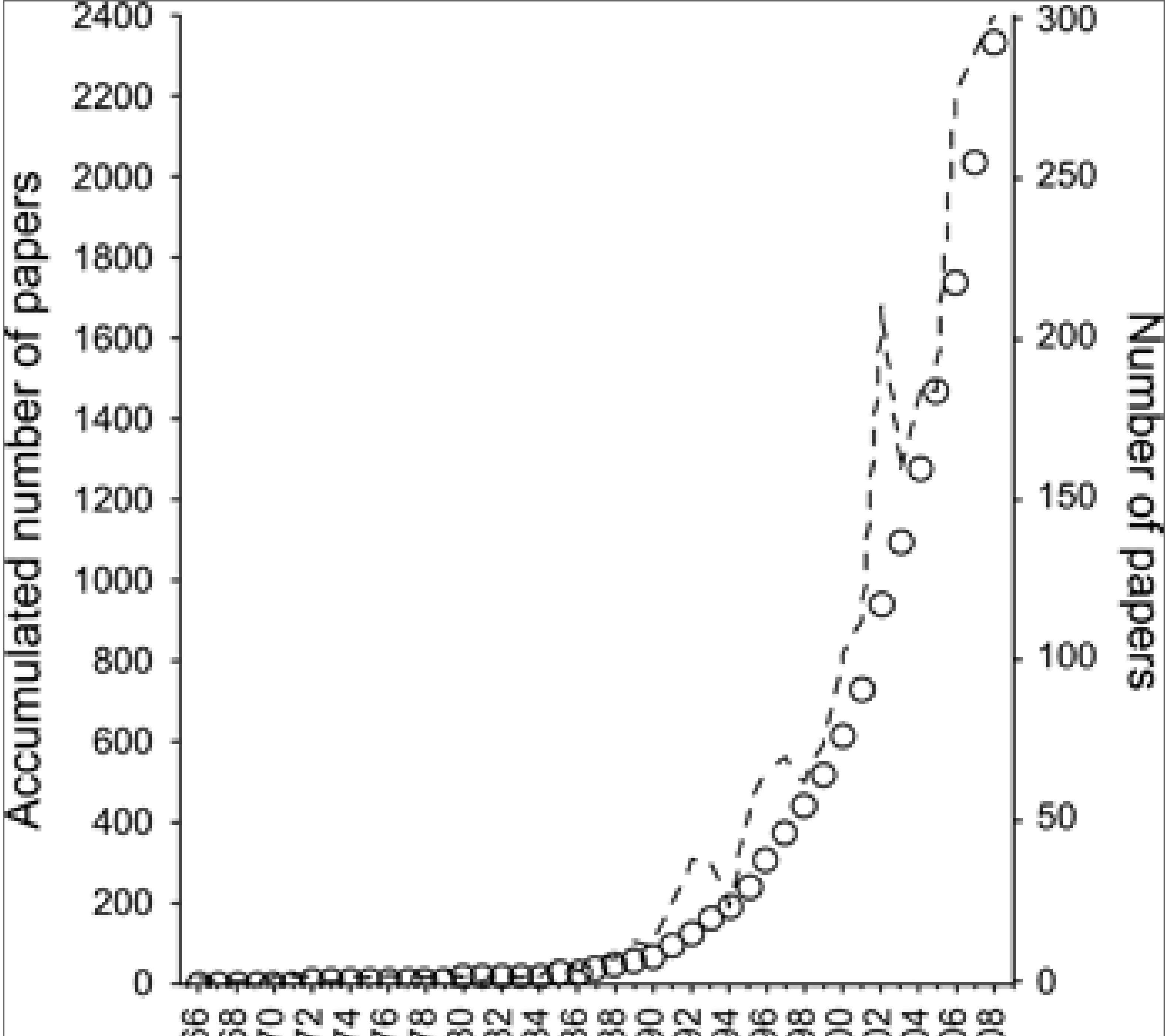
SPECIES DISTRIBUTION MODELS

DAVID ORME

OUTLINE

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

THE UNSTOPPABLE RISE OF SDMS



Accumulated number of papers
Number of papers
0
200
400
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800
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1200
1400
1600
1800
2000
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2400
0
50
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150
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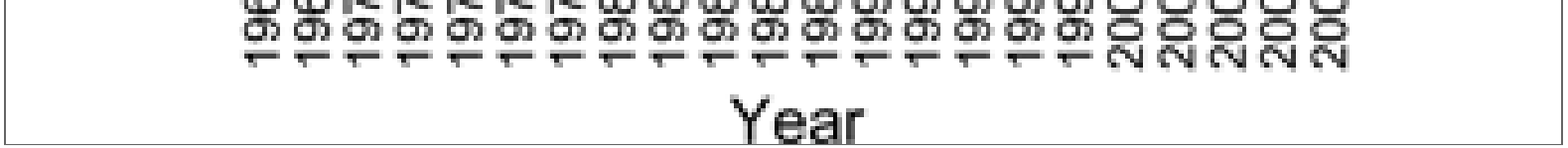
250
300



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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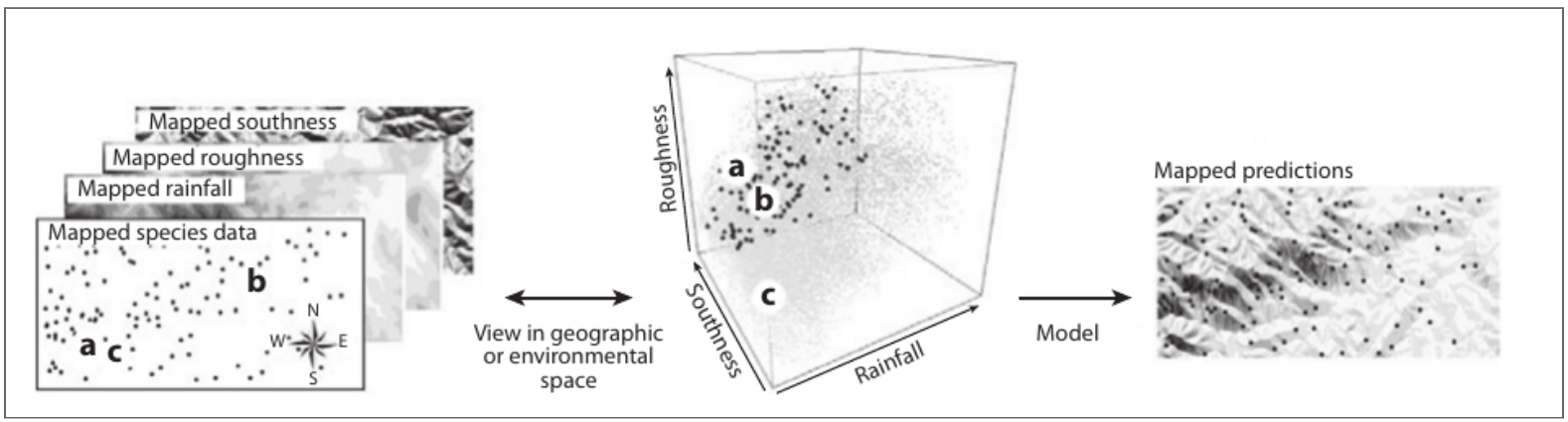
WHAT IS SPECIES DISTRIBUTION MODELLING?

- 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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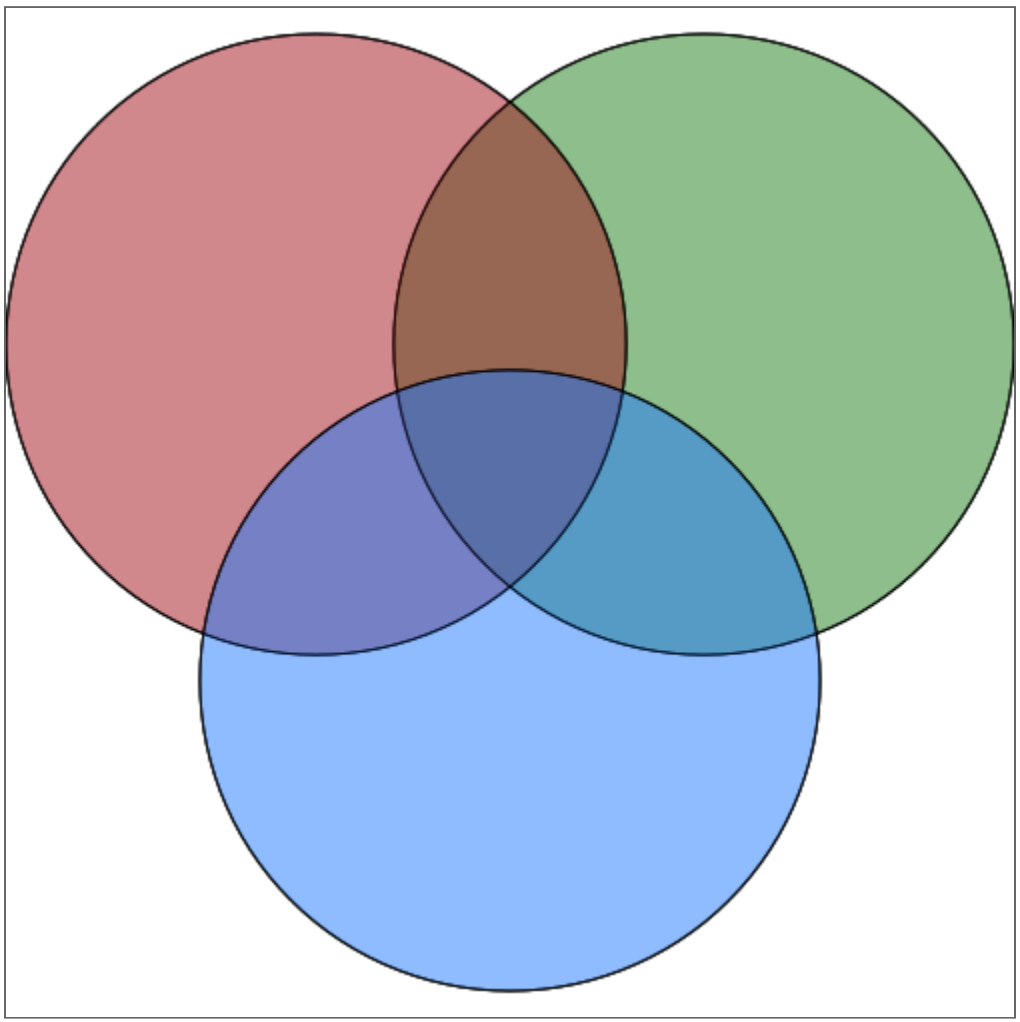
NICHE THEORY

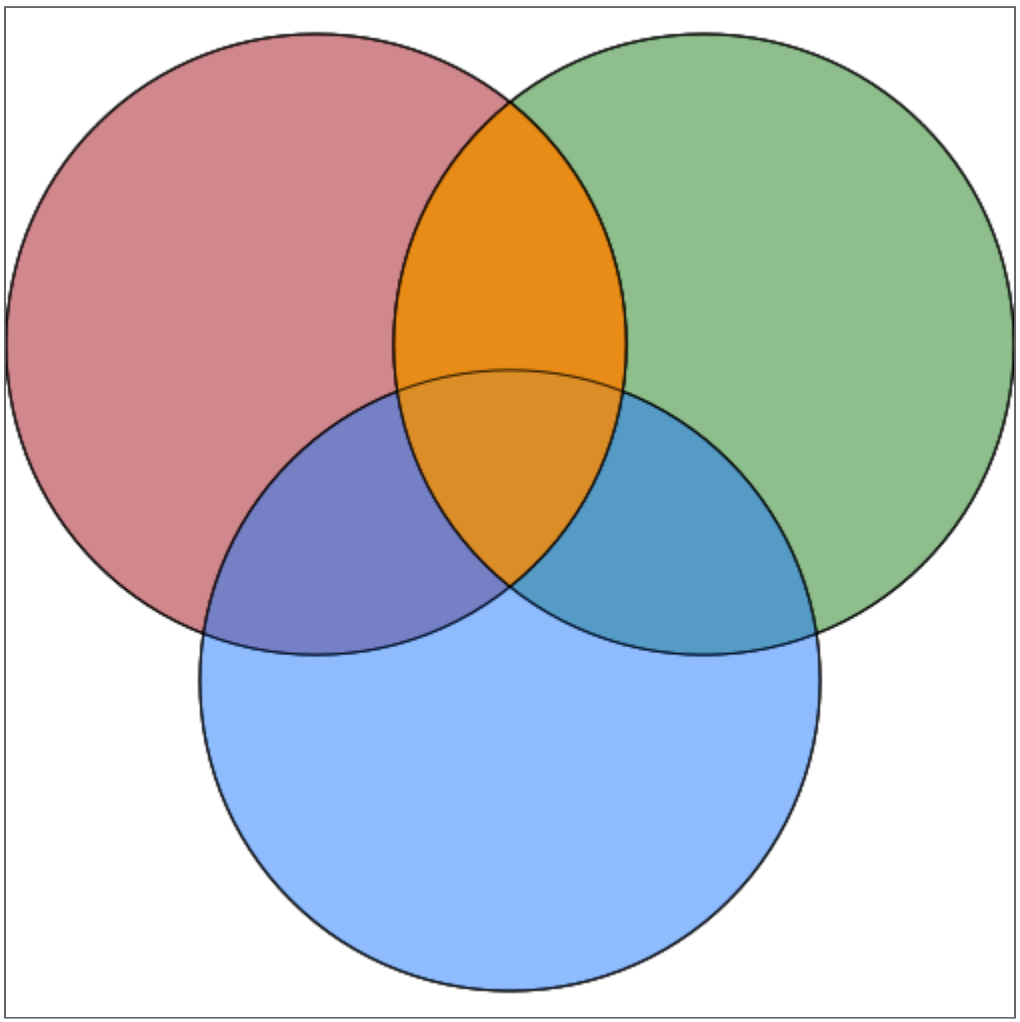


- Abiotic

- Biotic
- Accessible area

Soberón & Peterson (2005)

NICHE THEORY

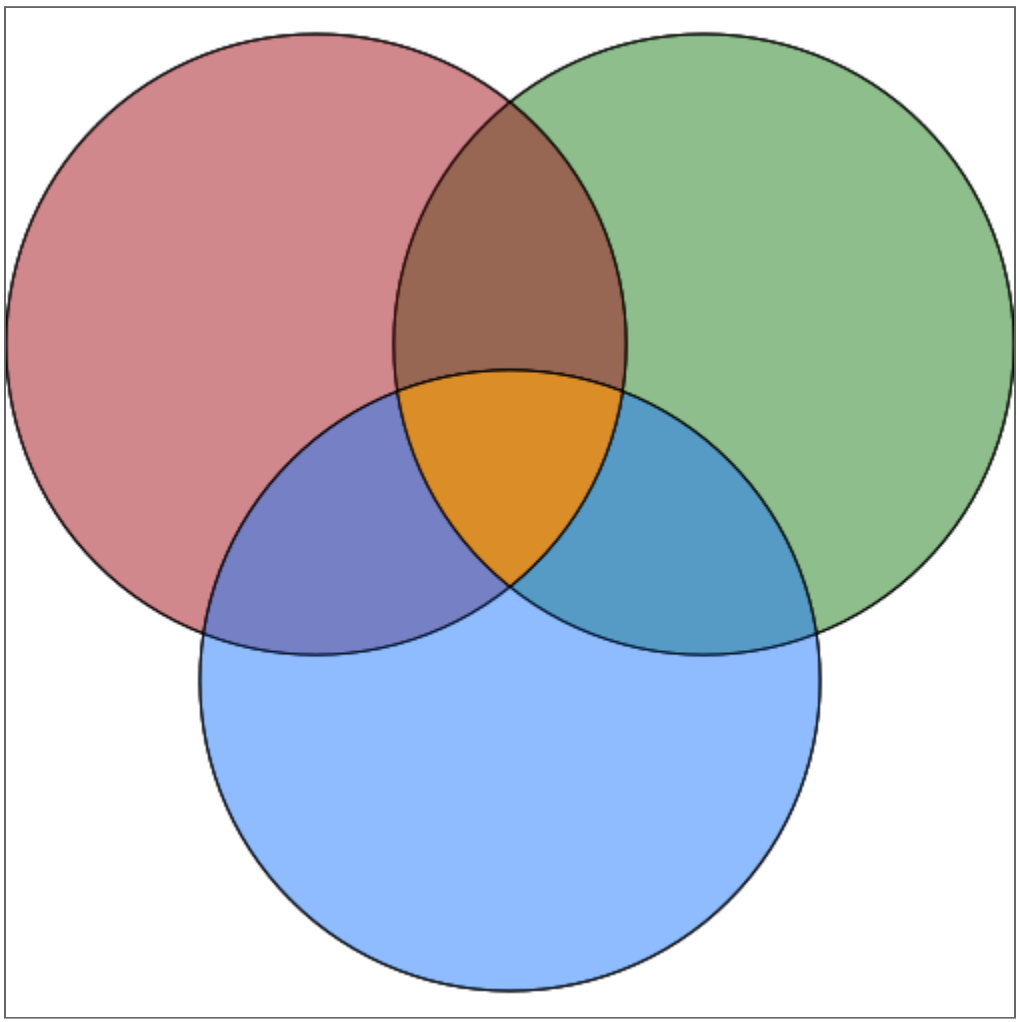


- Abiotic

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

Soberón & Peterson (2005)

