Niche Modelling: An Introduction

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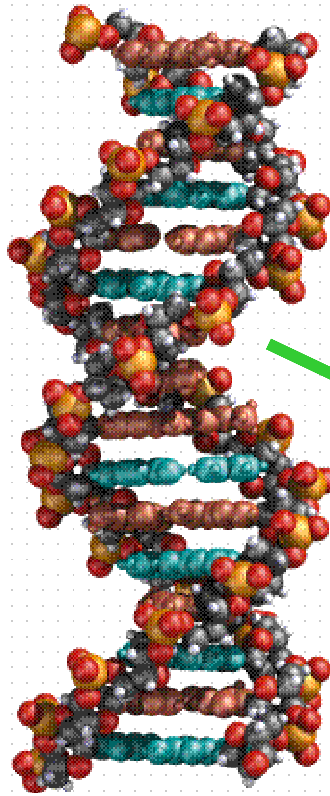
LIVING CONSERVATION

Where does diversity come from?

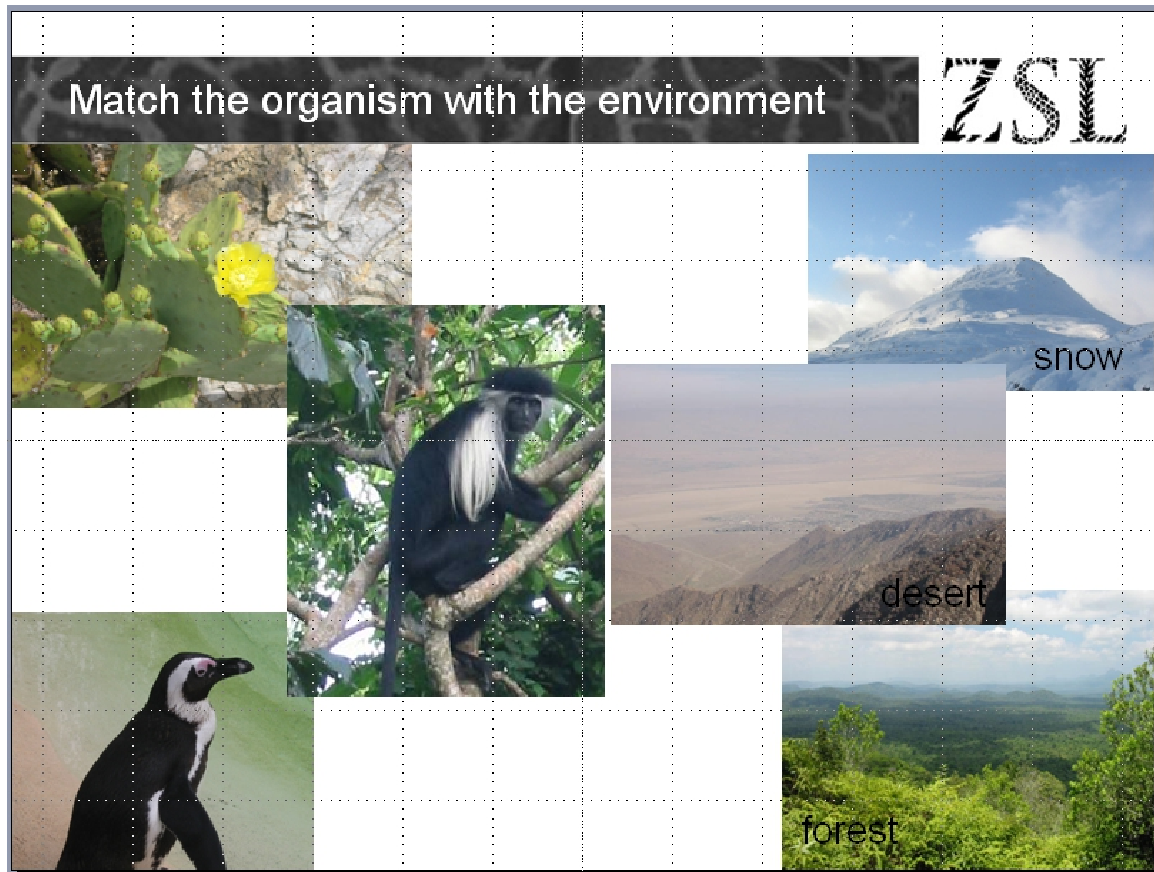
- Mutation
- Selection
- Chance
- Time

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



Niche concepts are innate

- *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

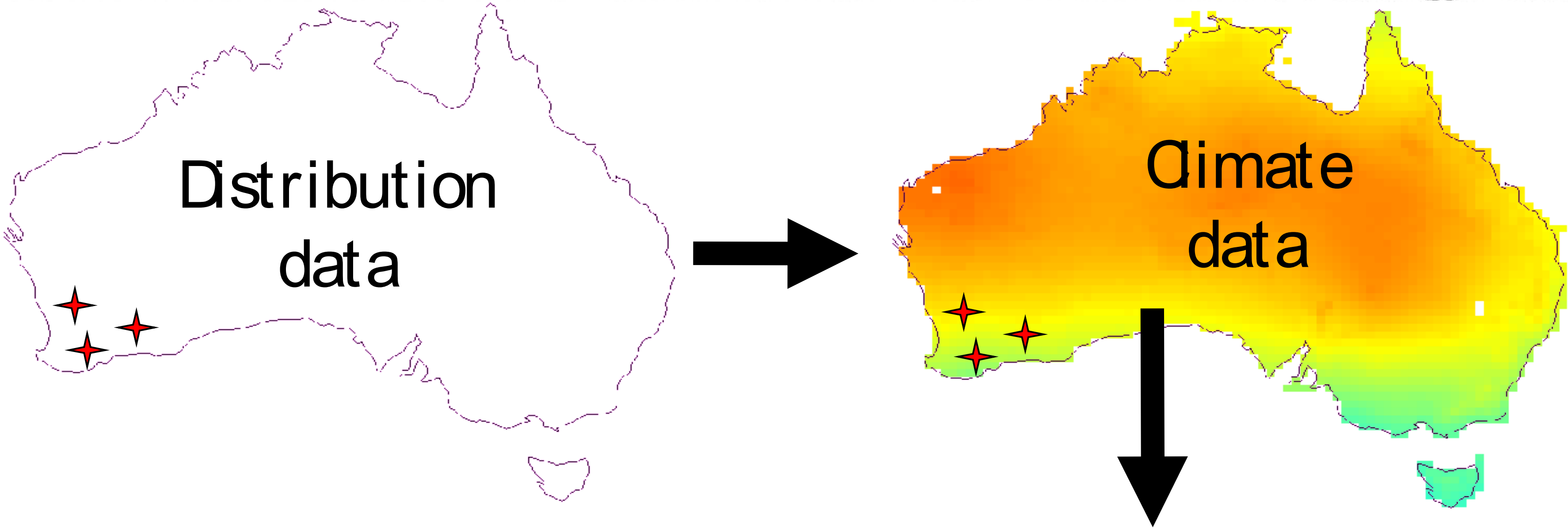
What is a climatic niche?

- 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

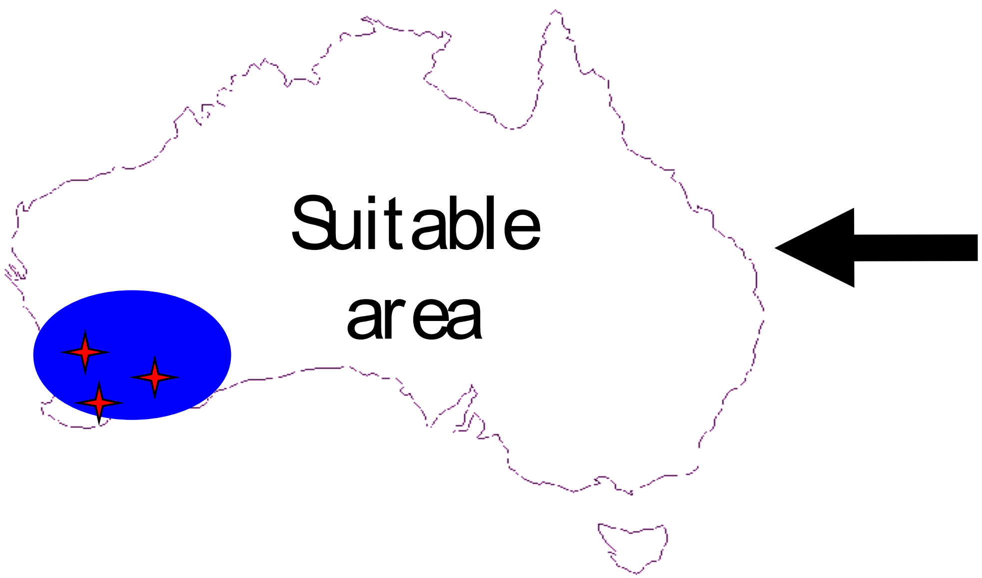
- One way to investigate species response to climate is through examination of climatic preferences by constructing bioclimatic niche models (=species distribution models = environmental niche models)
- Preferences of a given species, based on its known distribution
- Model using the climate parameters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

A niche model workflow



Point	Radiation	Temp	Precip.
A	15.1	25	5
B	10.5	24	6
C			7
Mean	**1**		**6**
Stddev	**3.47**	**2.65**	**1**
Min	**8.3**	**20**	**5**
Max	**15.1**	**25**	**7**

Model



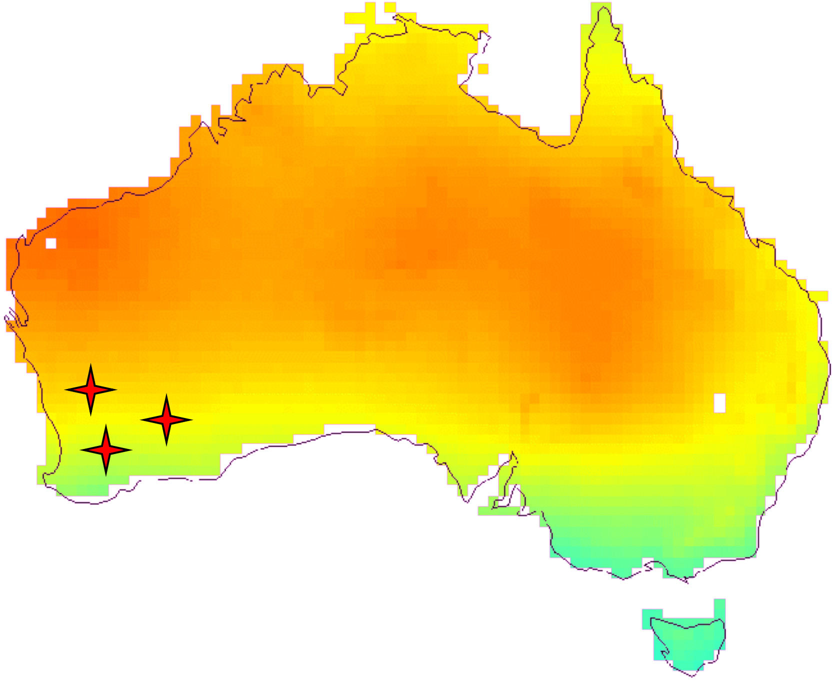
How niche modelling works

- Species Observations
- Climate variables
- **Analyse climate preferences**
- Establish niche

Point	Radiation	Temp	Precip.
A	15.1	25	5
B	10.5	24	6
C	8.3	20	7
Mean	**11.3**	**23**	**6**
Stddev	**3.47**	**2.65**	**1**
Min	**8.3**	**20**	**5**
Max	**15.1**	**25**	**7**

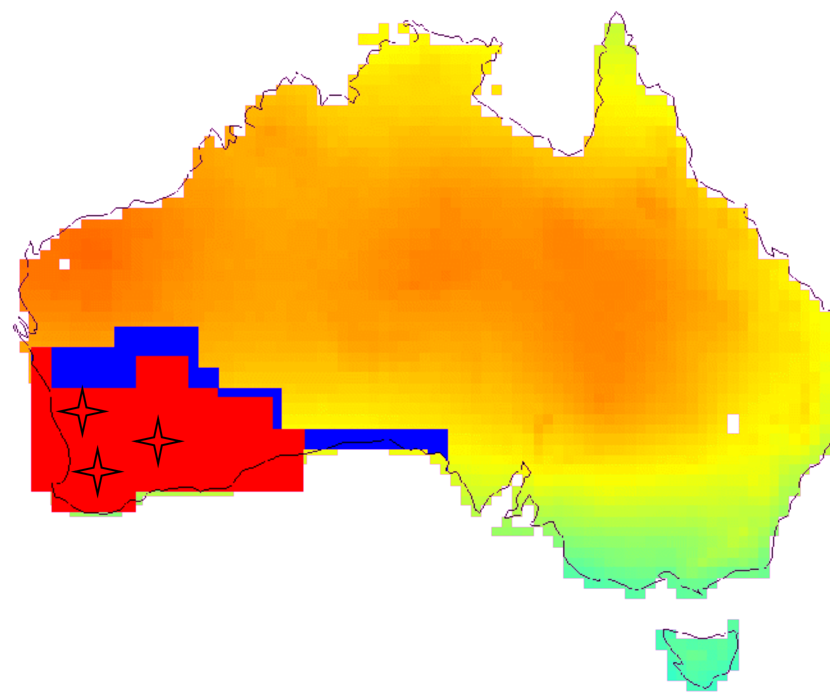
Niche modelling - climate

- Climate + distribution
- Climate parameters in the area of distribution can be quantified
- Build a picture of what a plant tolerates



Niche modelling
- there at last?

