Niche Modelling: An Introduction

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LIVING CONSERVATION

Where does diversity come from?

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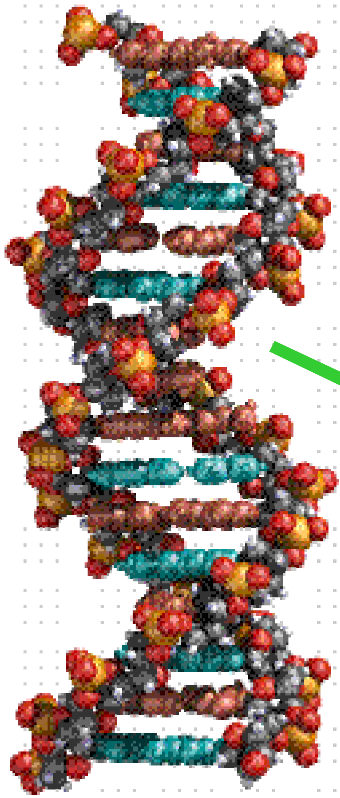
- Mutation
- Selection
- Chance
- Time

- **Geology**
- **Geography**
- **Climate**



Niche concepts are innate

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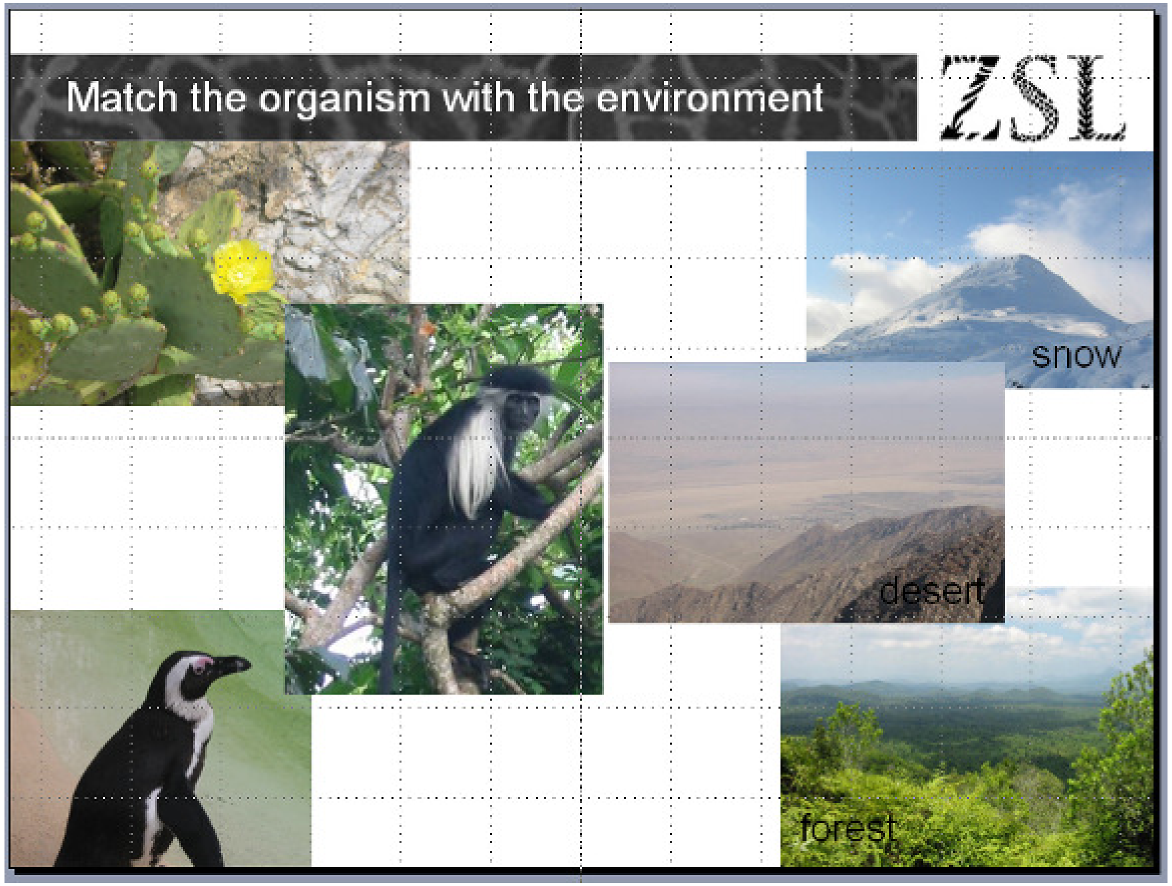
- *A fish out of water*
- *He took to it like a duck to water*
- *As happy as a pig in … clover*



What is a niche?

- A niche is an ecological construct defining the optimum environment for growth, reproduction and survival of a species
- Niches are defined by three main factors:
  - Substrate
  - Microclimate
  - Competition

What is a climatic niche?

- A bioclimatic niche is the area in which the climate is suitable for a species to succeed
- Consequentially it does not take into direct account other factors such as soil and competition
- Areas of a bioclimatic niche can be empty of the expected species because:
  - It can’t get there
  - The substrate is wrong
  - It can’t compete with other species

Bioclimatic niche models

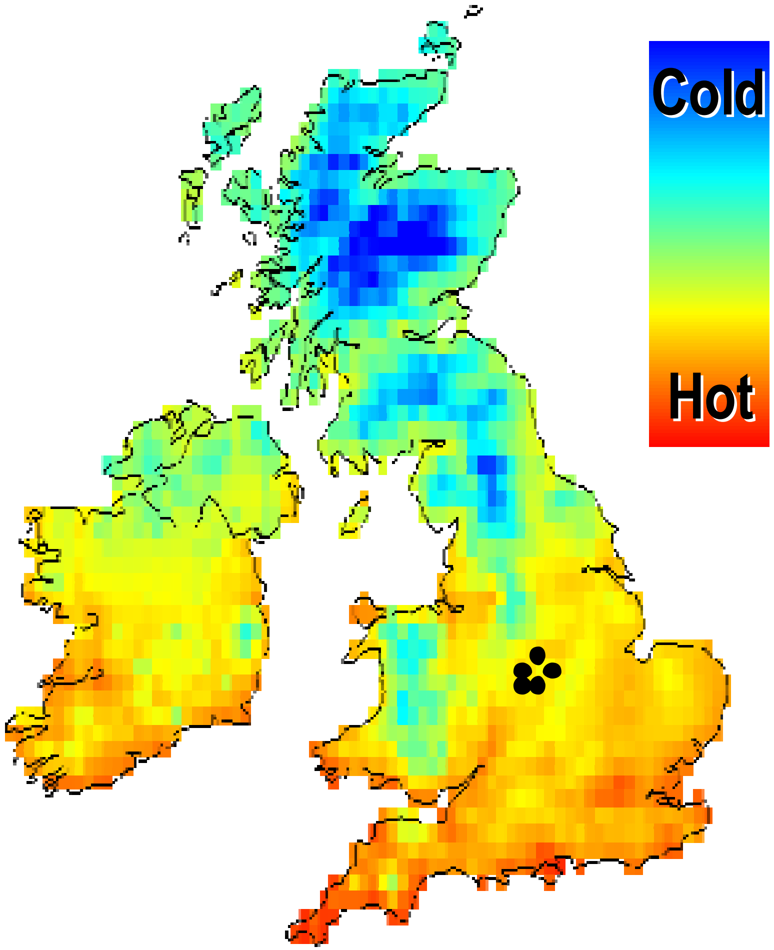
- One way to investigate species response to climate is through examination of climatic preferences by constructing bioclimatic niche models (=species distribution models = environmental niche models)
- Preferences of a given species, based on its known distribution
- Model using the climate parameters correlating with this

