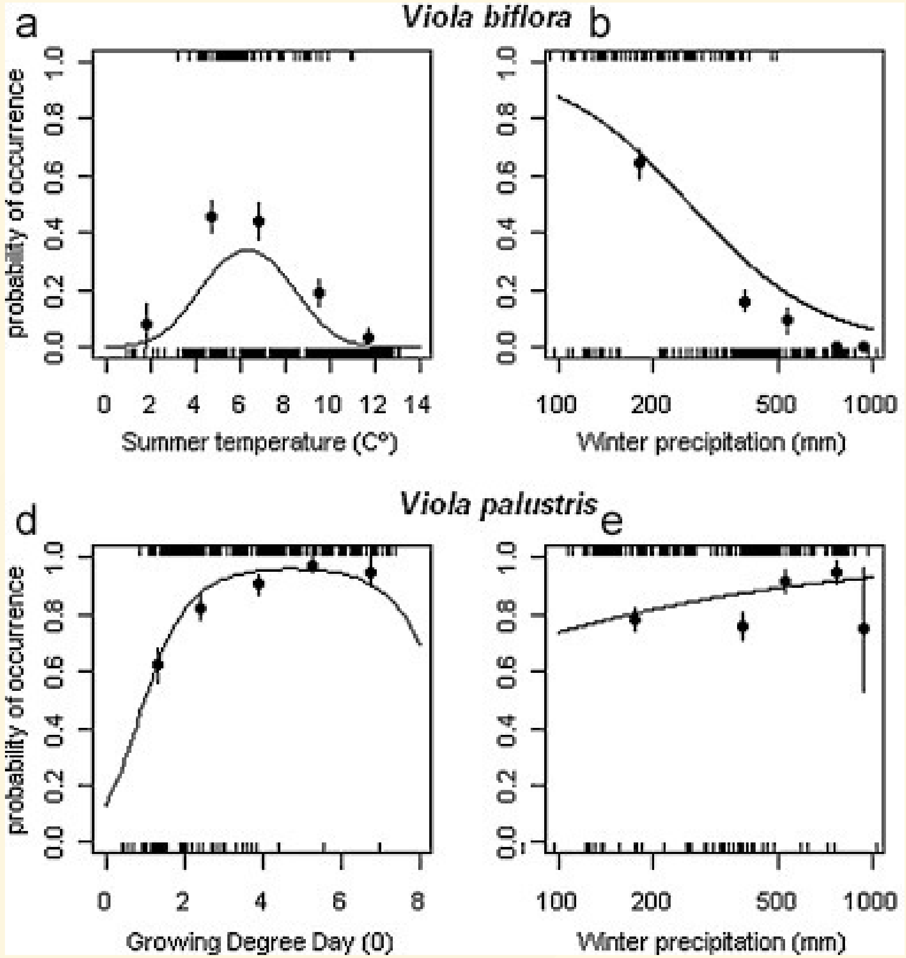
Pearson 2007., see also Peterson et al. 2011

Environmental & geographical space



Pearson 2007., see also Peterson et al. 2011

Modelled relationship



Meineri et al (2012) Ecol Modelling 231: 1-10

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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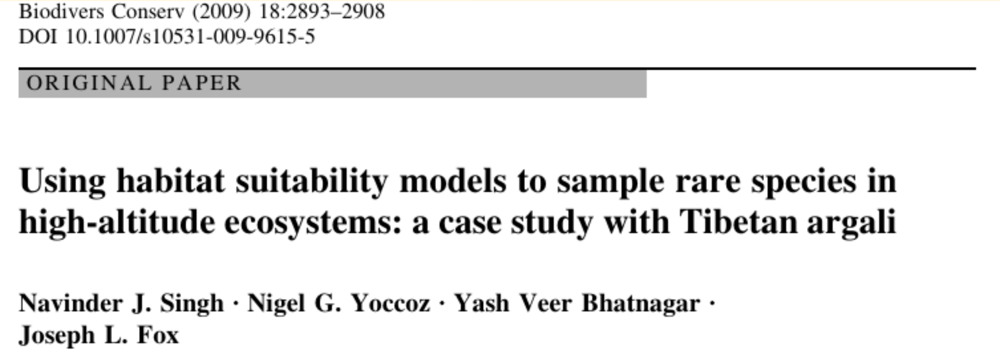
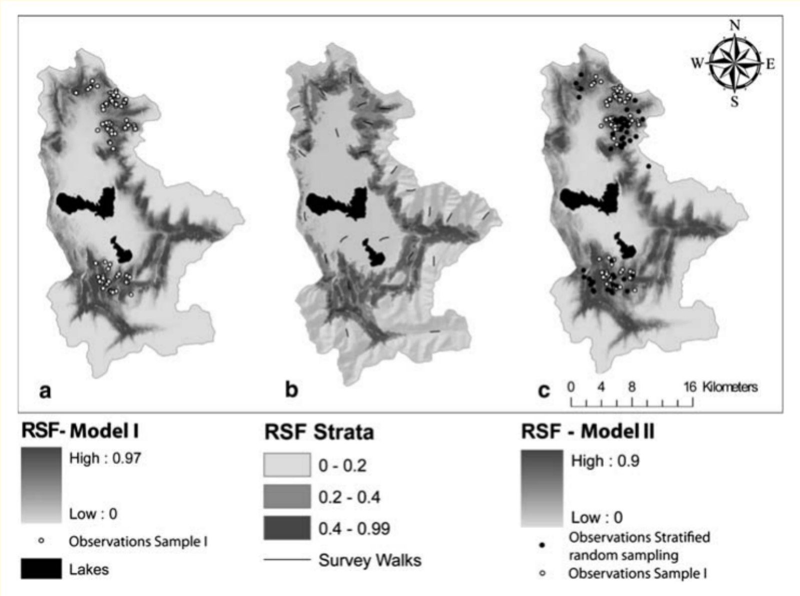
Guiding field studies


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 Rodríguez[2], Joaquín Hortal[3], Persaram Batra[4], Miguel B. Araújo[1]

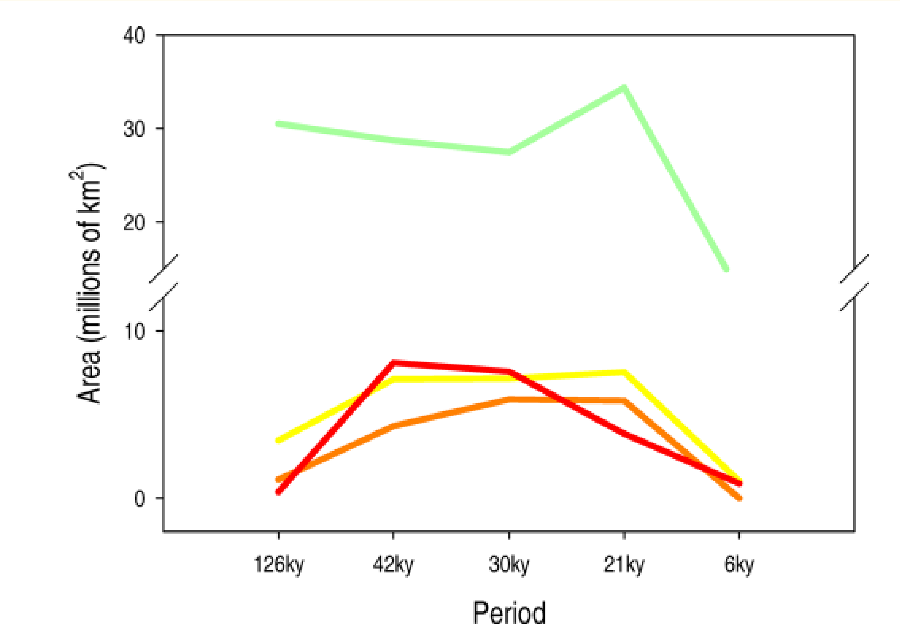
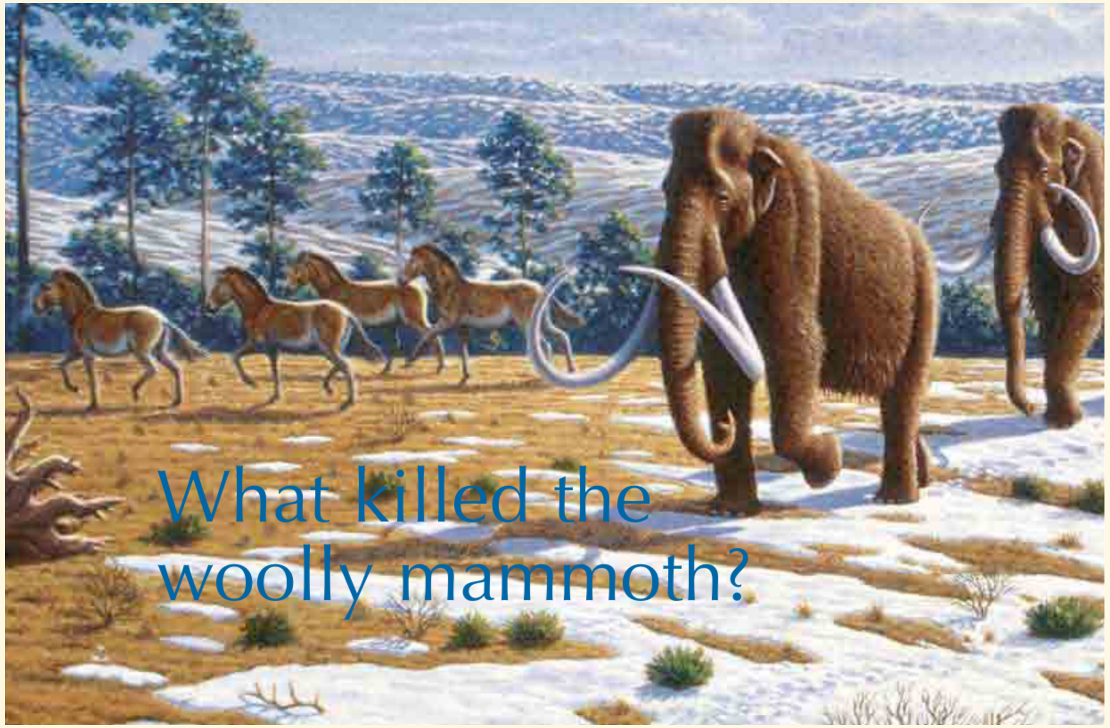