- Species Observations
- Climate variables
- Analyse climate preferences
- **Establish niche**



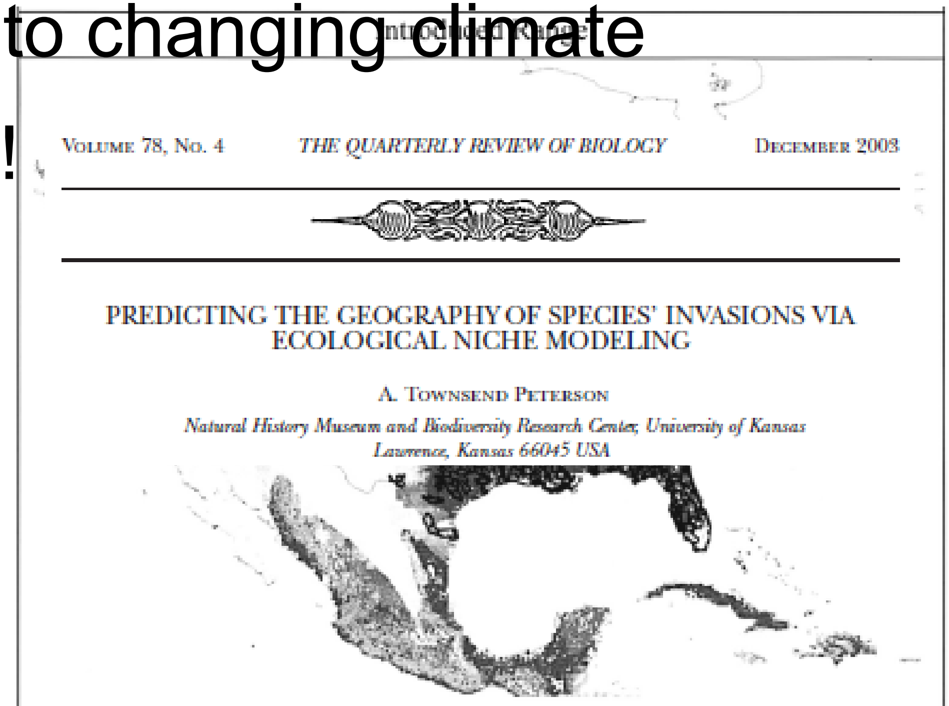
Niche Modelling studies

- 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



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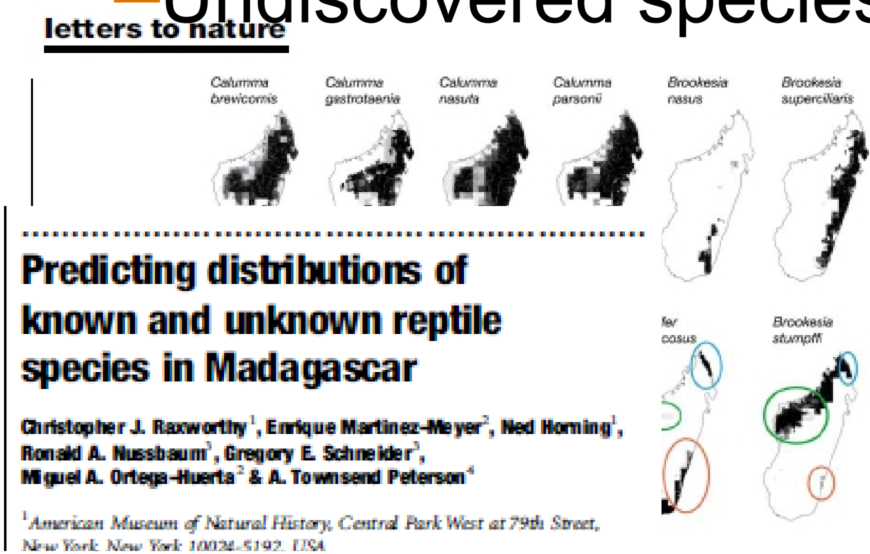
PREDICTING THE GEOGRAPHY OF SPECIES' INVASIONS VIA ECOLOGICAL NICHE MODELING

A. TOWNSEND PETERSON

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



letters to nature

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

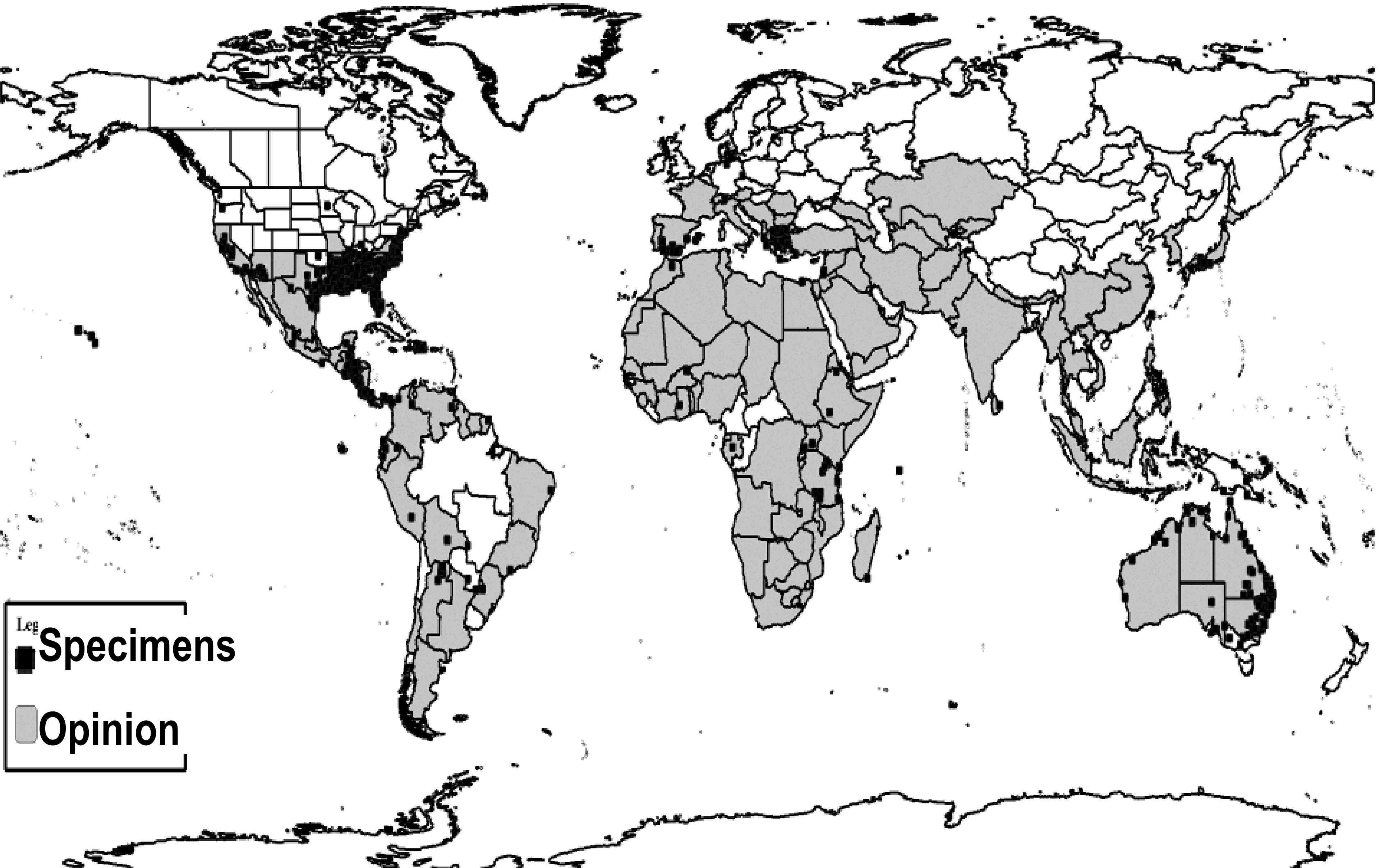
Examples

- Invasive species (weeds)
- Malaria
- Marine protected areas
- Climate change
- Diversity through time

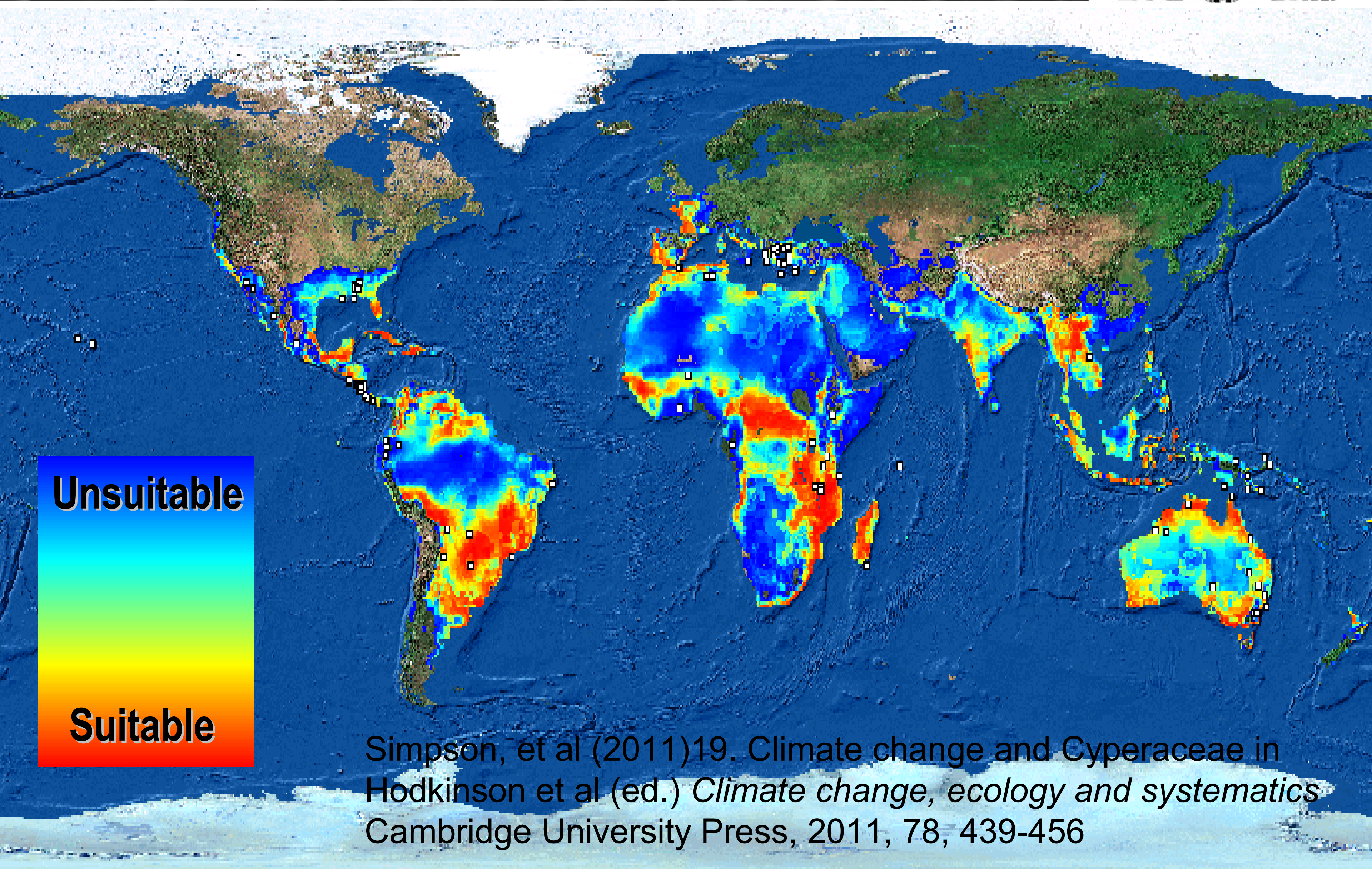
Practical applications - weeds

- *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

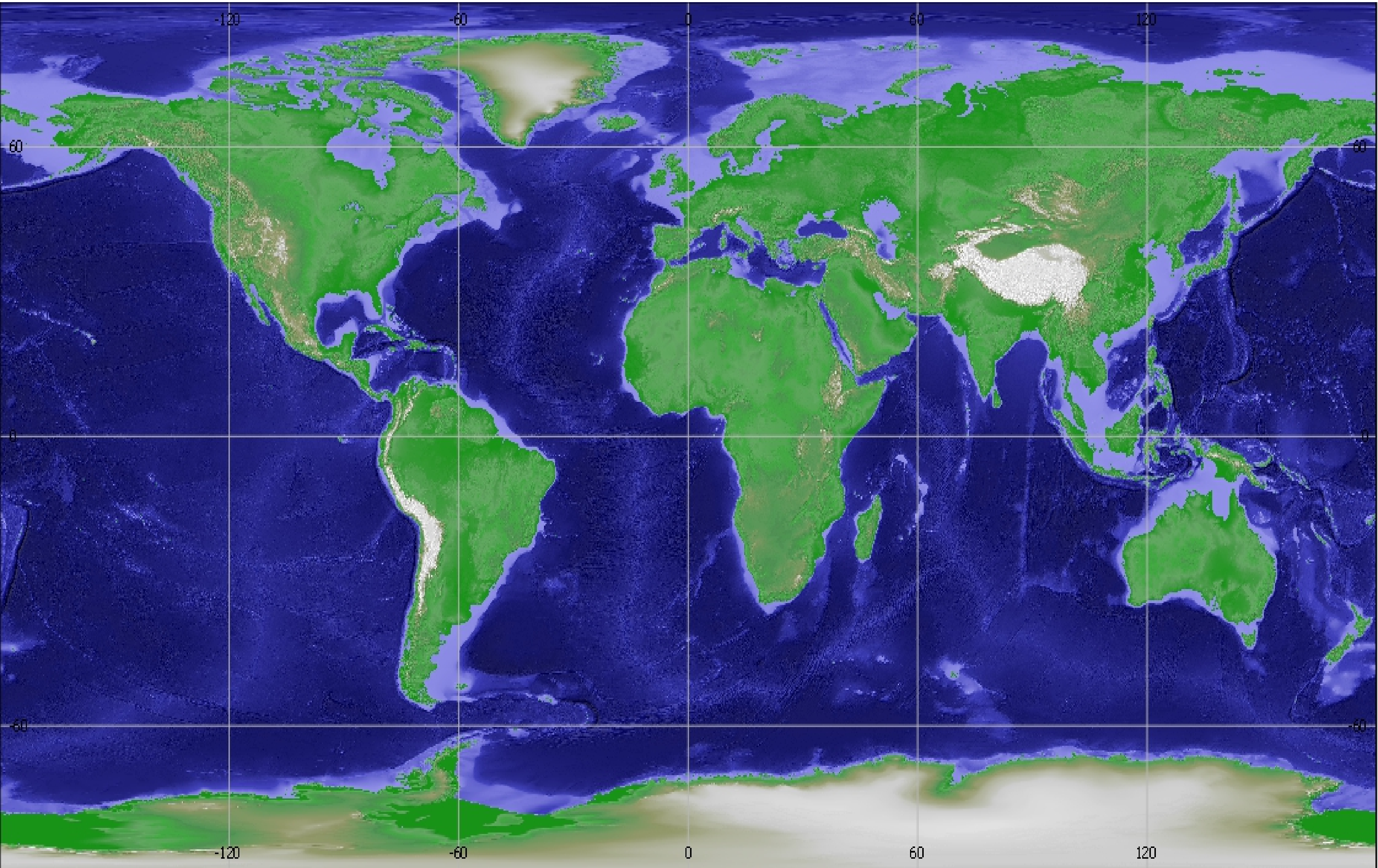


Simpson, et al (2011)19. Climate change and Cyperaceae in Hodkinson et al (ed.) *Climate change, ecology and systematics* Cambridge University Press, 2011, 78, 439-456