NICHE THEORY

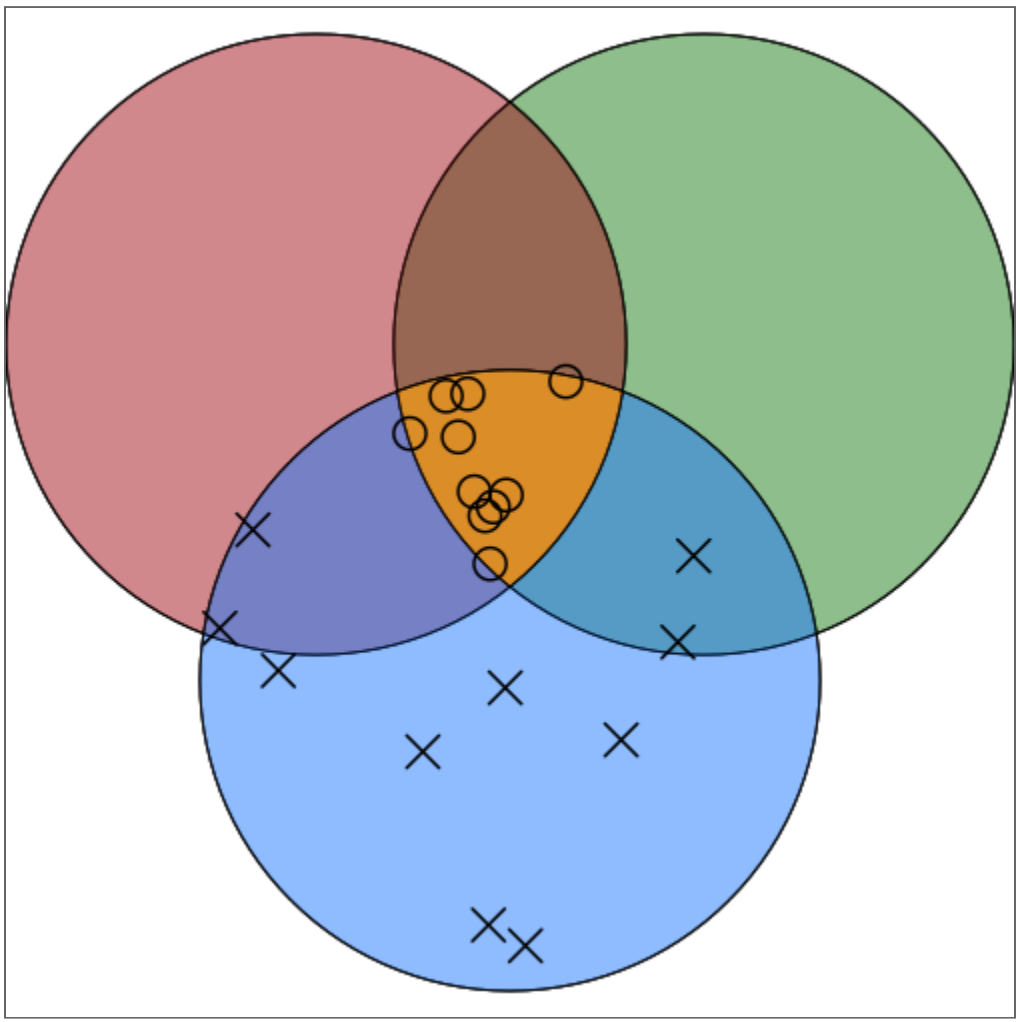


- Abiotic

- Biotic
- Accessible area
- **Realised niche:** accessible and in realised niche

Soberón & Peterson (2005)

NICHE THEORY



- Abiotic

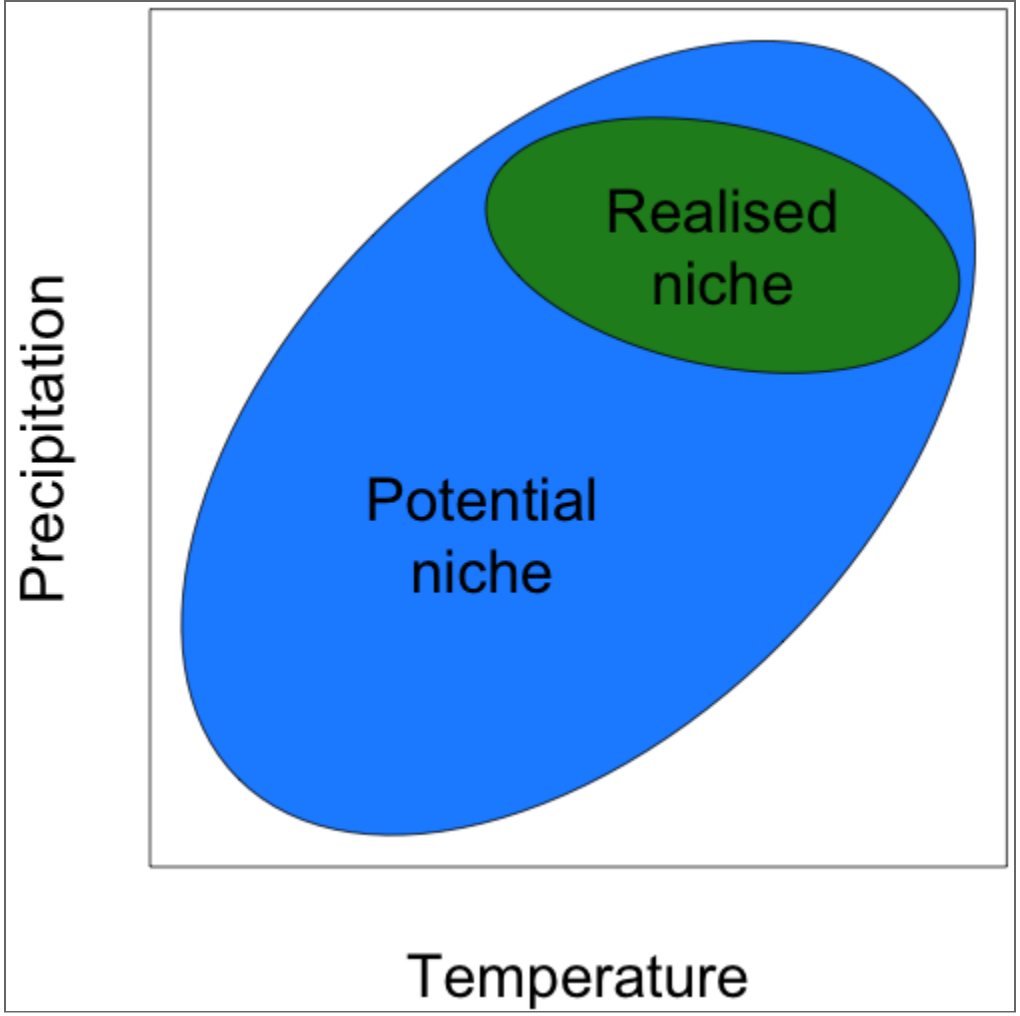
- Biotic
- Accessible area
- **Populations:** can be both source (o) and sink (x)

Soberón & Peterson (2005)

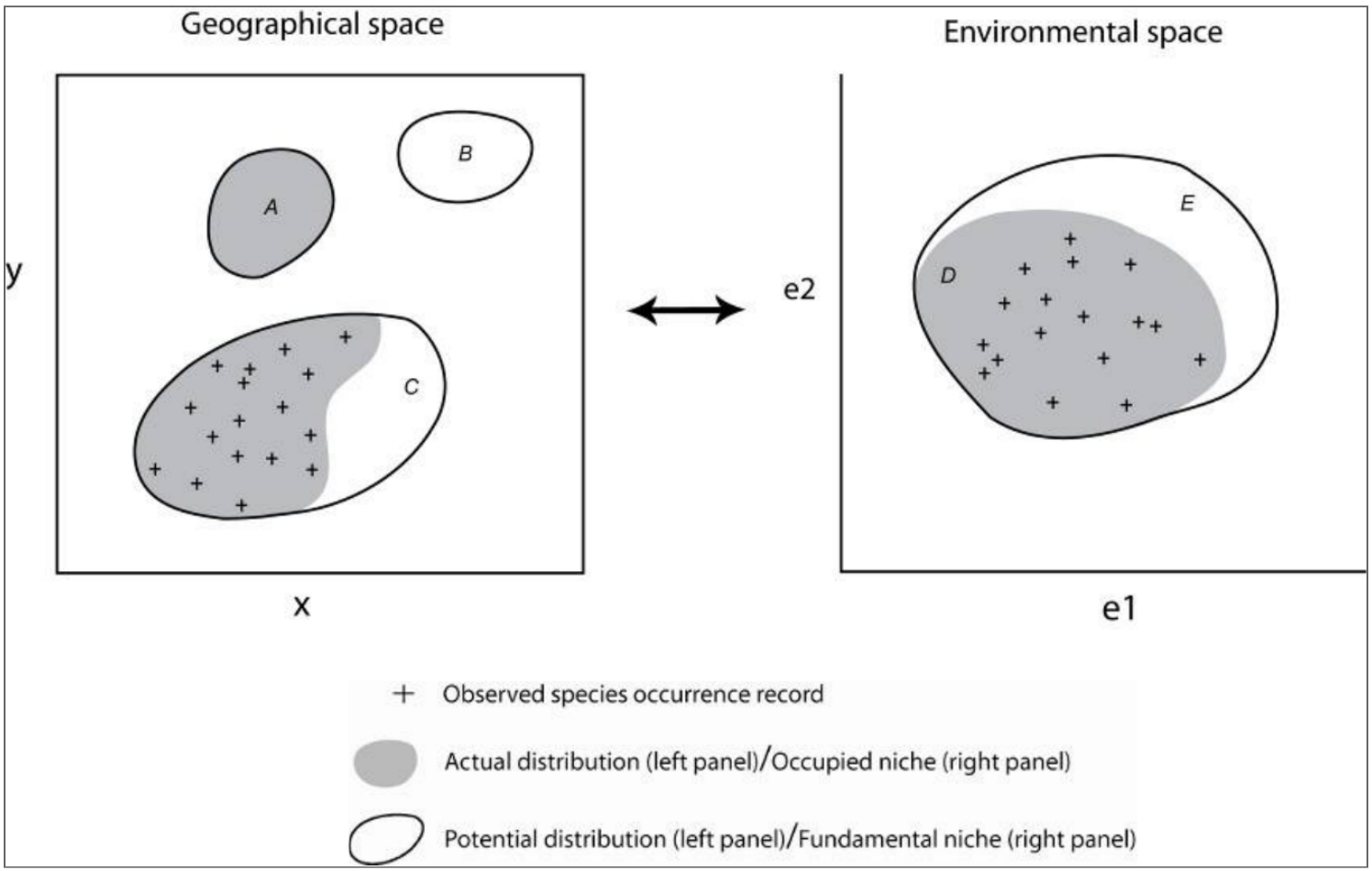
NICHE THEORY

> *"The n-dimensional hypervolume within which that species can survive and reproduce"*

Hutchinson (1957)

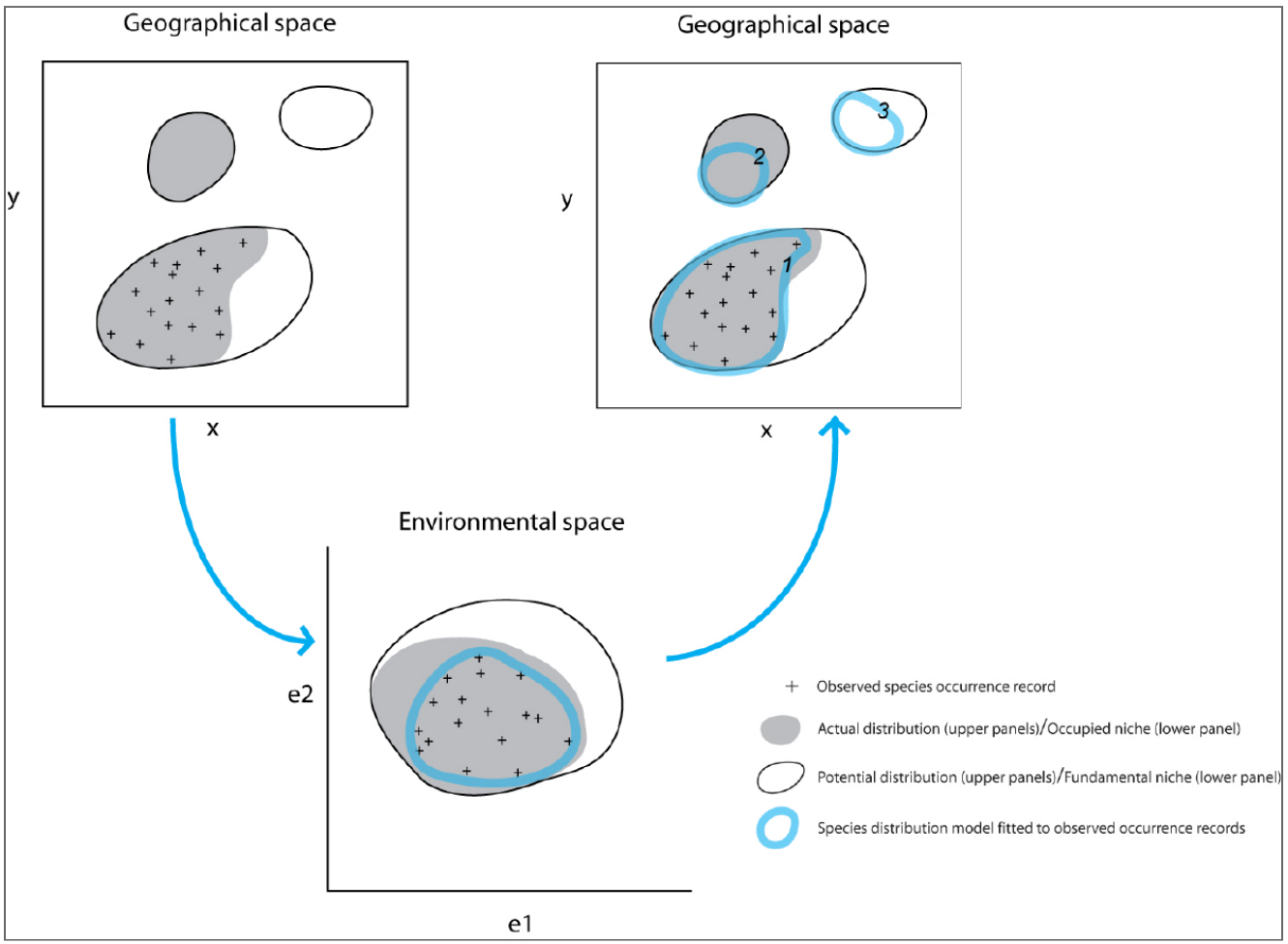

Realised
niche
Potential
niche
Precipitation
Temperature

ENVIRONMENTAL AND GEOGRAPHICAL SPACE



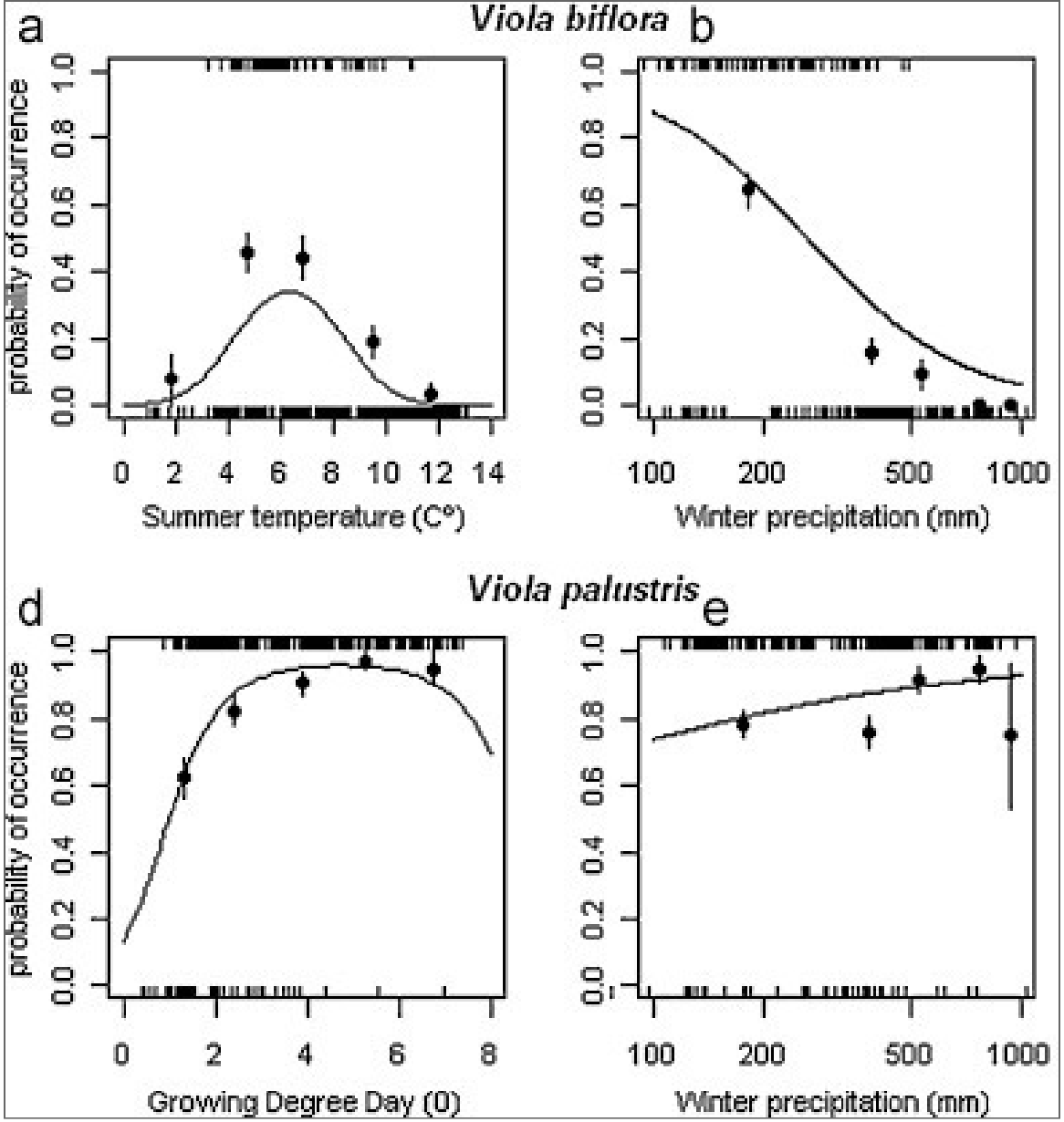
Pearson 2007., see also Peterson et al. 2011