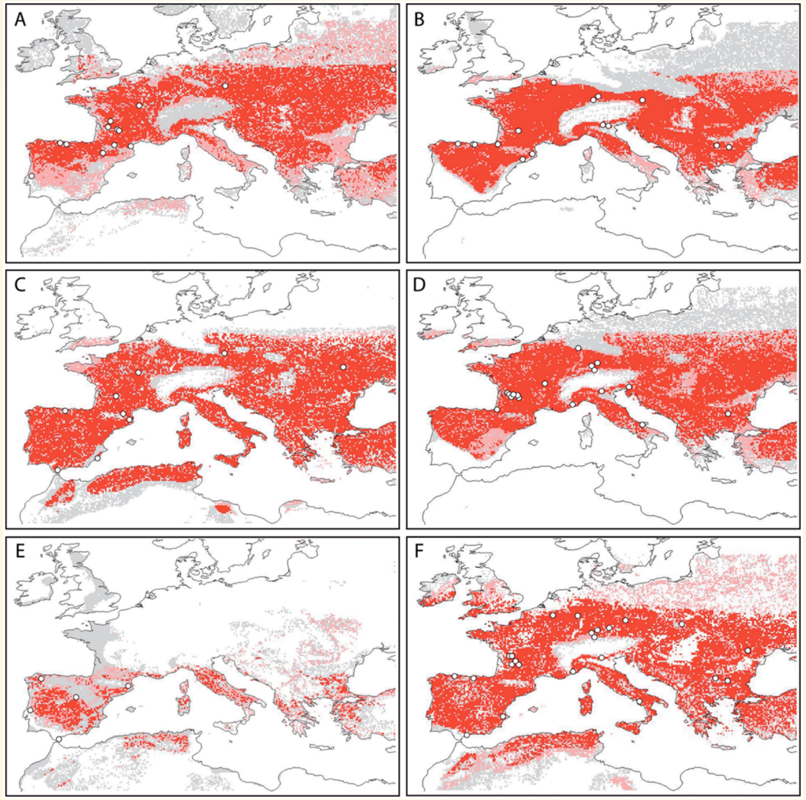
Figure 2. Change in the Area (%) of the Different Suitable Climatic Conditions for Woolly Mammoths



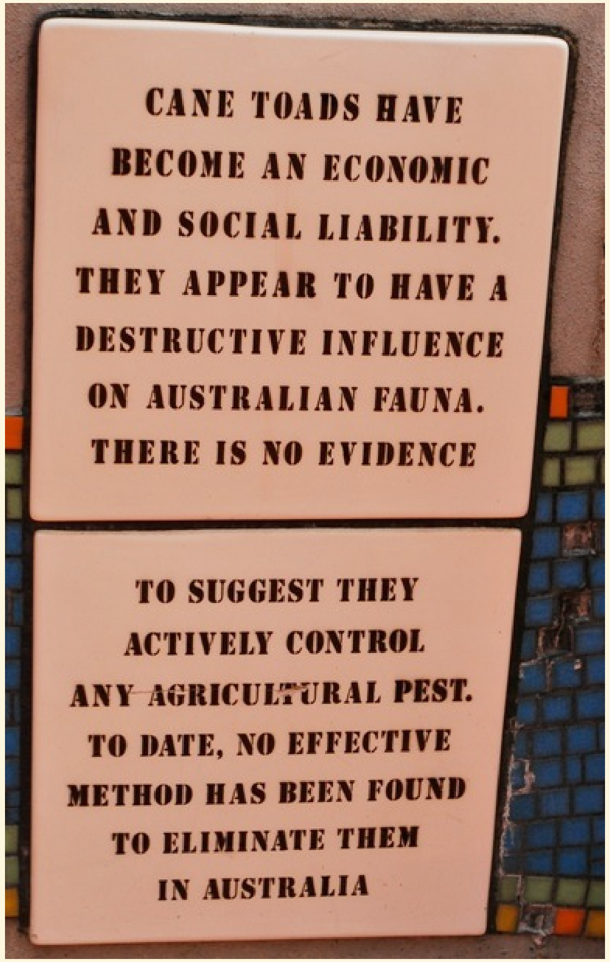
Informing our view of the past

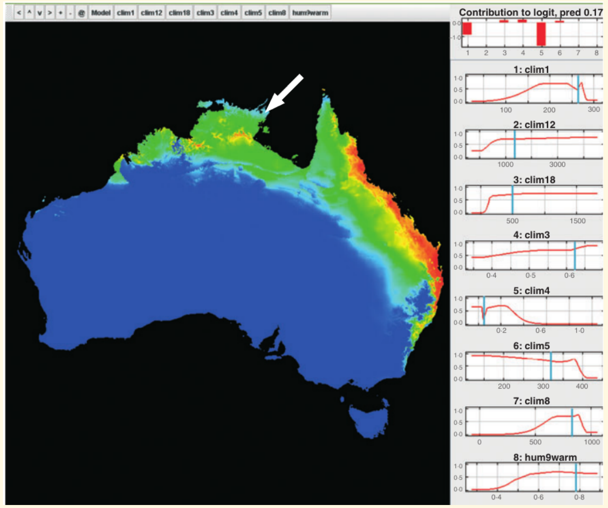
Neanderthal Extinction by Competitive Exclusion

William E. Banks[1]*, Francesco d'Errico[1,2], A. Townsend Peterson[3], Masa Kageyama[4], Adriana Sima[4], Maria-Fernanda Sánchez-Goñi[5]



Spread of invasive species





Impacts of climate change

theguardian

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

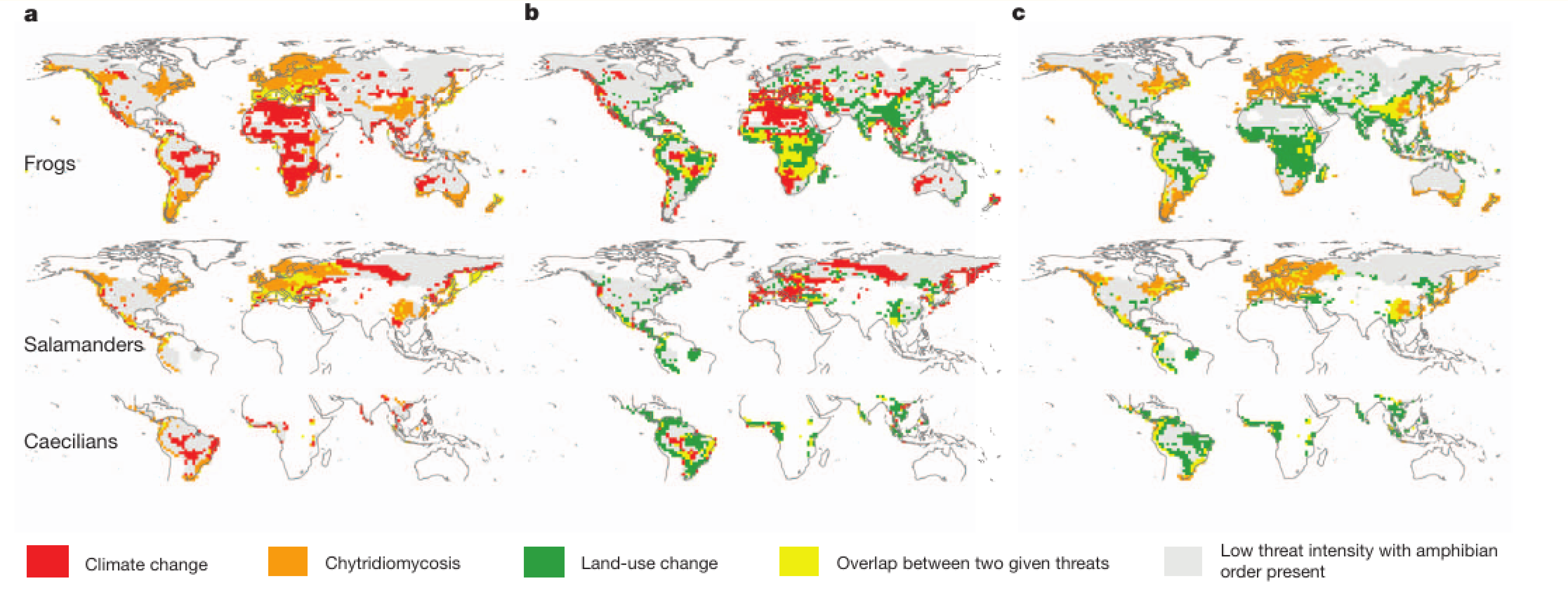
Fiona Harvey, environment correspondent
The Guardian, Thursday 18 August 2011 19.00 BST