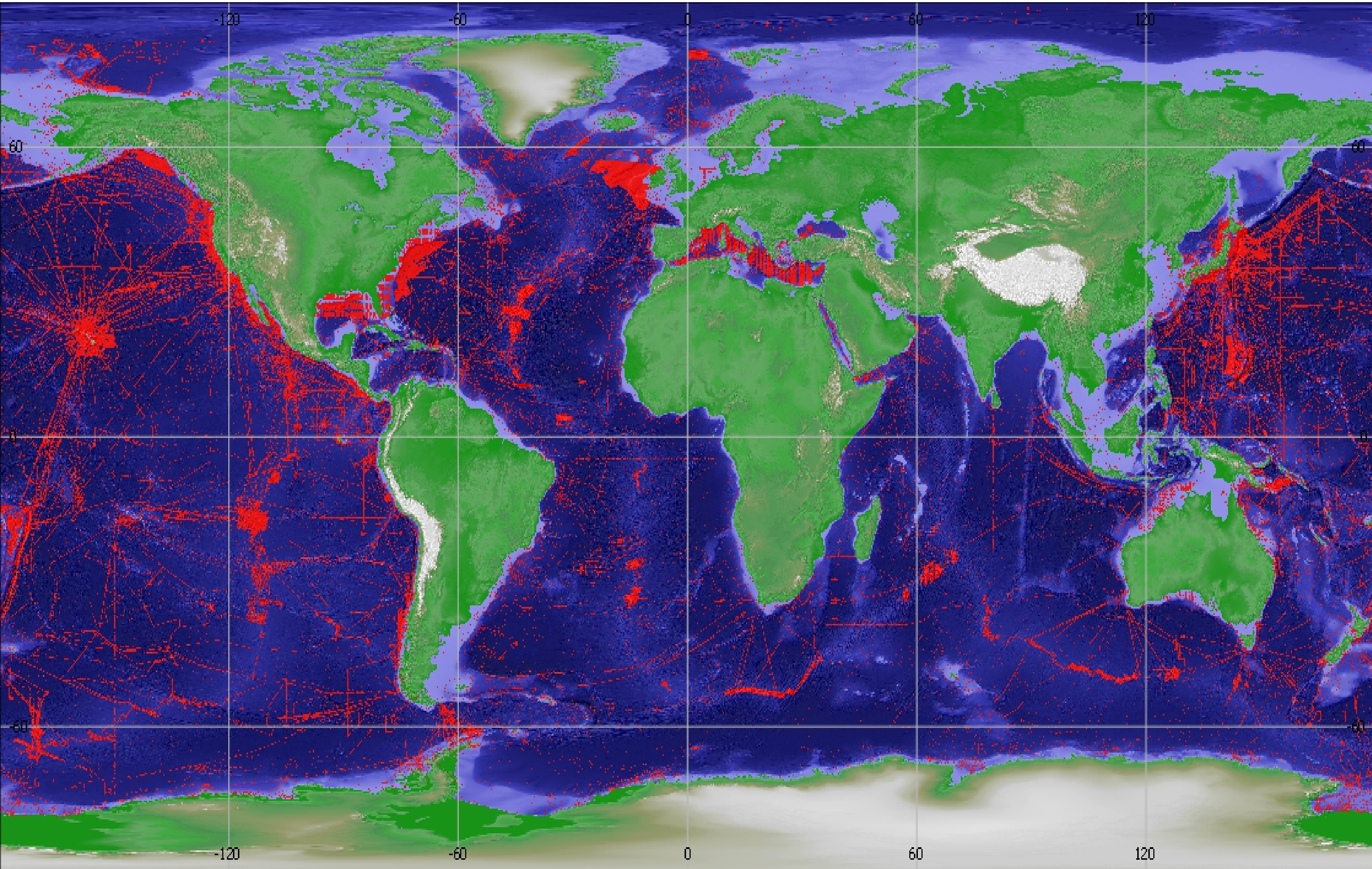
Cold water corals

- Cold water corals have been found at depths beyond 8,000m
- They can live thousands of years
- They create complex 3d habitats
- Corals form important habitats for other animals, including commercial fish species
- Identified as Vulnerable Marine Ecosystems that are threatened by fishing impacts

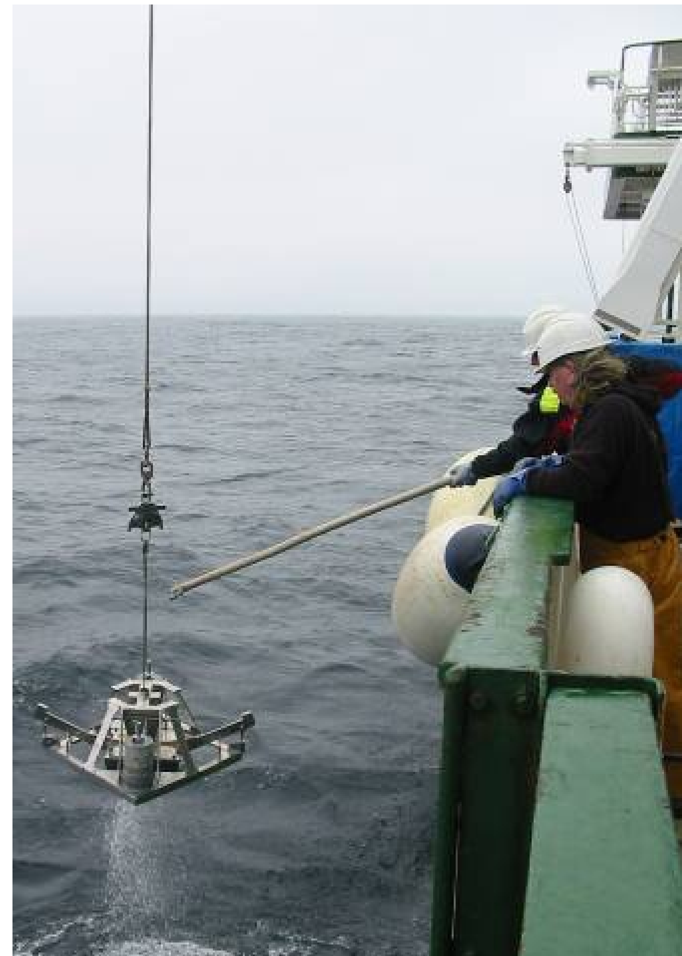
Global bathymetry (depth) grid



Global bathymetry – Acoustic data

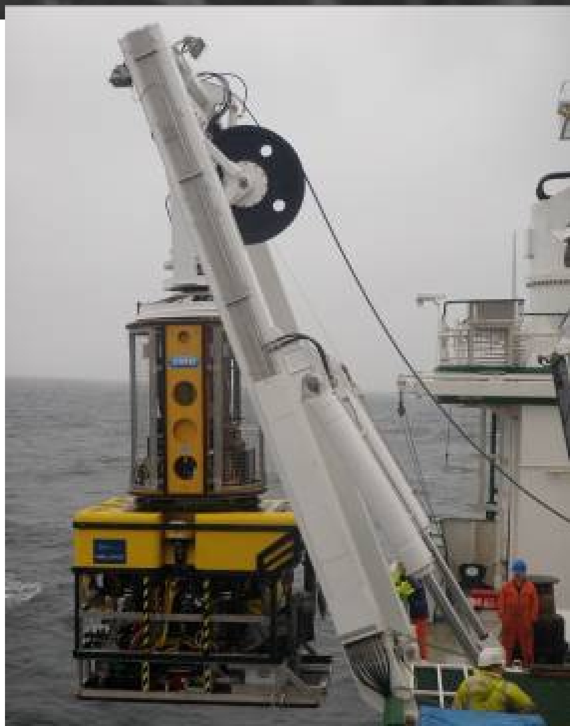


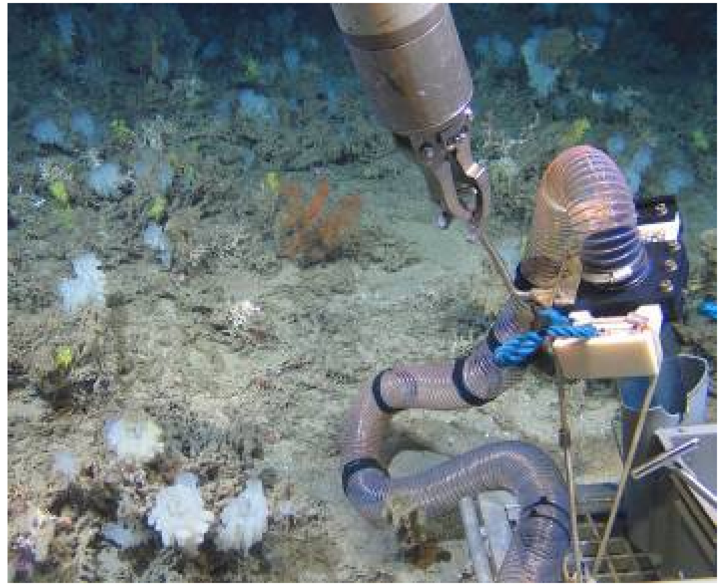
How can we collect from the deep sea?

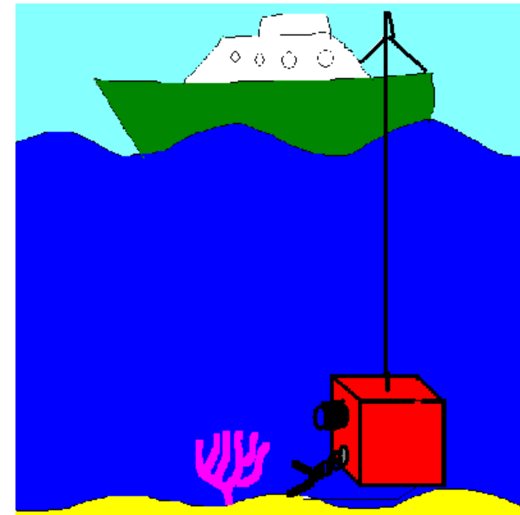


A remote operated vehicle (ROV)

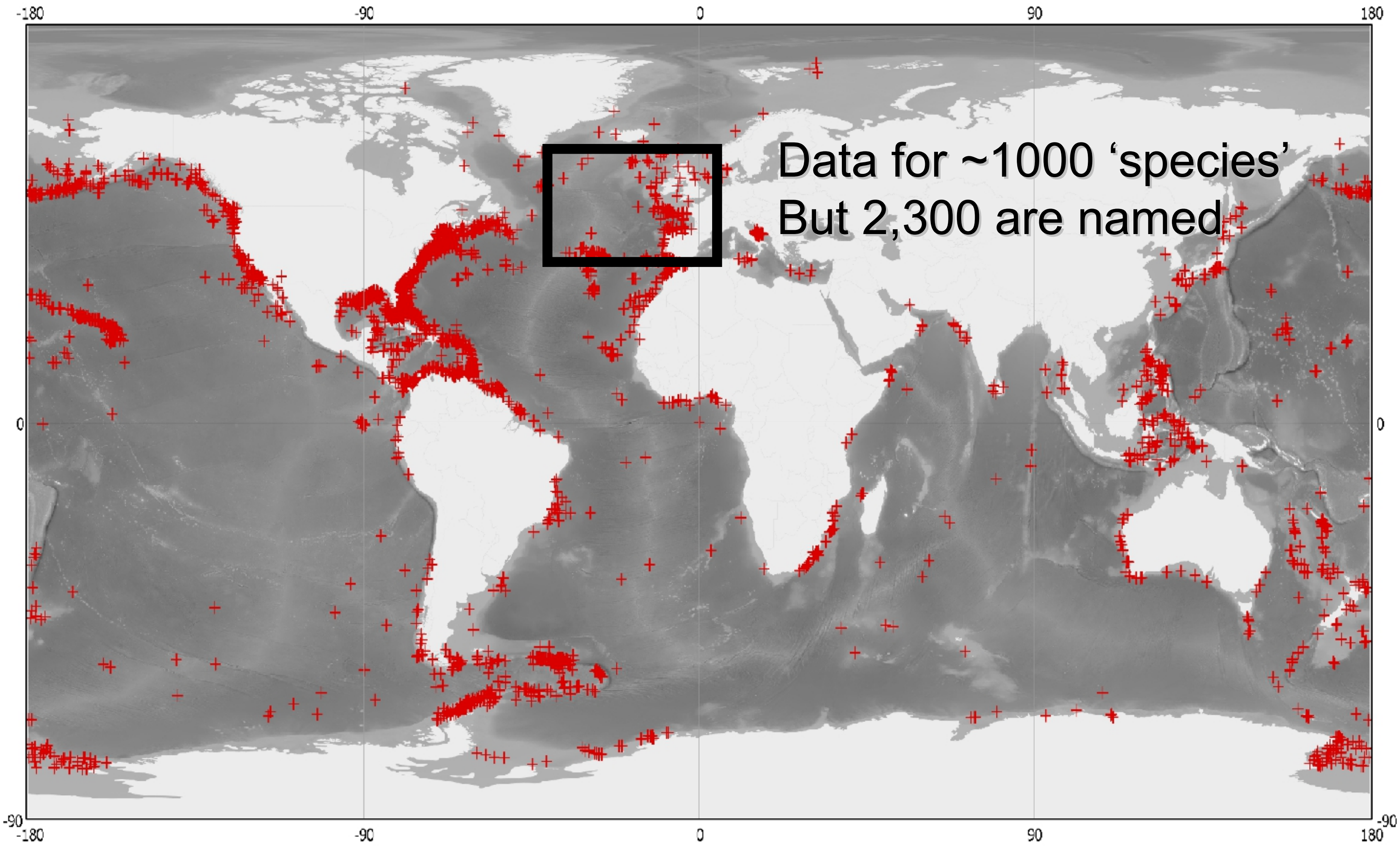
ZSL



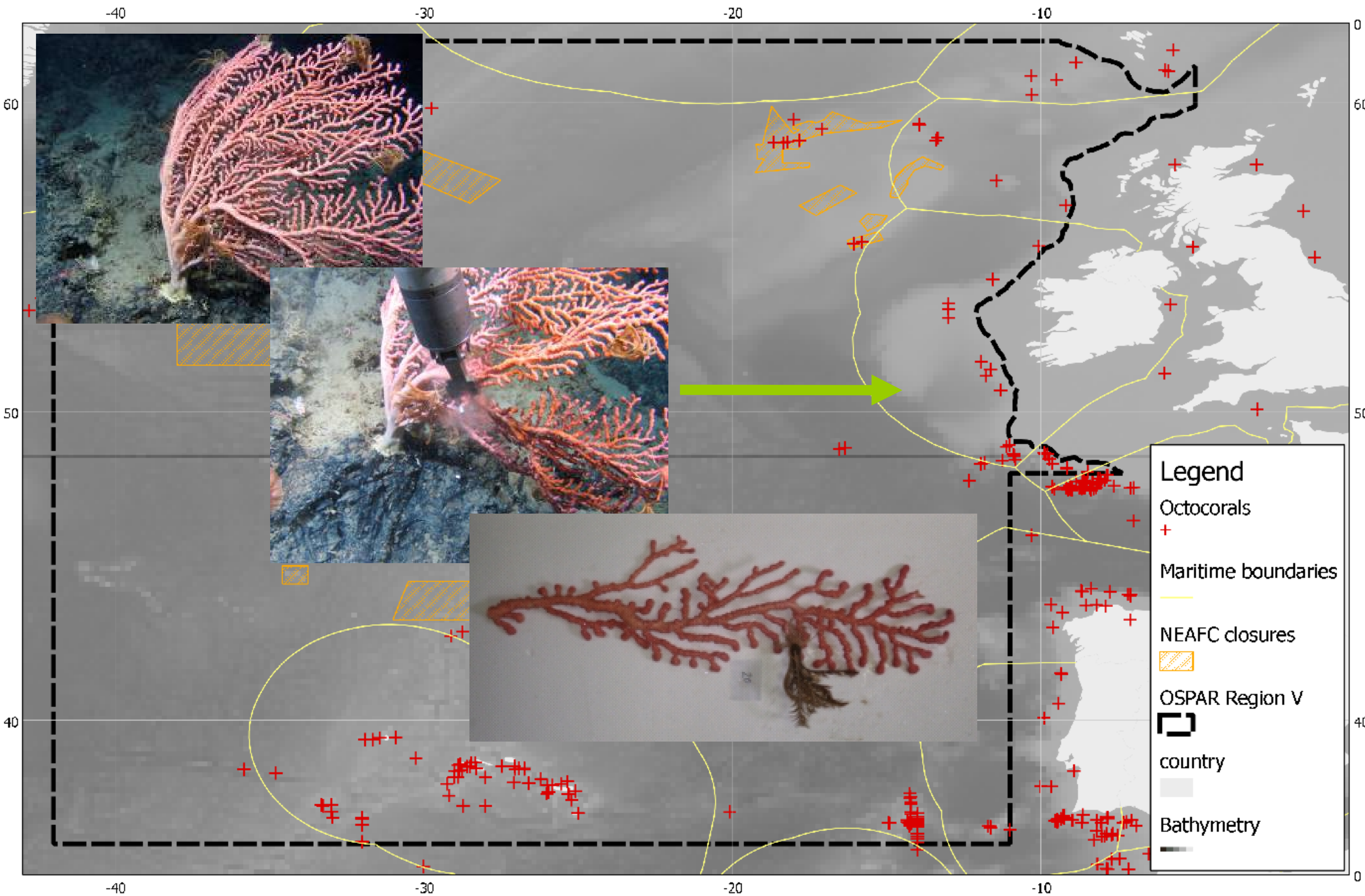




Database of octocorals



Octocoral database is incomplete



Corals need Calcium Carbonate

- Stony corals utilise the aragonite form of calcium carbonate to build their hard skeleton
- Soft corals contain calcium carbonate sclerites and scales made predominantly from