Developing predictive 'niche' models

1. Distribution data

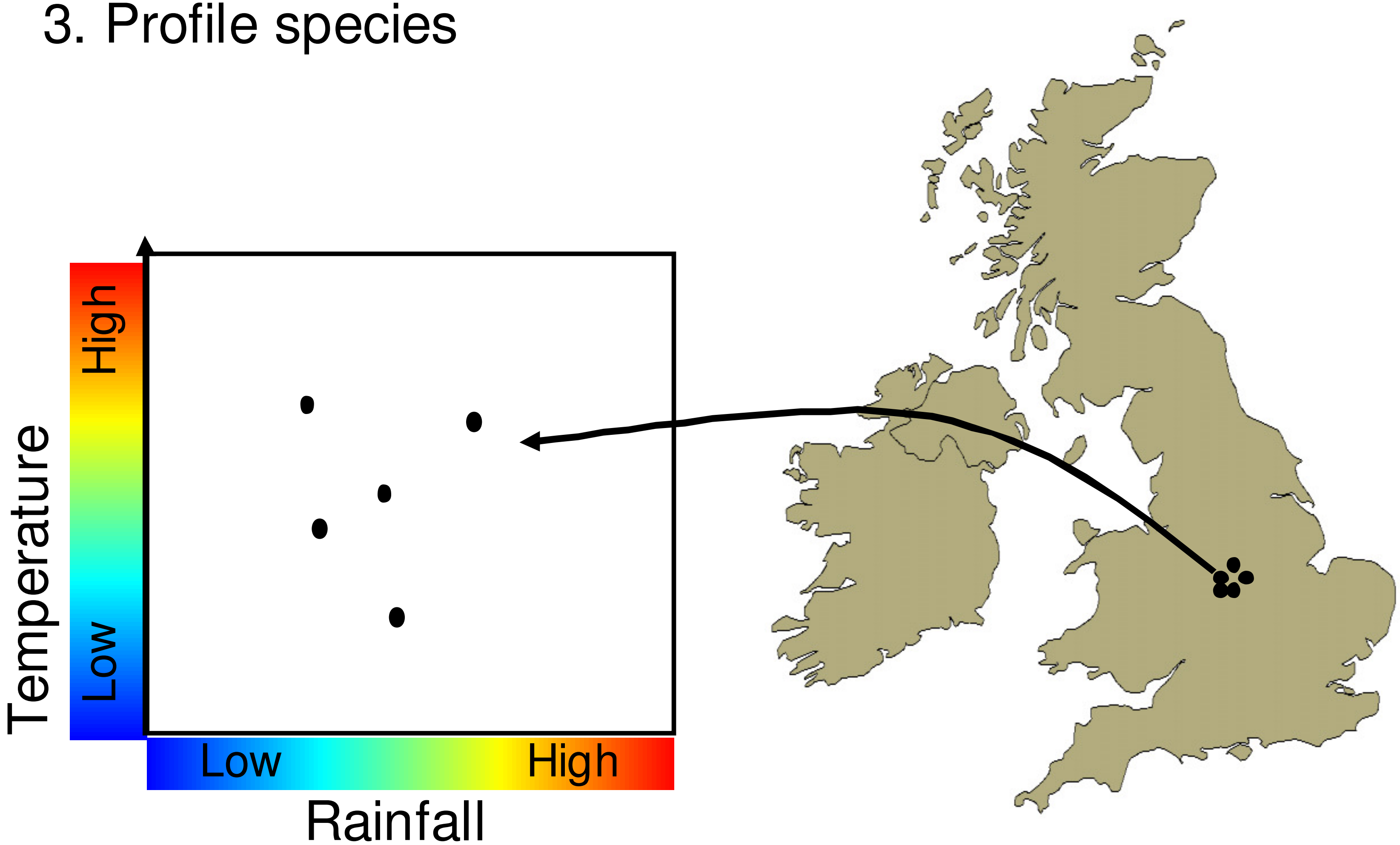
Developing predictive 'niche' models

2. Environmental data



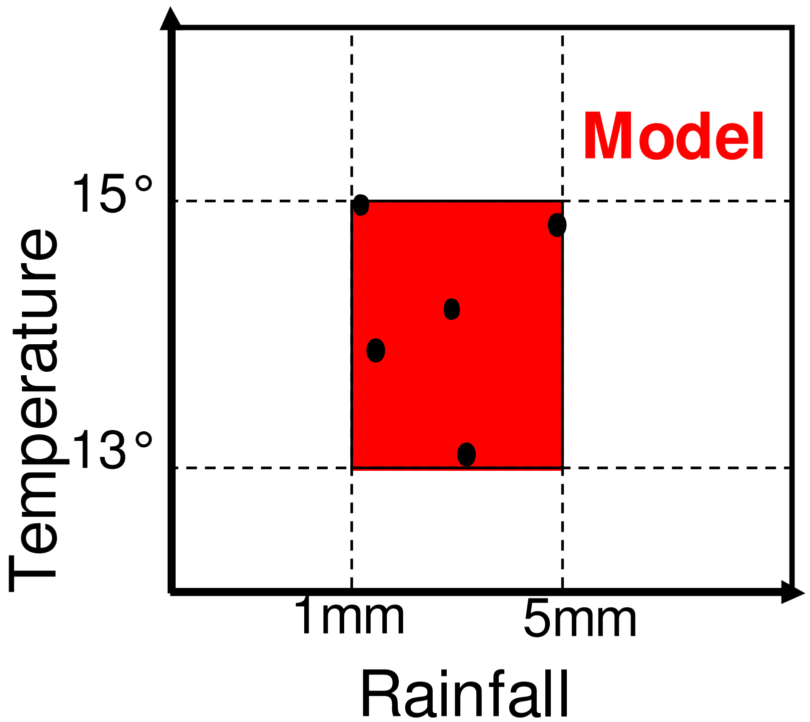
Developing predictive 'niche' models

3. Profile species



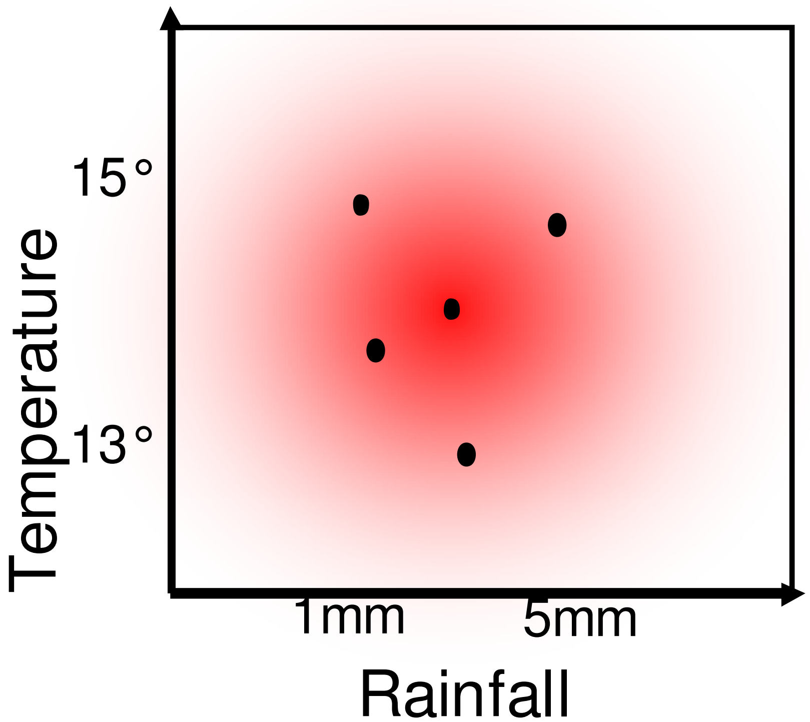
Developing predictive 'niche' models

4. Develop model



Developing predictive ‘niche’ models

4. Develop model



Developing predictive 'niche' models

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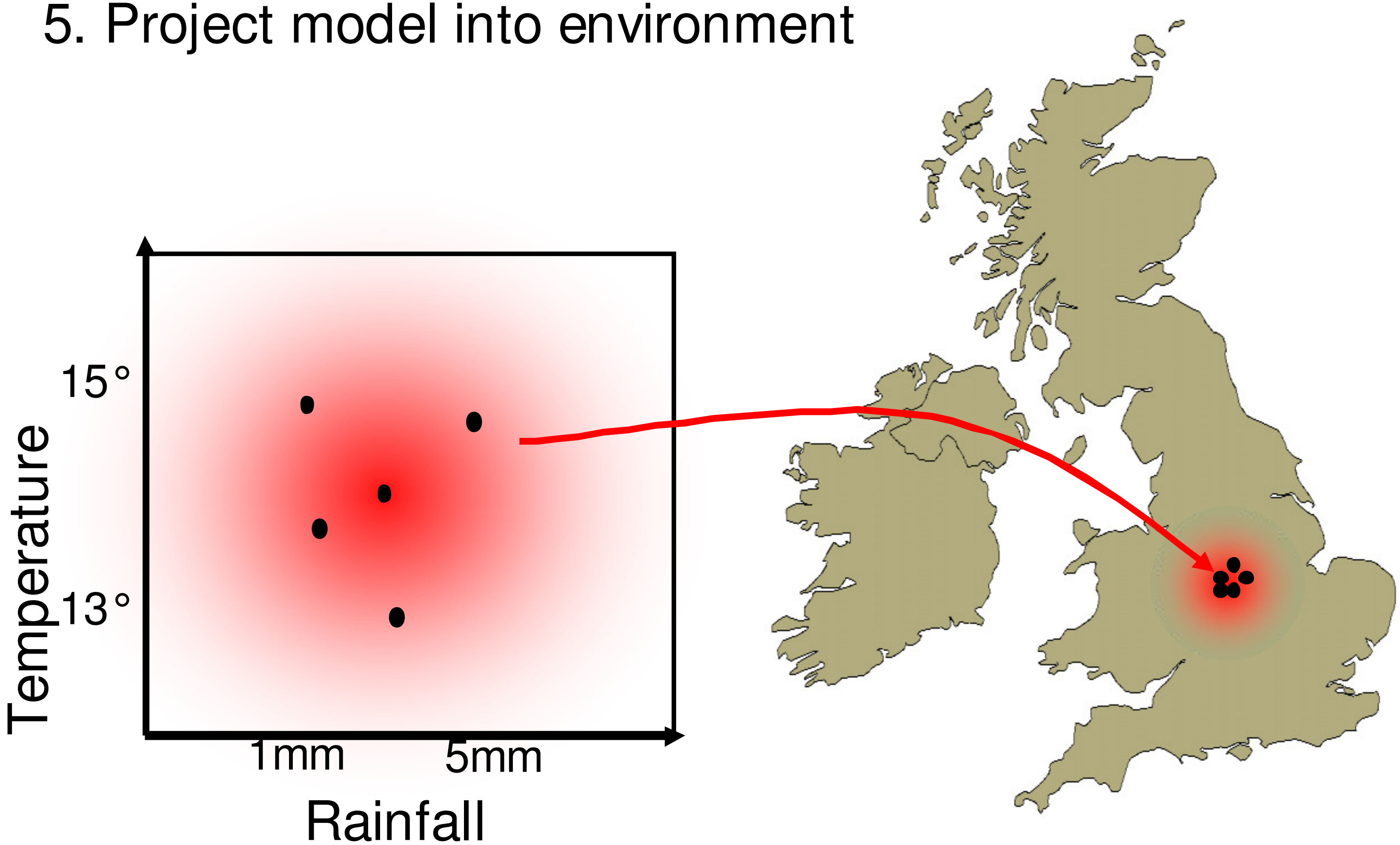
5. Project model into environment



Developing predictive 'niche' models

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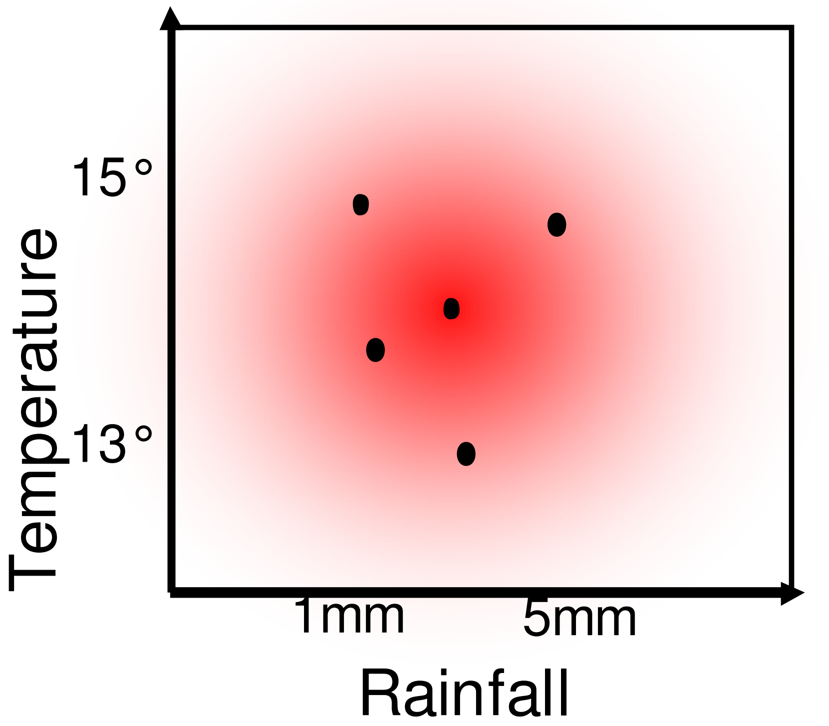
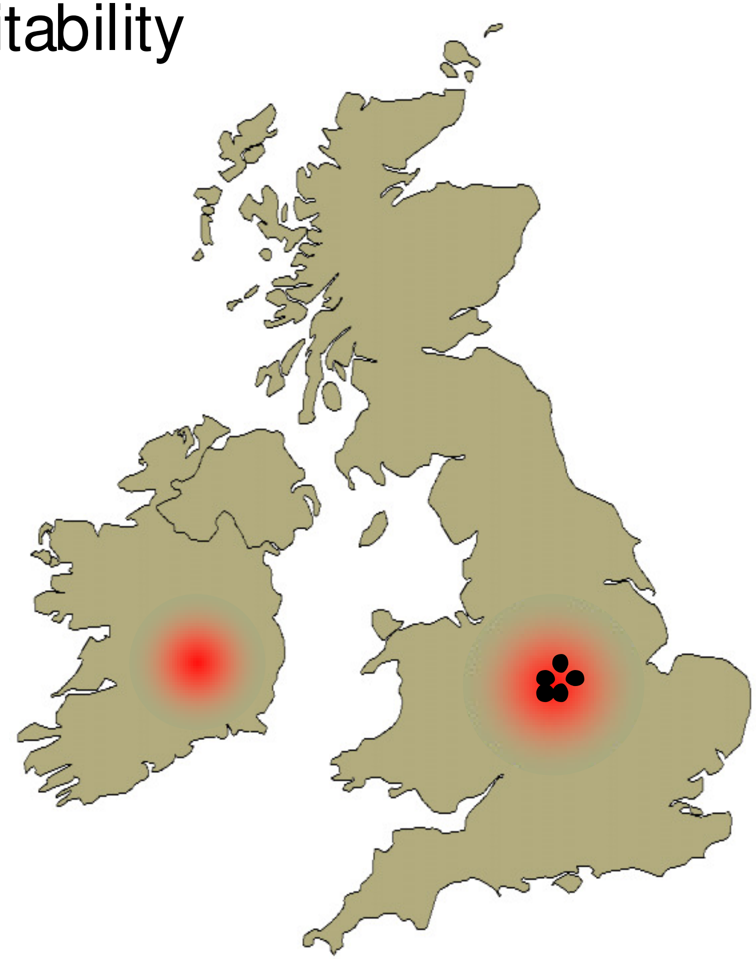
6. Discover areas of niche suitability





Common data sources

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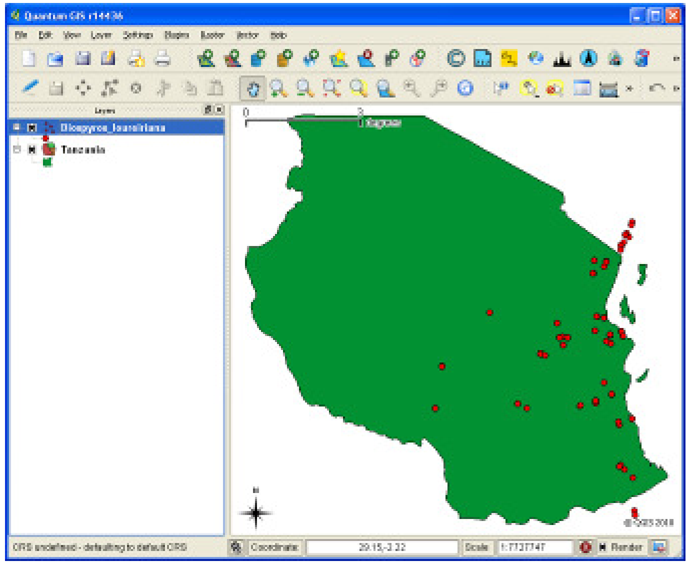
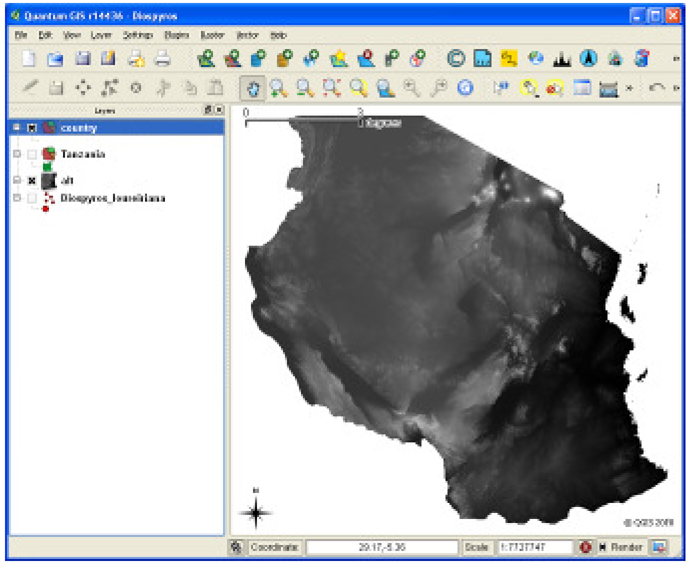
- Species distribution
  - museums / herbaria (http://data.gbif.org/)
  - literature
- Environmental data
  - Global climate grids (http://www.worldclim.org/)
  - Global topographic grids (strm30)
- *More details this afternoon*



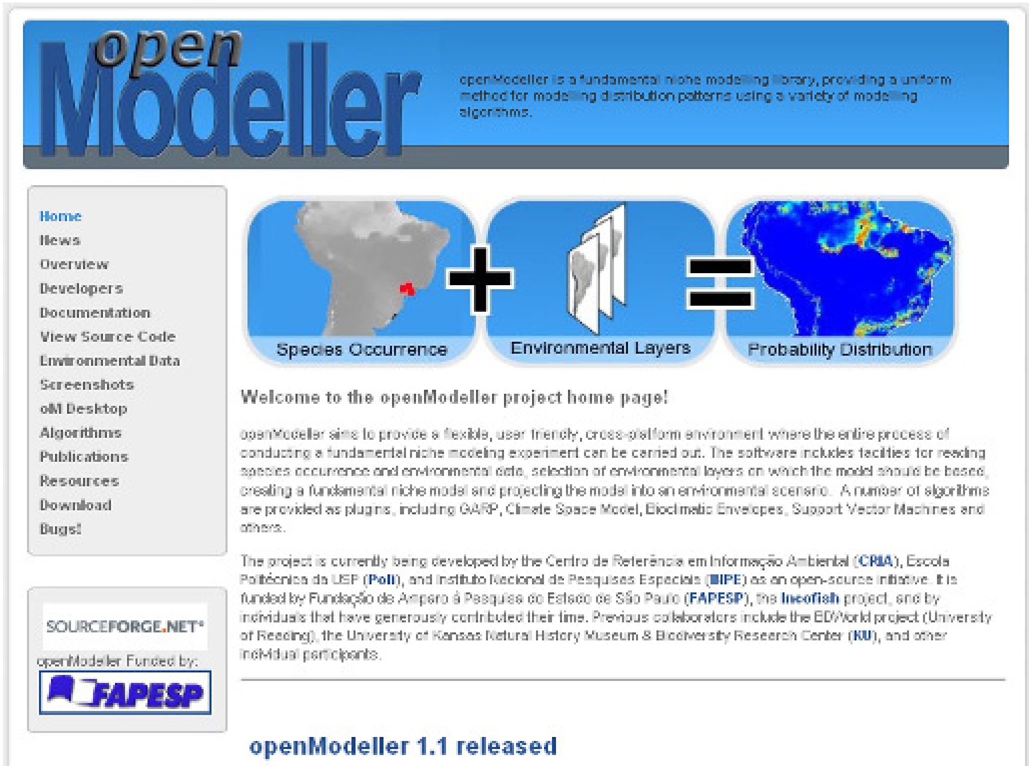


Niche modelling software

- Biomapper
- Desktop GARP*
- DIVA-GIS
- Maxent
- R packages
- Many others

… and

- **openModeller**



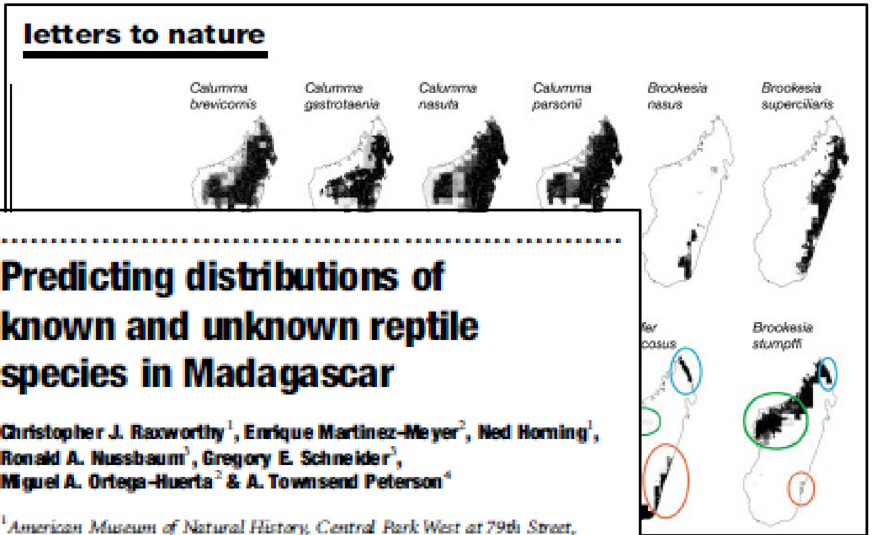
Niche Modelling studies

- Used to predict distributions
  - –Closely related species
  - –Invasive species
  - –Distribution shifts due to changing climate
  - –Undiscovered species!