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

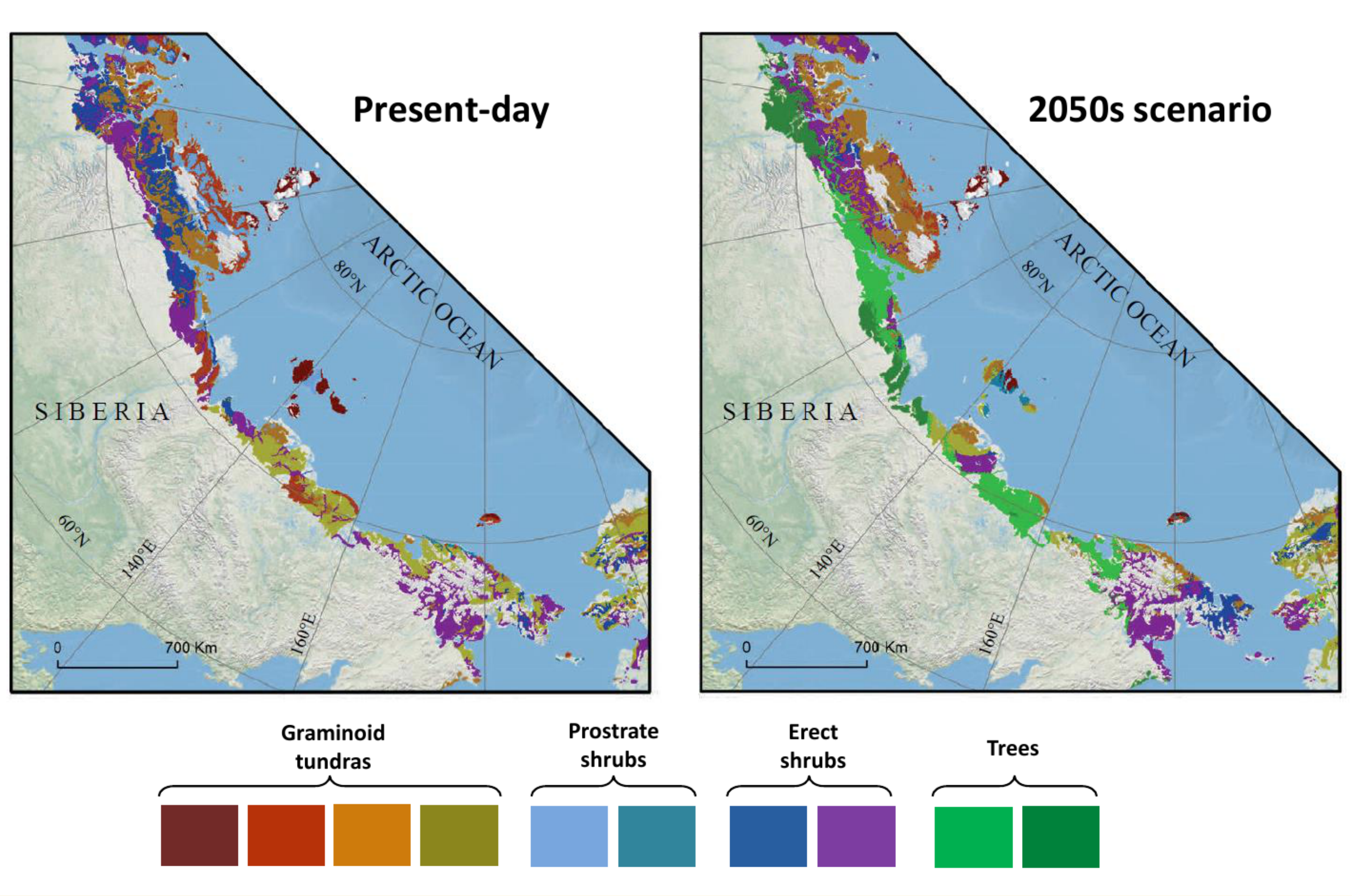
Chris D. Thomas[1], Alison Cameron[1], Rhys E. Green[2], Michel Bakkenes[3], Linda J. Beaumont[4], Yvonne C. Collingham[5], Barend F. N. Erasmus[6], Marinez Ferreira de Siqueira[7], Alan Grainger[8], Lee Hannah[9], Lesley Hughes[4], Brian Huntley[5], Albert S. van Jaarsveld[10], Guy F. Midgley[11], Lera Miles[8*], Miguel A. Ortega-Huerta[12], A. Townsend Peterson[13], Oliver L. Phillips[8] & Stephen E. Williams[14]

Comparing drivers



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

Future predictions



Pearson et al. 2013

Nature Climate Change

3:673–677

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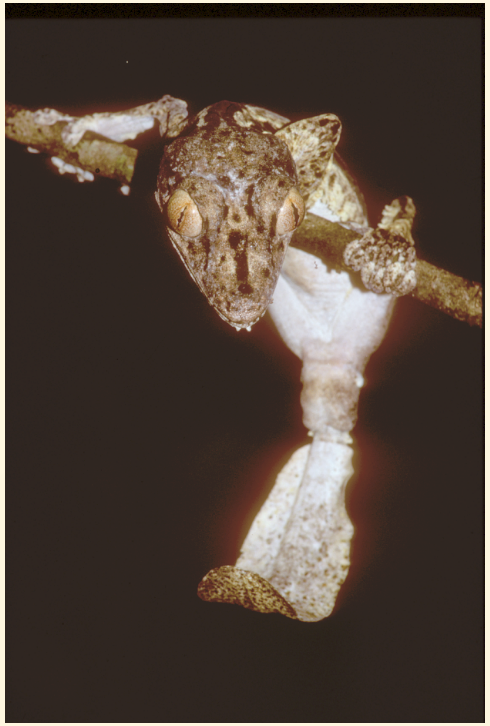
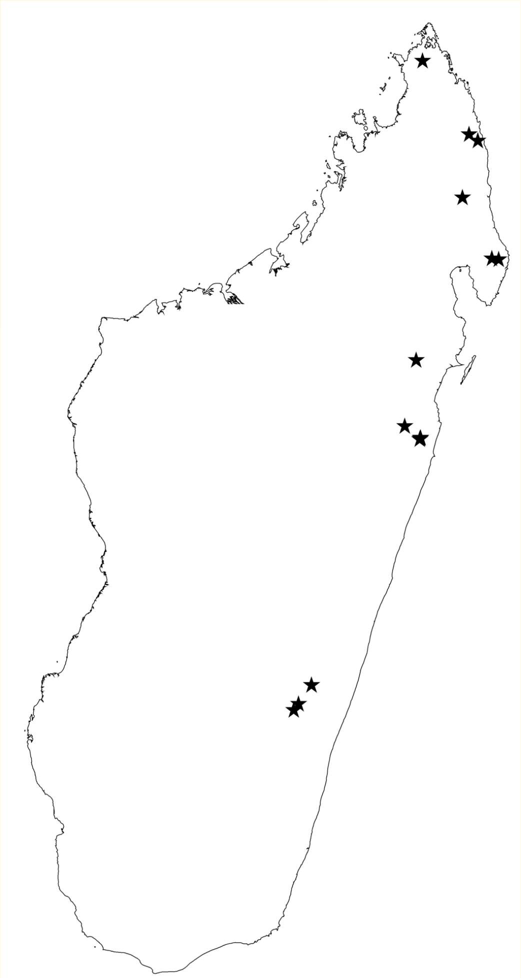
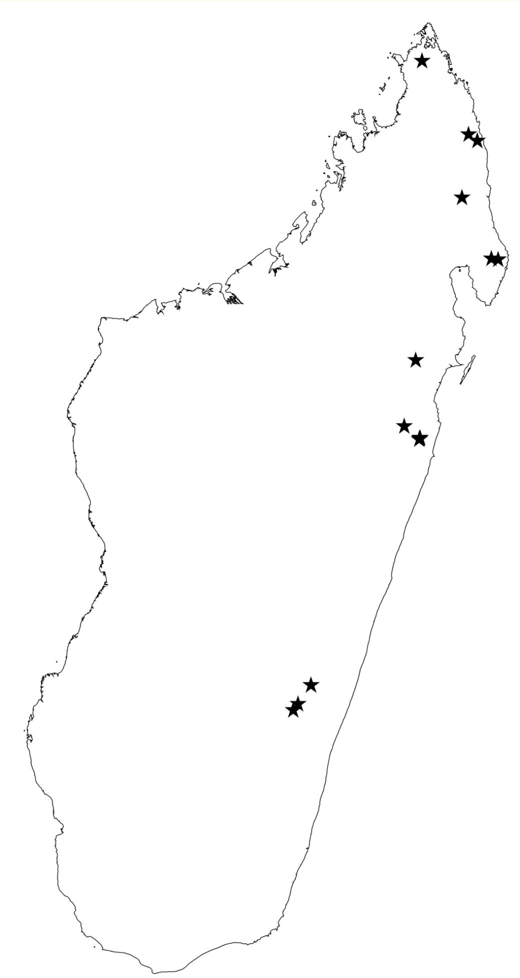
Madagascan geckos