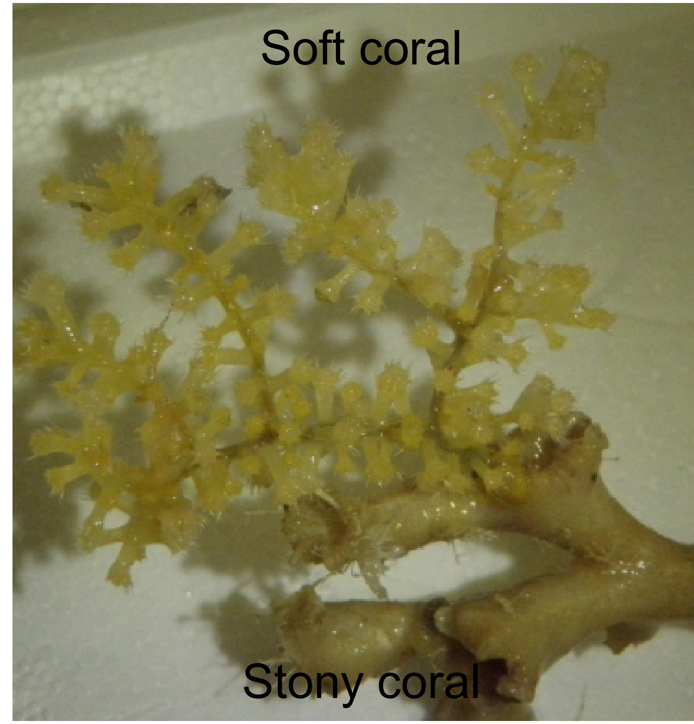
Vol 437|29 September 2005|doi:10.1038/nature04095

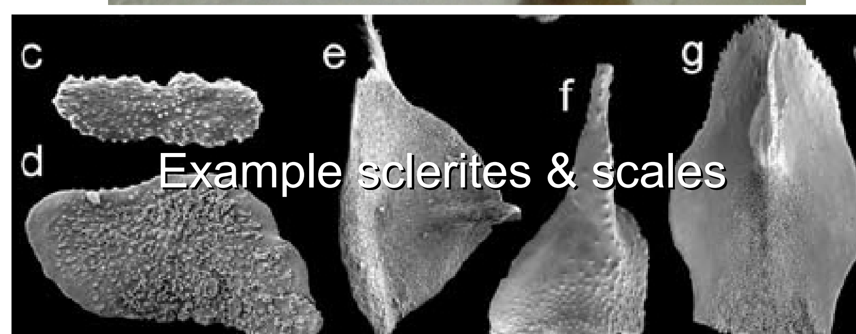
nature

ARTICLES

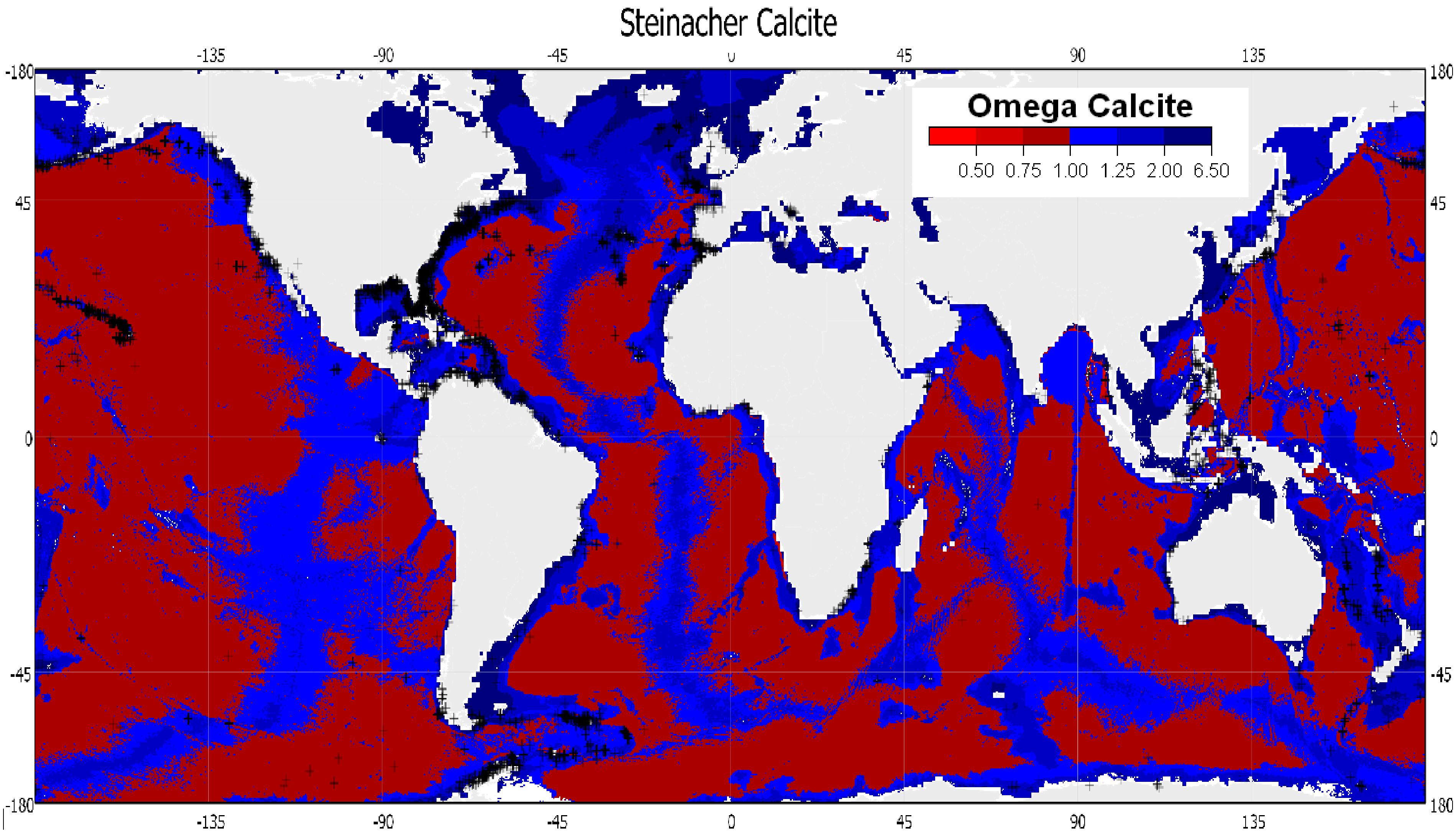
Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms

James C. Orr[1], Victoria J. Fabry[2], Olivier Aumont[3], Laurent Bopp[1], Scott C. Doney[4], Richard A. Feely[5], Anand Gnanadesikan[6], Nicolas Gruber[7], Akio Ishida[8], Fortunat Joos[9], Robert M. Key[10], Keith Lindsay[11], Ernst Maier-Reimer[12], Richard Matear[13], Patrick Monfray[1]†, Anne Mouchet[14], Raymond G. Najjar[15], Gian-Kasper Plattner[7,9], Keith B. Rodgers[1,16]†, Christopher L. Sabine[5], Jorge L. Sarmiento[10], Reiner Schlitzer[17], Richard D. Slater[10], Ian J. Totterdell[18]†, Marie-France Weirig[17], Yasuhiro Yamanaka[8] & Andrew Yool[18]