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]

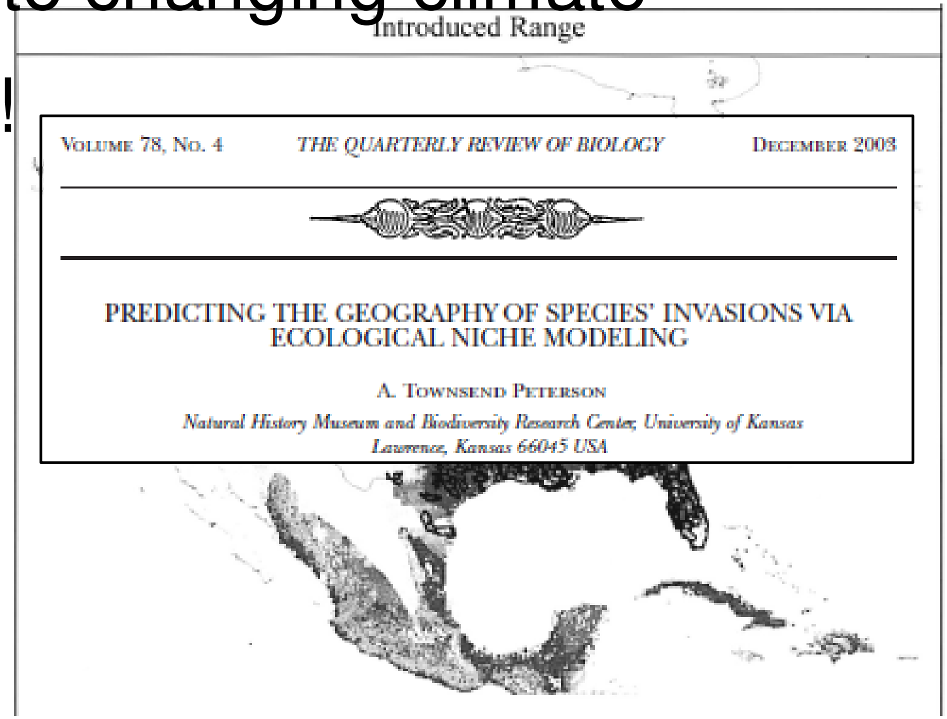
[1]Centre for Biodiversity and Conservation, School of Biology, University of Leeds, Leeds LS2 9JT, UK



Predicting distributions of known and unknown reptile species in Madagascar

Christopher J. Raxworthy[1], Enrique Martinez-Meyer[2], Ned Horning[1], Ronald A. Nussbaum[3], Gregory E. Schneider[3], Miguel A. Ortega-Huerta[2] & A. Townsend Peterson[4]

[1]American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024-5192, USA



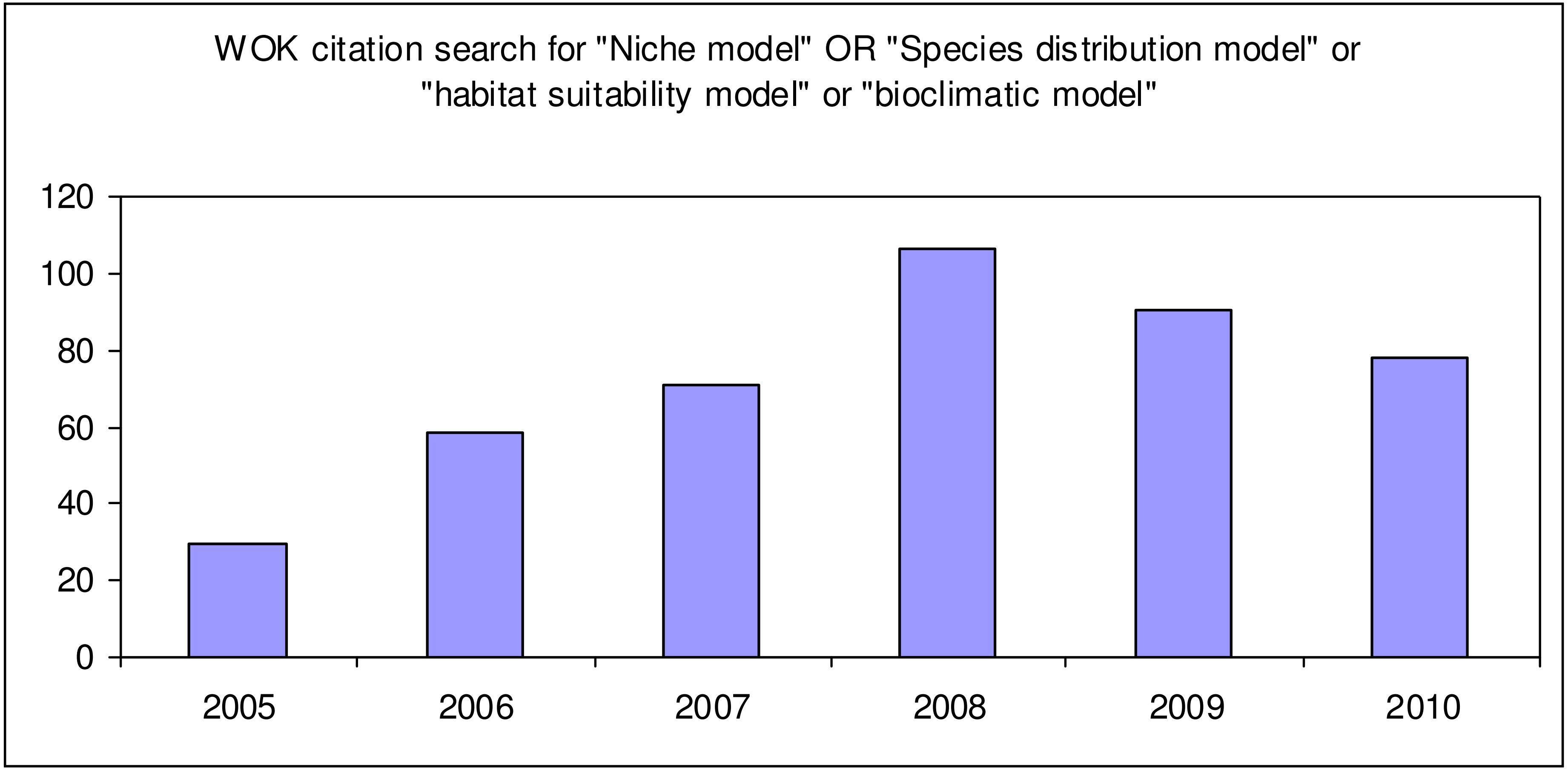
VOLUME 78, NO. 4 THE QUARTERLY REVIEW OF BIOLOGY DECEMBER 2003

PREDICTING THE GEOGRAPHY OF SPECIES' INVASIONS VIA ECOLOGICAL NICHE MODELING

A. TOWNSEND PETERSON

Natural History Museum and Biodiversity Research Center, University of Kansas Lawrence, Kansas 66045 USA

Niche modelling studies



Thomas et al. (2004) Extinction risk from climate change. Nature 427: 145-148

- Meta analysis of niche modelling studies using many different methodologies
- Modelled thousands of terrestrial plants & animals
- Projected models into a mid-range future scenario
- 15 - 37% species “will be ‘committed to extinction’”

- Lots of publicity, lots of criticism, lots of citations (>1,500)

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]

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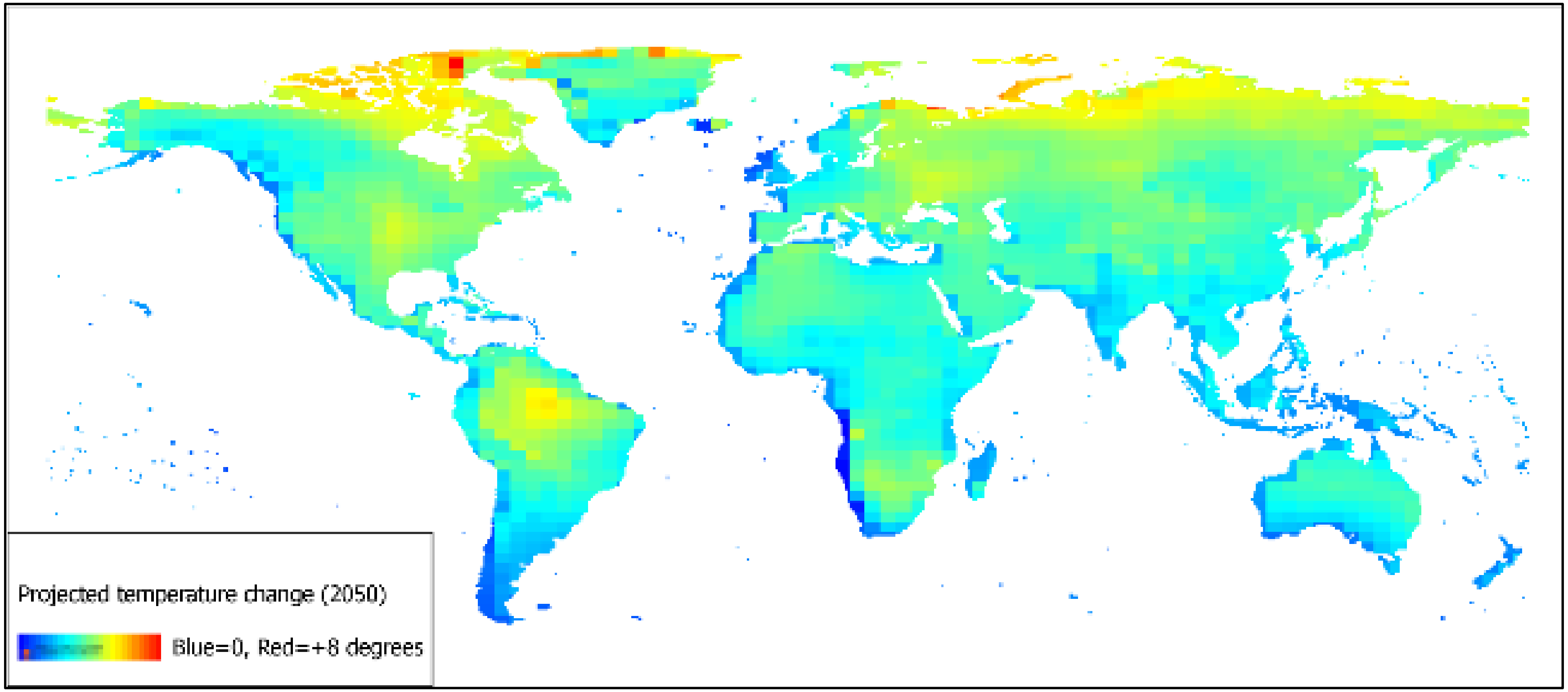
Practical applications – climate change

- How will climate change affect species distribution?



Legumes

- Legumes (Pea family) include ~20,000 species
- Many are economically important for food (beans & peanuts), wood (*Acacia*) and other uses (e.g. dyes, forage)

- How will climate change affect global diversity?