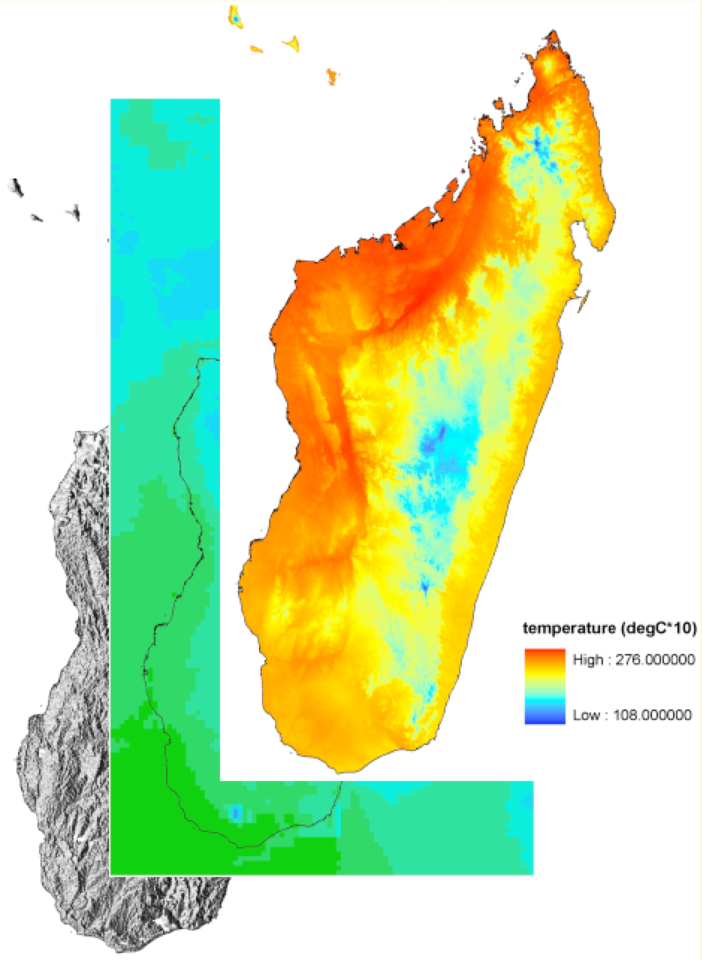


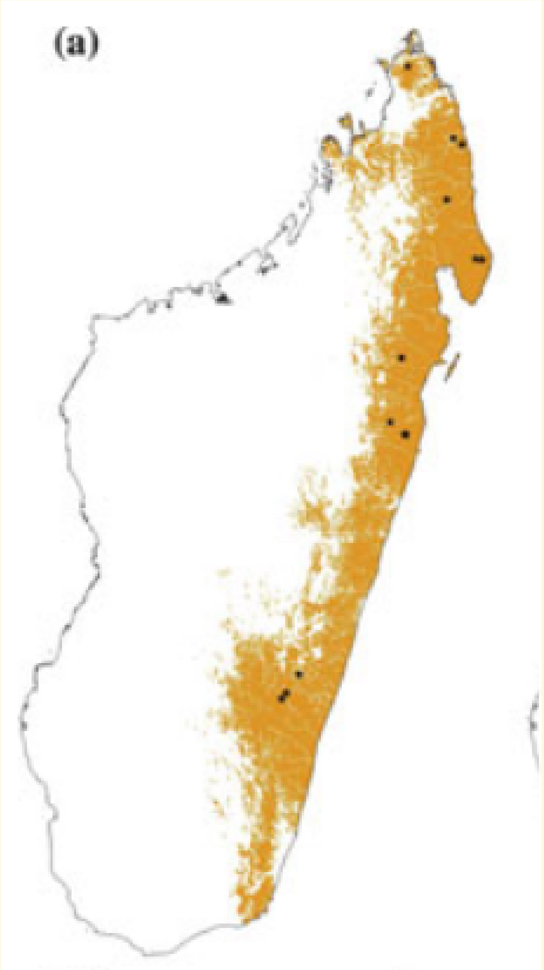


Uroplatus sp. Pearson et al. (2007) J. Biogeog 34: 102-117

Madagascan geckos







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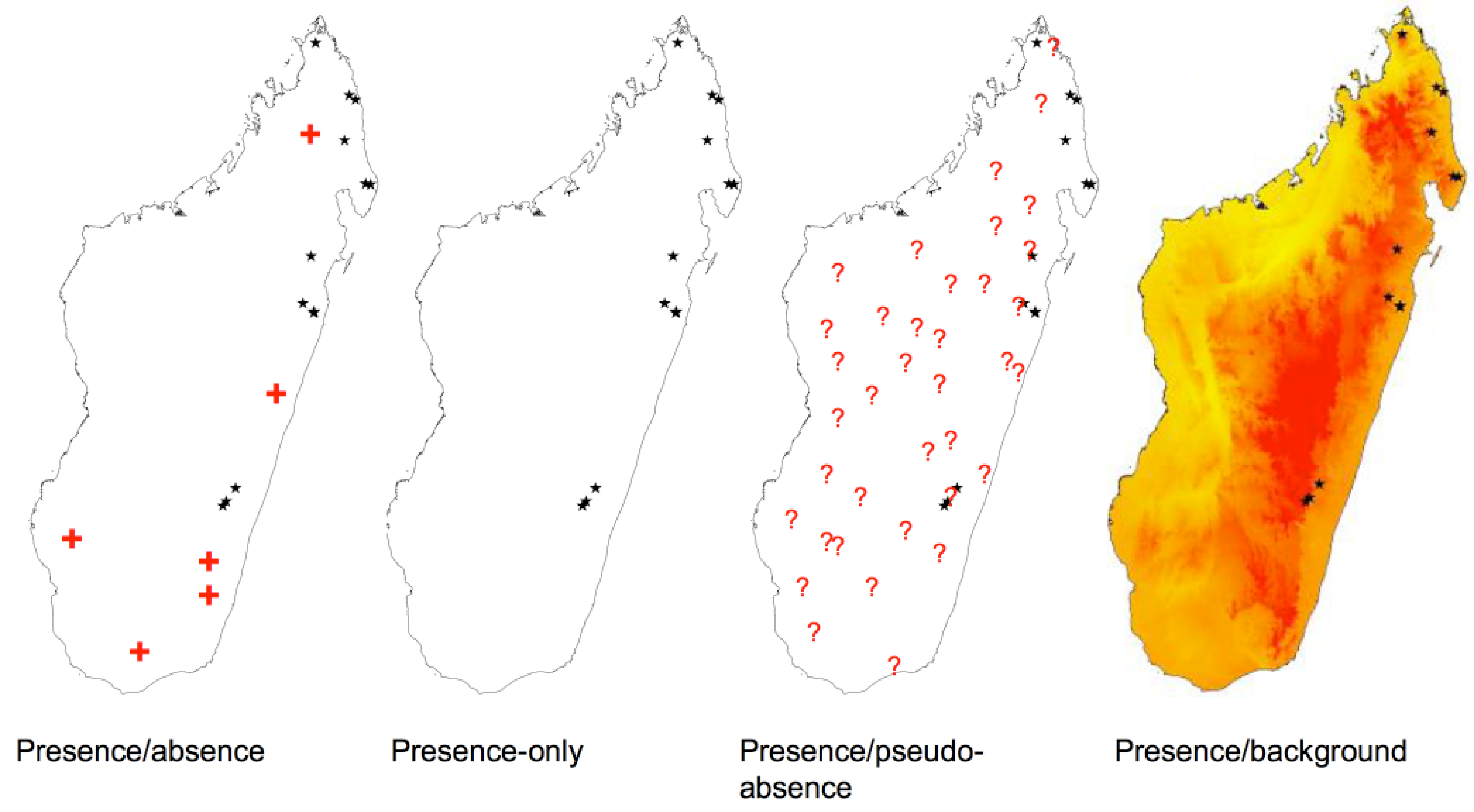
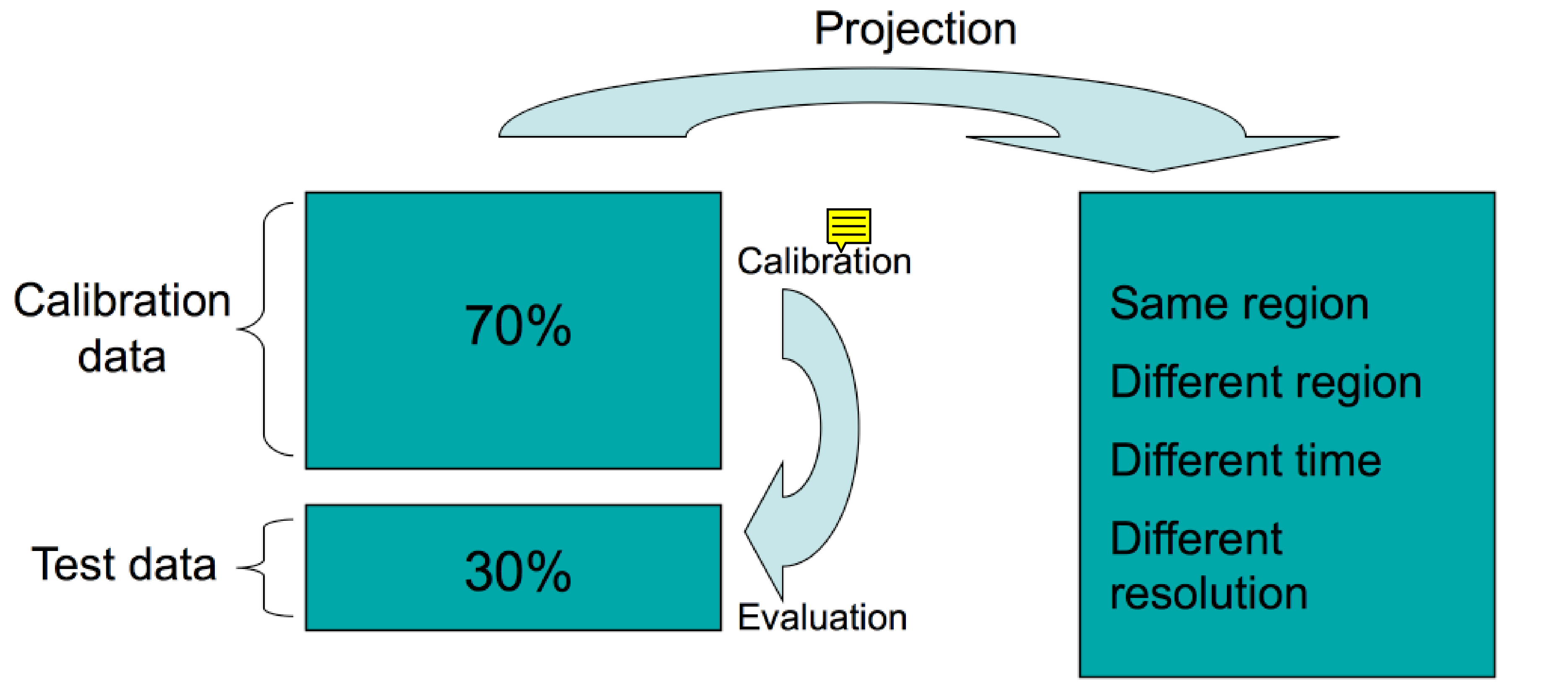
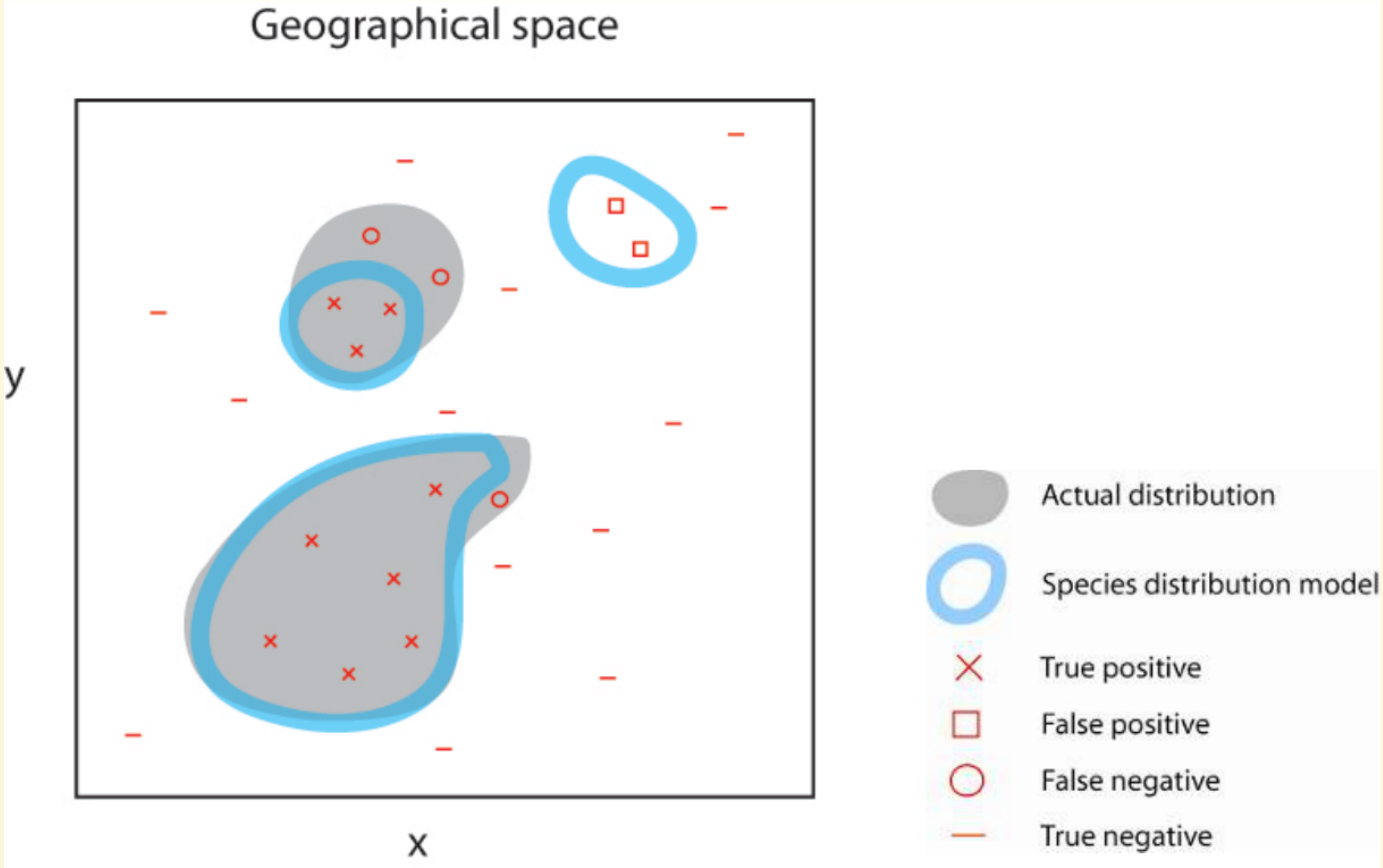