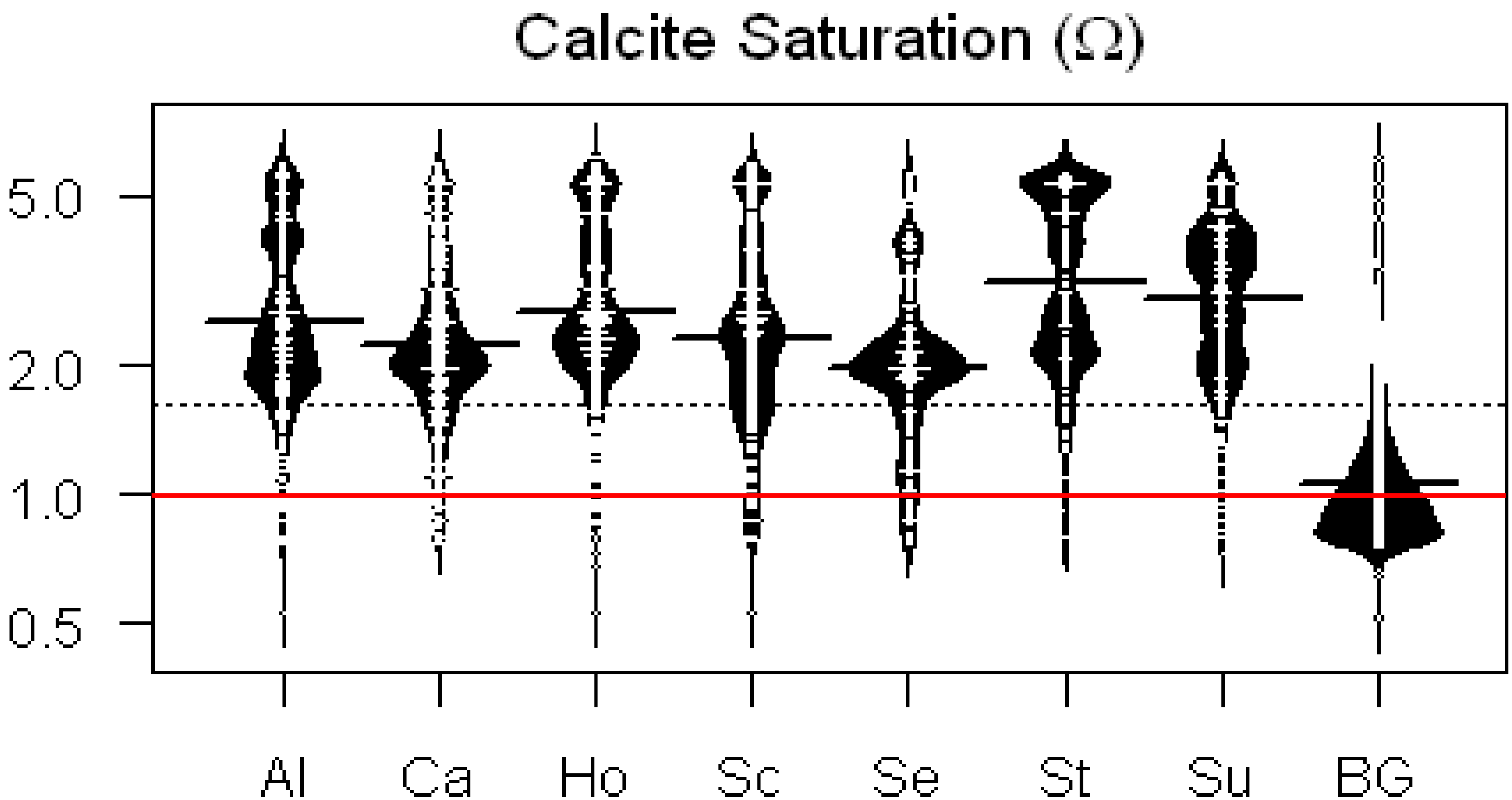




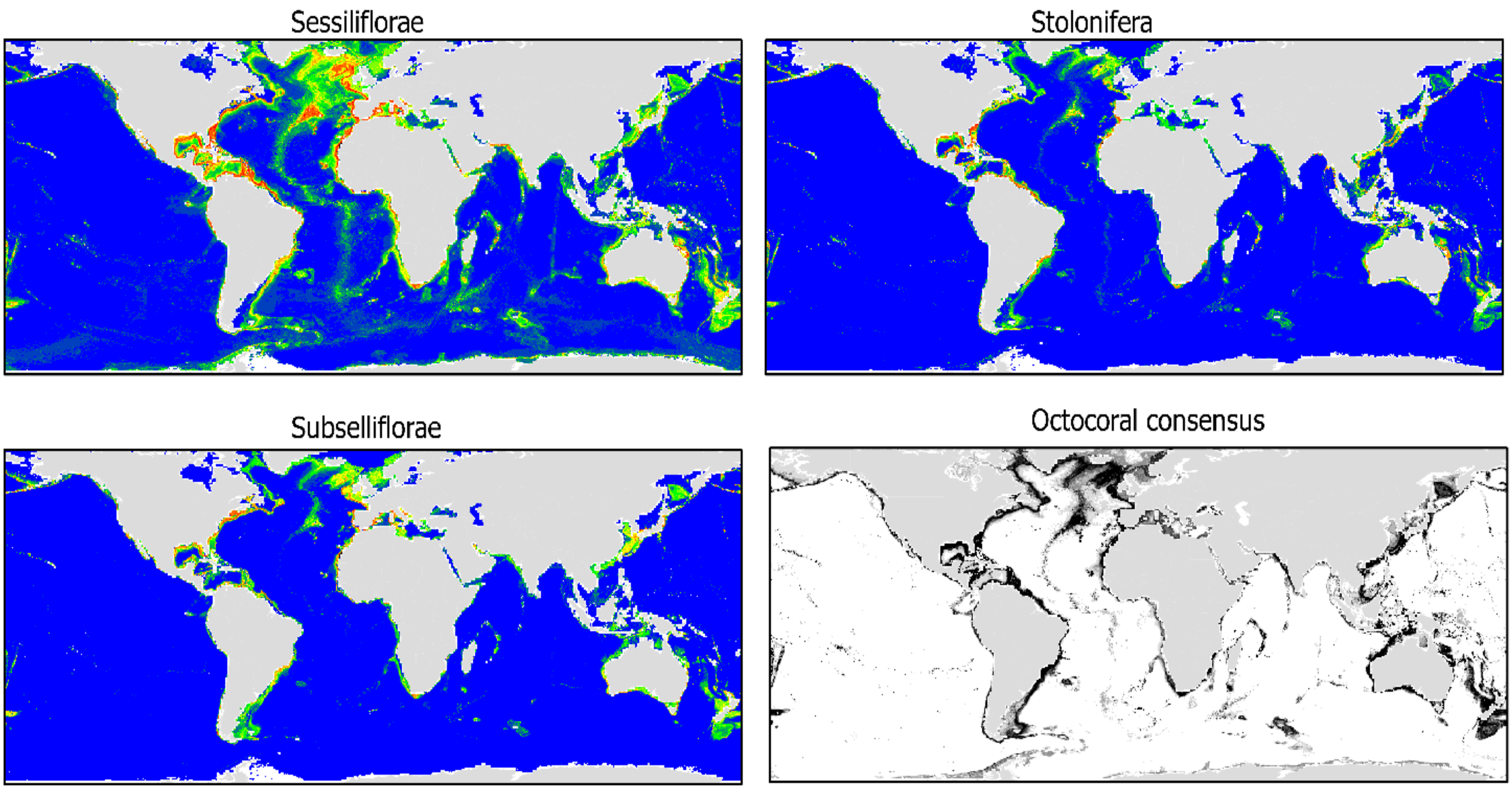
Calcite saturation at sea bottom



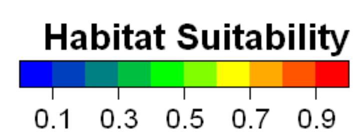
Only 3% in under saturated areas



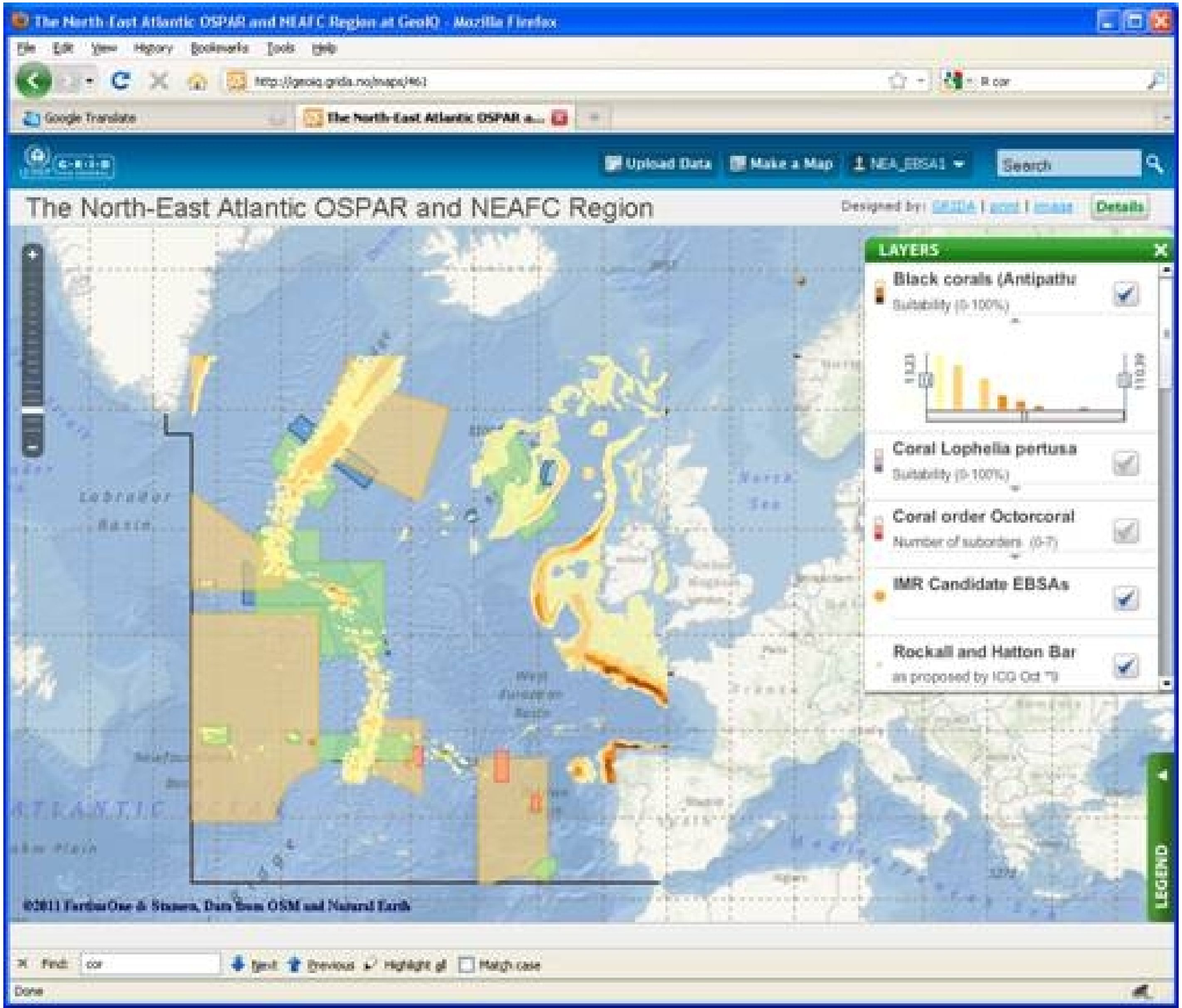
Octocoral suborders



Final model using 7 variables	Sessiliflorae	Stolonifera	Subselliflorae
AUC	**0.945**	**0.981**	**0.975**
% Ocean area suitable	11.5%	5.5%	7.9%

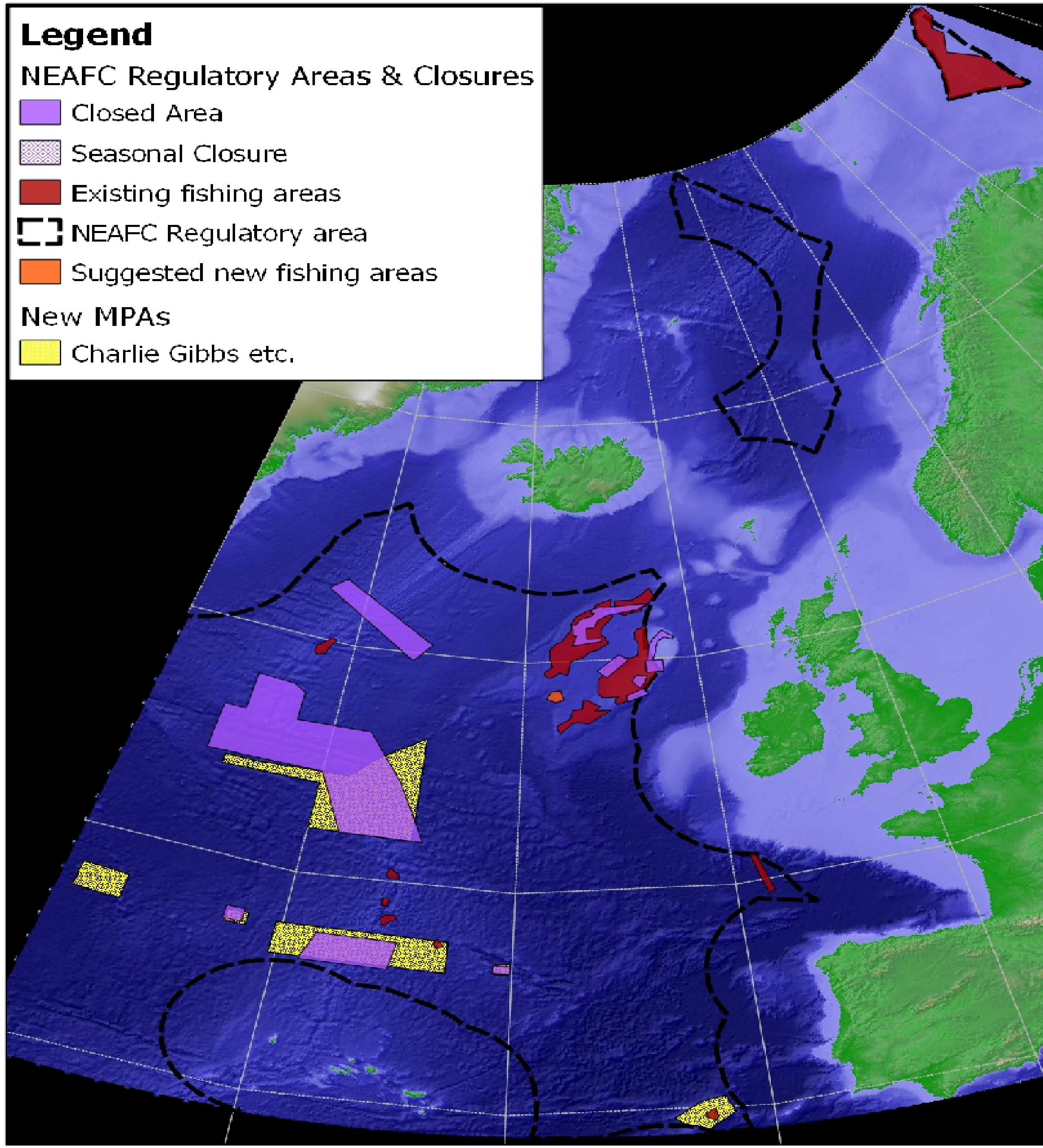


Models as tools for planning



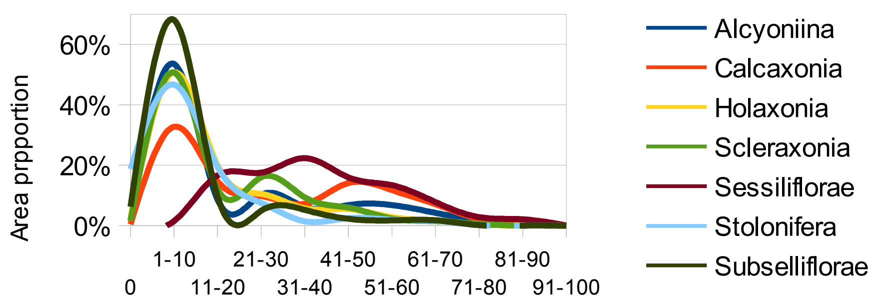
NEAFC Areas

- Some areas open to fishing
- Some areas closed
- What VMEs could be found in these areas?

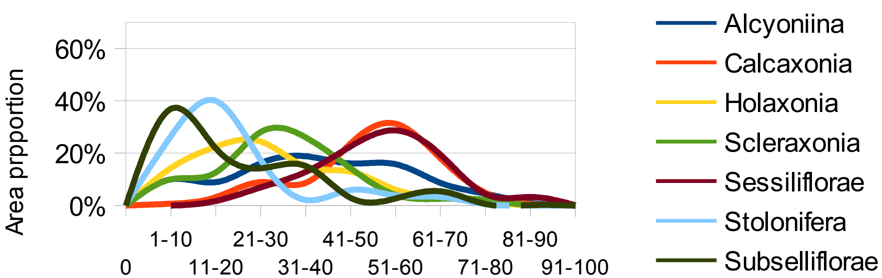


Distribution of habitat suitability

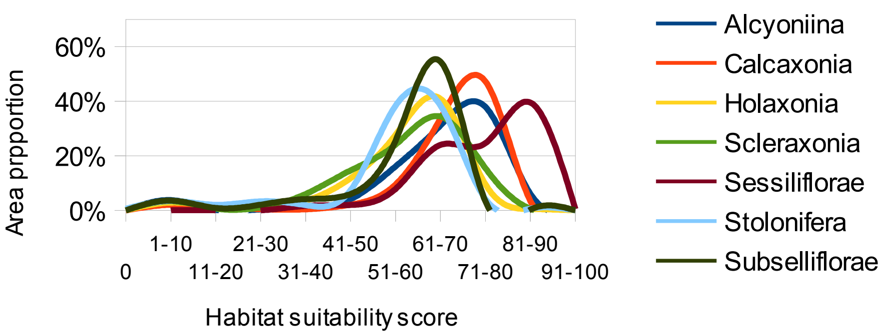
Regulatory Area

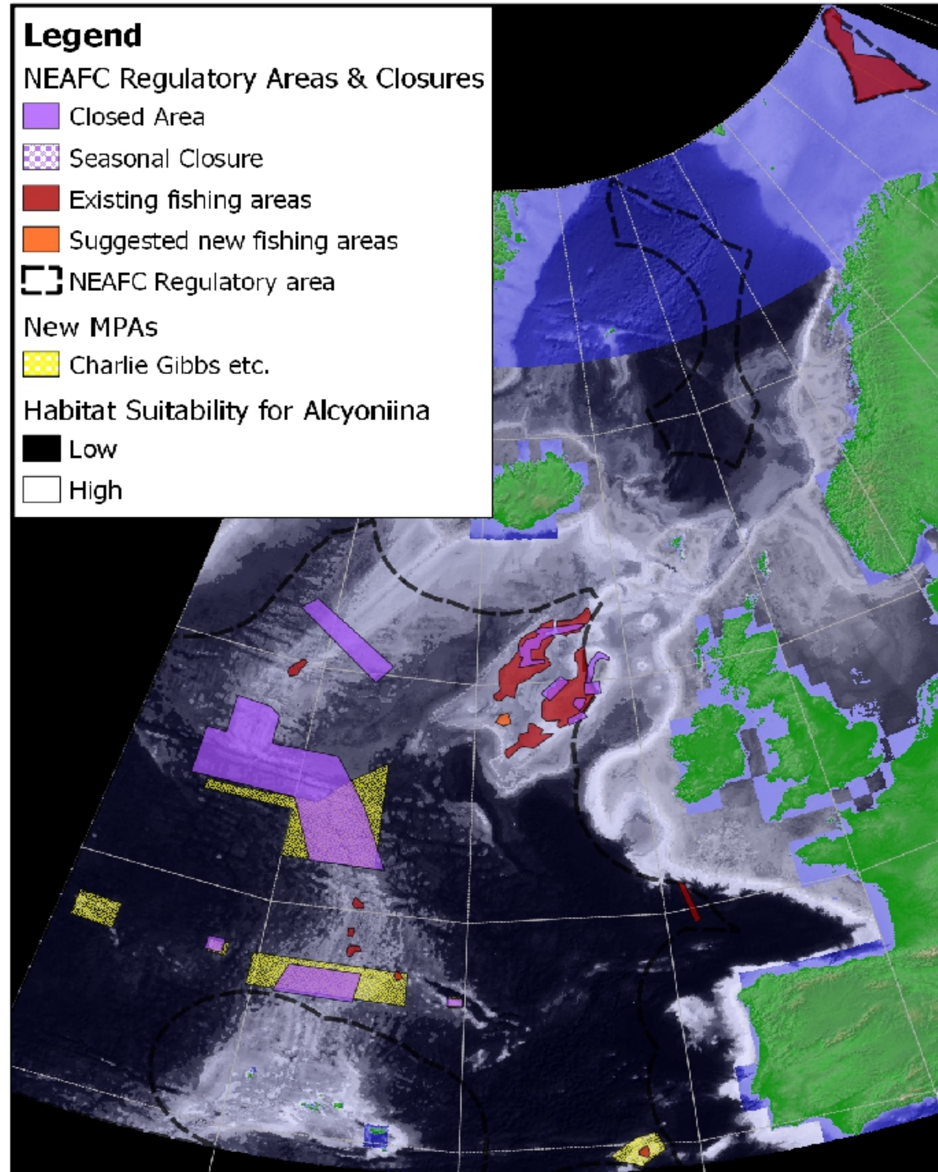


Closed Areas



Fishing Area





Which factors are important for Corals?

- Depth
- Temperature
- Ocean chemistry

Which may change in the near future?