Legumes – assessing global diversity

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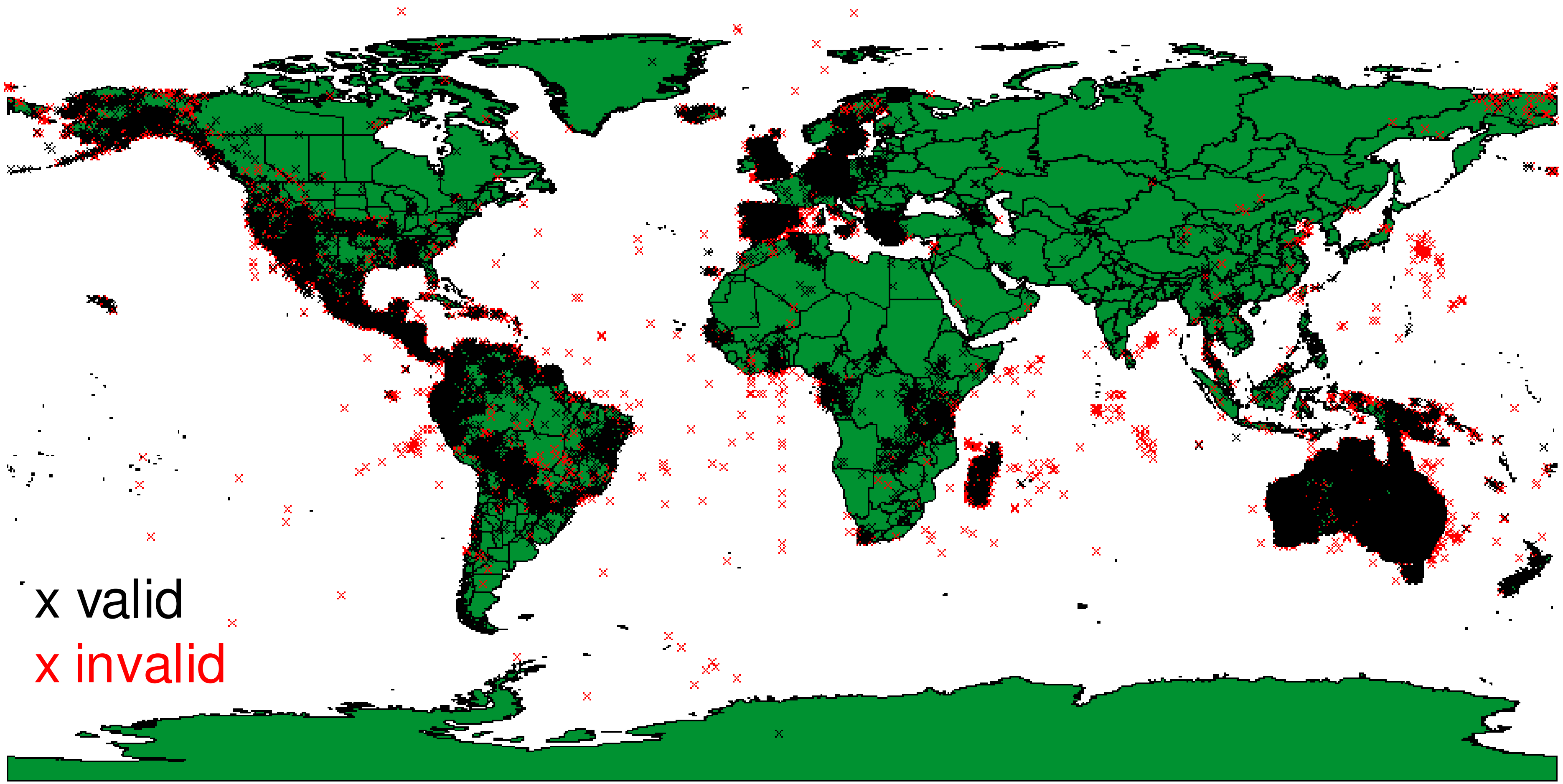
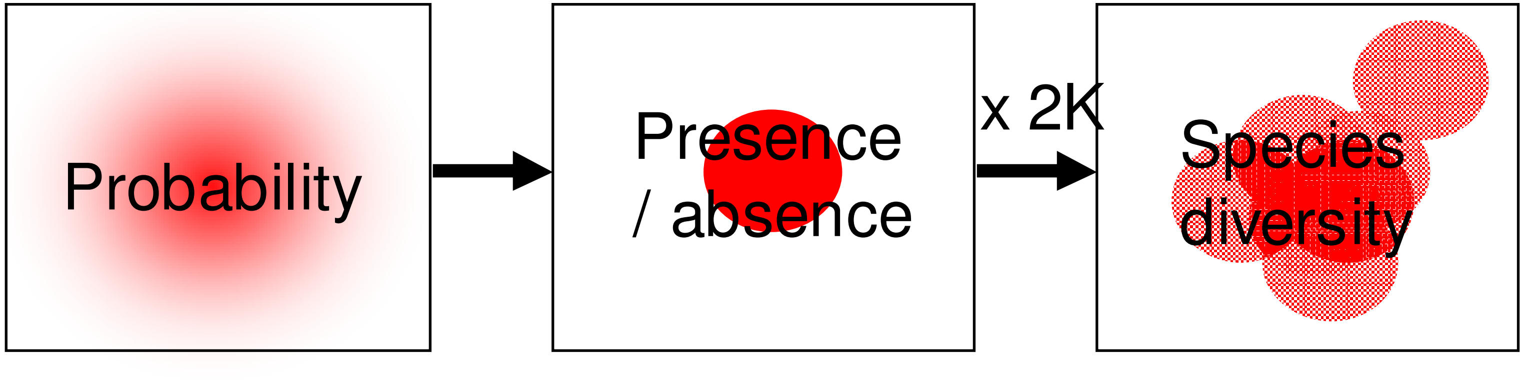
- **20K species**
- **Only 2K species with valid data!**

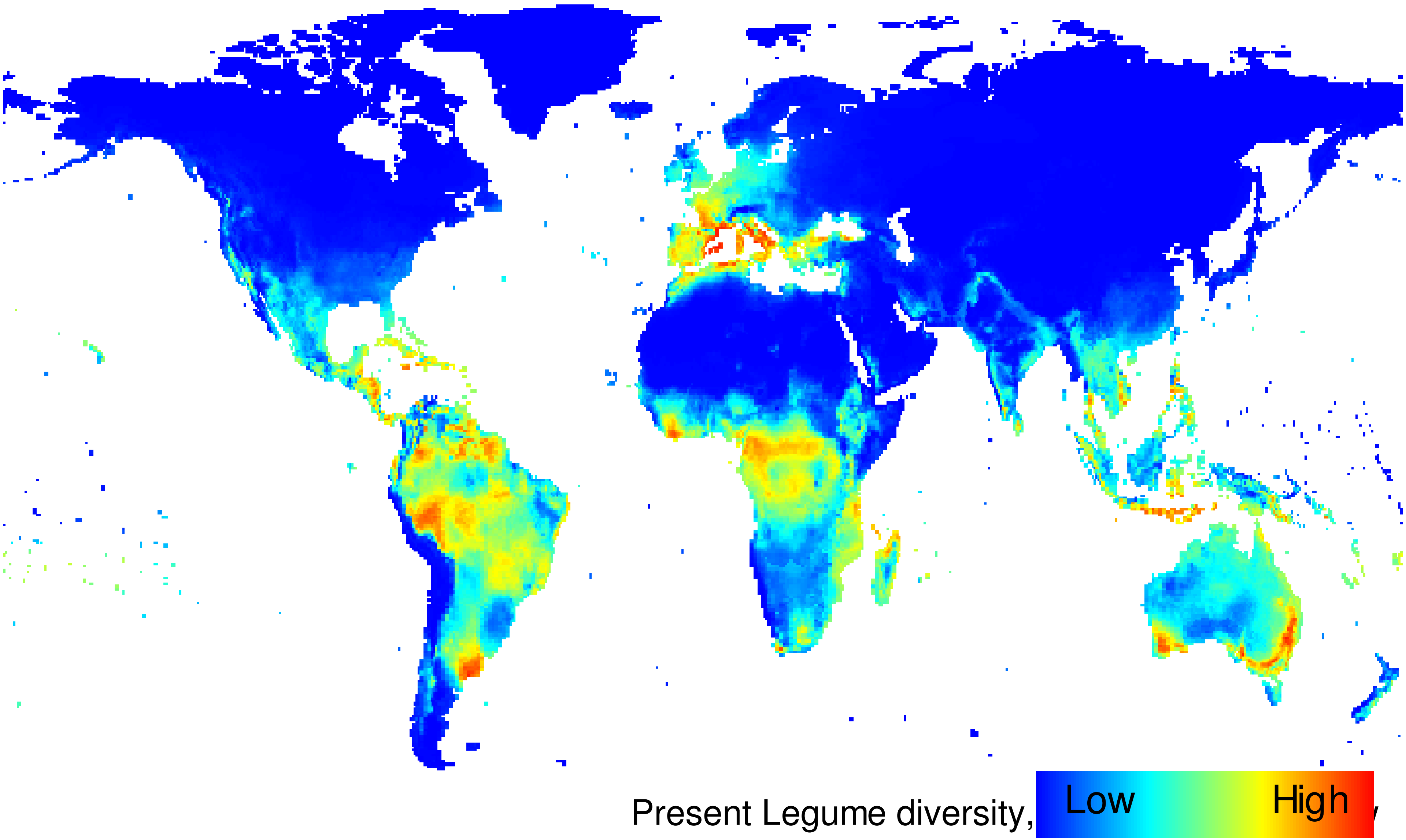


Legumes

- Model species with data
- Choose threshold to estimate presence-absence
- Overlay models to produce map of diversity