ENVIRONMENTAL AND GEOGRAPHICAL SPACE



Pearson 2007., see also Peterson et al. 2011

MODELLED RELATIONSHIP


a
Viola biflora
b
probability of occurrence
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14
Summer temperature (C°)
100
200
500
1000
Winter precipitation (mm)
d
Viola palustris
e
probability of occurrence
Growing Degree Day (0)
Winter precipitation (mm)

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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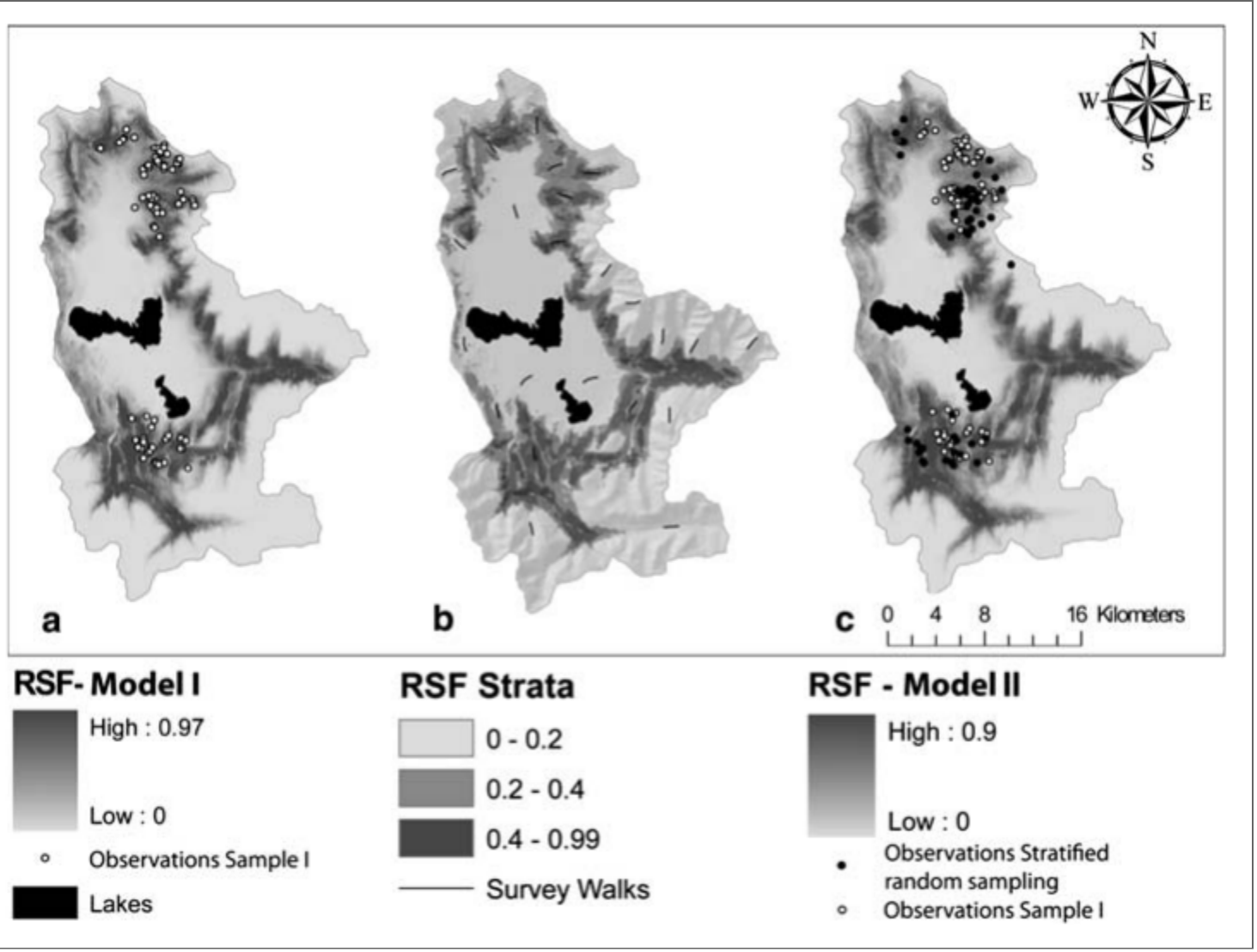
GUIDING FIELD STUDIES

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


N
W
E
S
a
b
c
0 4 8 16 Kilometers
RSF- Model I
High : 0.97
Low : 0
Observations Sample I
Lakes
RSF Strata
0 - 0.2
0.2 - 0.4
0.4 - 0.99
Survey Walks
RSF - Model II
High : 0.9
Low : 0
Observations Stratified random sampling
Observations Sample I

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]

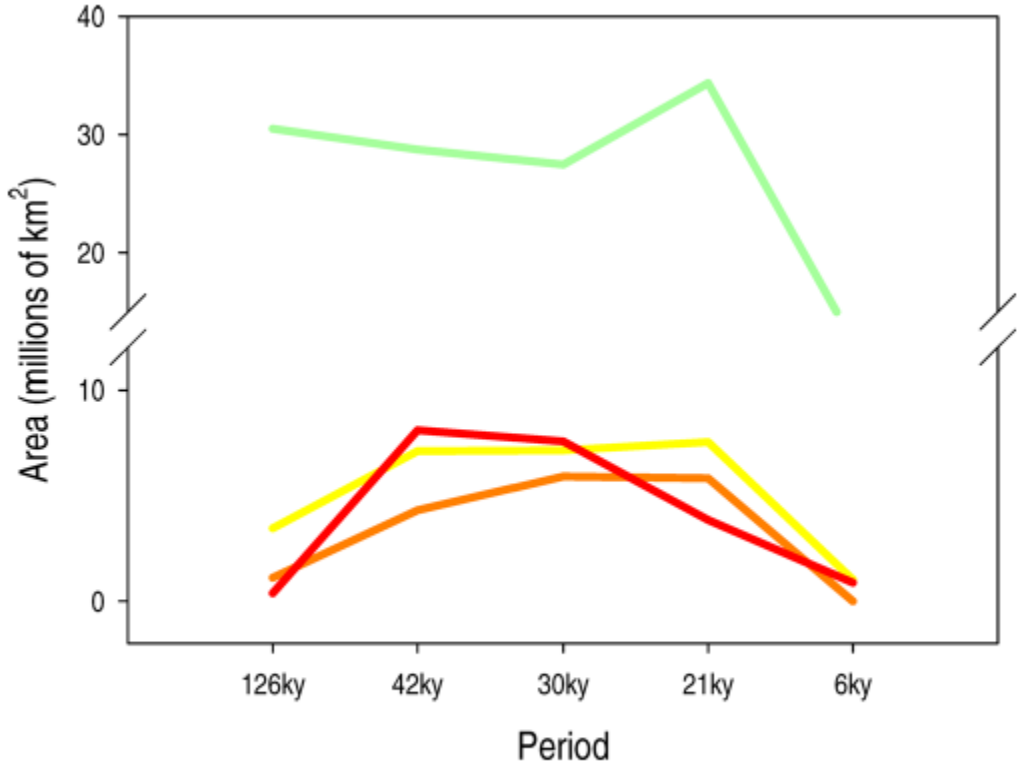
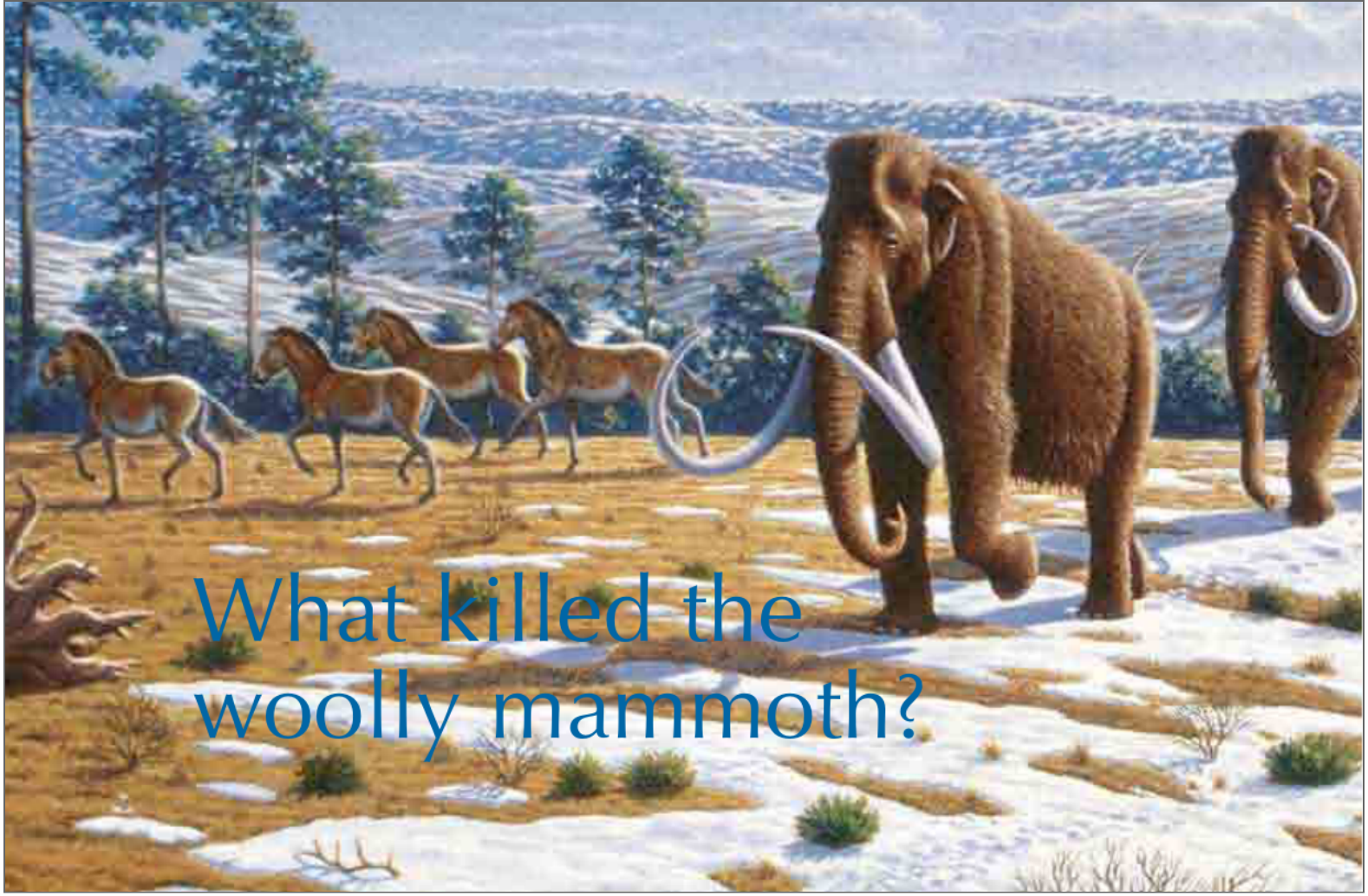


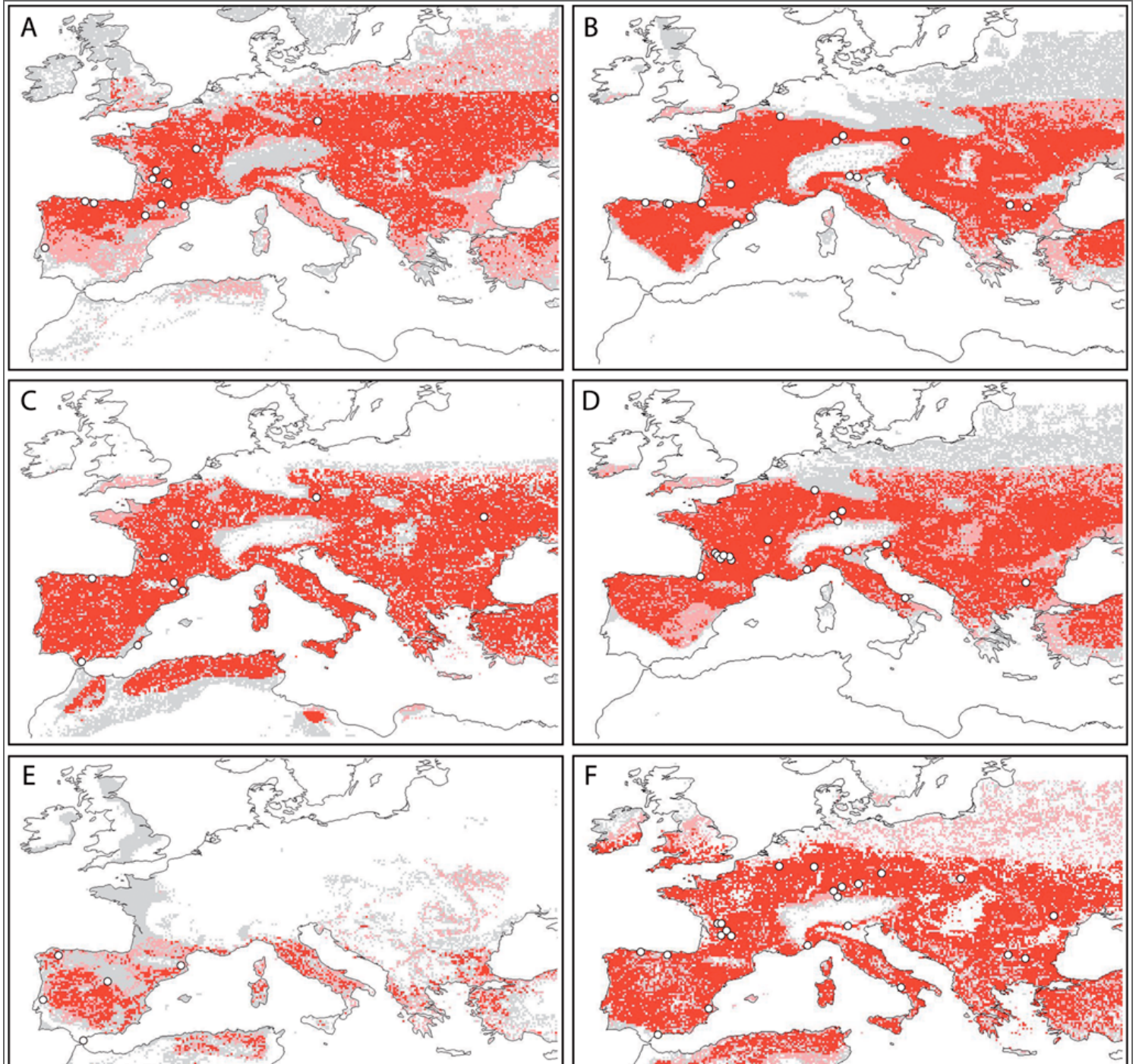
Figure 2. Change in the Area (%) of the Different Suitable Climatic Conditions for Woolly Mammoths


What killed the
woolly mammoth?