- Depth – sea level rise
- Temperature – global warming
- Ocean chemistry - acidification

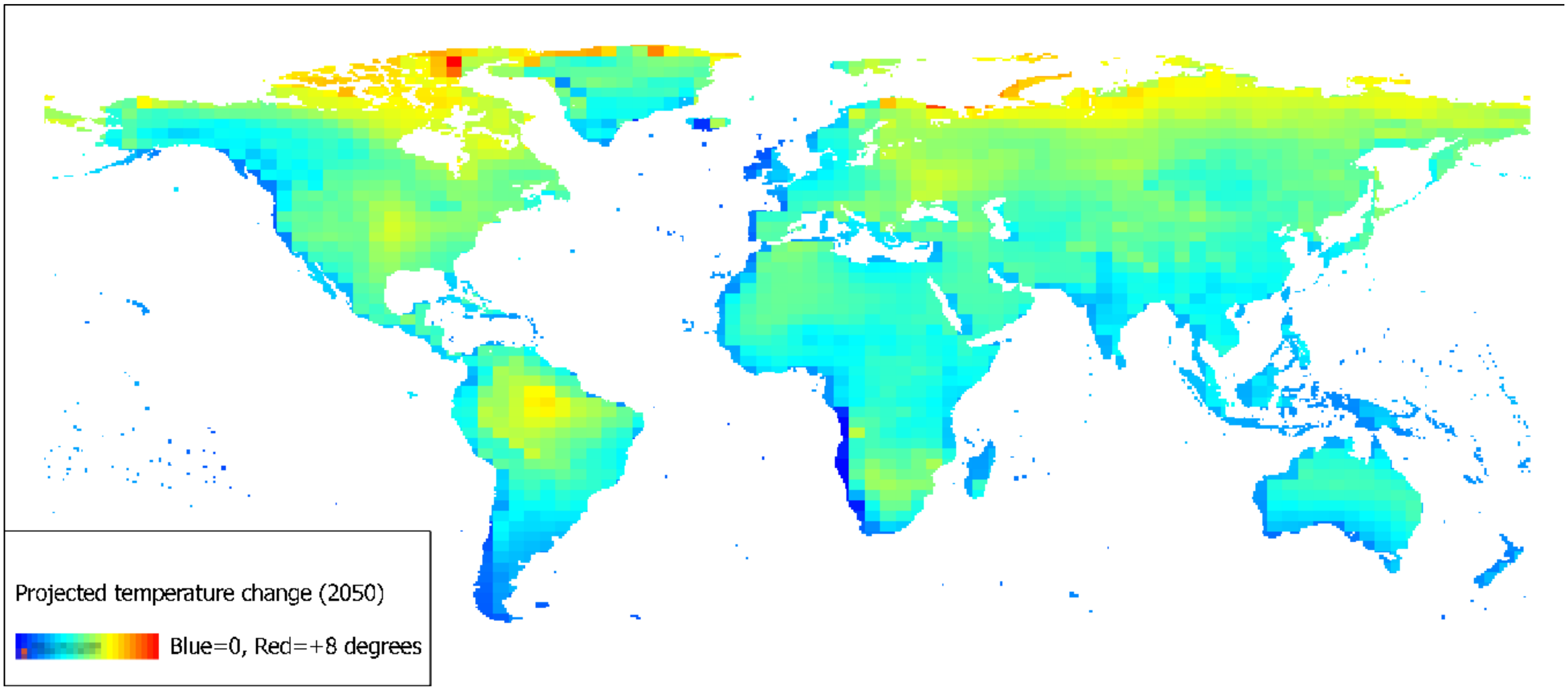
One-Third of Reef-Building Corals Face Elevated Extinction Risk from Climate Change and Local Impacts

Kent E. Carpenter,[1*] Muhammad Abrar,[2] Greta Aeby,[3] Richard B. Aronson,[4] Stuart Banks,[5] Andrew Bruckner,[6] Angel Chiriboga,[7] Jorge Cortés,[8] J. Charles Delbeek,[9] Lyndon DeVantier,[10] Graham J. Edgar,[11,12] Alasdair J. Edwards,[13] Douglas Fenner,[14] Héctor M. Guzmán,[15] Bert W. Hoeksema,[16] Gregor Hodgson,[17] Ofri Johan,[18] Wilfredo Y. Licuanan,[19] Suzanne R. Livingstone,[1] Edward R. Lovell,[20] Jennifer A. Moore,[21] David O. Obura,[22] Domingo Ochavillo,[23] Beth A. Polidoro,[1] William F. Precht,[24] Miledel C. Quibilan,[25] Clarissa Reboton,[26] Zoe T. Richards,[27] Alex D. Rogers,[28] Jonnell Sanciangco,[1] Anne Sheppard,[29] Charles Sheppard,[29] Jennifer Smith,[1] Simon Stuart,[30] Emre Turak,[10] John E. N. Veron,[10] Carden Wallace,[31] Ernesto Weil,[32] Elizabeth Wood[33]

The conservation status of 845 zooxanthellate reef-building coral species was assessed by using International Union for Conservation of Nature Red List Criteria. Of the 704 species that could be assigned conservation status, 32.8% are in categories with elevated risk of extinction.

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)

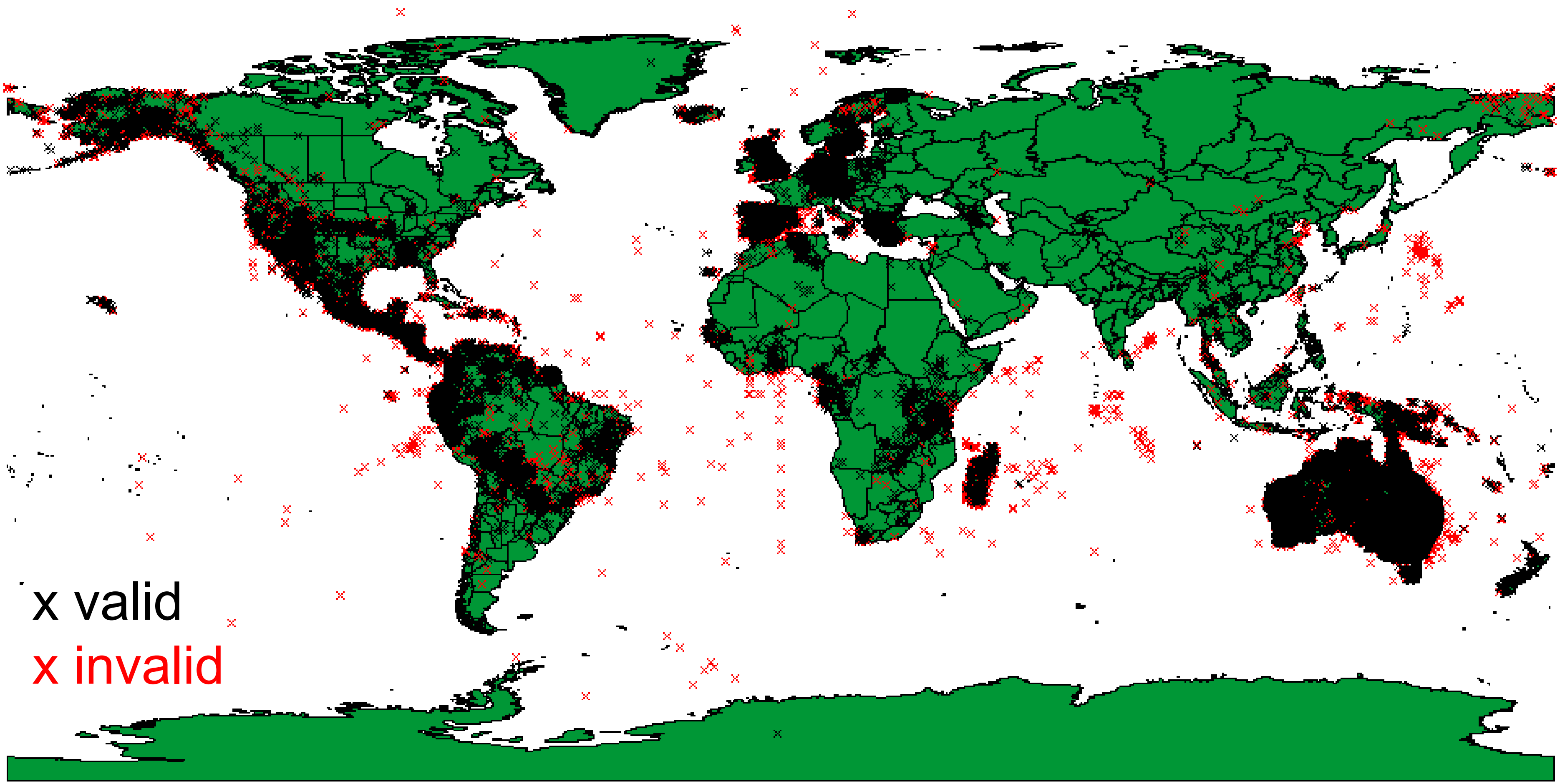
- How will climate change affect global diversity?