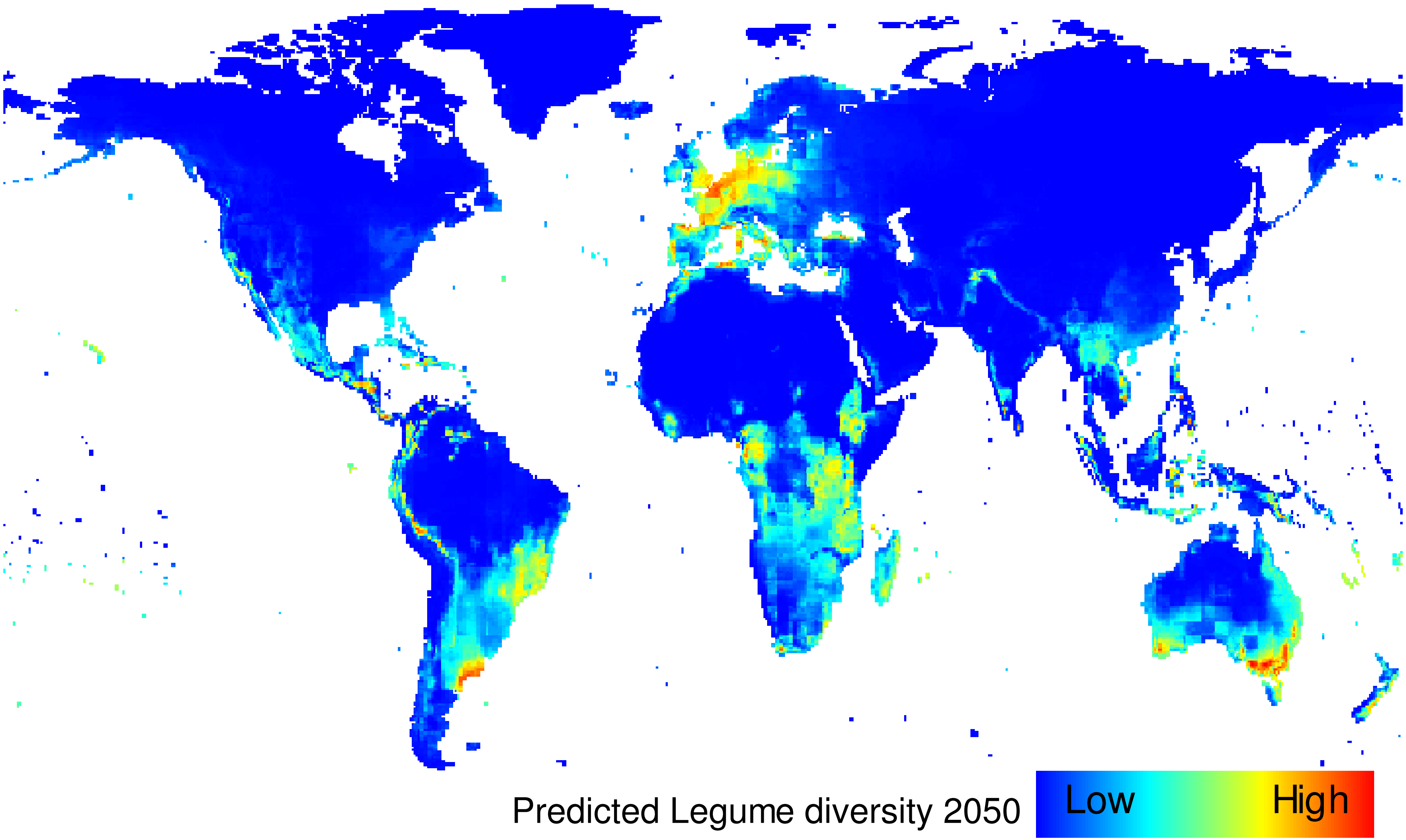


Estimating change in diversity



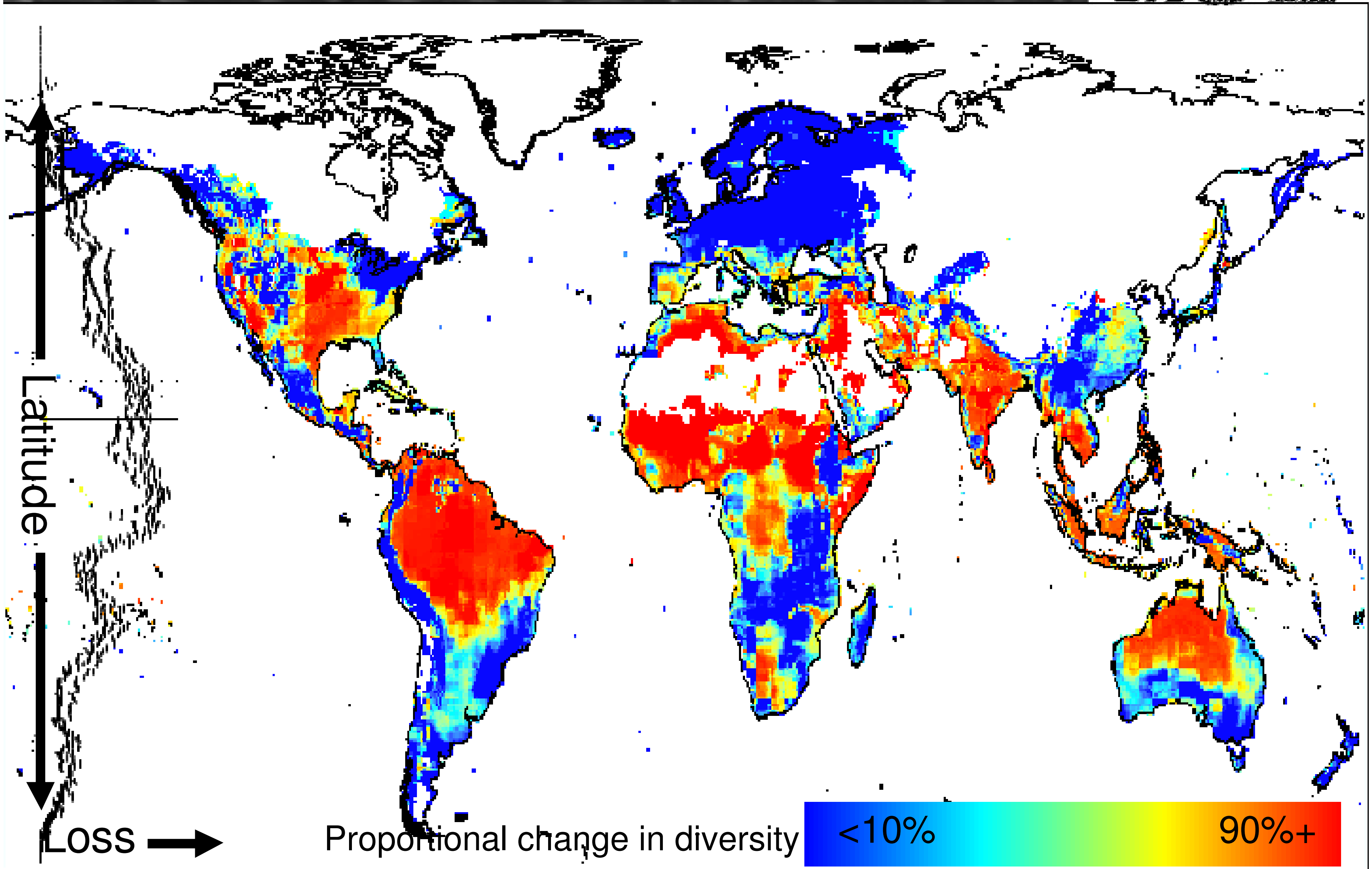
Present Legume diversity,

Estimating change in diversity

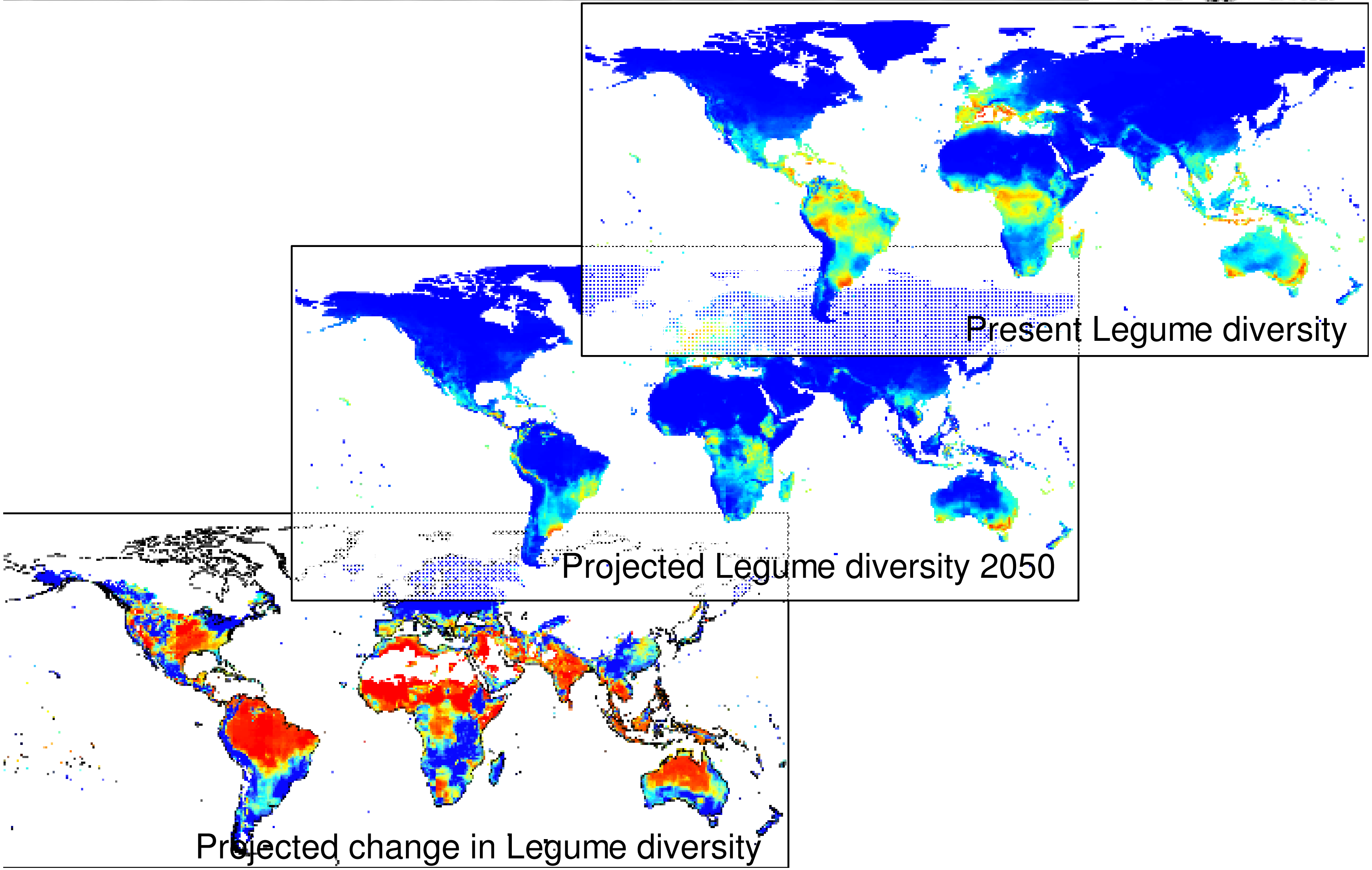


Predicted Legume diversity 2050

Estimating change in diversity



Estimating change in diversity



Niche model applications

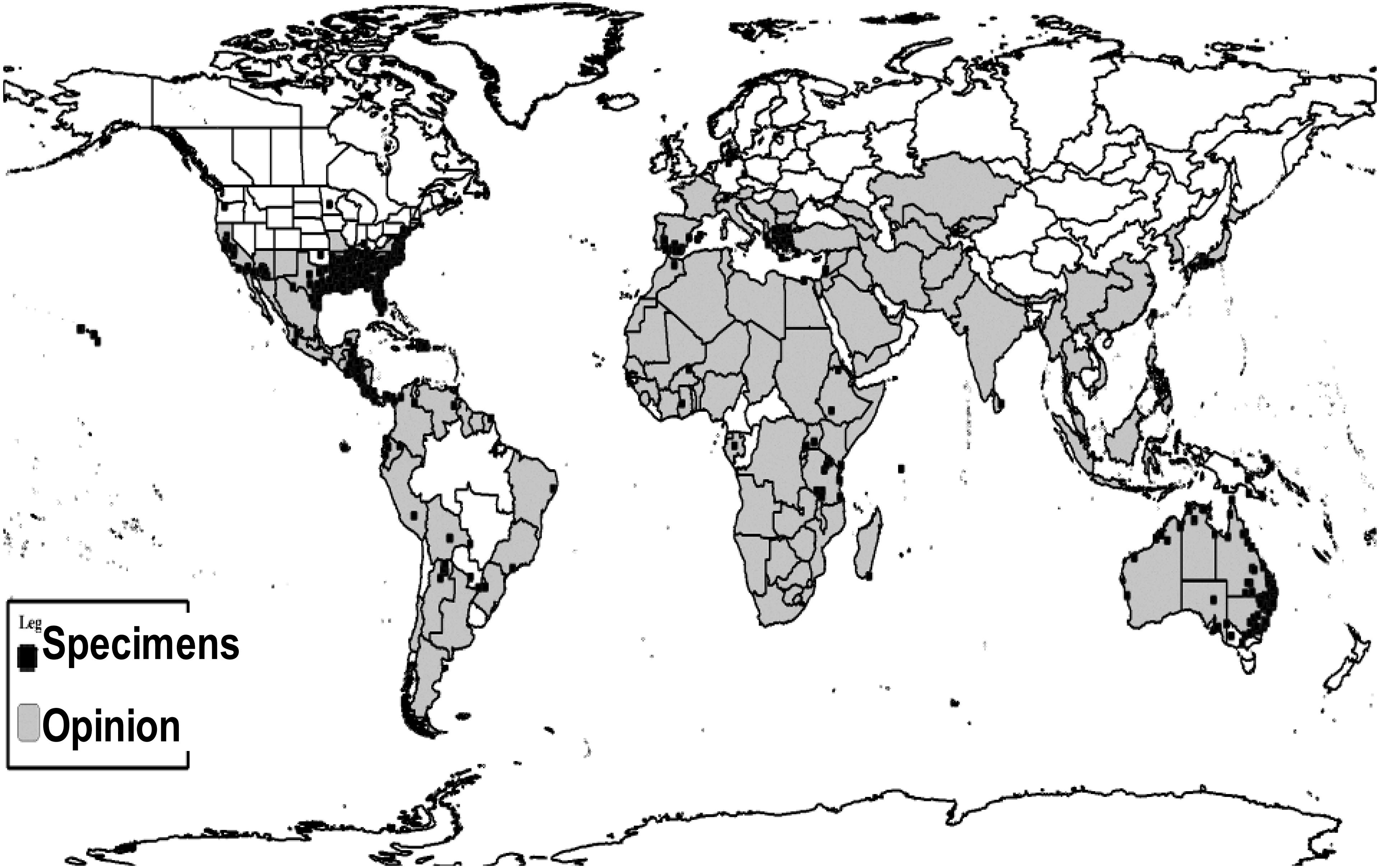
- **Practical**
  - –Invasive species (weeds)
  - –Disease
  - –Data deficient species
  - –Marine protected areas

- Theoretical
  - –Diversity through time
  - –Evolutionary patterns

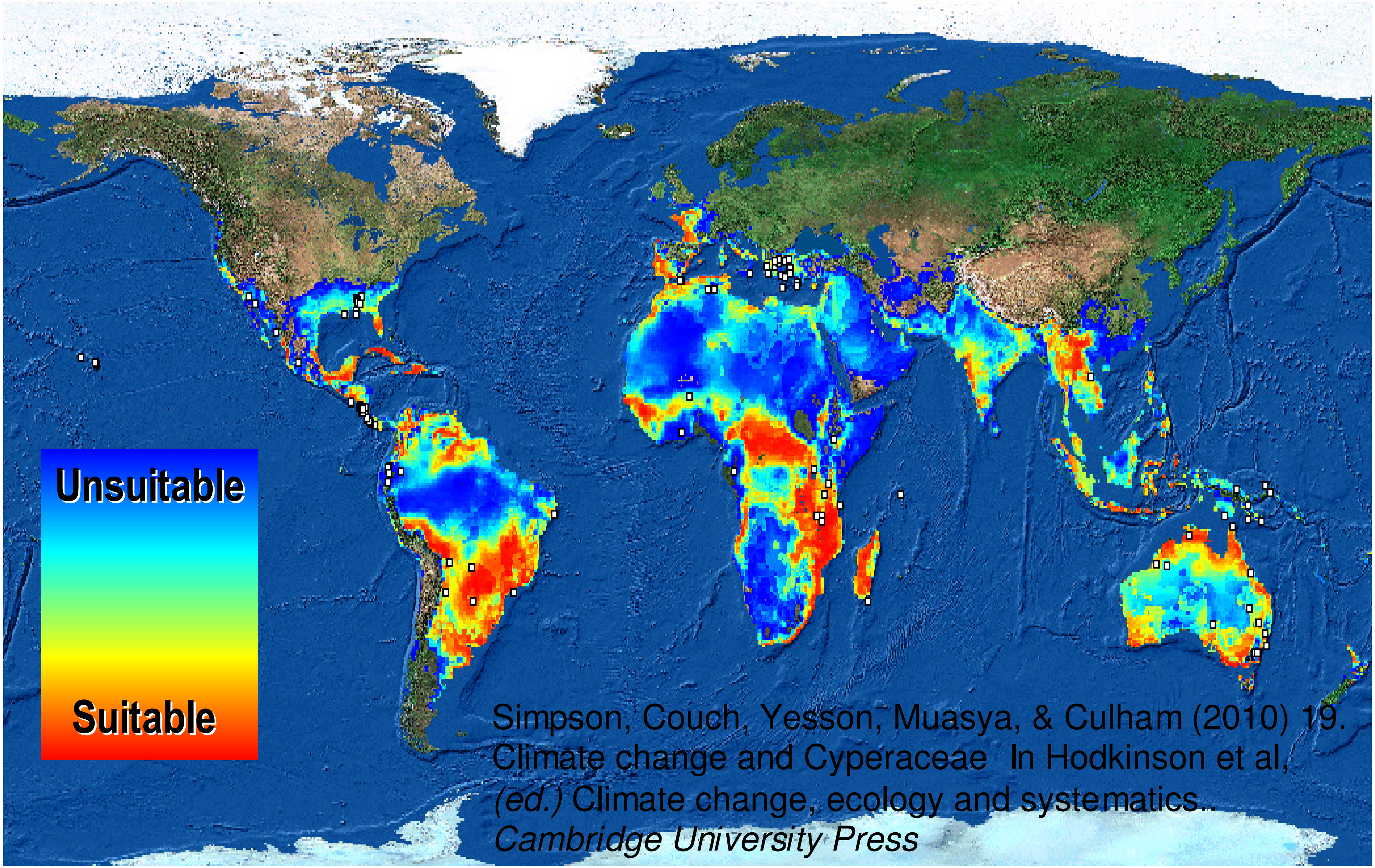
Practical applications - weeds

- *Cyperus rotundus* is *the world's worst weed*
- It can dramatically reduce crop production
- Are some areas at risk from the spread of this weed?