Model evaluation



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

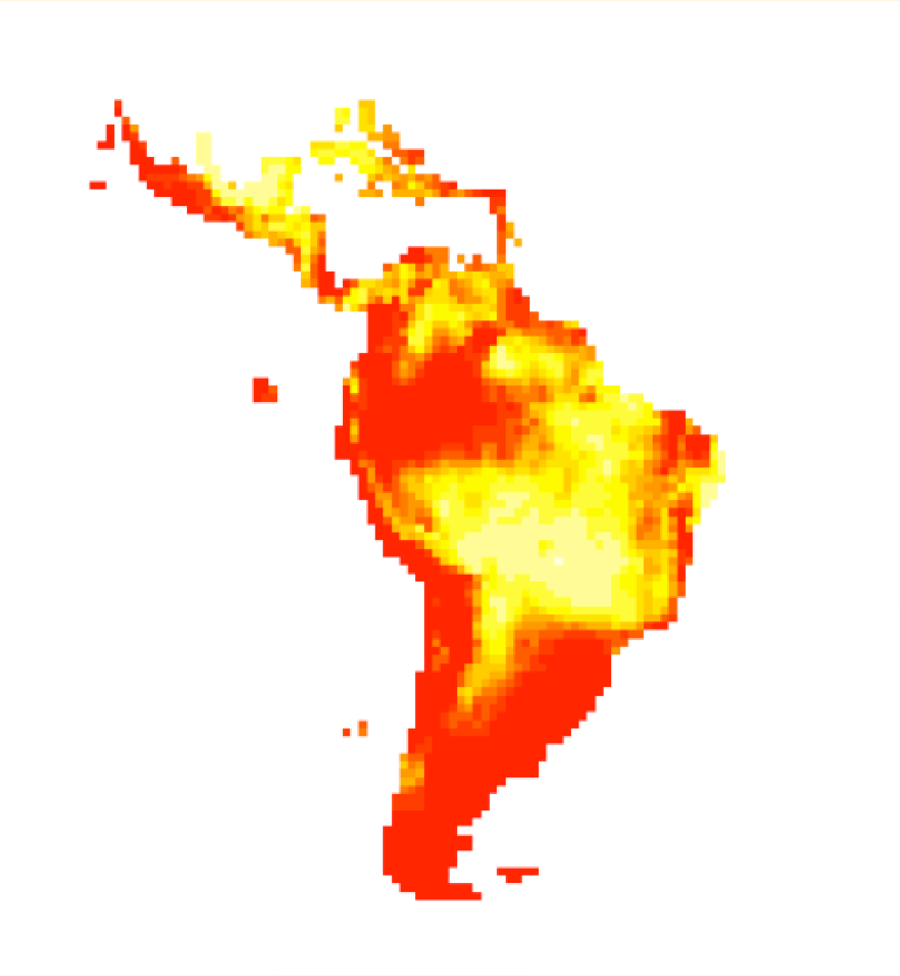
Model errors



Confusion matrix

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

Probability to presence



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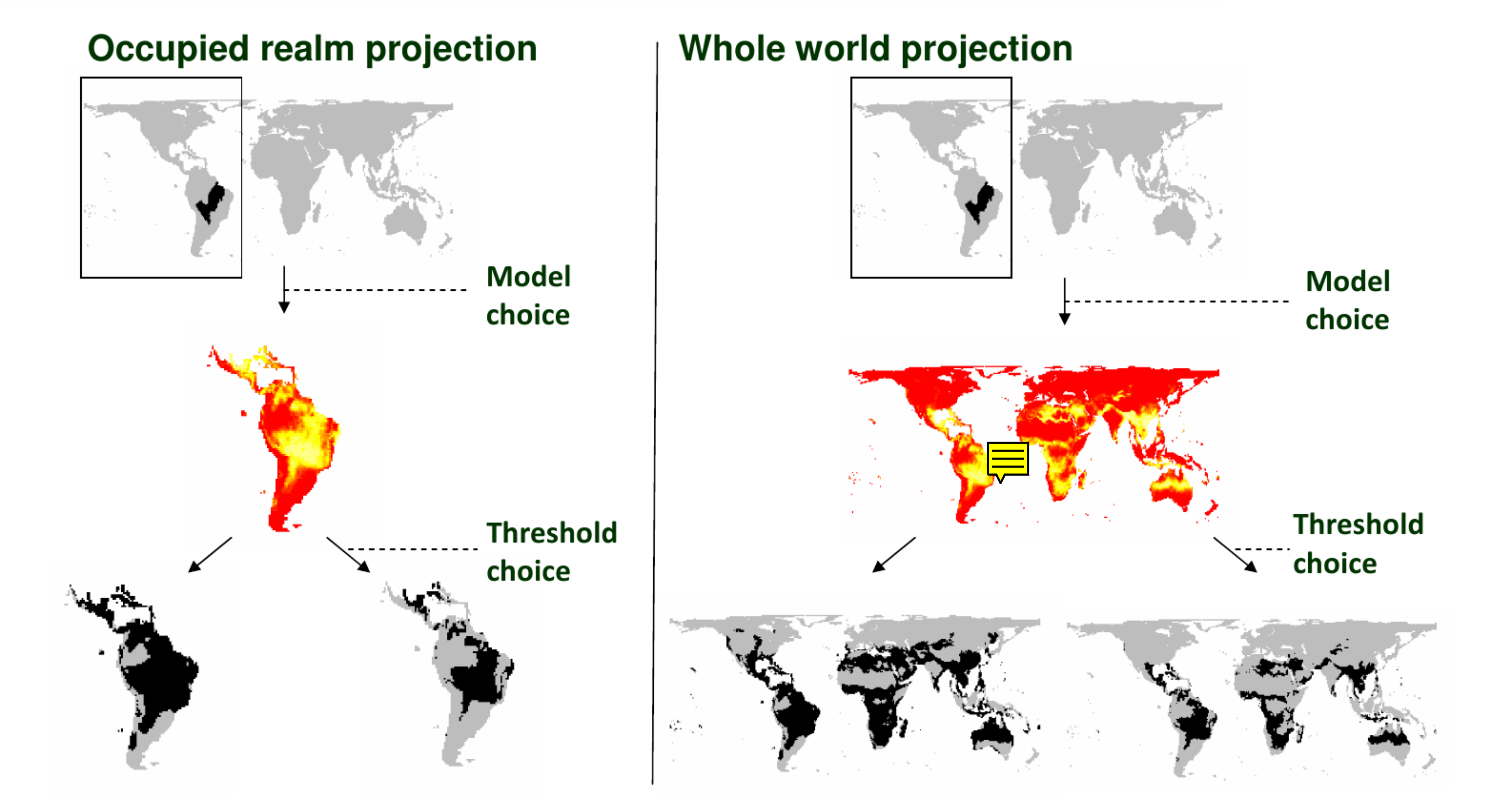
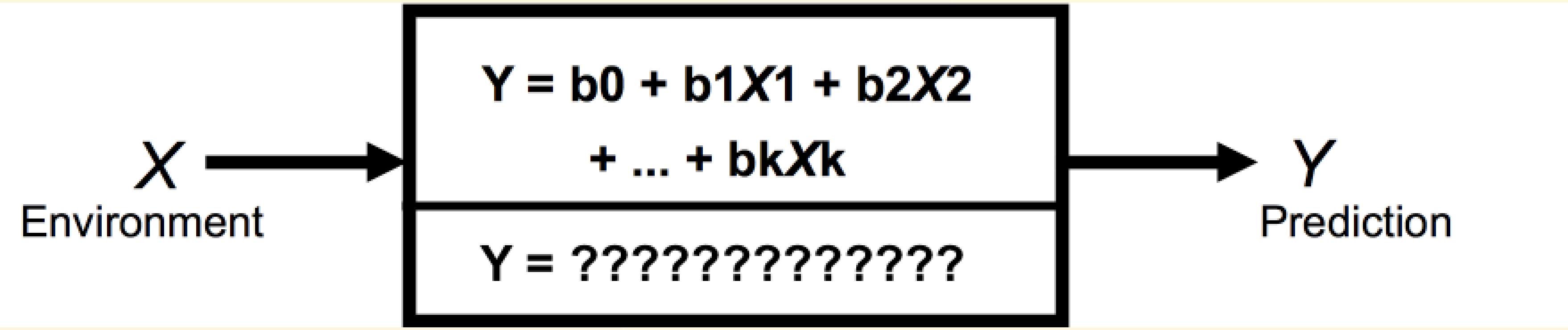
Model choices matter

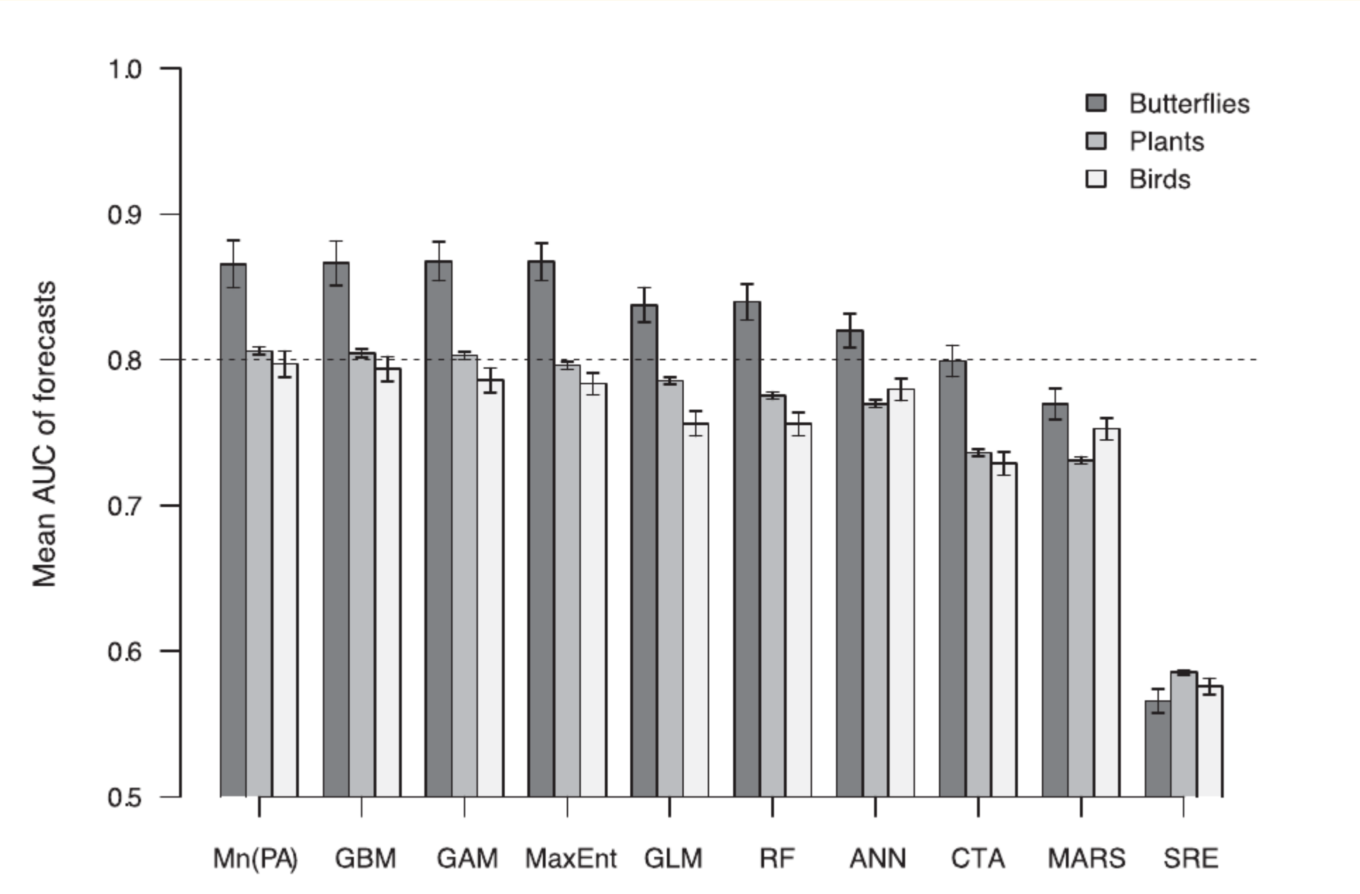


Explain vs. Predict

- 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.