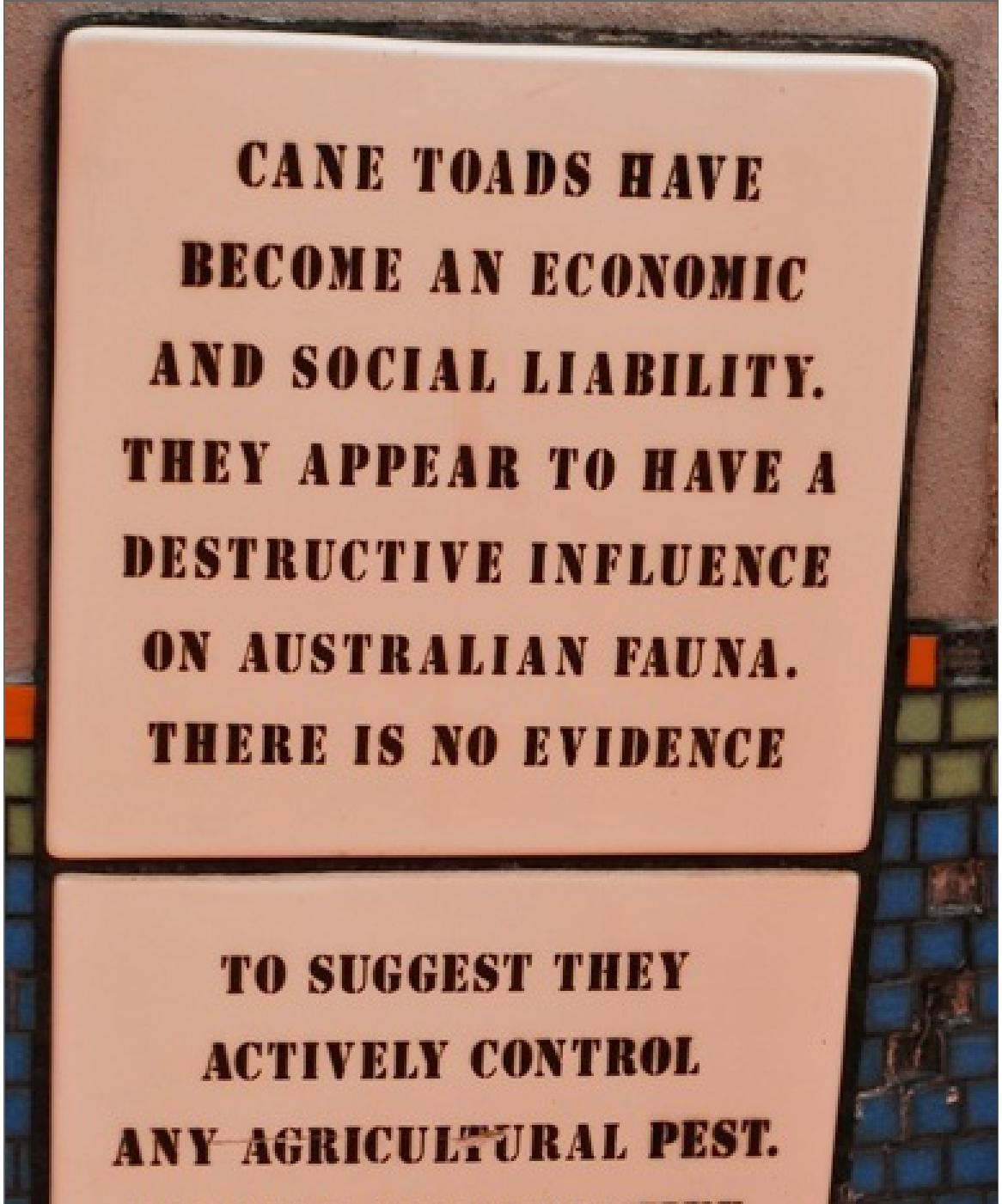
INFORMING OUR VIEW OF THE PAST

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]

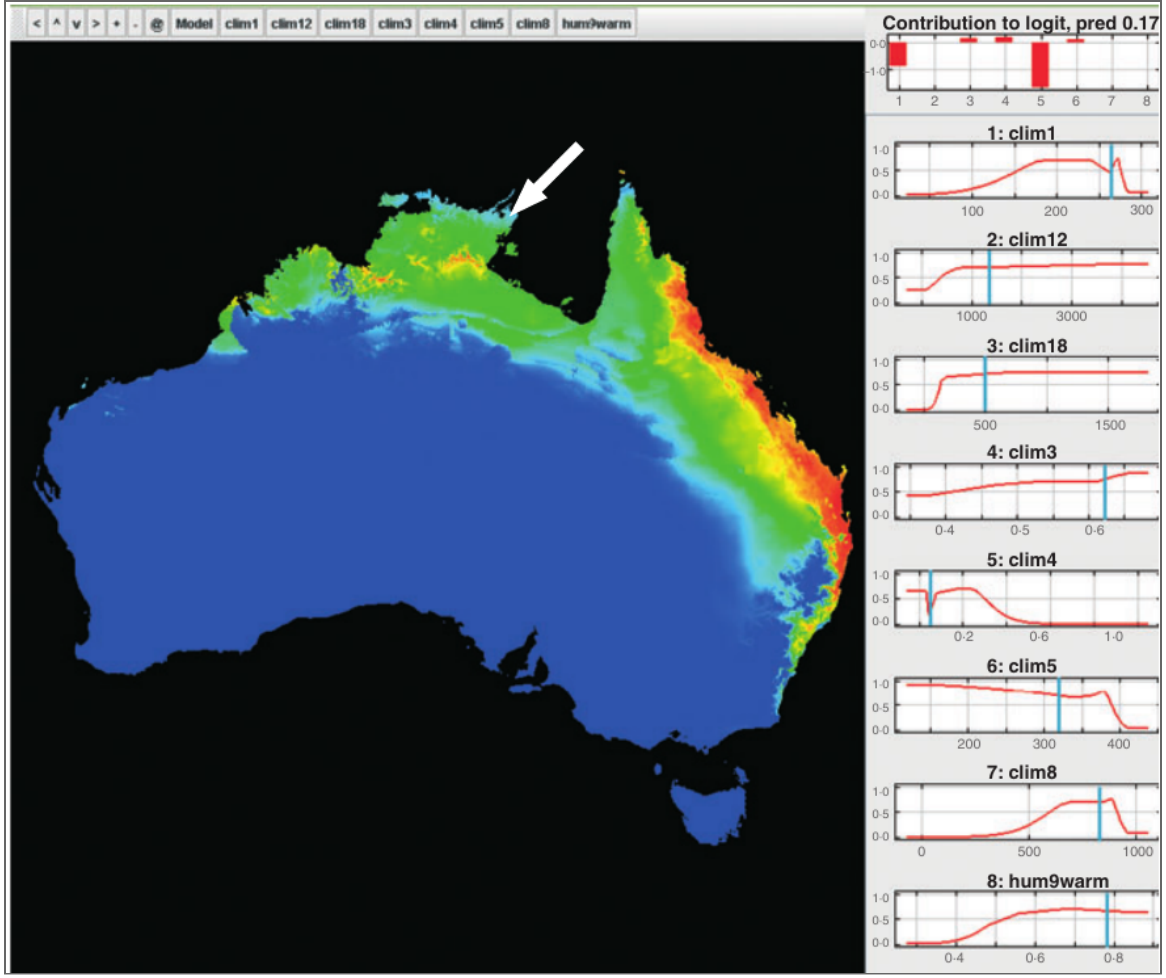

A
B
C
D
E
F

SPREAD OF INVASIVE SPECIES


CANE TOADS HAVE
BECOME AN ECONOMIC
AND SOCIAL LIABILITY.
THEY APPEAR TO HAVE A
DESTRUCTIVE INFLUENCE
ON AUSTRALIAN FAUNA.
THERE IS NO EVIDENCE
TO SUGGEST THEY
ACTIVELY CONTROL
ANY AGRICULTURAL PEST.


TO DATE, NO EFFECTIVE
METHOD HAS BEEN FOUND
TO ELIMINATE THEM
IN AUSTRALIA


(a)


< ^ v > + - @ Model clim1 clim12 clim18 clim3 clim4 clim5 clim8 hum9warm
Contribution to logit, pred 0.17
0·0
-1·0
1 2 3 4 5 6 7 8
1: clim1
1·0
0·5
0·0
100 200 300
2: clim12
1·0
0·5
0·0
1000 3000
3: clim18
1·0
0·5
0·0
500 1500
4: clim3
1·0
0·5
0·0
0·4 0·5 0·6
5: clim4
1·0
0·5
0·0
0·2 0·6 1·0
6: clim5
1·0
0·5
0·0
200 300 400
7: clim8
1·0
0·5
0·0
0 500 1000
8: hum9warm
1·0
0·5
0·0
0·4 0·6 0·8

IMPACTS OF CLIMATE CHANGE

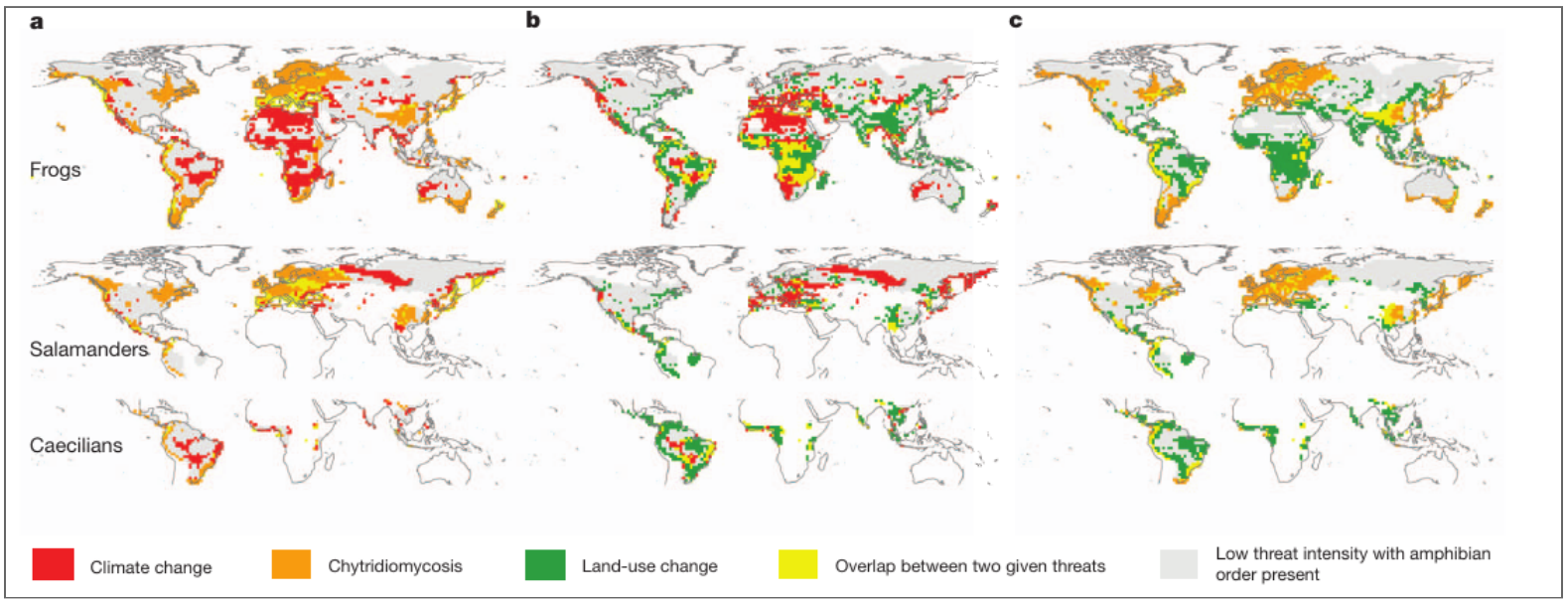
![Thomas Guardian]
(images/thomas_guardian.png)

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]

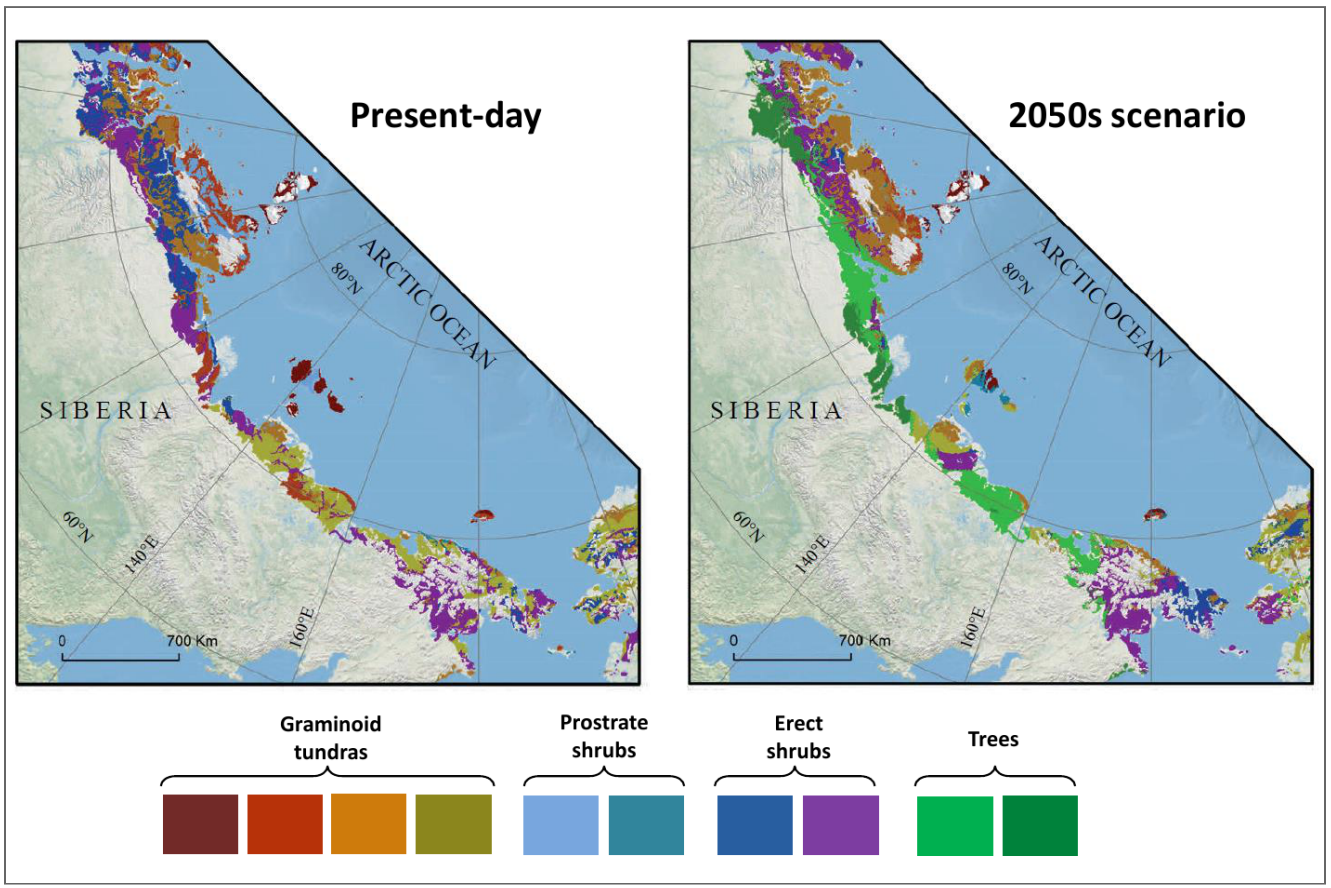

nature
Feeling the heat
Climate change and biodiversity loss
Supernova 1993J
Embryonic stem cells
Earth's early atmosphere

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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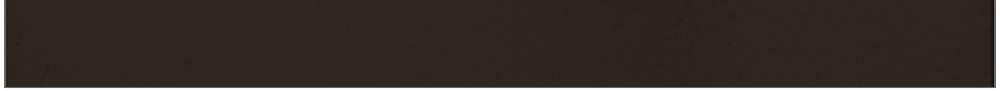
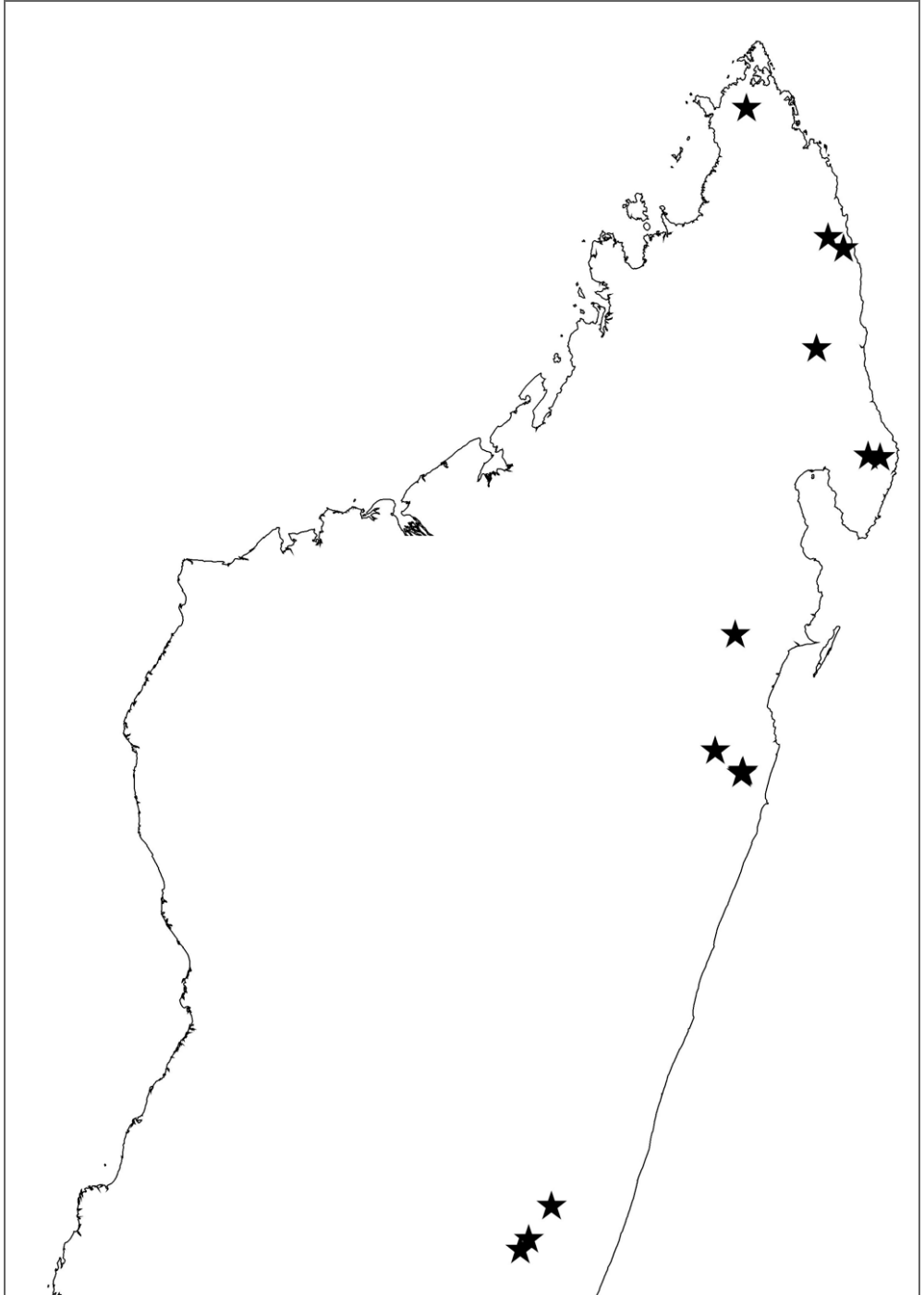
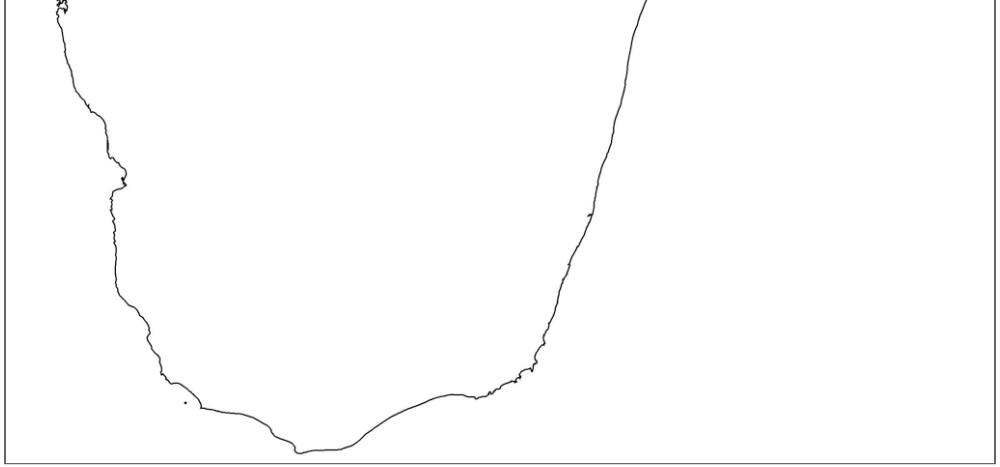
MADAGASCAN GECKOS