Practical applications - weeds

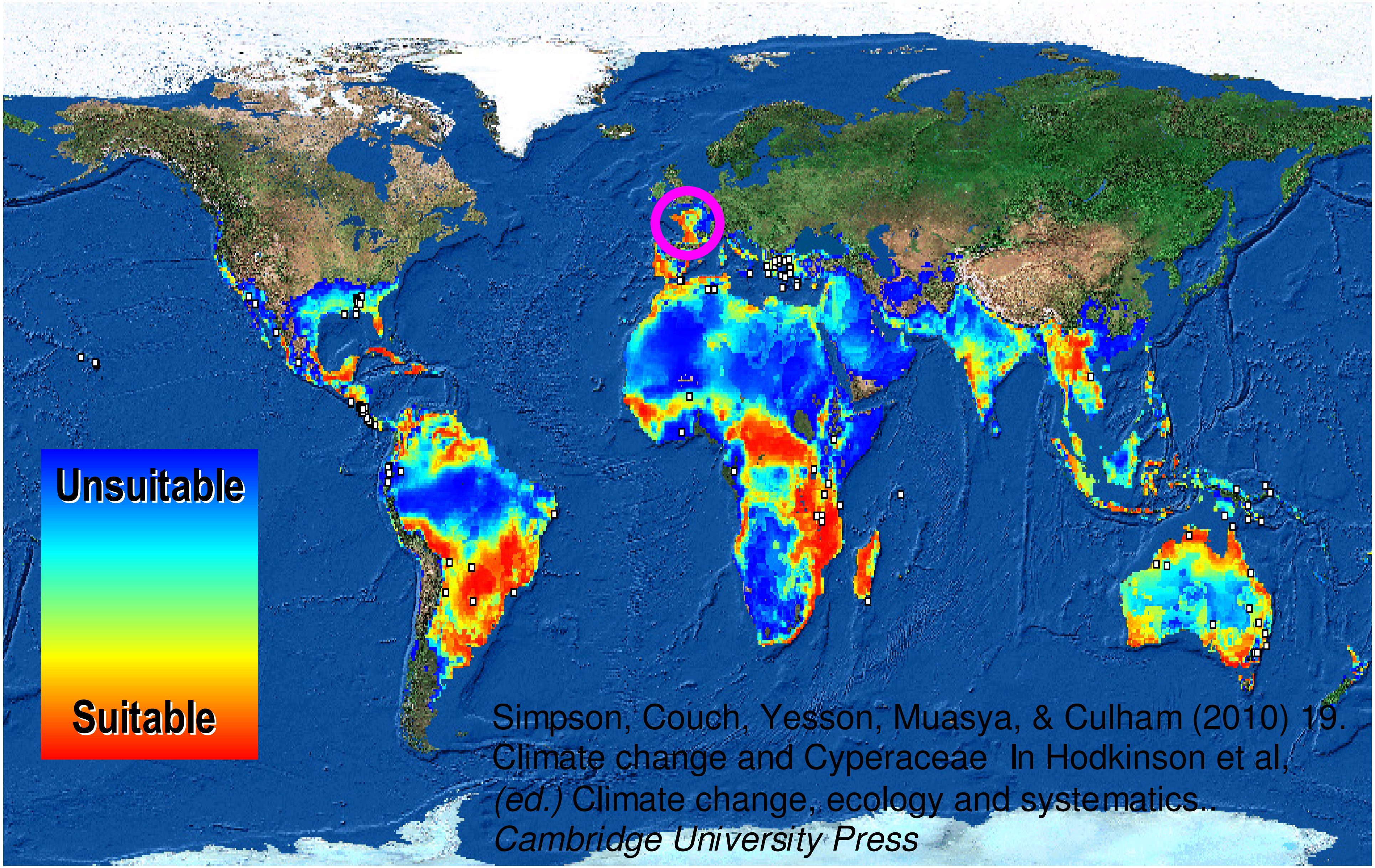


Practical applications - weeds



Simpson, Couch, Yesson, Muasya, & Culham (2010) 19. Climate change and Cyperaceae In Hodkinson et al, *(ed.)* Climate change, ecology and systematics.. *Cambridge University Press*

Practical applications - weeds



Simpson, Couch, Yesson, Muasya, & Culham (2010) 19. Climate change and Cyperaceae In Hodkinson et al, *(ed.)* Climate change, ecology and systematics.. *Cambridge University Press*

Practical applications - disease

Distribution of African Malaria Mosquitoes Belonging to the *Anopheles gambiae* Complex

M. Coetzee, M. Craig and D. le Sueur

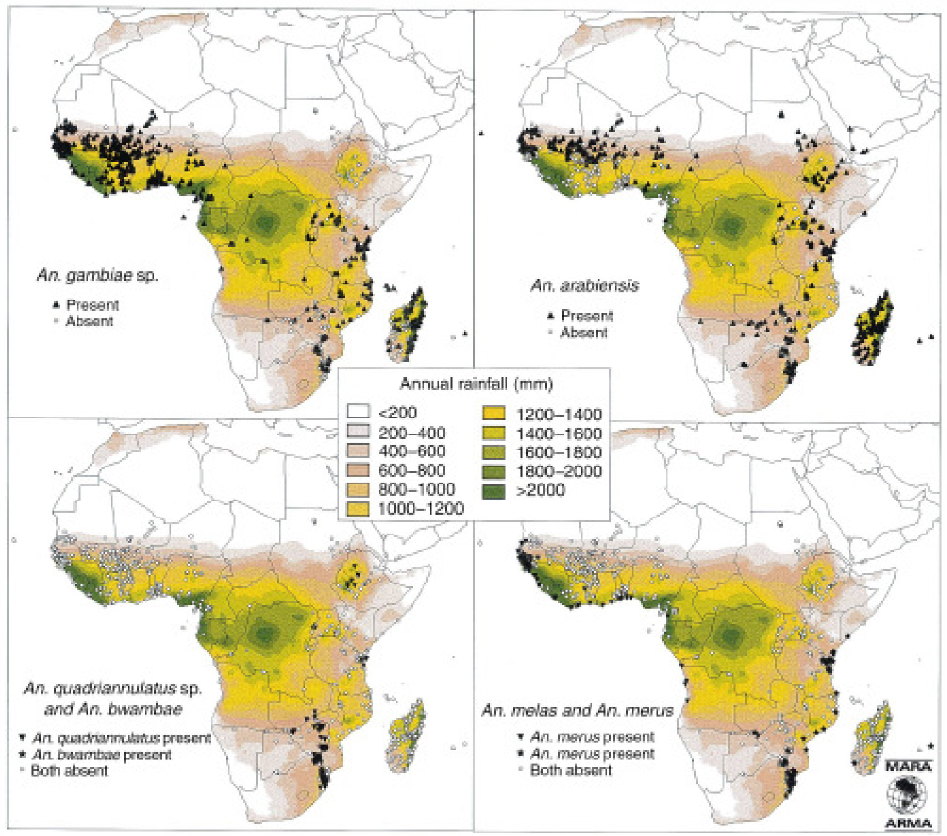


Fig. 1. Collection sites where the six named species of the *Anopheles gambiae* complex have been found (closed symbols), against mean annual rainfall. Open circles indicate collection sites where the species were not recorded, although this does not mean that they are absent from these sites (see text). (*An. gambiae*, $n = 542$; *An. arabiensis*, $n = 475$; *An. quadriannulatus*, $n = 93$; *An. bwambae*, $n = 1$; *An. melas*, $n = 65$; *An. merus*, $n = 55$). 'sp.' after *An. gambiae* and *An. quadriannulatus* indicates that these taxa include more than one species.

- Understanding habitat requirements helps estimate the distribution of disease vectors

Coetzee & le Sueur (2000) Parasitology Today, vol. 16, no. 2, 2000

Practical applications - disease

Human population A. gambiae A. arabiensis

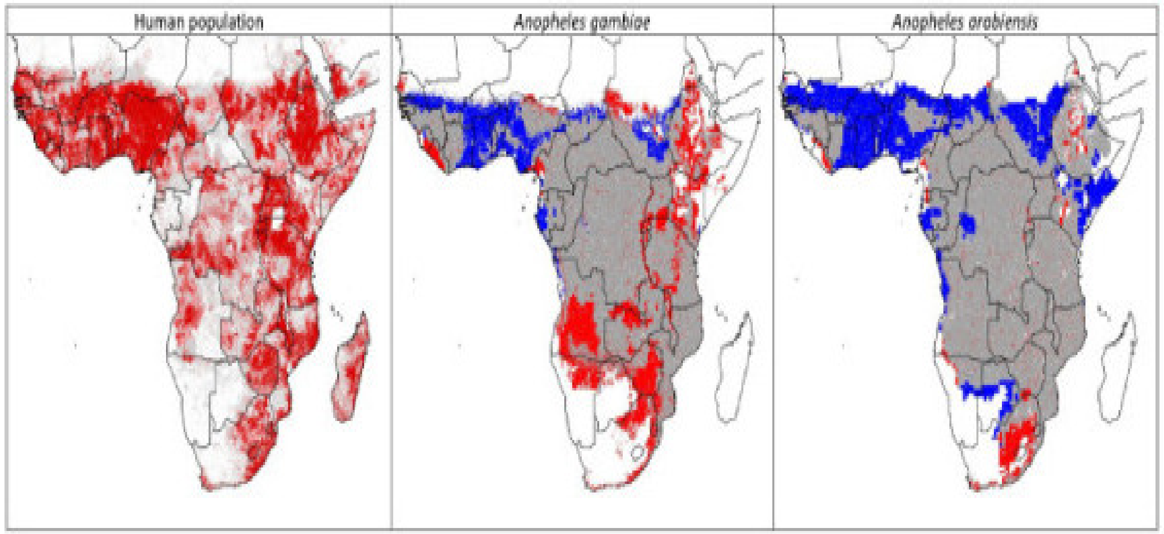


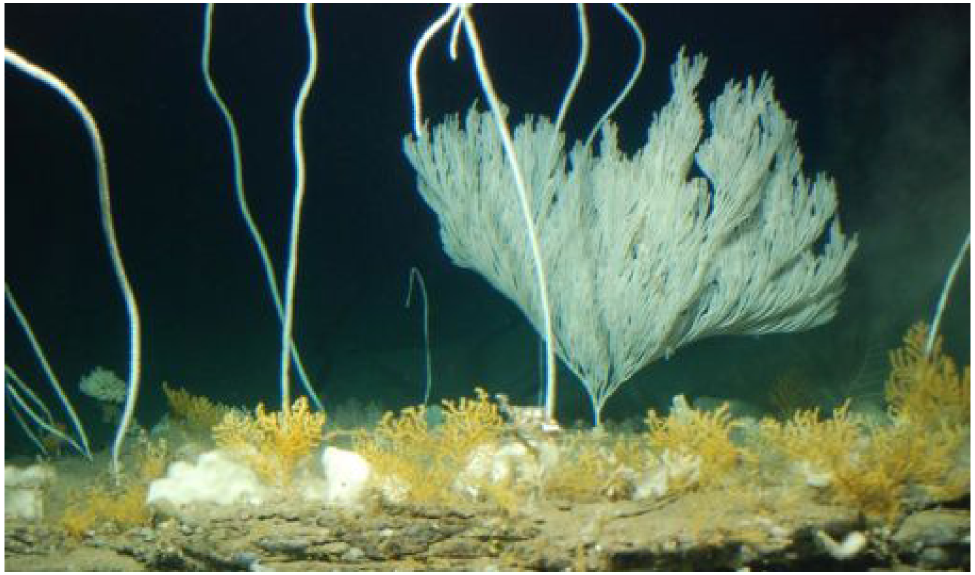
Figure 1 Human distributions and modeled present and future malaria vector distributions in Africa

- Understanding disease vector habitat requirements and population dynamics helps understand the spread of disease

Peterson et al (2009) BMC Infectious Diseases **9**:59

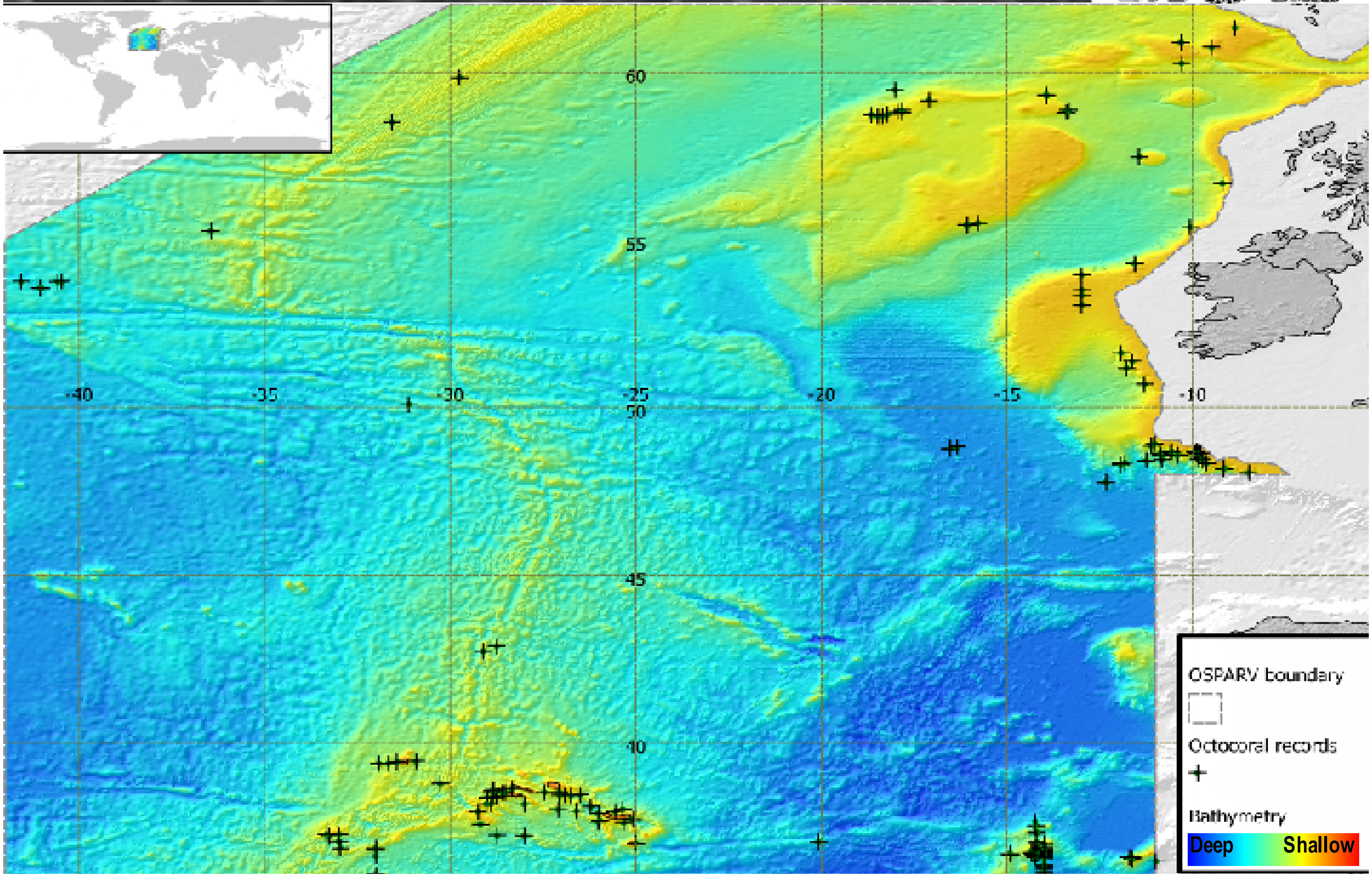
Practical applications – deep sea

- Where do corals live?
- Some are thousands of metres below the surface
- Very expensive and difficult to observe