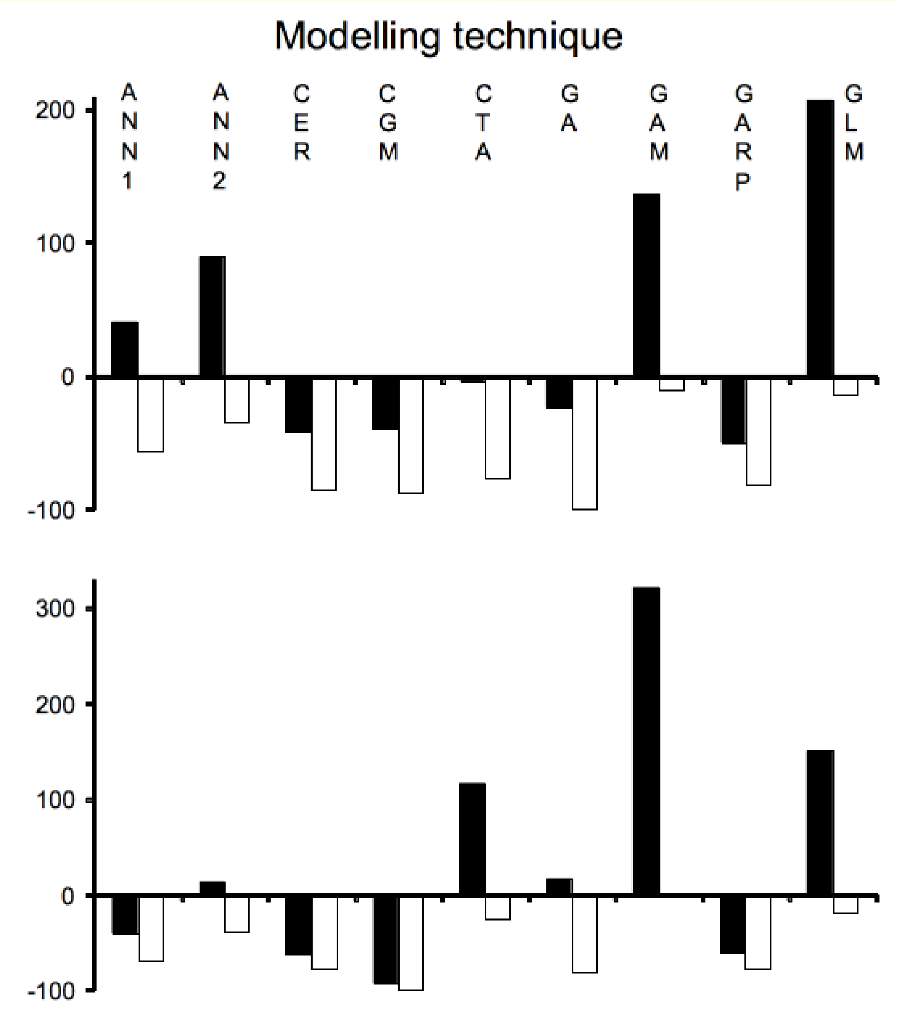


Model performance



Rapacciuolo et al 2012 PLoS One (7) 7 e40212

Model uncertainty

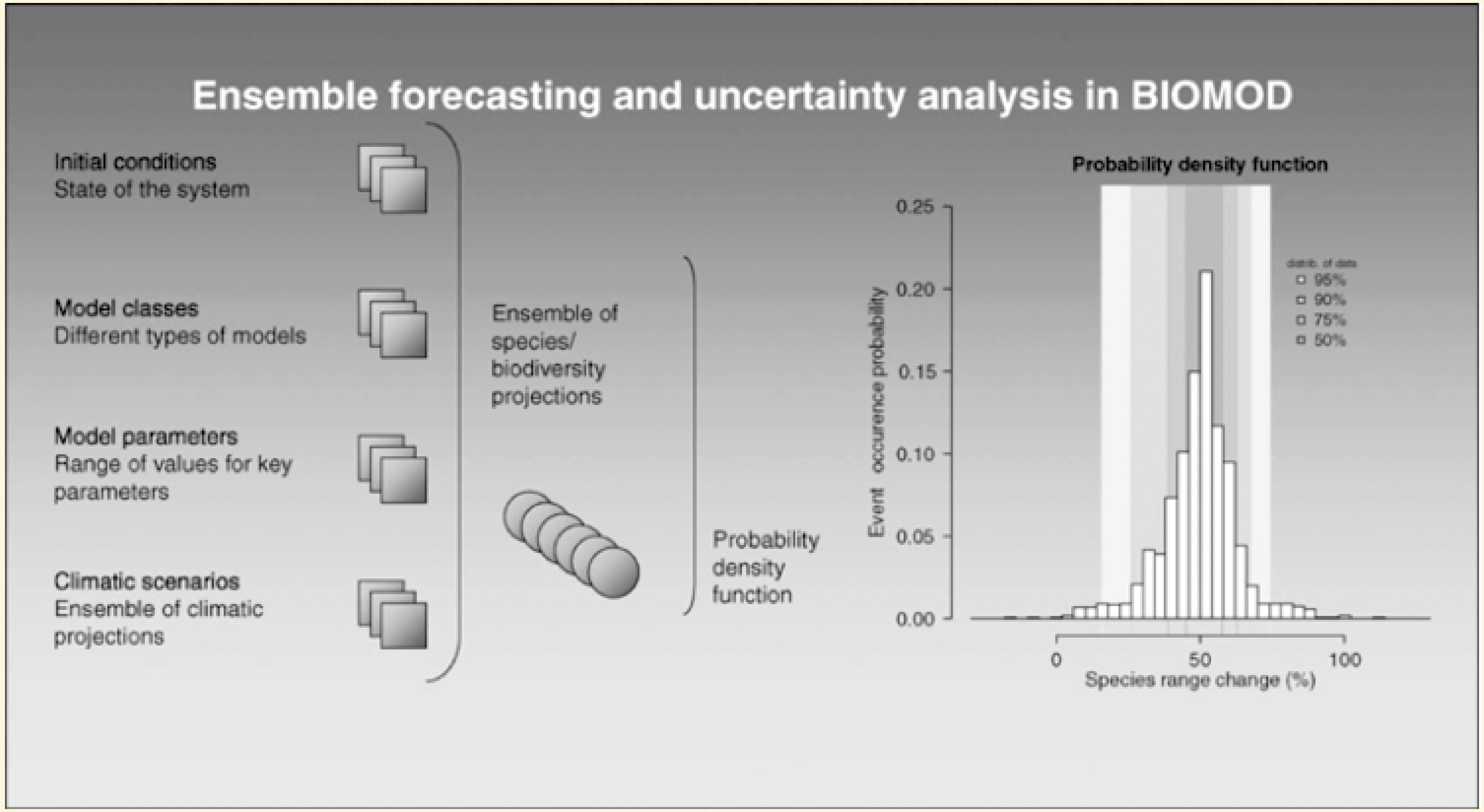


D. divaricata

L. hypophyllocarpodendrum

Pearson et al., 2006 "Biogeography"