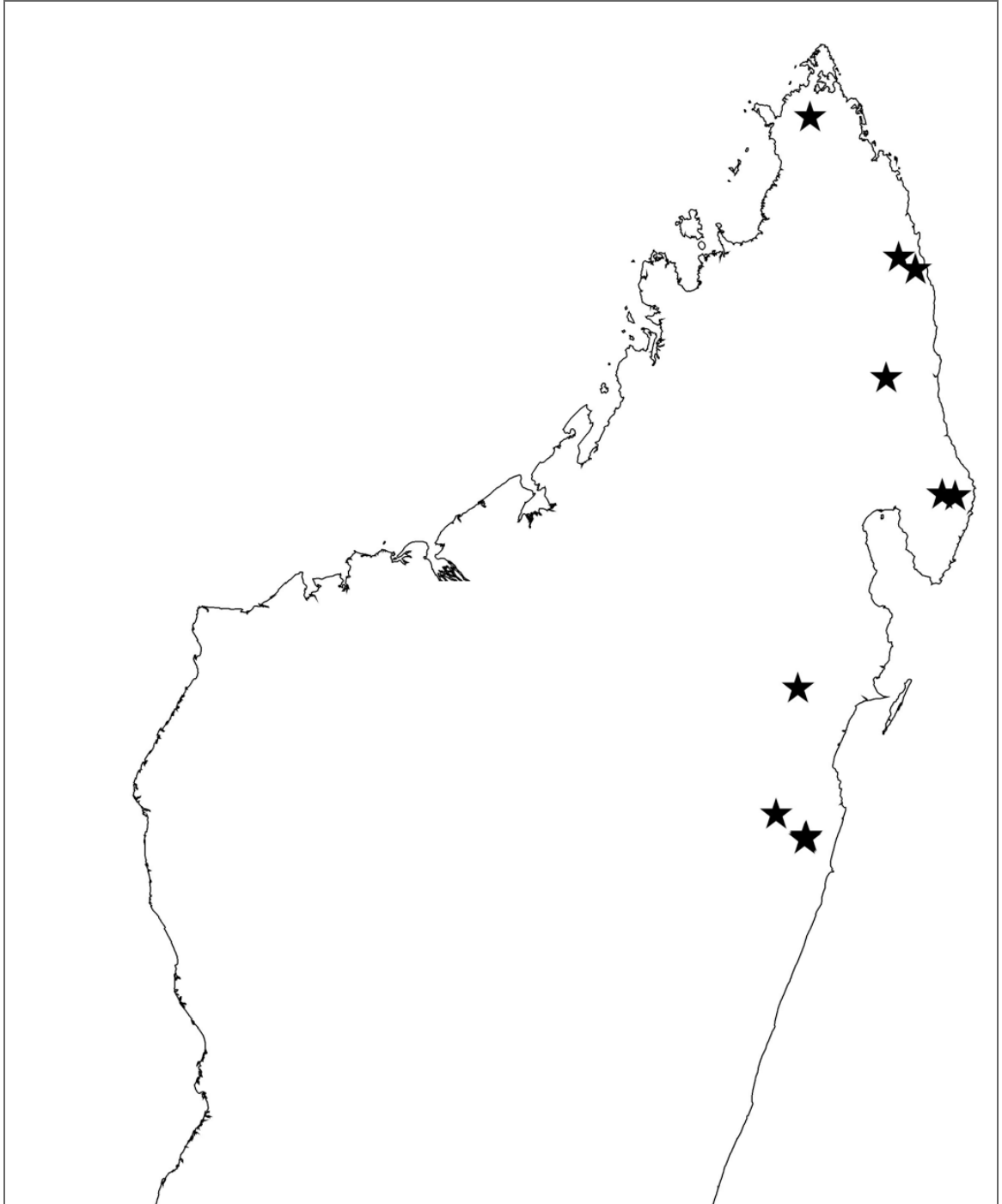
Uroplatus sp.

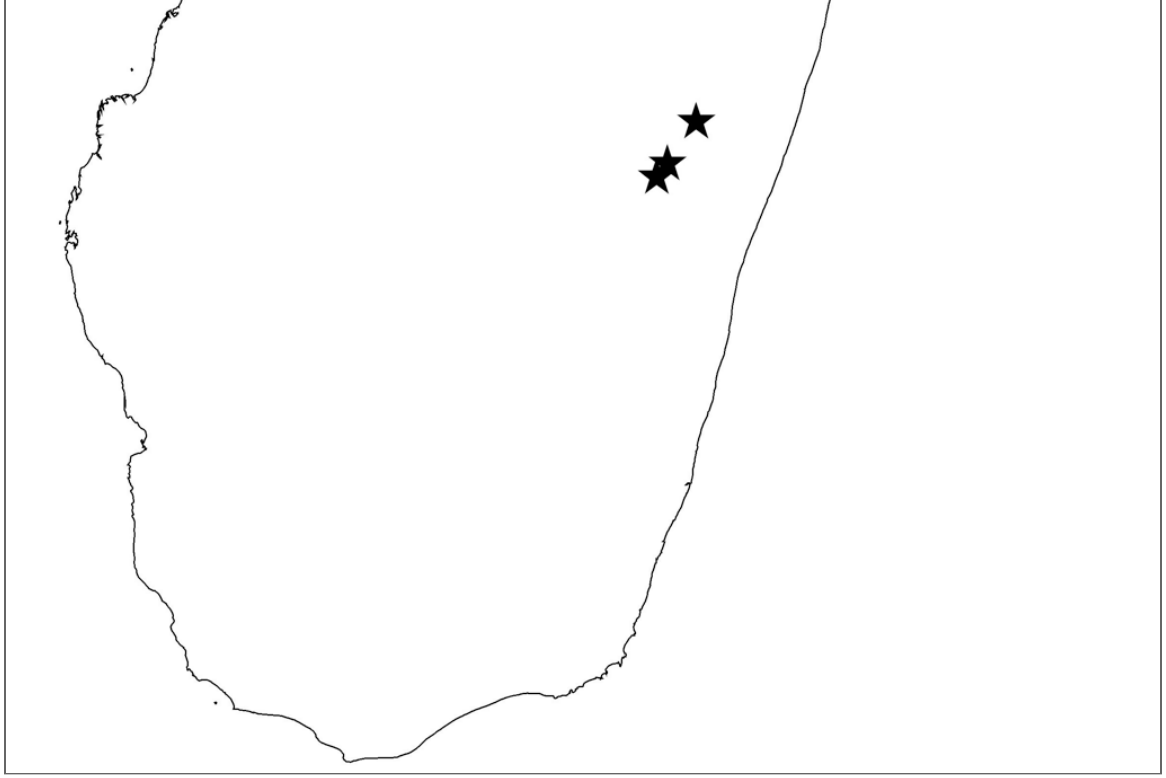
Pearson et al. (2007) J. Biogeog 34: 102-117