Legumes – assessing global diversity

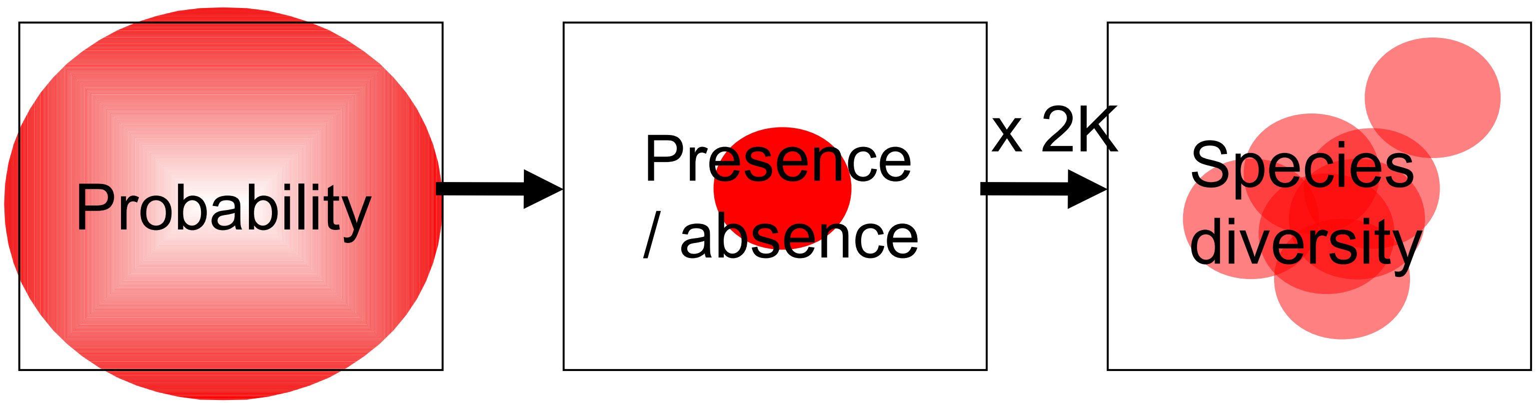
ZSL

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

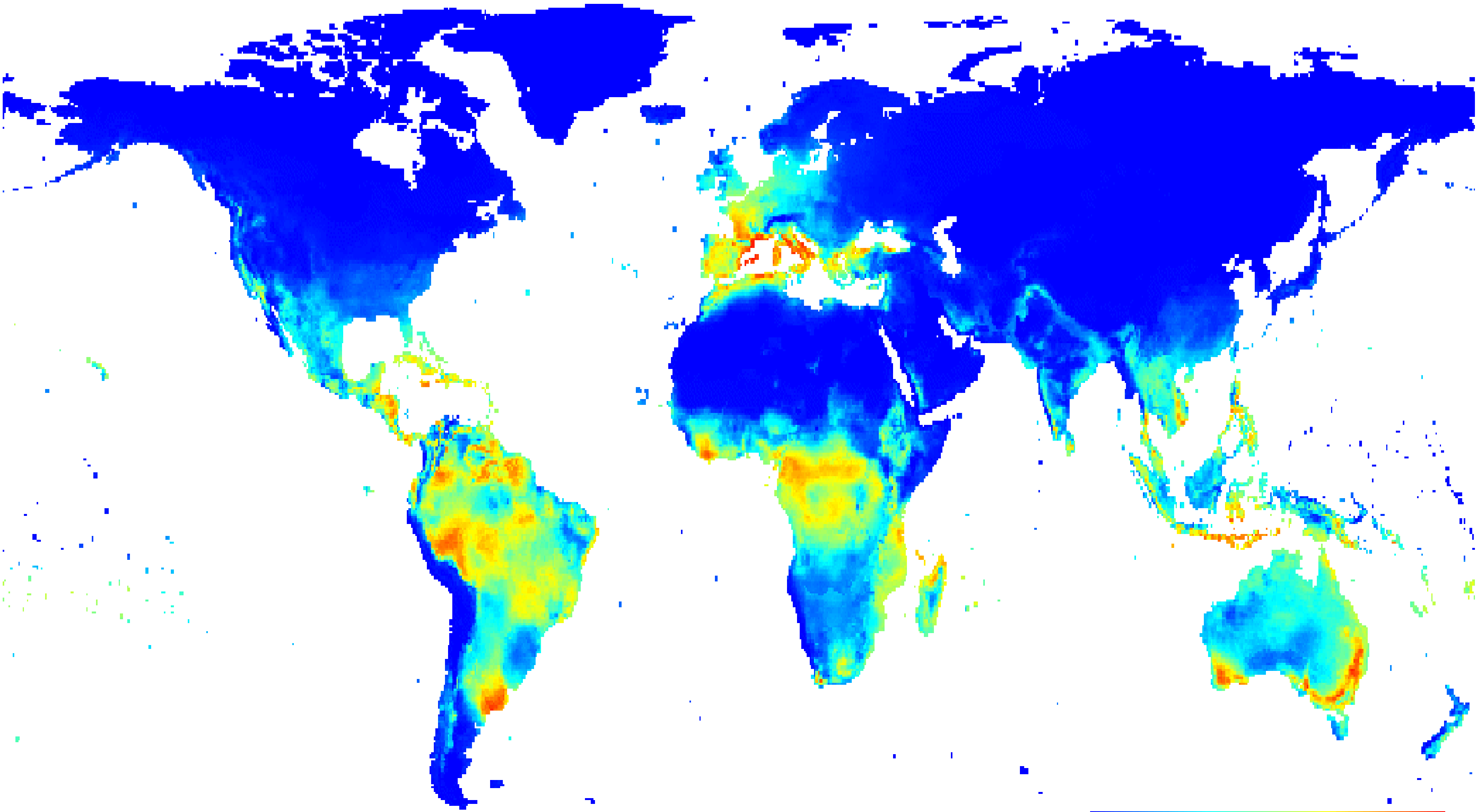


Legumes

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

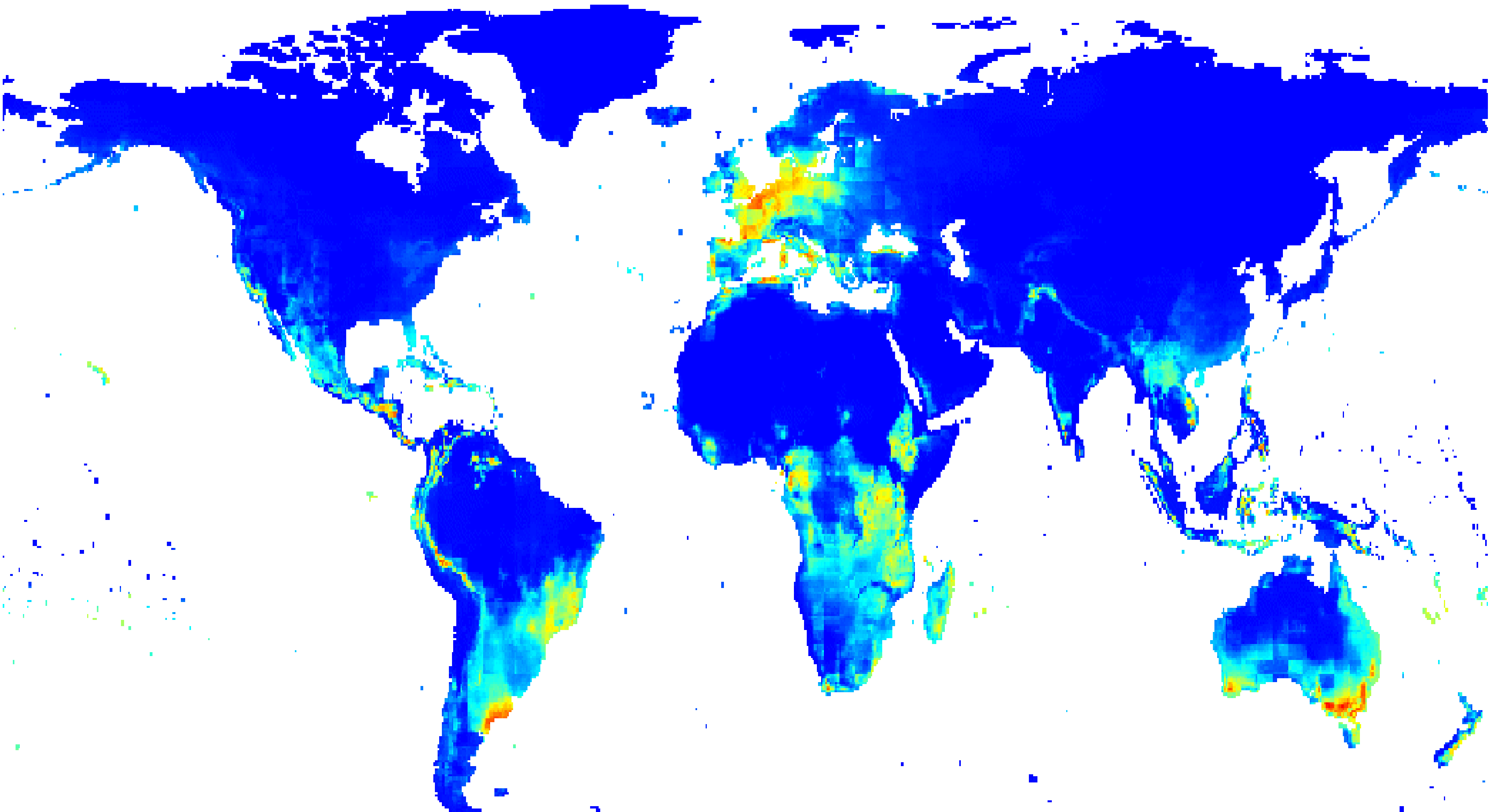


Estimating change in diversity



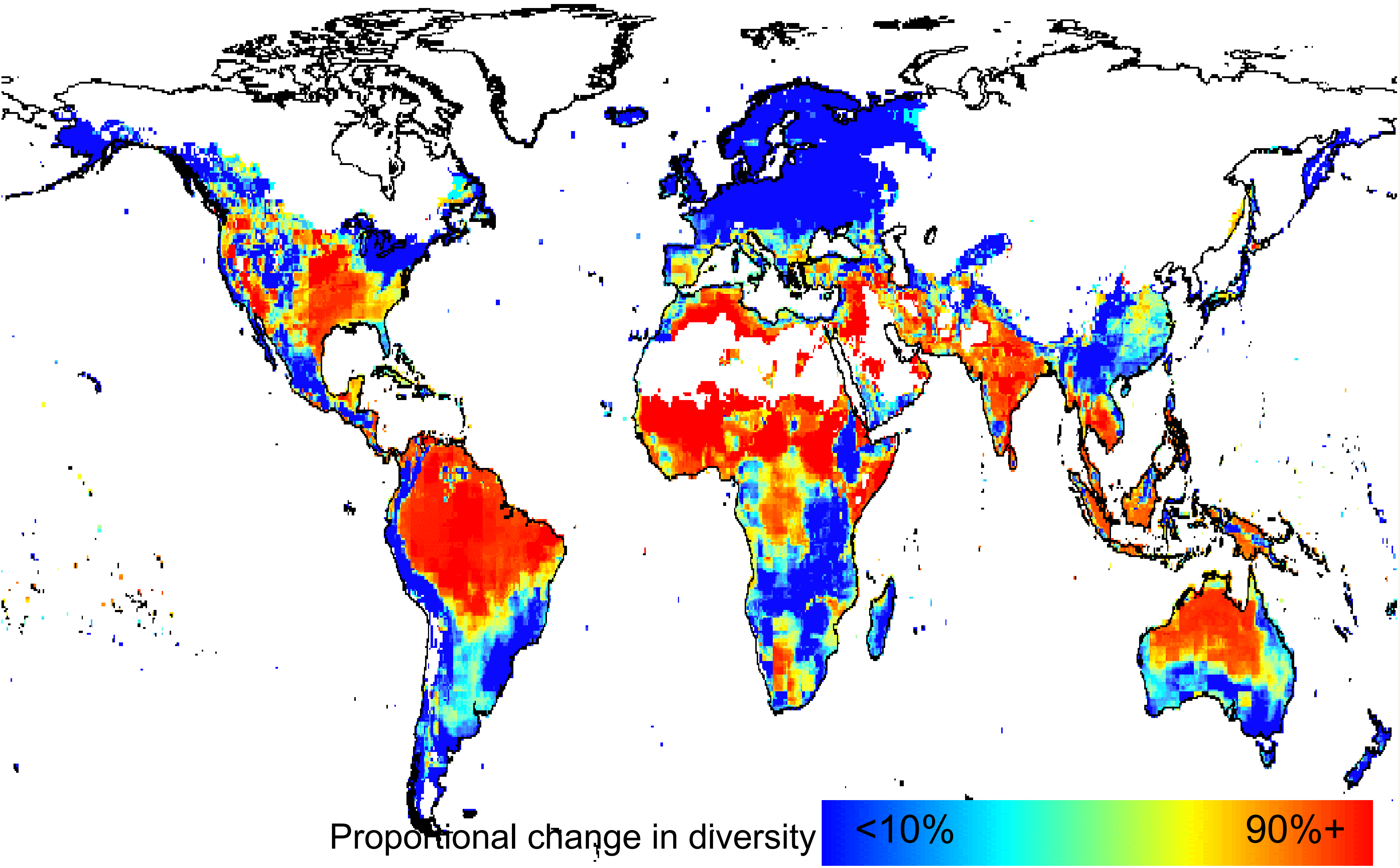
Present Legume diversity,

Estimating change in diversity

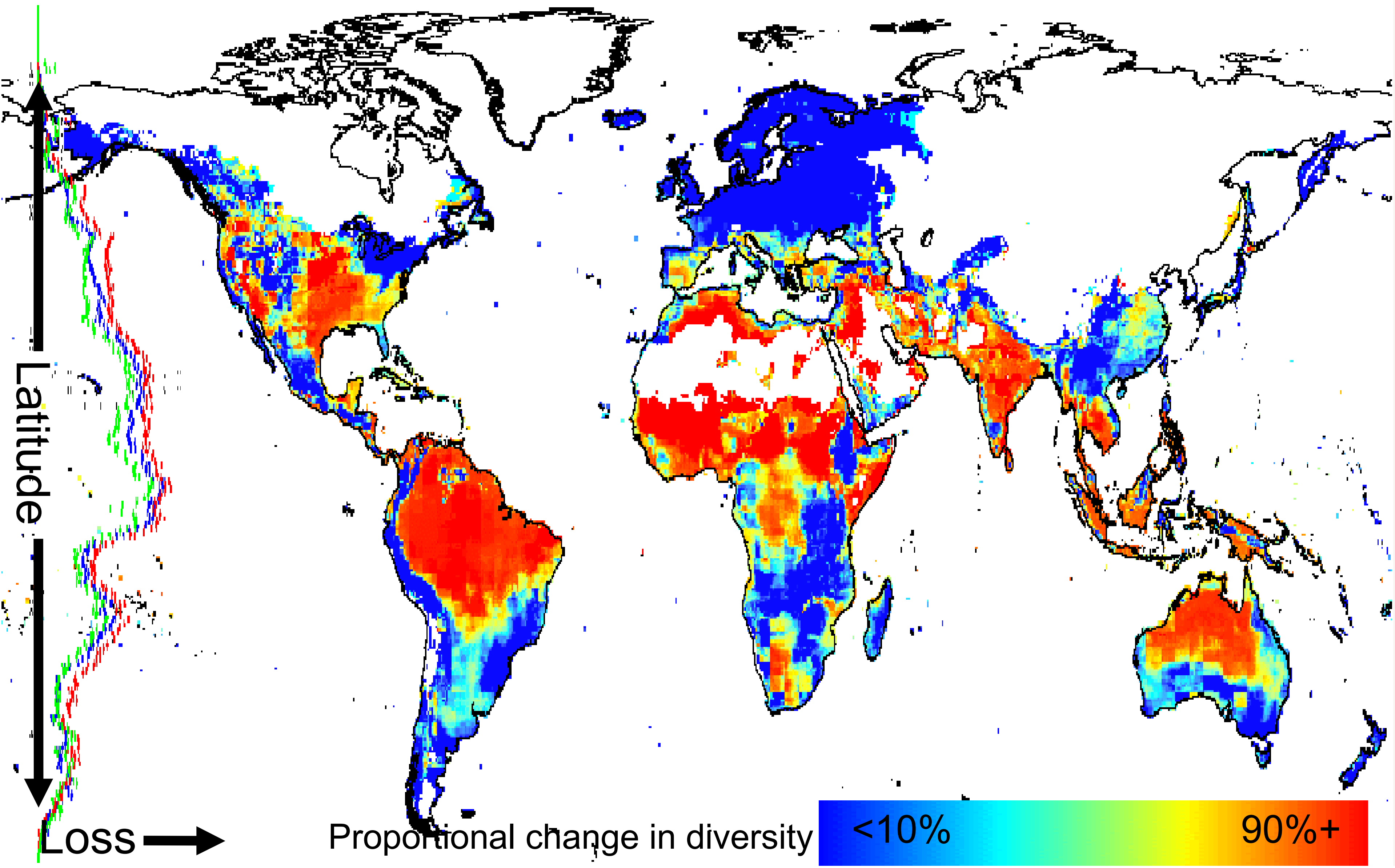


Predicted Legume diversity 2050

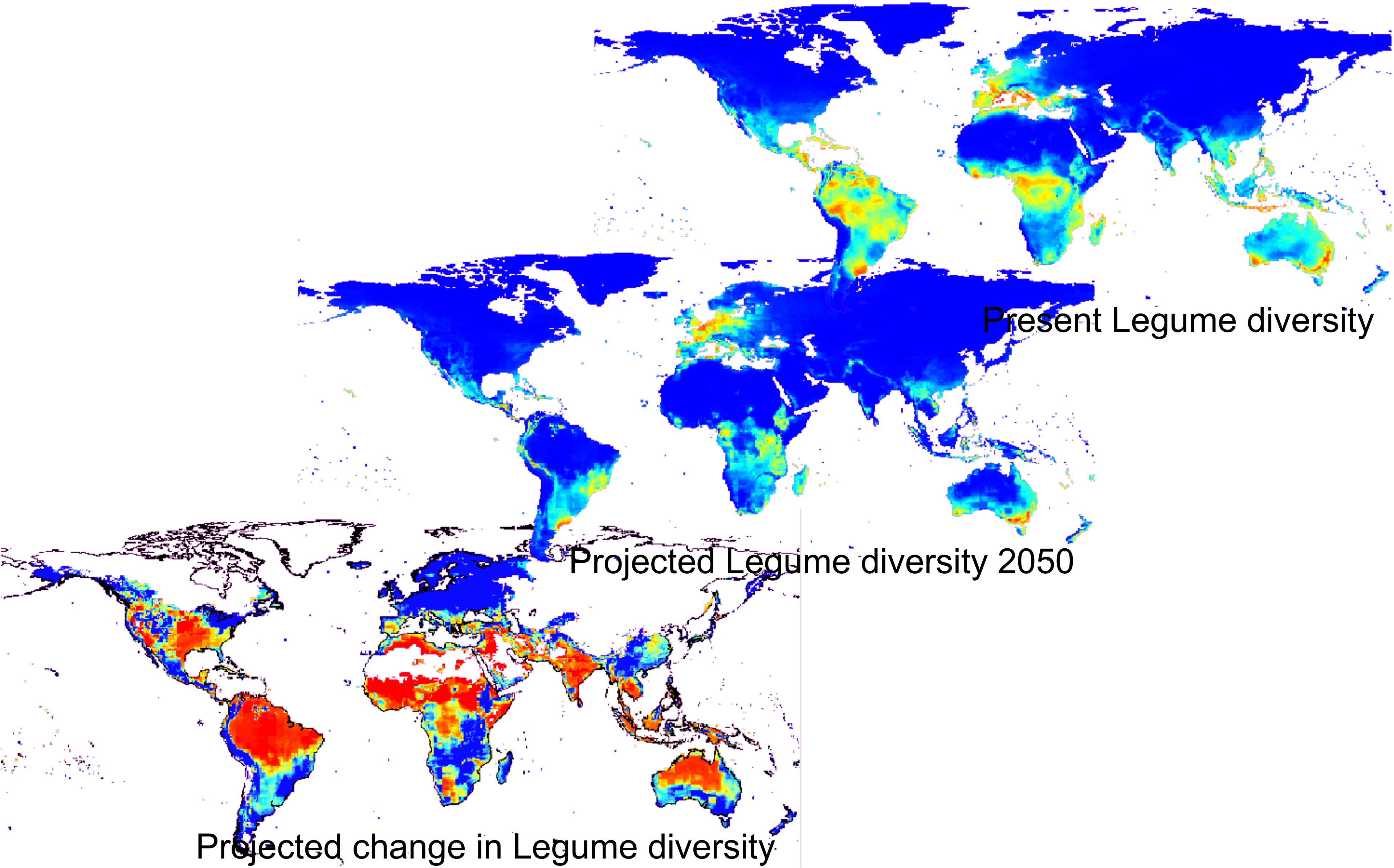
Estimating change in diversity



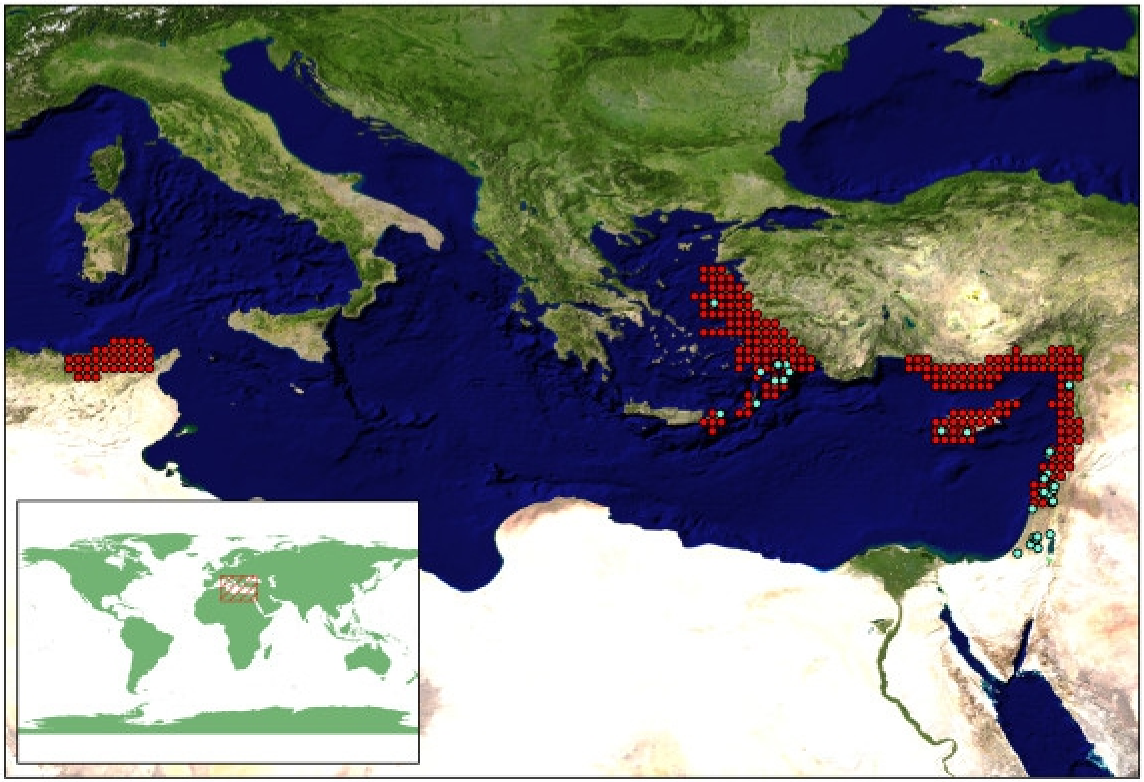
Estimating change in diversity



Estimating change in diversity

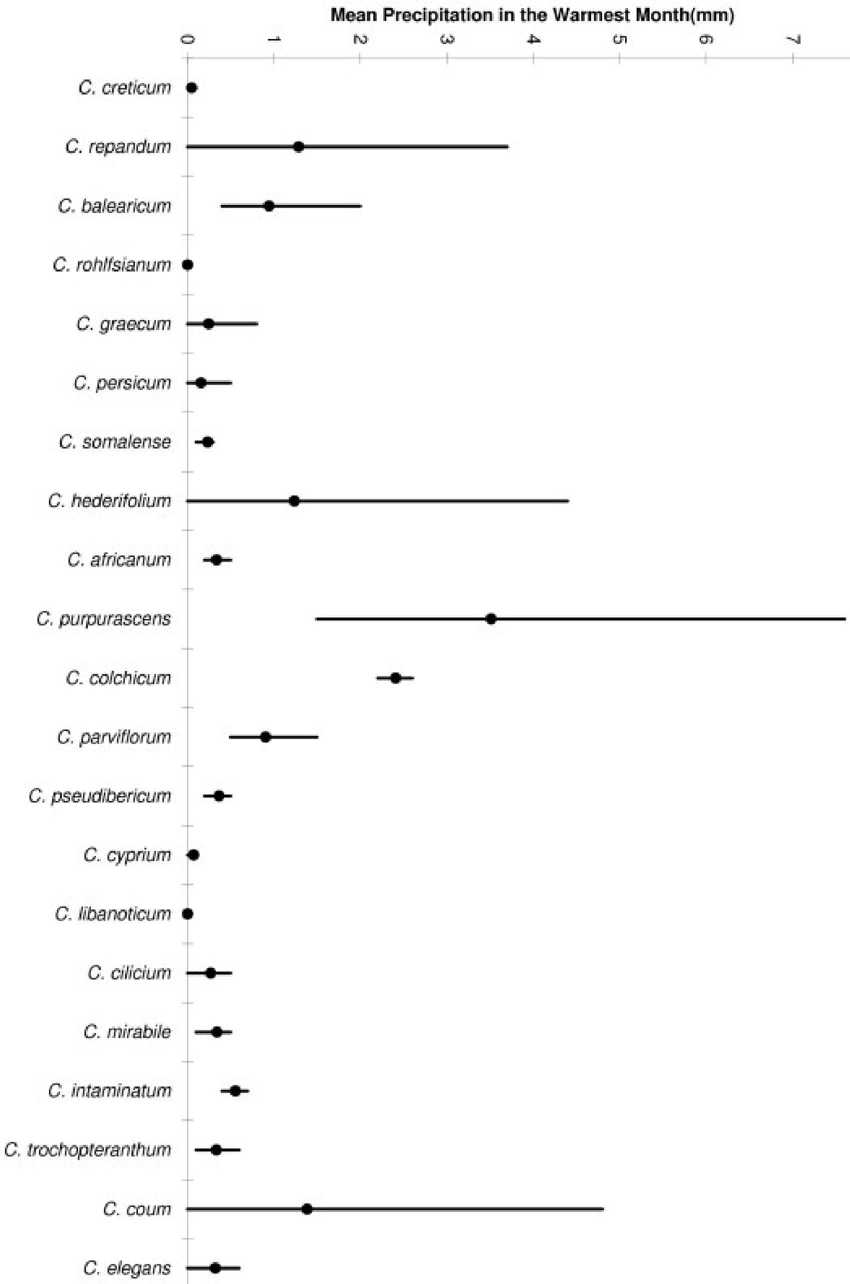


Adding a phylogenetic perspecitve



***Cyclamen persicum* distribution data**. Observed point data (pale blue) and points extrapolated from distribution map (red) for *C. persicum.* Blue Marble satellite image.

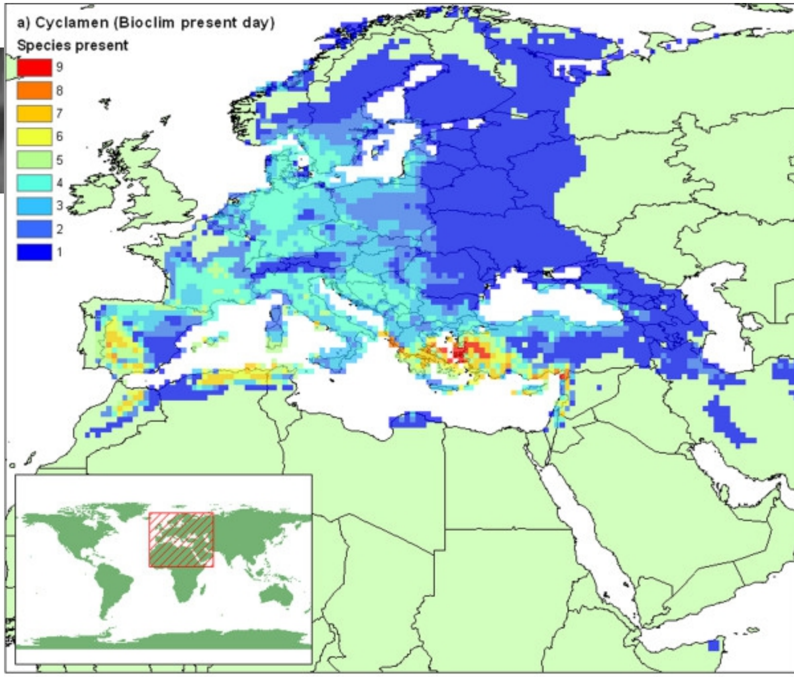