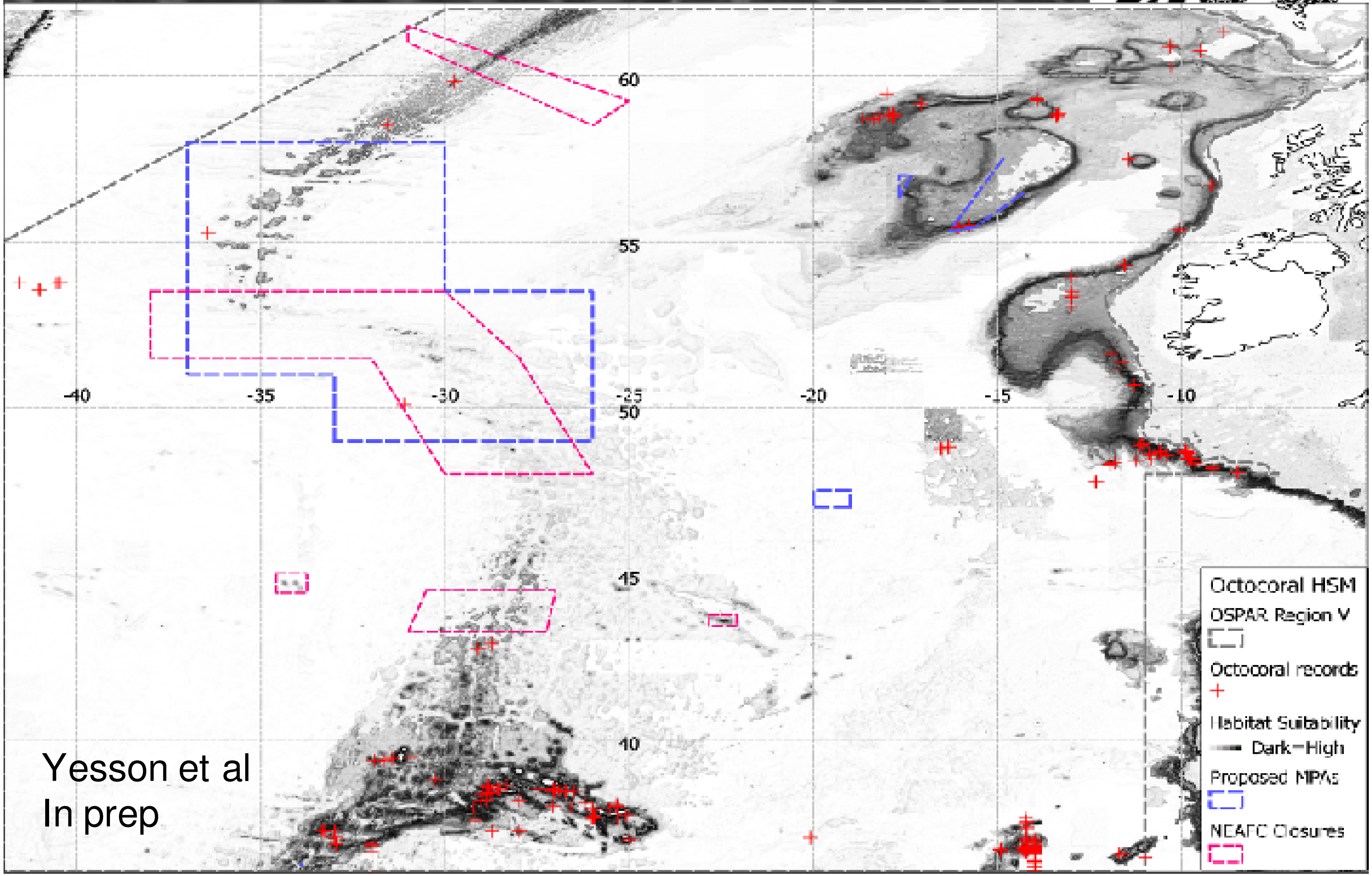


- Trawling can devastate coral gardens
- Which areas should we protect from trawling?

Octocoral records from N. Atlantic

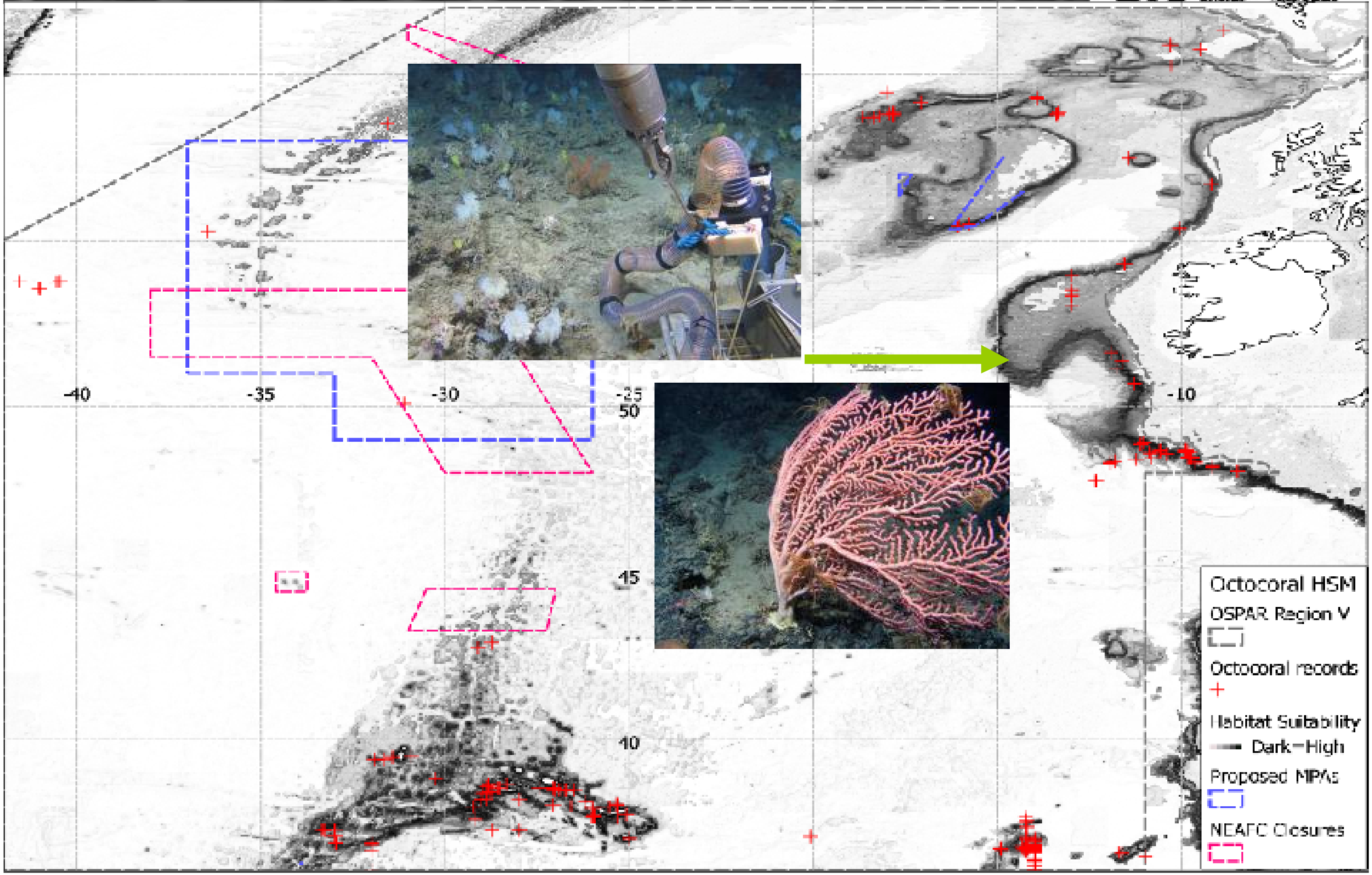


Estimated distribution based on niche



Yesson et al
In prep

Estimated distribution based on niche



Conclusion

- Habitat suitability modelling of corals is potentially useful due to a lack of distribution data

- Habitat suitability modelling of corals is difficult (see left)

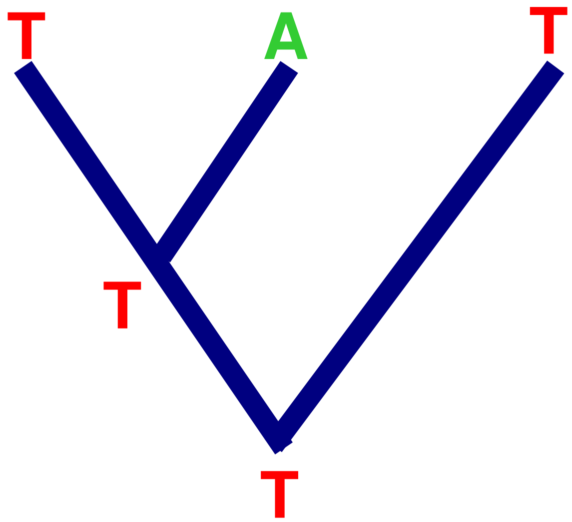
Niche model applications

- Practical
  - –Invasive species (weeds)
  - –Disease
  - –Data deficient species
  - –Marine protected areas

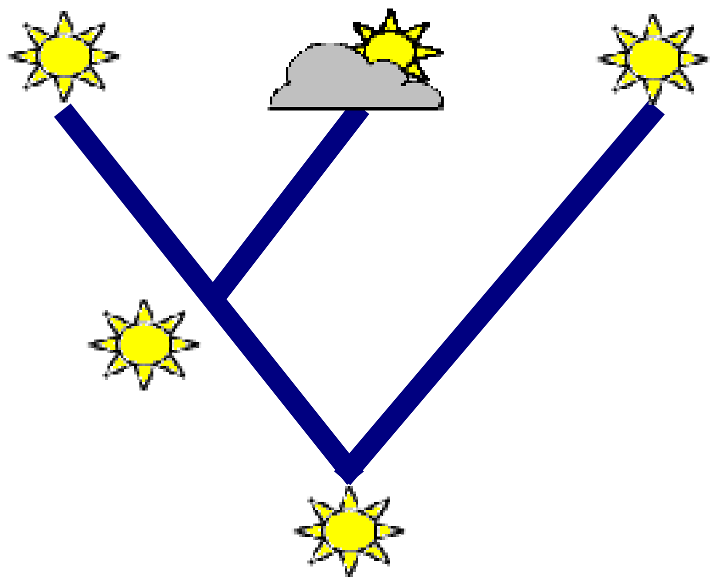
- **Theoretical**
  - –Diversity through time
  - –Evolutionary patterns

Theoretical work

- Using palaeoclimate reconstructions to estimate historical, palaeohistorical and ancestral niches