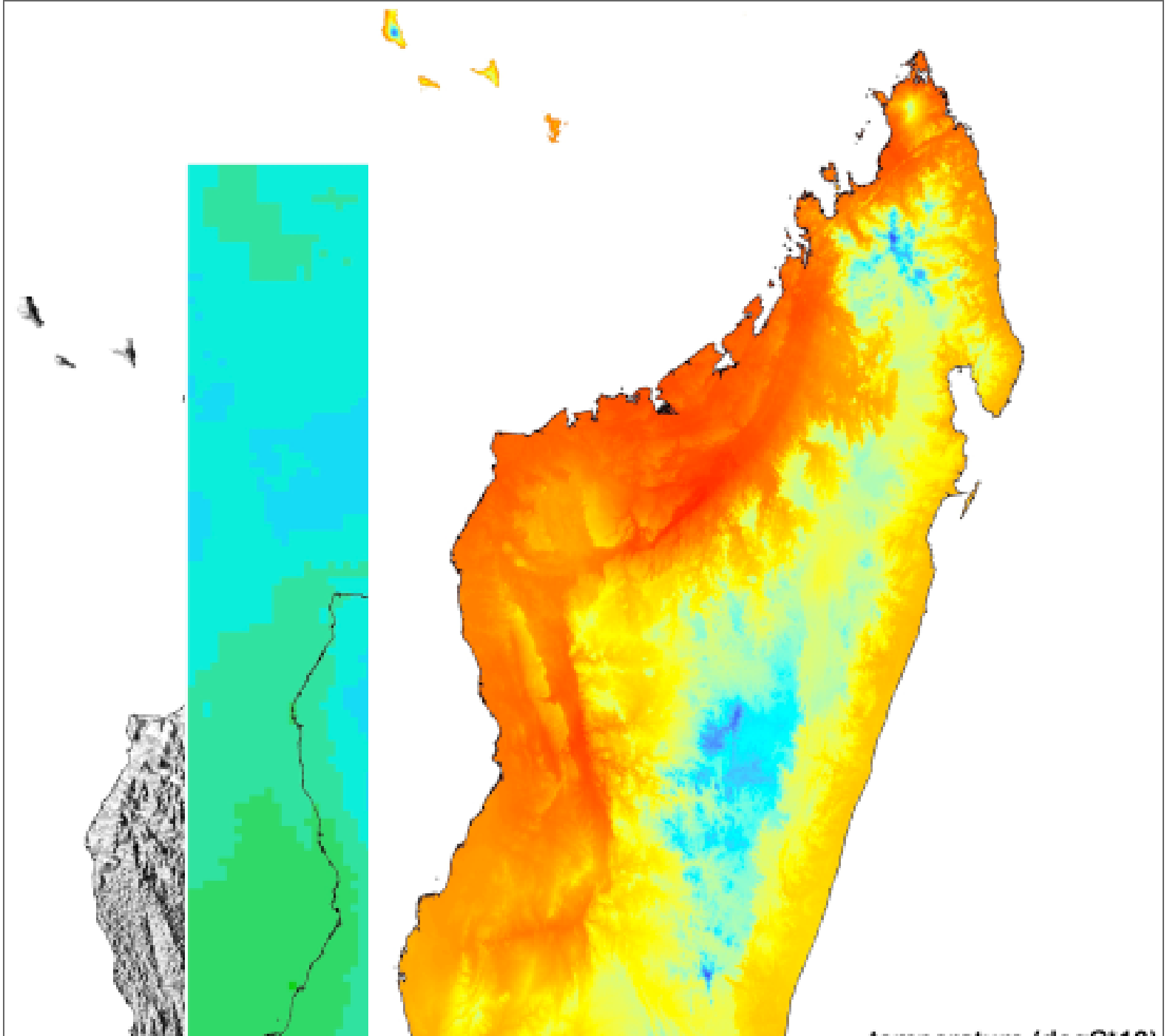


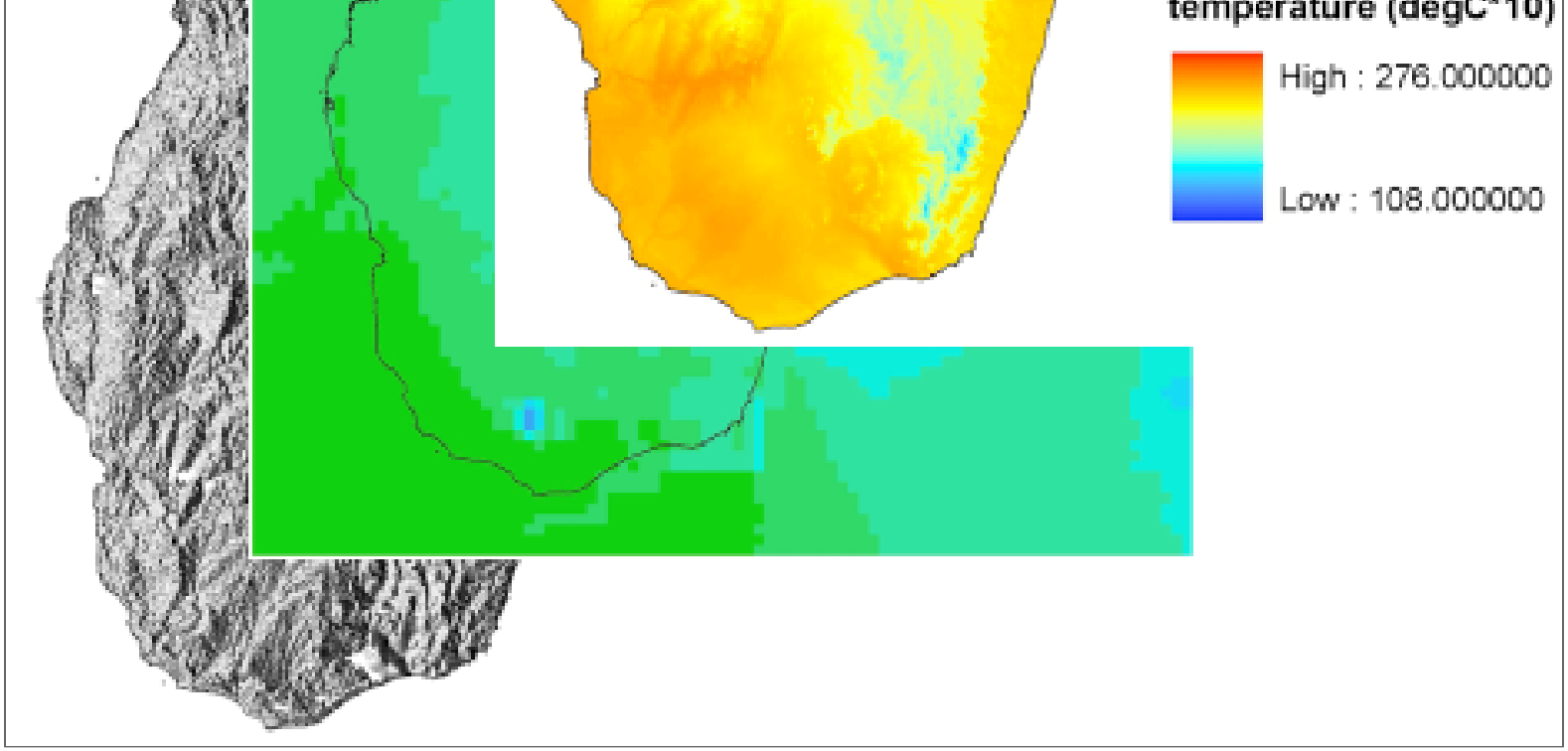


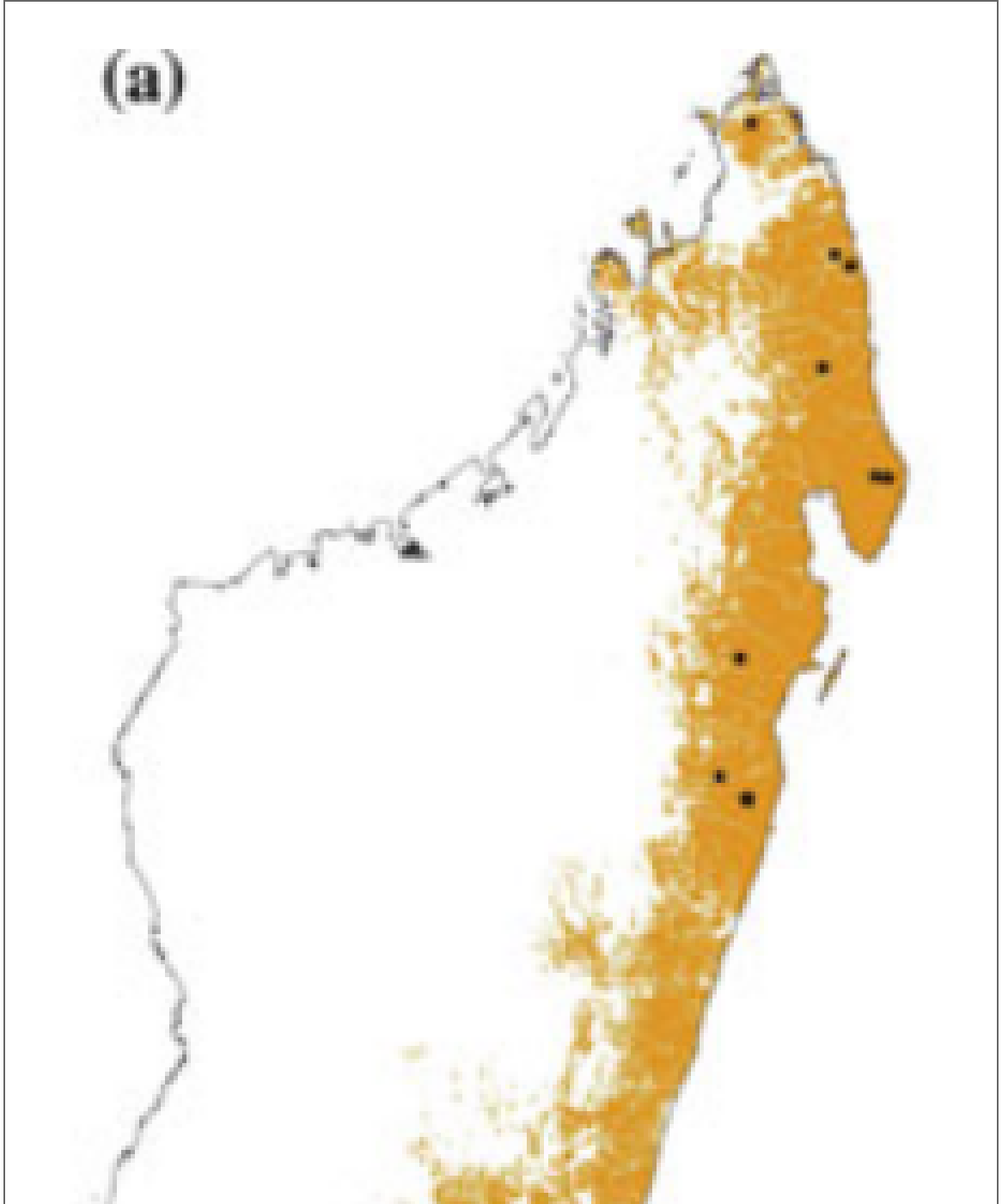
MADAGASCAN GECKOS

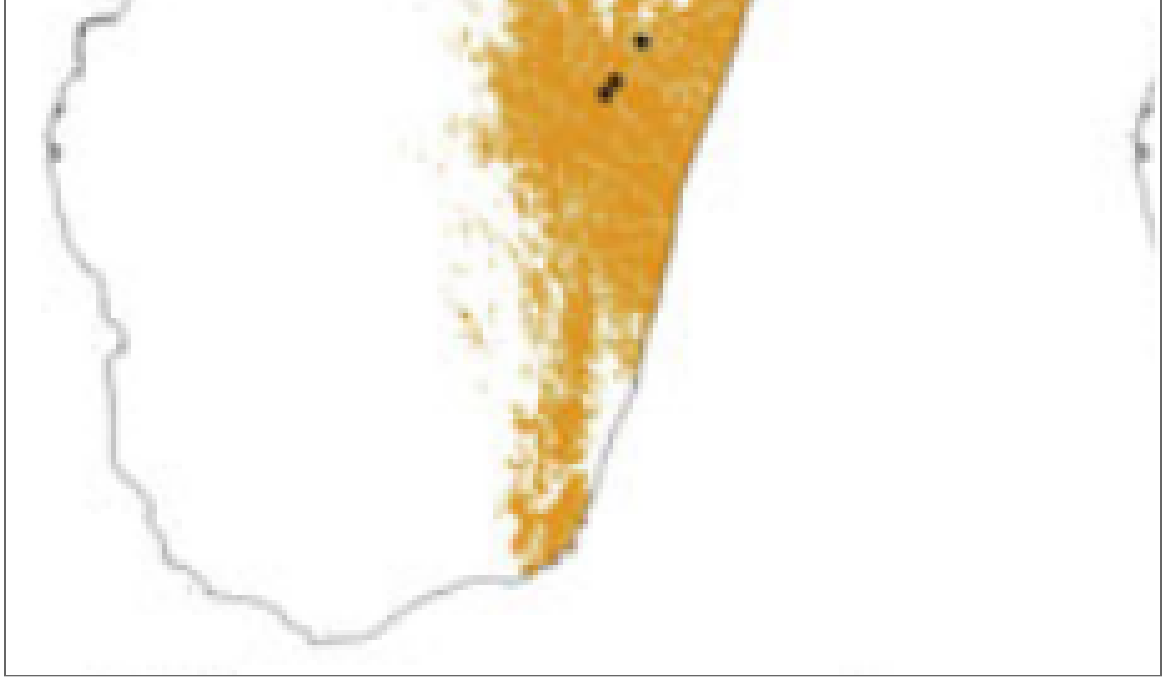




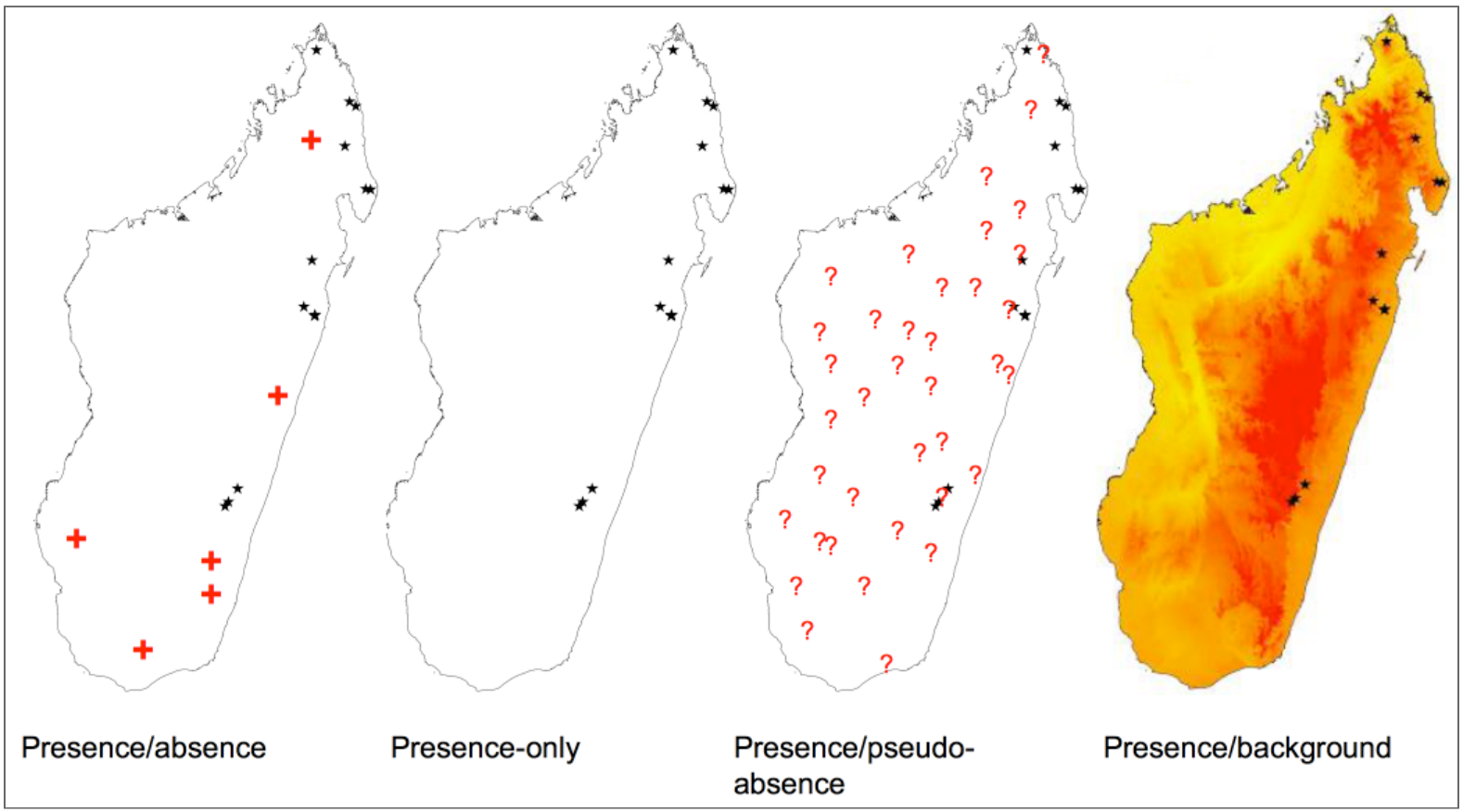



temperature (degC*10)
High : 276.000000
Low : 108.000000

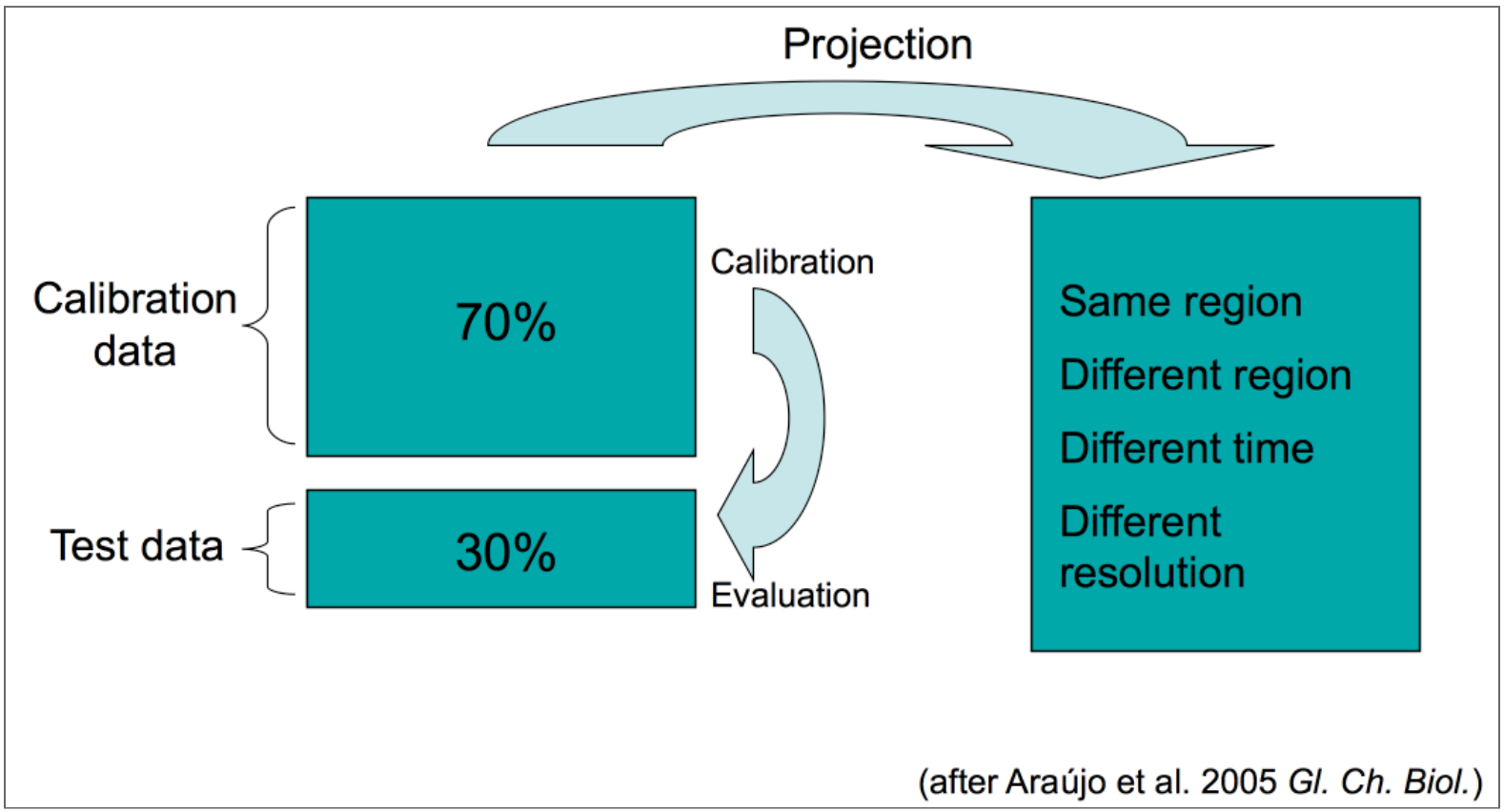

(a)