Ensemble forecasting



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

Danger, Will Robinson

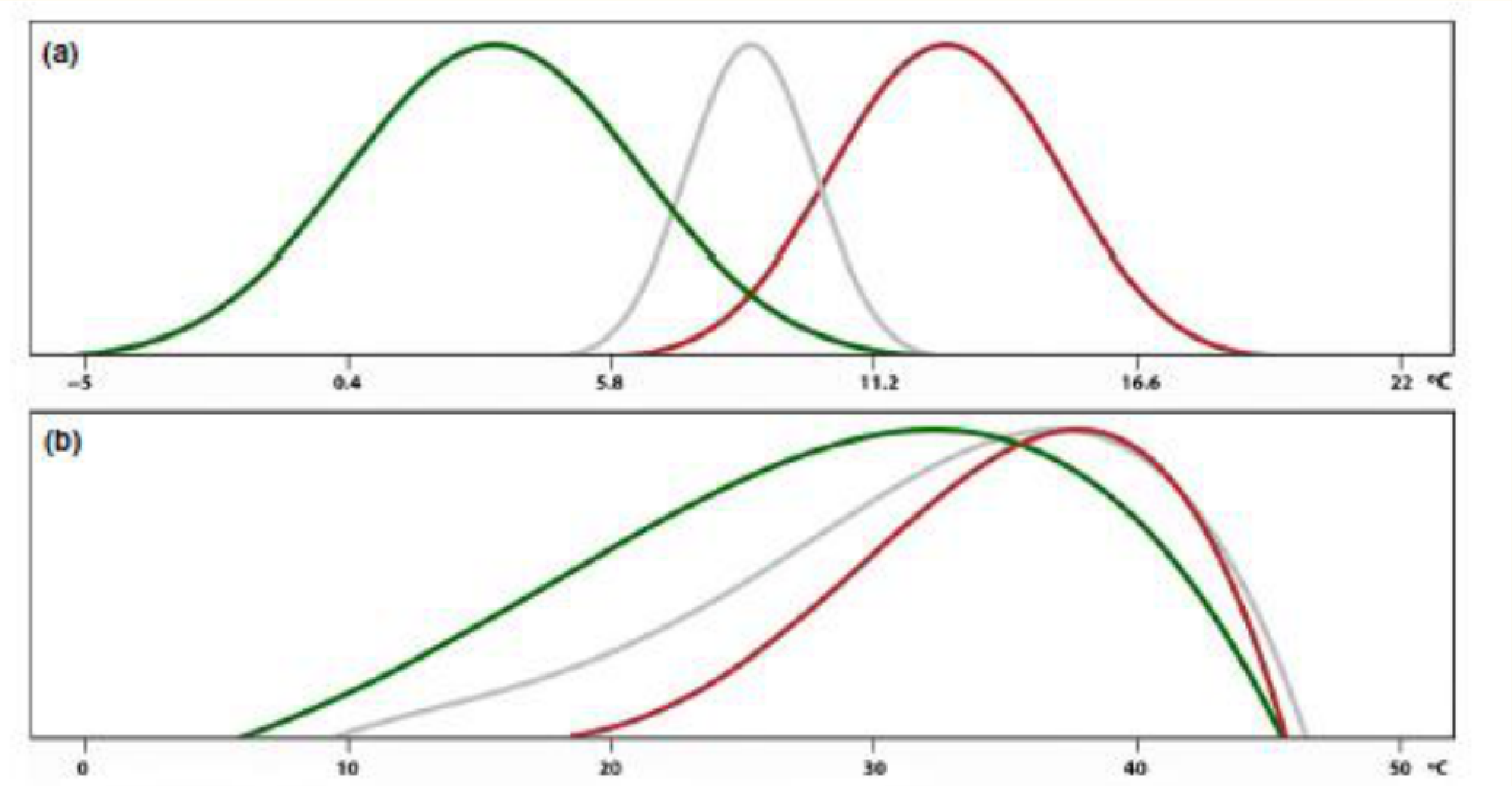
Assumptions

- 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

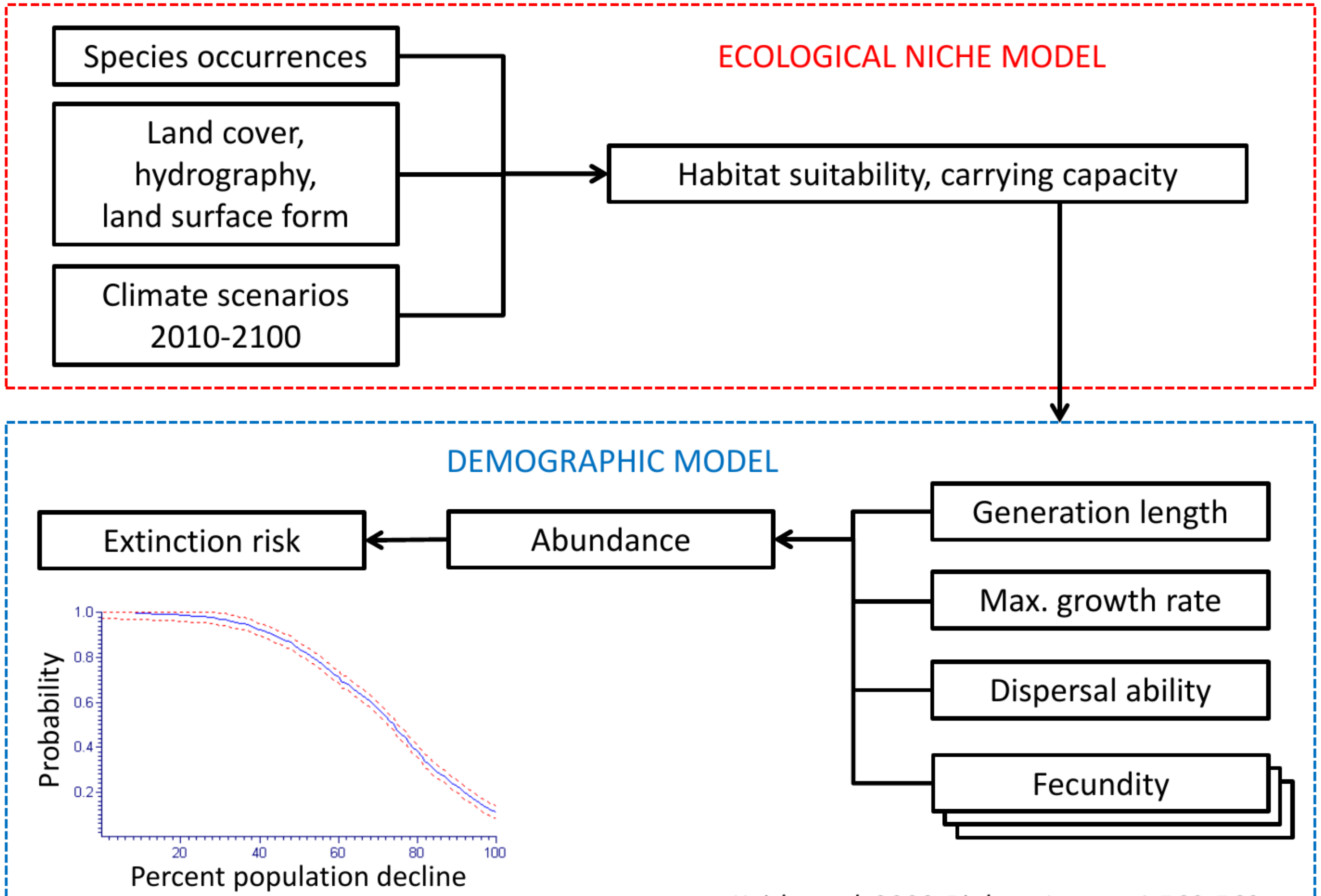


Araujo et al (2013) Ecology Letters 16: 1206 - 1209

Future directions

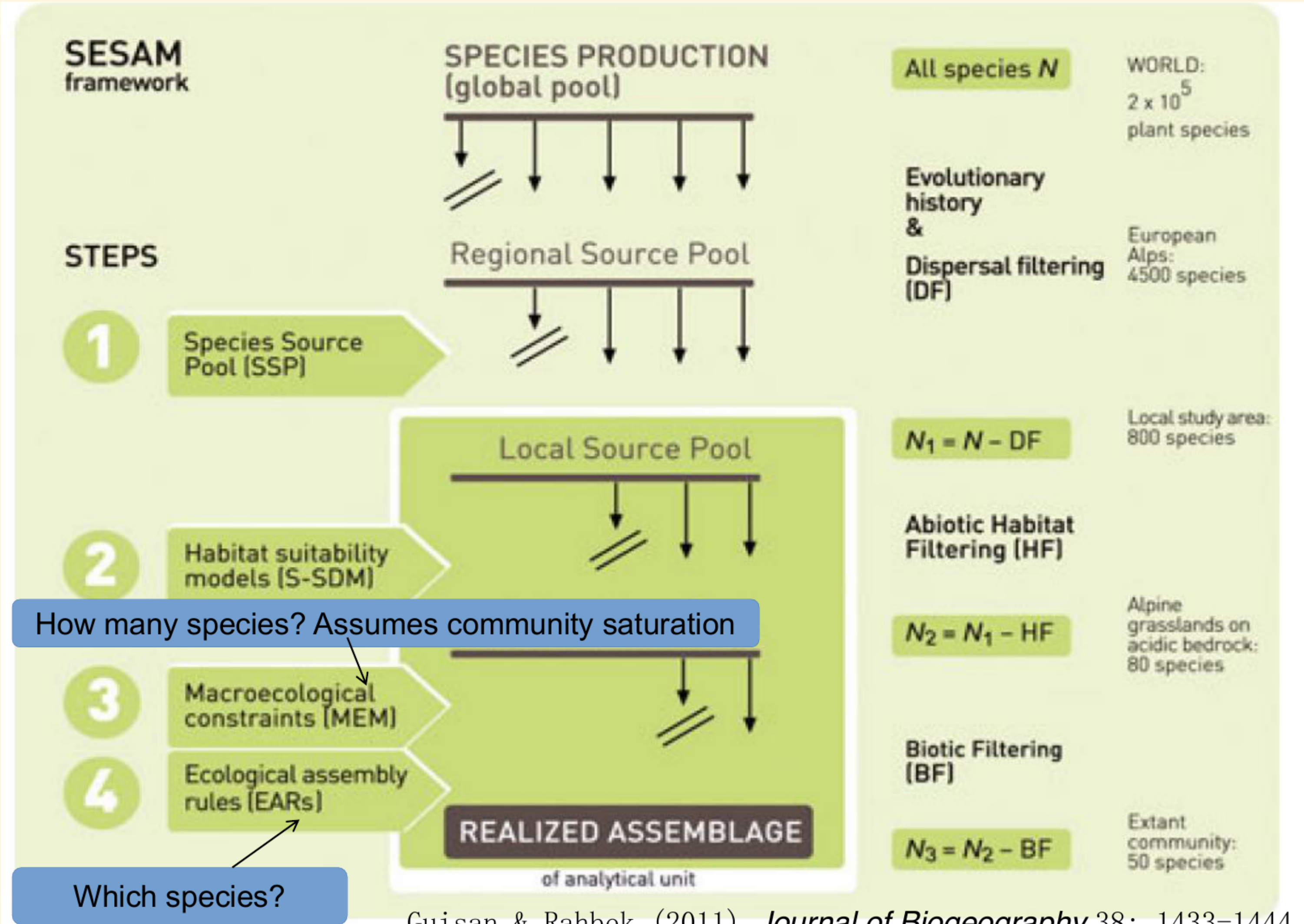
- Incorporating **dispersal**
- Incorporating **biotic** interactions
- More **mechanistic** models