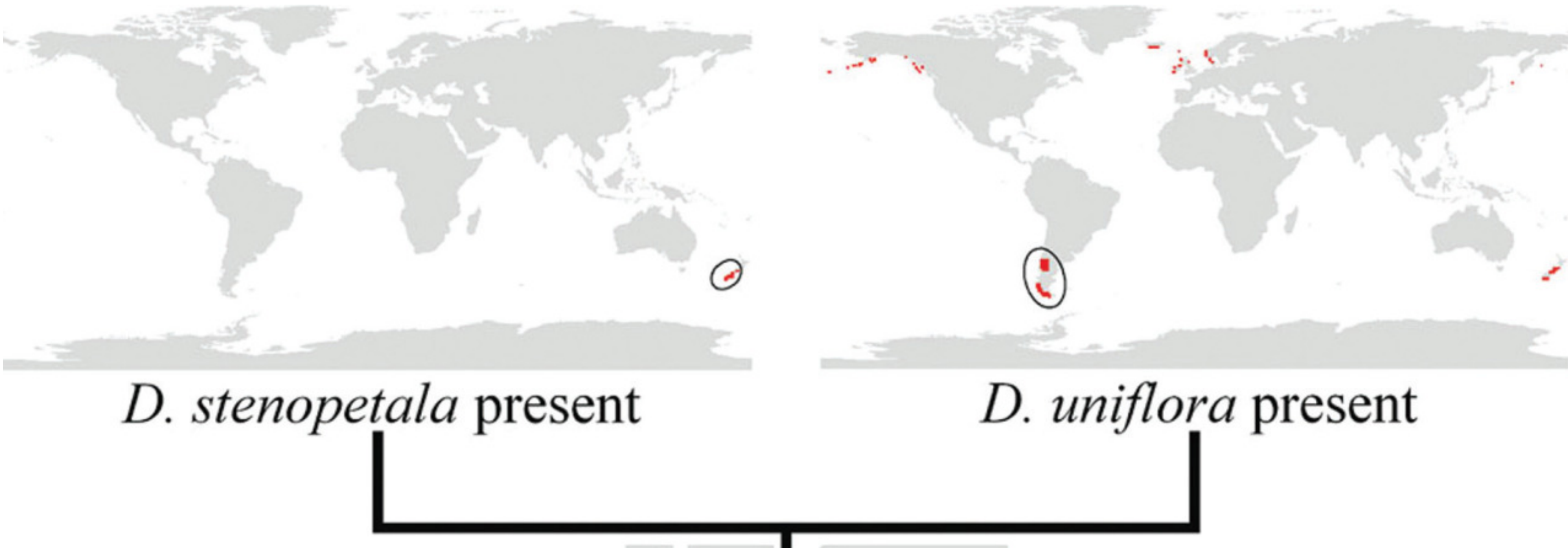


Parsimony optimisation on a phylogenetic tree



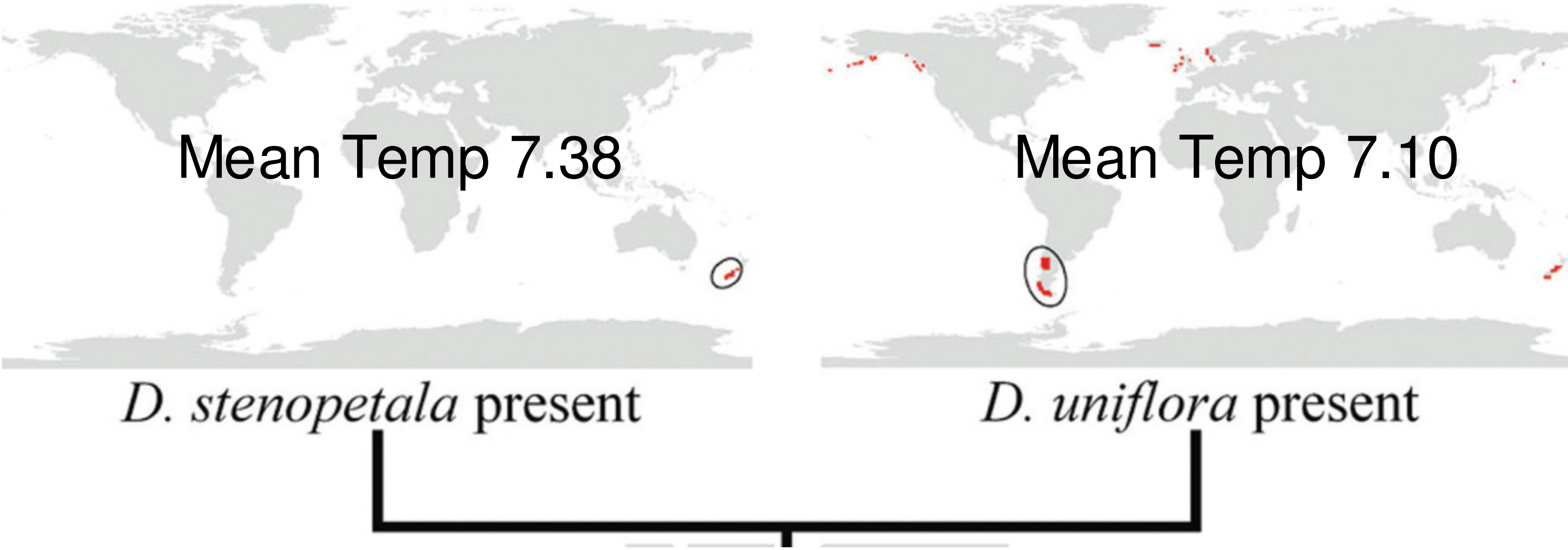
Parsimony optimisation of environmental character

Phyloclimatic modelling – an example



- D. stenopetala and D. uniflora are sister taxa
- One is from New Zealand, the other is from South America
- We estimate an ancestral area?

Phyloclimatic modelling – an example

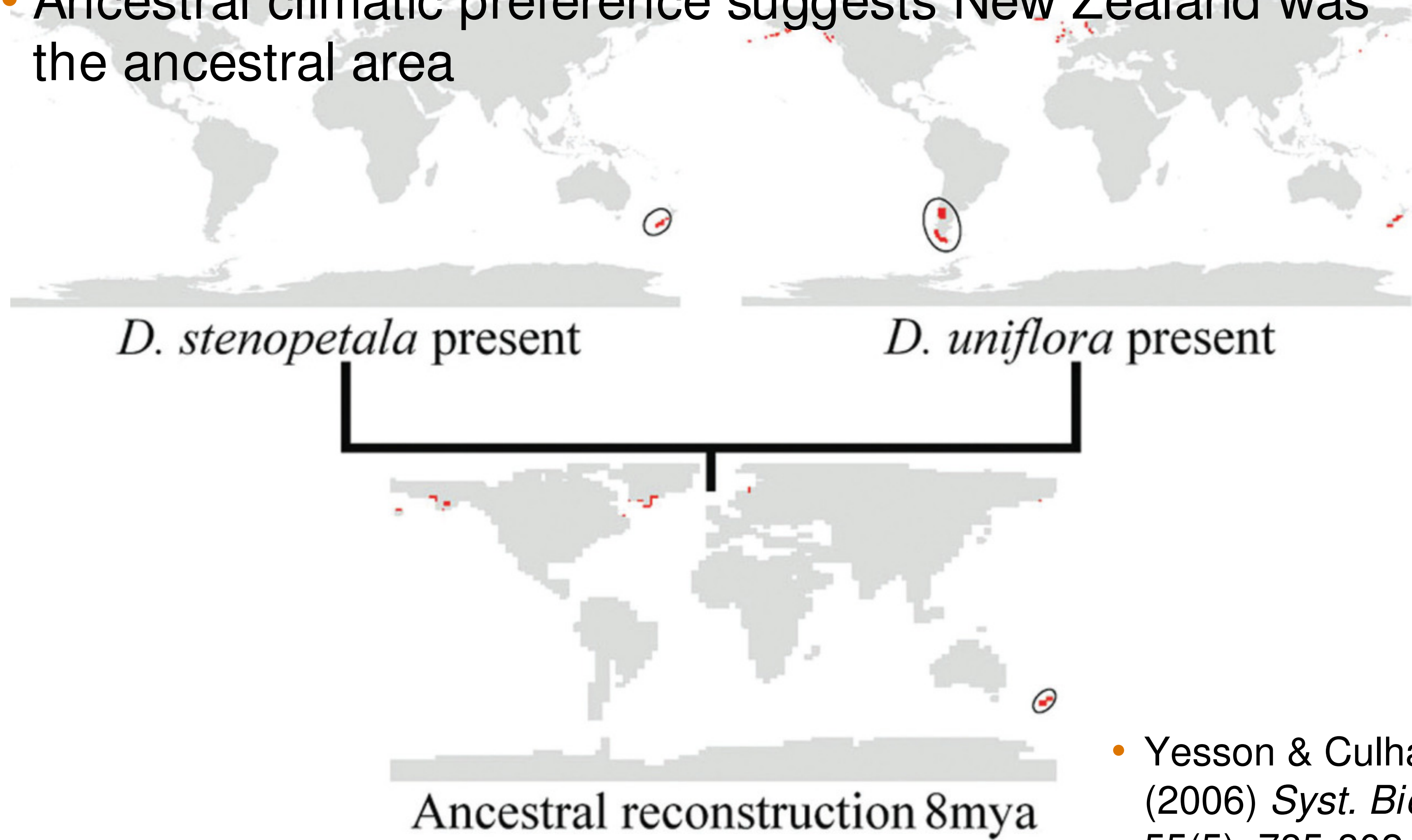


Ancestral node
Mean Temp 9.87
Age ~8.40-7.95 Ma

Project ancestral niche into palaeoclimate for ~8Ma

Phyloclimatic modelling – an example

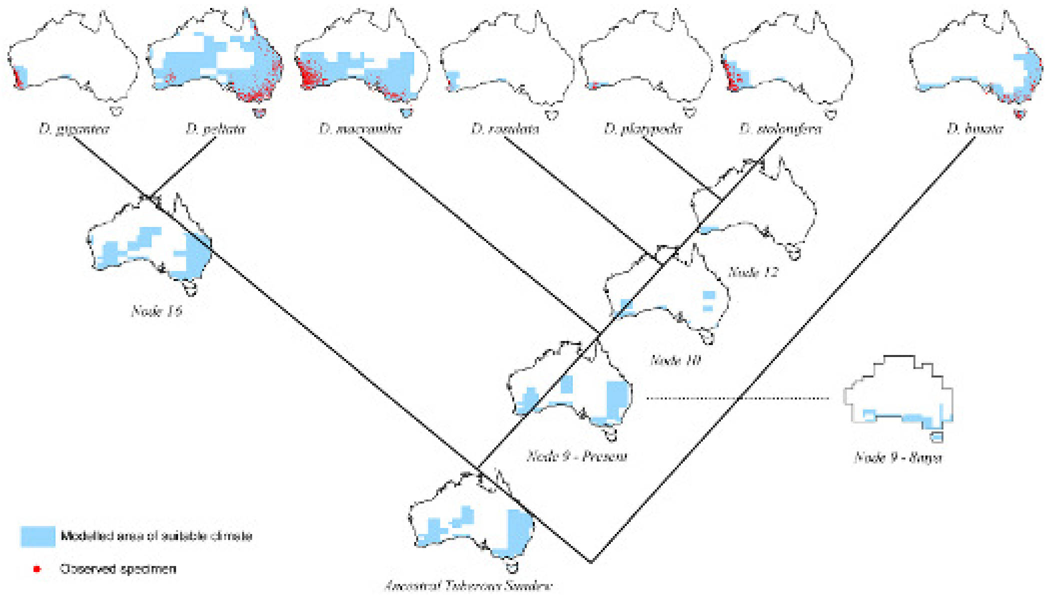
- Ancestral climatic preference suggests New Zealand was the ancestral area



- Yesson & Culham (2006) *Syst. Biol.* 55(5): 785-802.

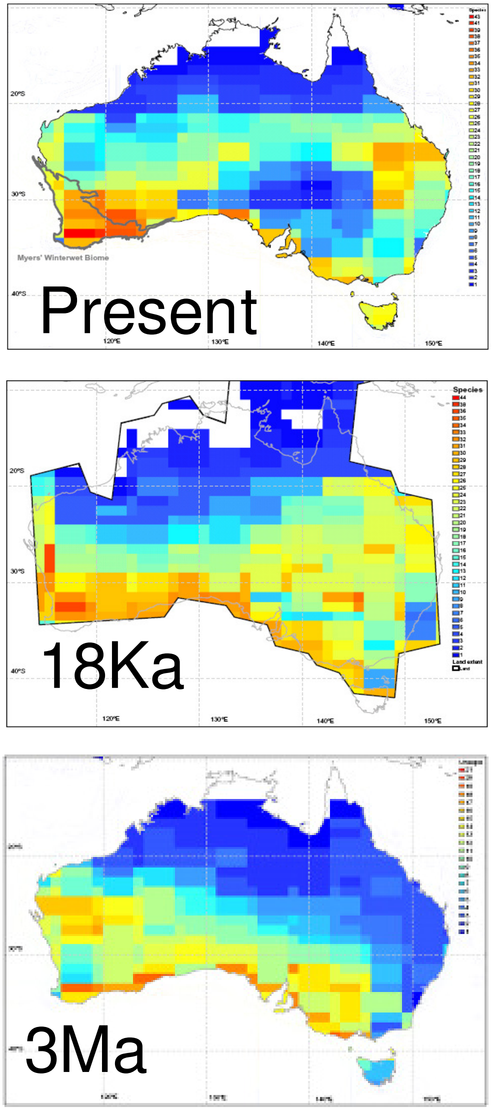
Diversity through time

Evolutionary & ecological diversity of sundews



- Yesson & Culham (2006) *Syst. Biol.* 55(5): 785-802.

Gastrolobium diversity



- Yesson & Culham In prep

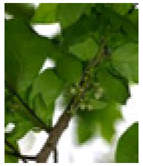
Practical – run your own niche model

openModeller Practical

Obtaining specimen data

Before you can do any species distribution modelling you need some specimen data with associated point localities. For this practical we have prepared a sample file containing specimens from Tanzania.

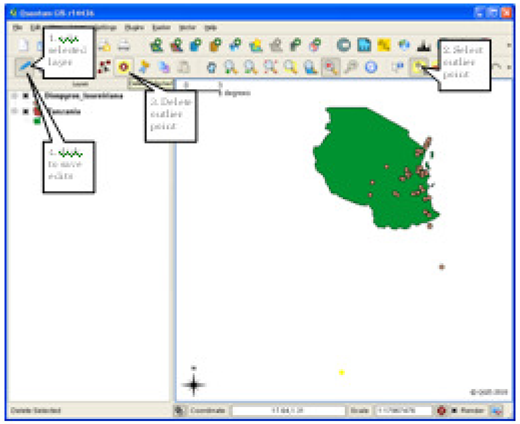
Typically you would search for data by inspecting museum catalogues or searching through literature. The GBIF portal is a good place to start (http://data.gbif.org/). openModeller has a search utility that allows you to search GBIF for data and feed the results directly into your model. Instructions for this are provided as an appendix.



I have prepared an example using the star apple *Diospyros loureiriana*, an East African endemic shrub, using data from GBIF (including TanBIF). Data for this practical is in the Data directory in the handouts.

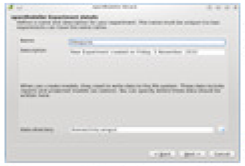
Modelling setup

- Start by opening a reference map (Tanzania.shp)
- open the file Specimens\Diospyros_loureiriana.shp in qgis
- check the distribution – some records are outside the reference map
- use the qgis edit function to remove the outliers
- *Note that removing outliers is not essential as these will be automatically excluded*



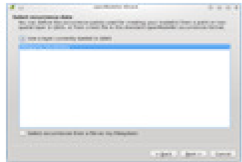
Modelling

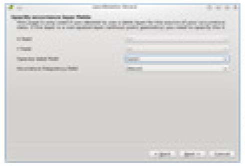
- open raster environmental layers for modelling, use present day climate data minimum & maximum temperature and precipitation (tmin, tmax, precip in Worldclim/Present/)
- select new experiment in the openModeller plugin menu
- follow the wizard instructions



1. (left) Type in an experiment name – click next

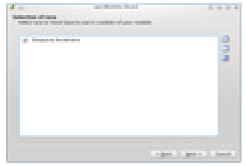
2. (right) Select the Diospyros data – click next

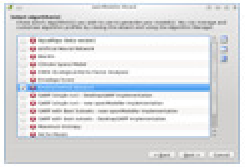




3. (left) Select species label field "taxon" – click next

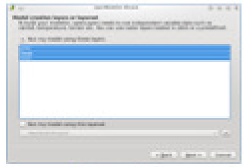
4. (right) Select taxon name Diospyros loureiriana – click next

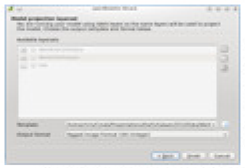




5. (left) Select algorithm "Environmental distance" – click next

6. (right) Select environmental layers "prec", "tmin", "tmax" – click next

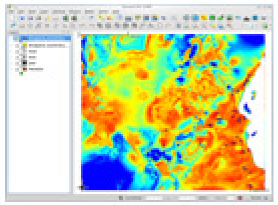




7. (left) Click finish to run the model

8. (right) Monitor progress of model run – Click OK when finished

- When finished your projected model will appear in QGIS as a raster layer. Red is high suitability (maximum=100), blue is low suitability (minimum=0). Move the occurrence data to the topmost layer to see if the model is a good fit to the data
- Your output should look like this



How do the results change if you use a different algorithm or environmental layers?