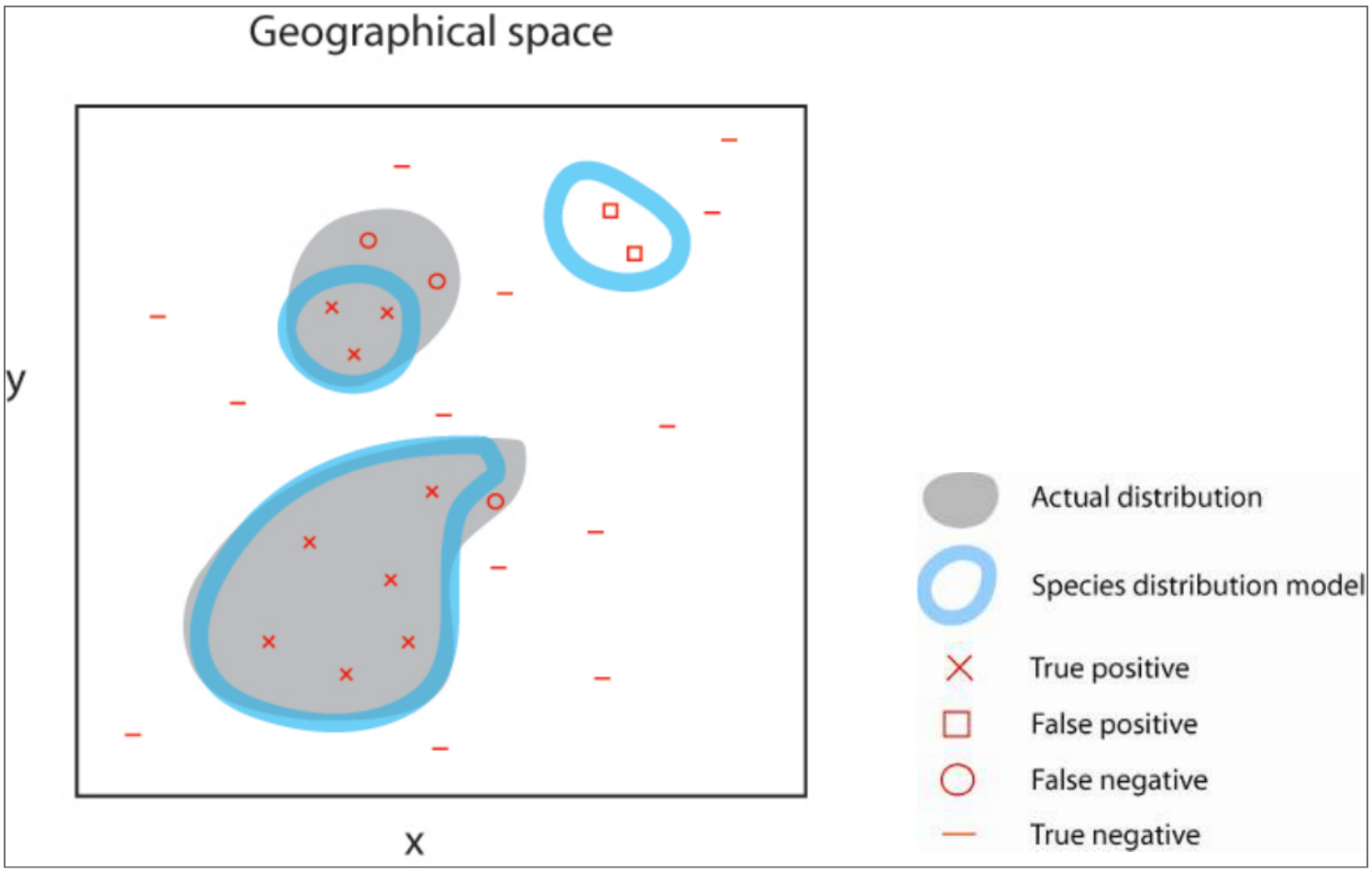
MADAGASCAN GECKOS



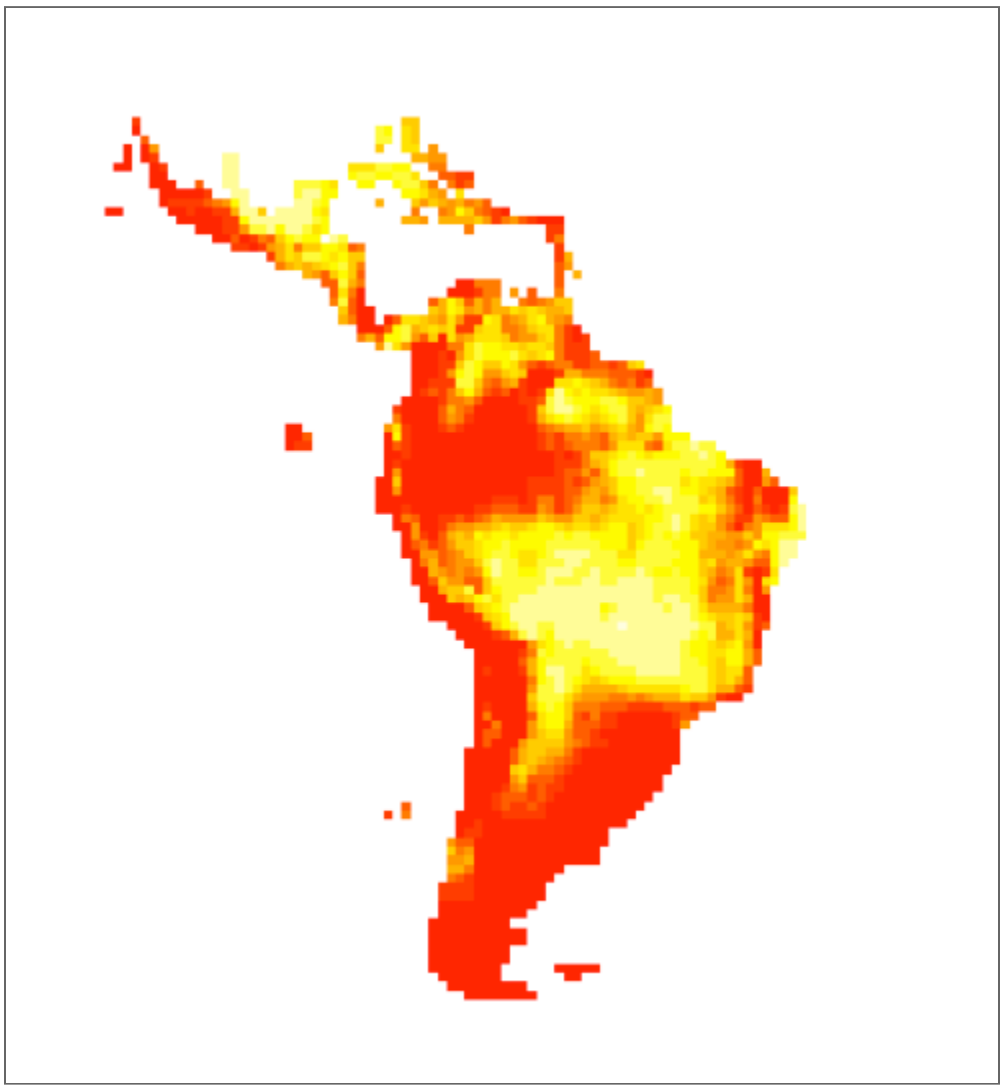
MODEL EVALUATION



MODEL ERRORS



PROBABILITY TO PRESENCE



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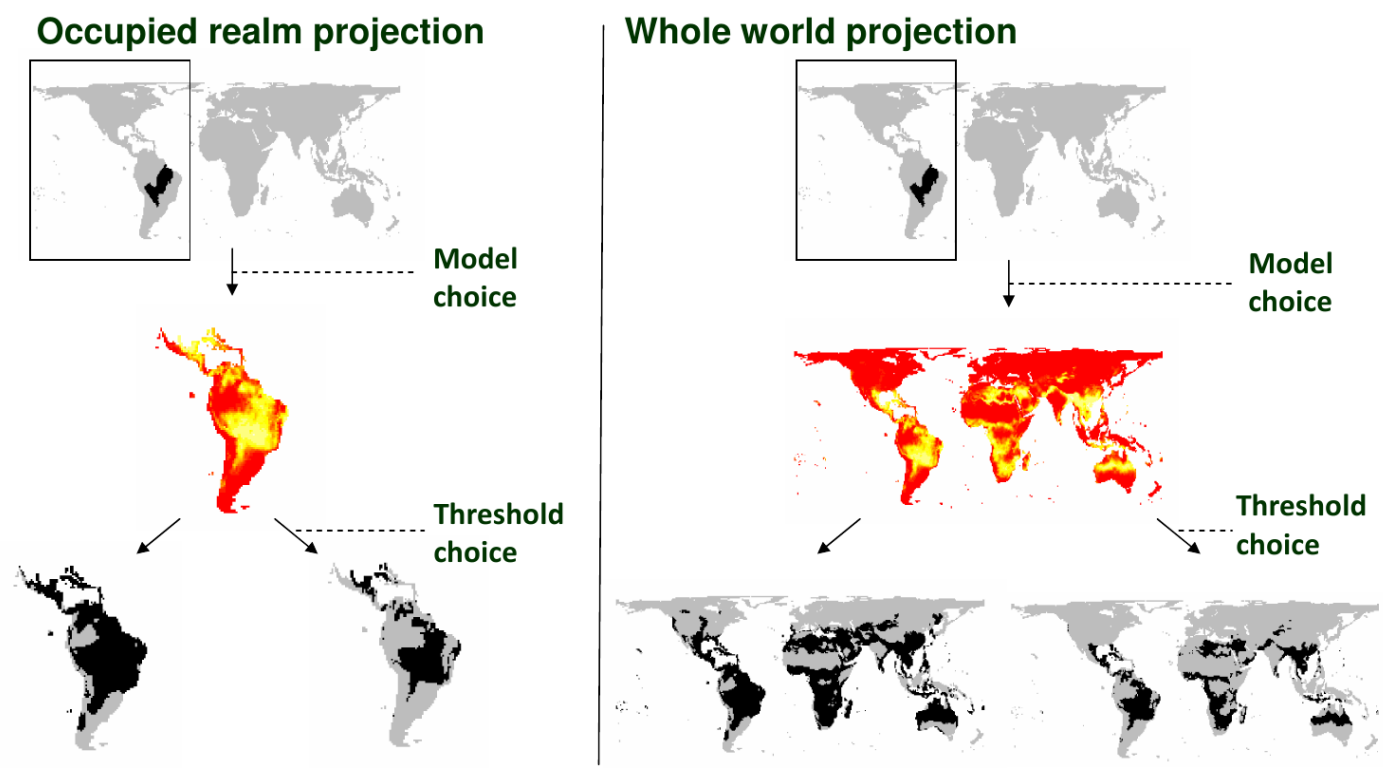
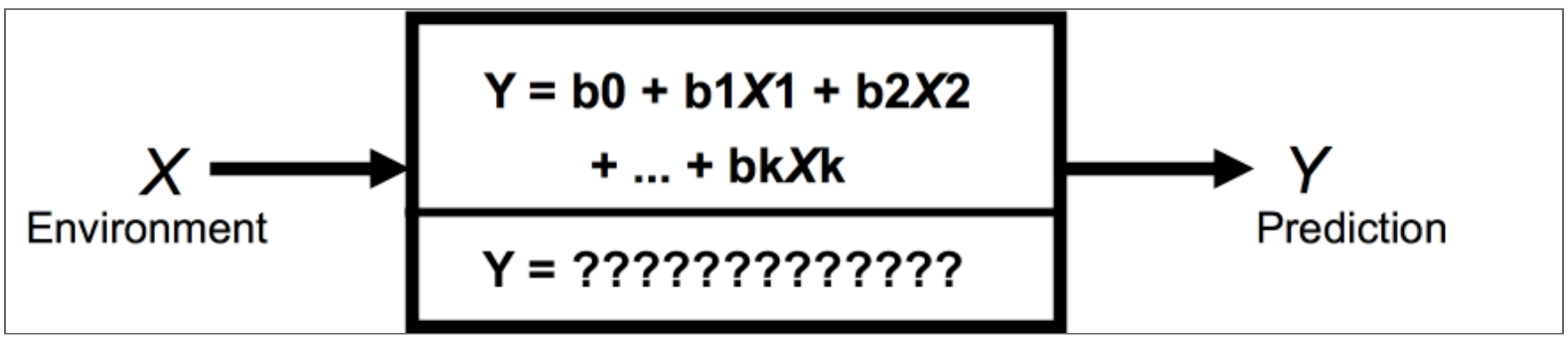
MODEL CHOICES MATTER

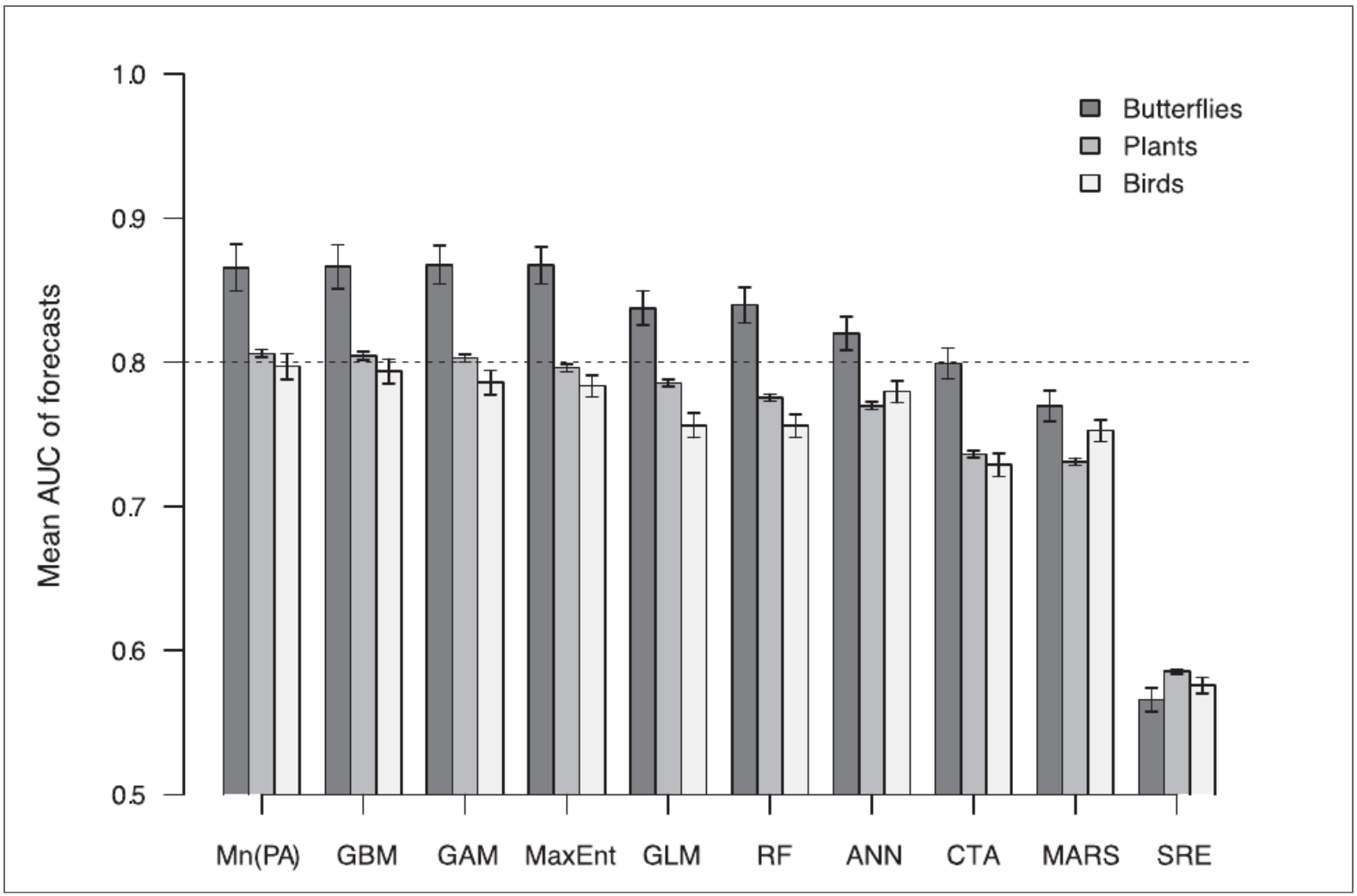

Occupied realm projection
Model choice
Threshold choice
Whole world projection
Model choice
Threshold choice

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.