Connect to demography



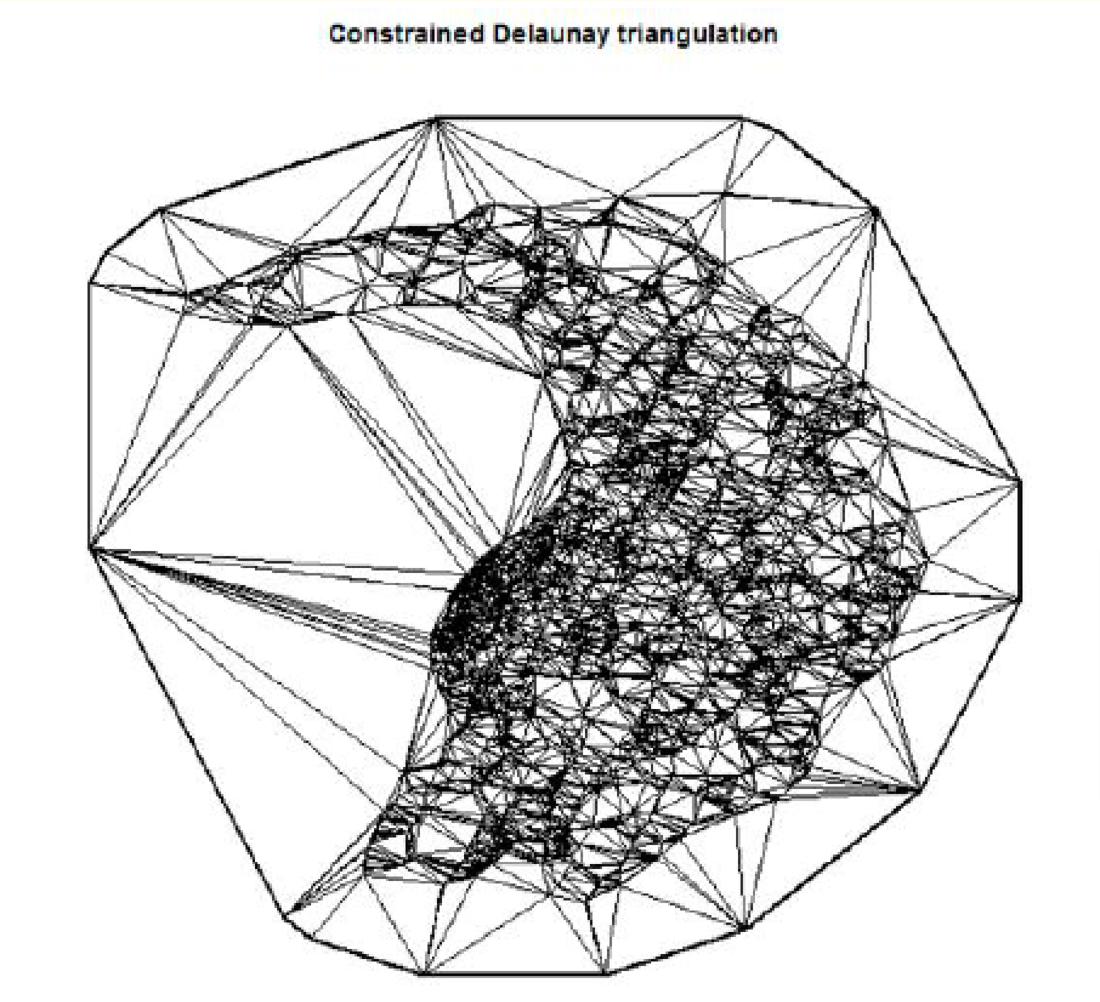
Keith *et al.* 2008 *Biology Letters* 4:560-563

Community assembly



Guisan & Rahbek (2011) *Journal of Biogeography* 38: 1433–1444

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

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- 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.

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. Laforcade, 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.