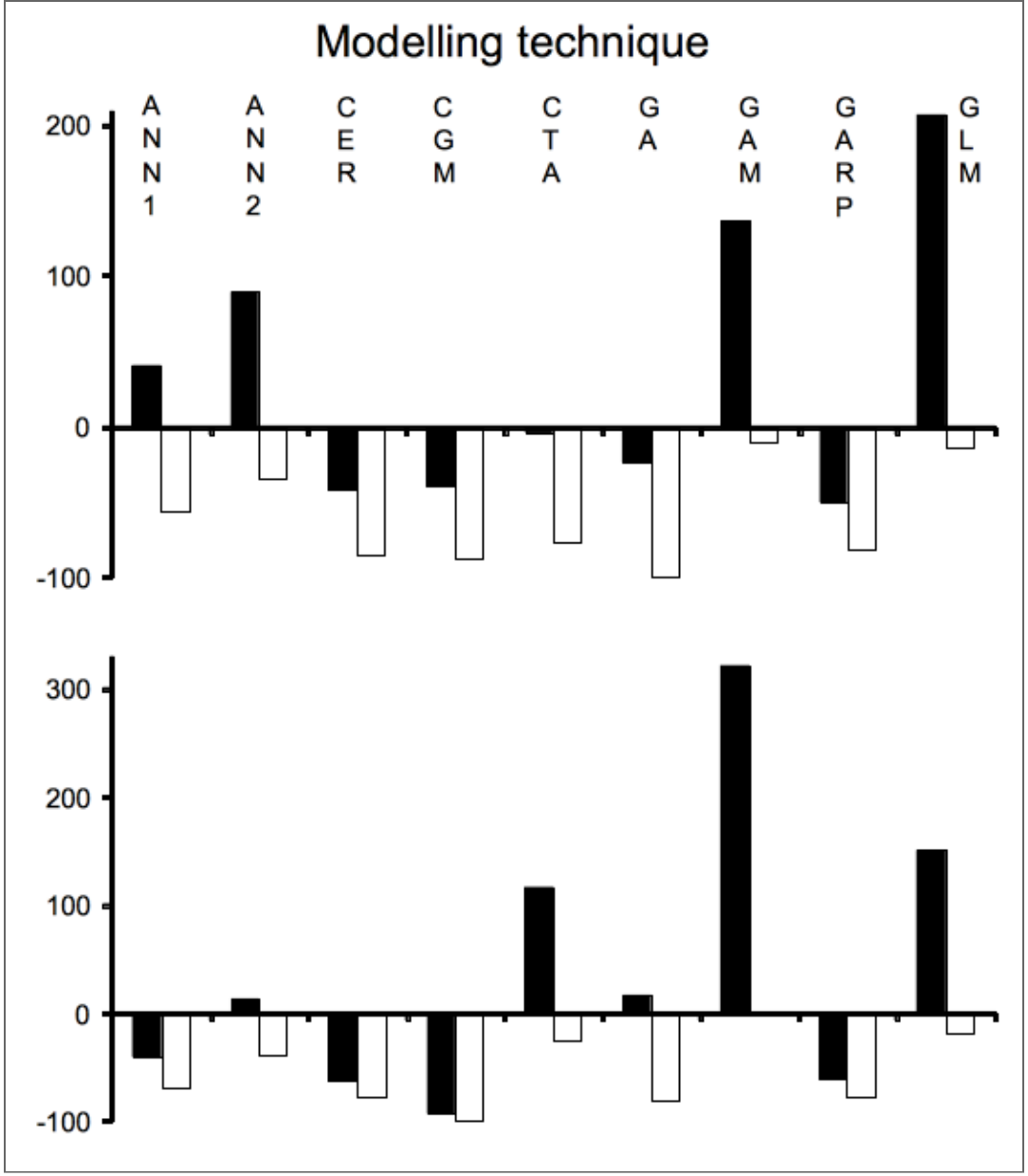


MODEL PERFORMANCE



Rapacciuolo et al 2012 PLoS One (7) 7 e40212

MODEL UNCERTAINTY

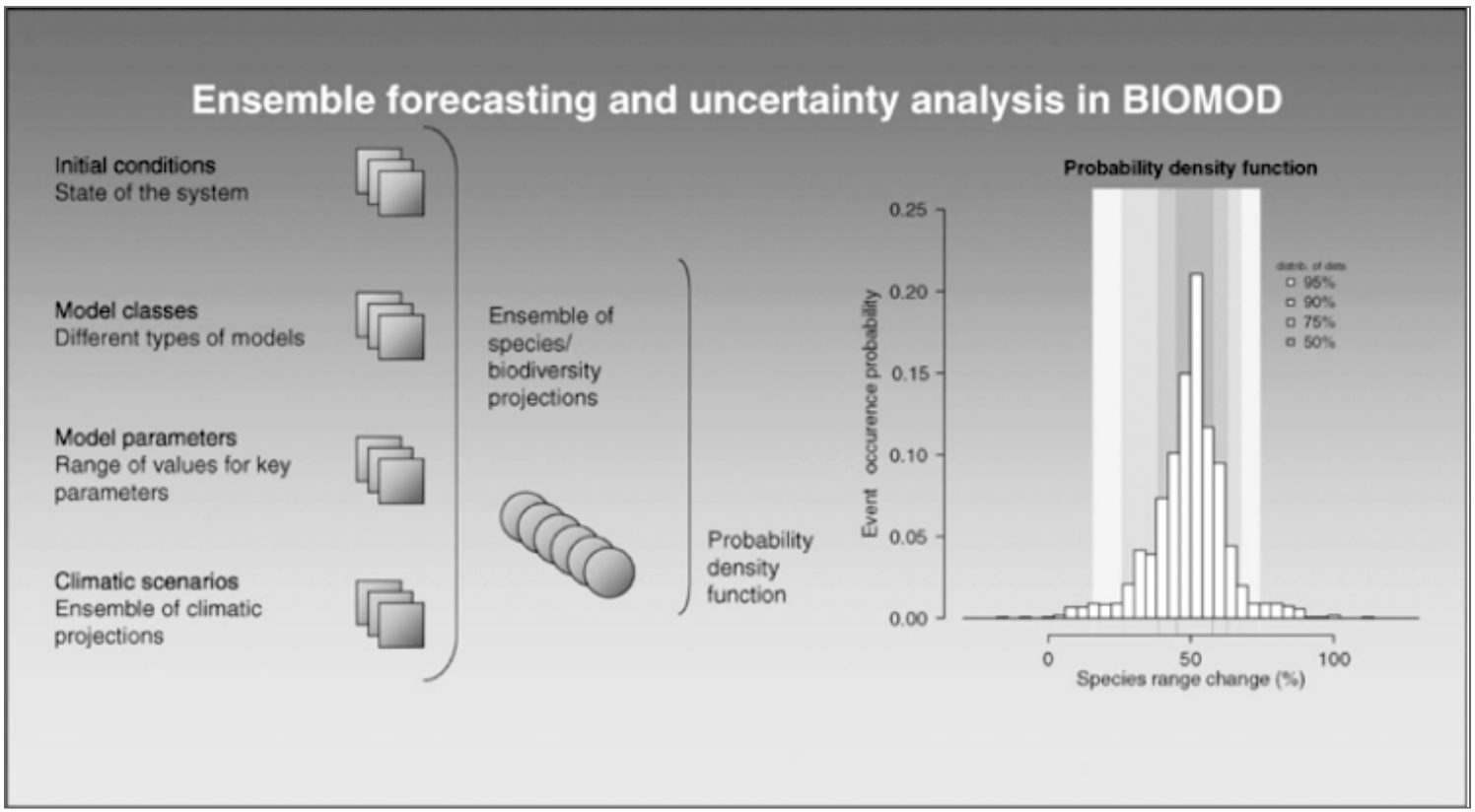


Diastella divaricata

Leucospermum hypophyllocarpodendrum

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

ENSEMBLE FORECASTING



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

DANGER, WILL ROBINSON

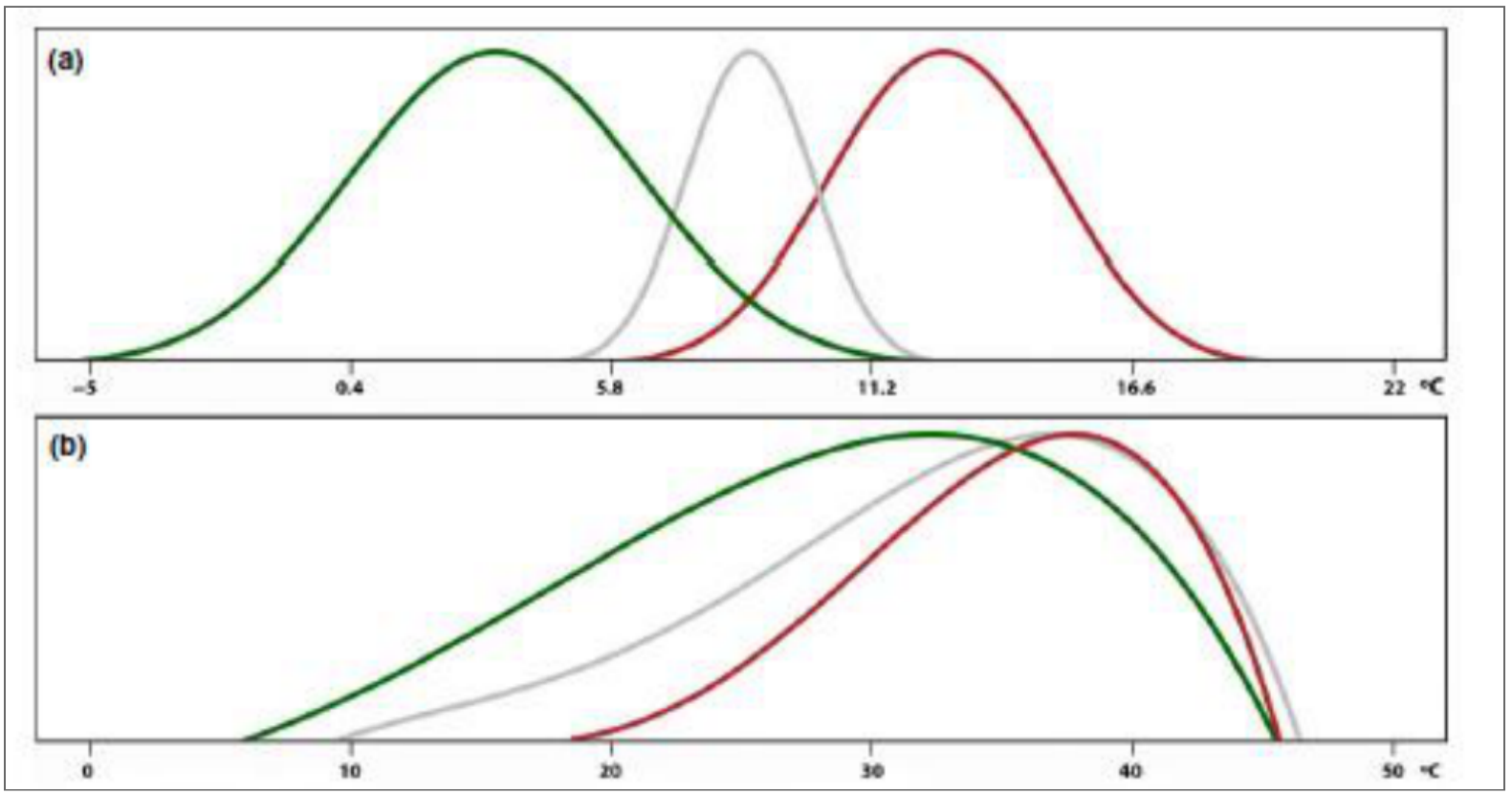
Assumptions

- 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

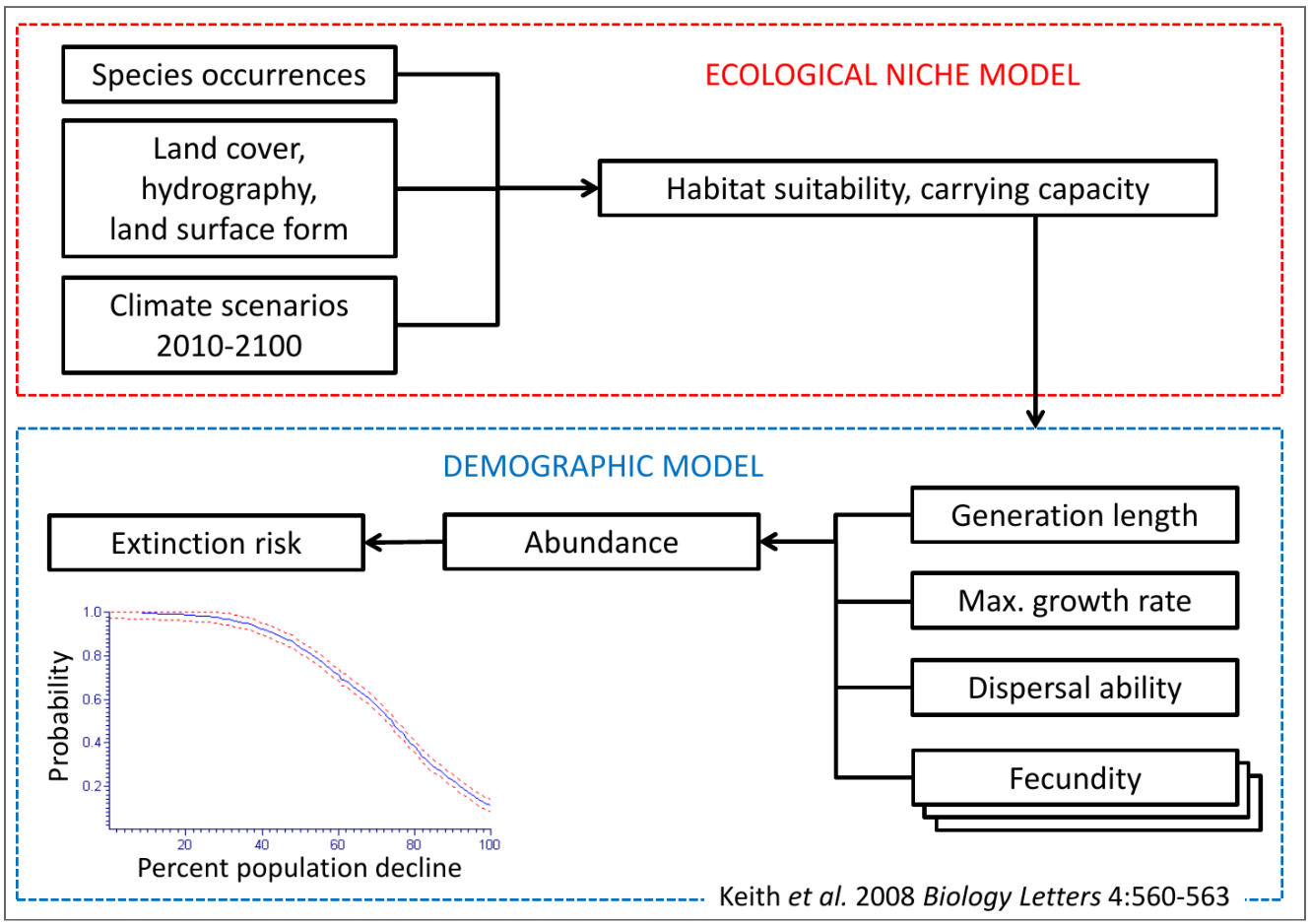


Araujo et al (2013) Ecology Letters 16: 1206 - 1209

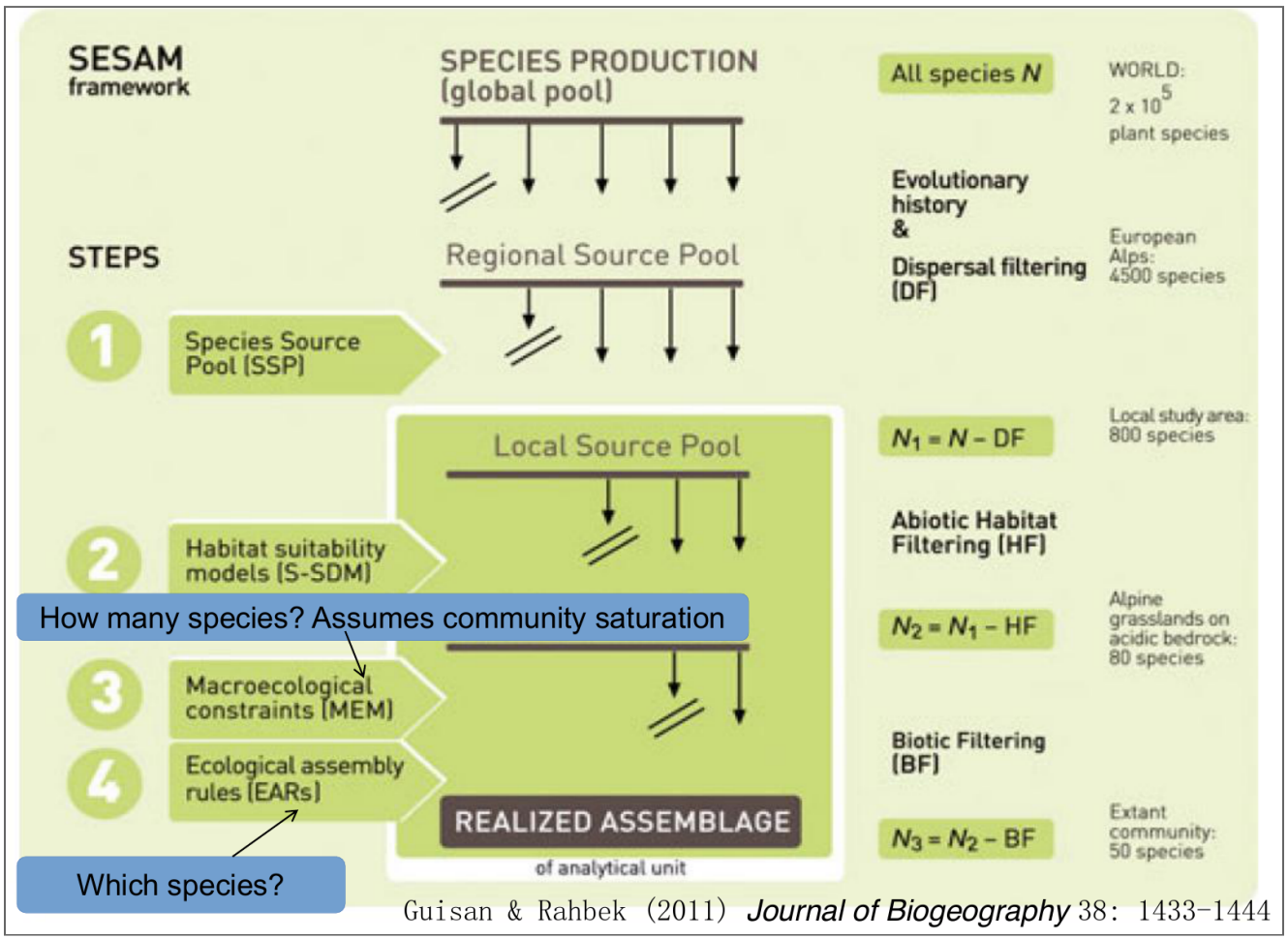
FUTURE DIRECTIONS

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

CONNECT TO DEMOGRAPHY

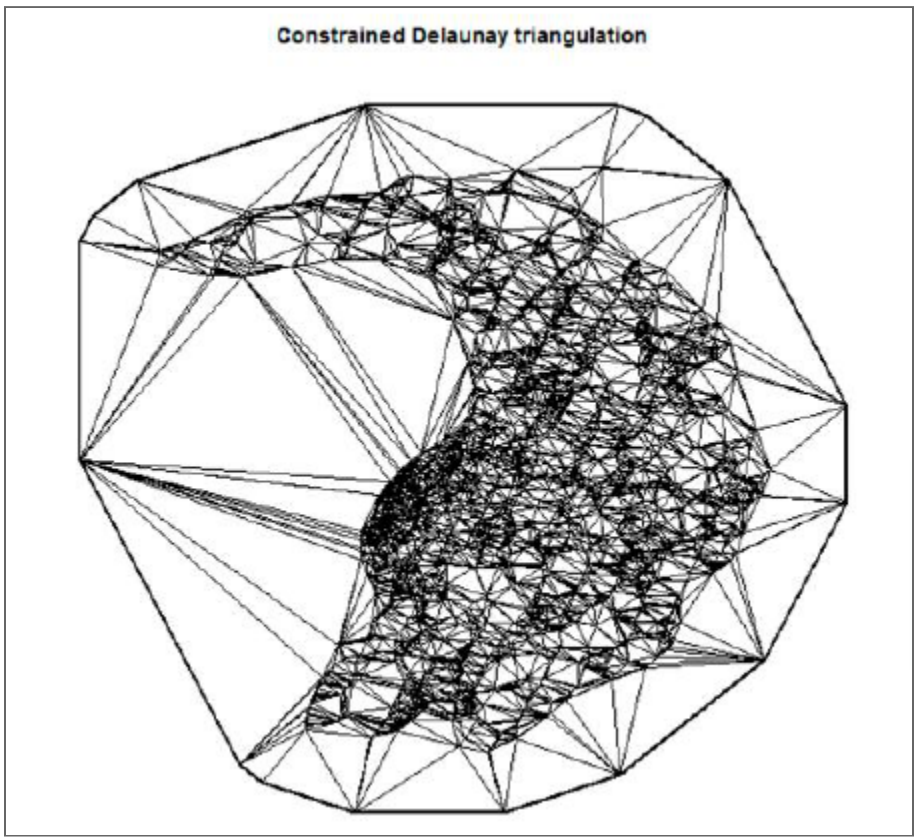


COMMUNITY ASSEMBLY



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

BAYES AND SPATIAL AUTOCORRELATION



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METHODS BACKGROUND

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