Model detail

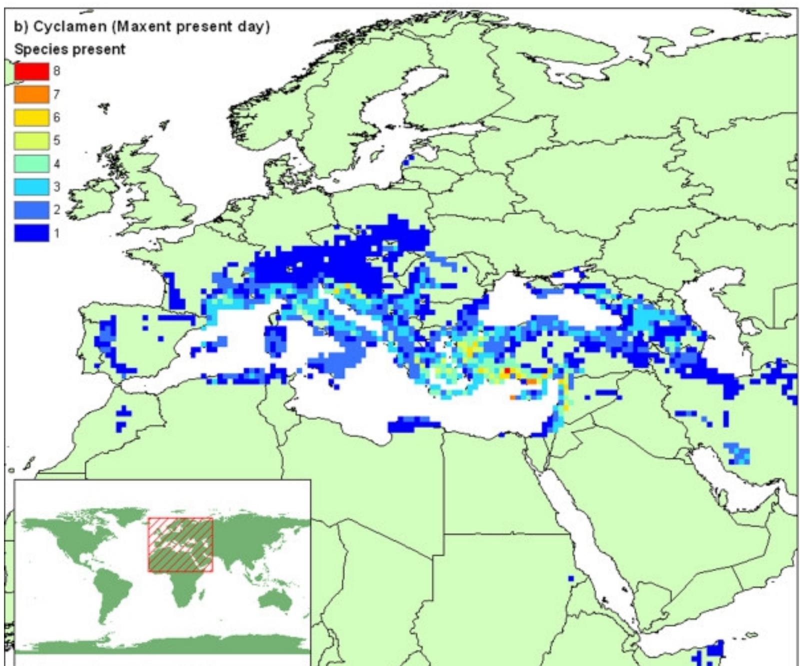


Range of summer precipitation

Range of the climatic variable: “mean daily precipitation in the warmest month”

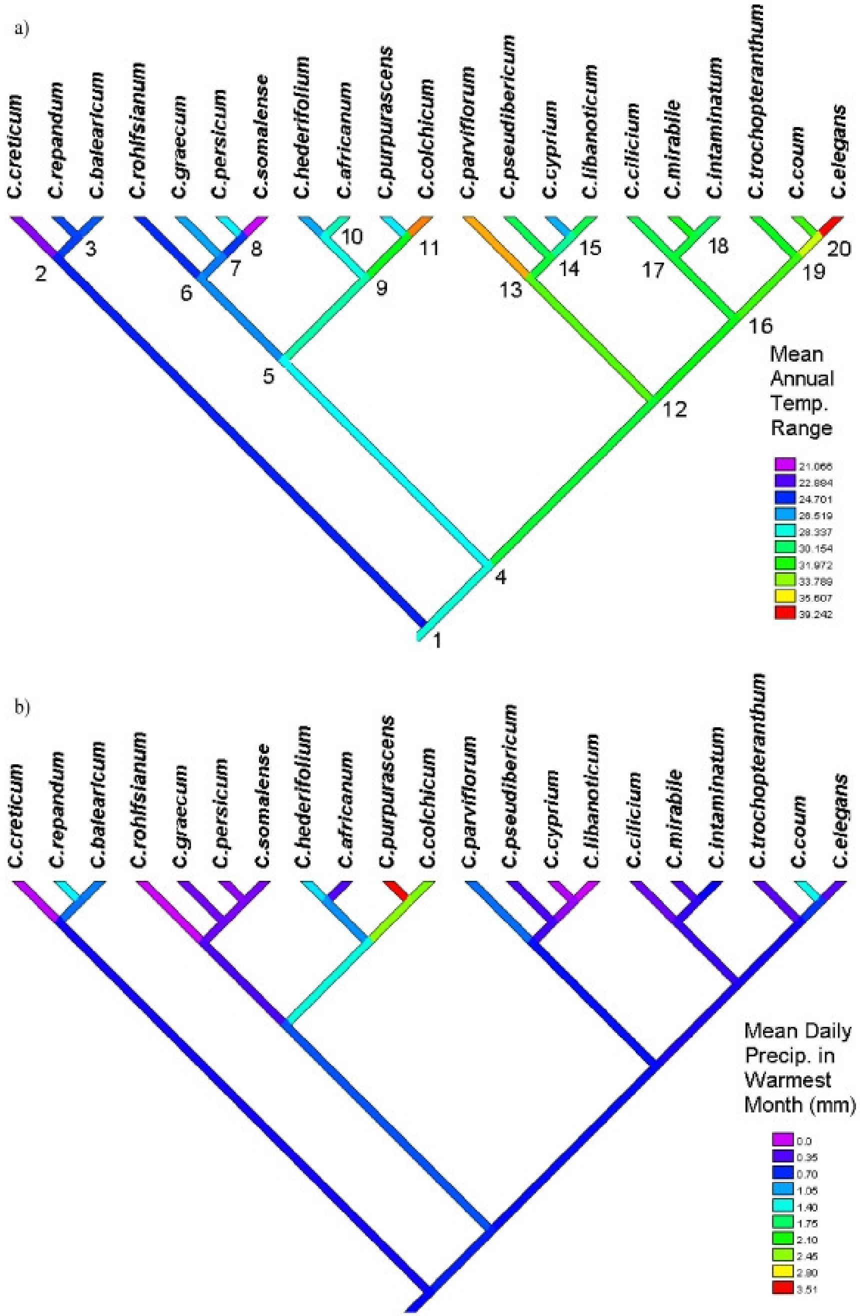
Different models





Modelled *Cyclamen* diversity
Species diversity mapped on 1/4 degree grid squares, generated by cumulative overlaying climatically of suitable areas for individual species defined by
a)BIOCLIM
b)Maxent models.

Phylogenetic pattern?



Square change parsimony optimisation of

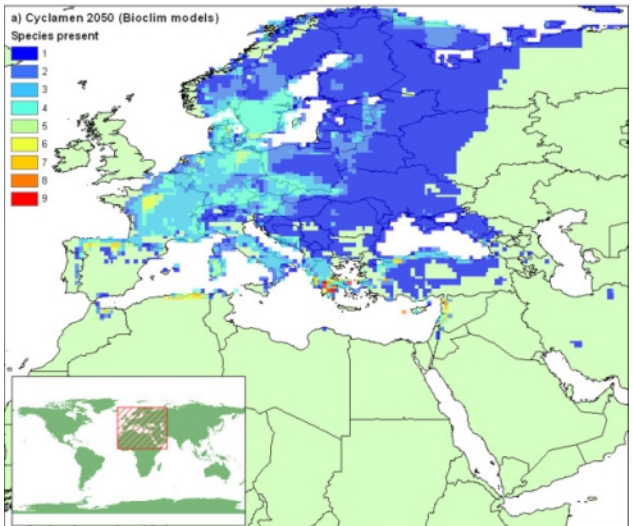
a)Mean Annual Temperature Range (°C), (QVI = 0.37)*.

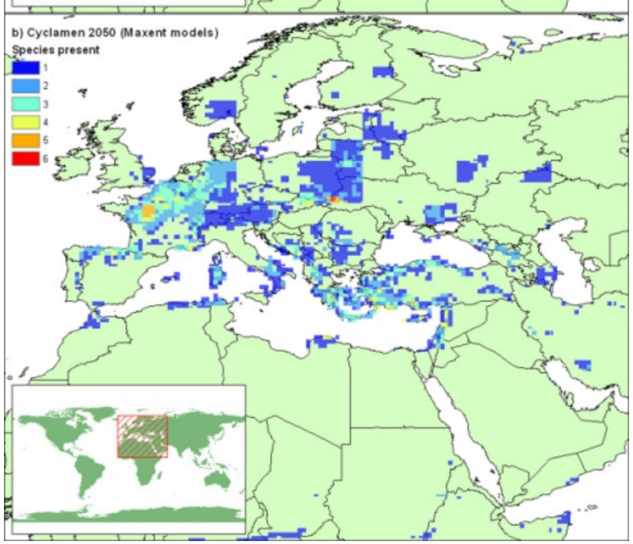
b)Mean daily precipitation in the warmest month (QVI = 0.26)*.

* Both variables show QVI significantly different from random.

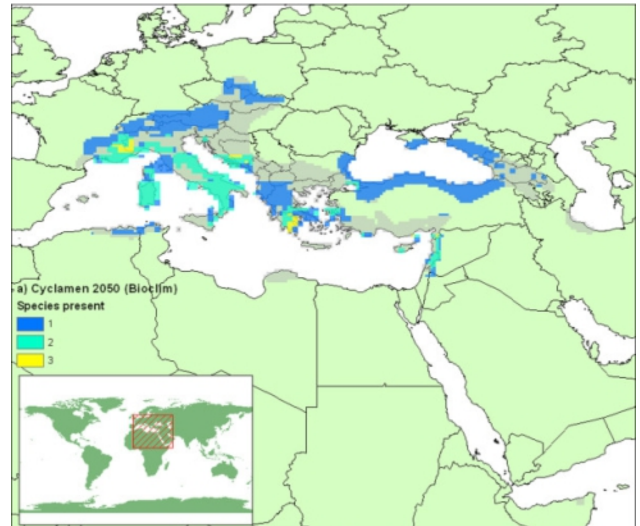
Modelling the future

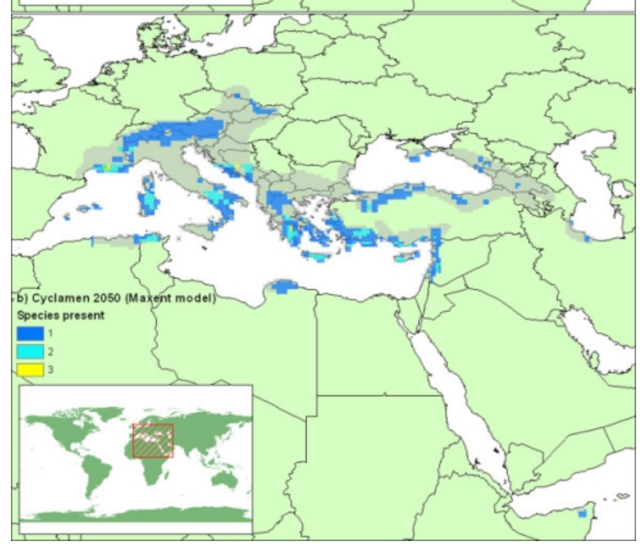
Unlimited Dispersal





Limited Dispersal





Extinction Risk

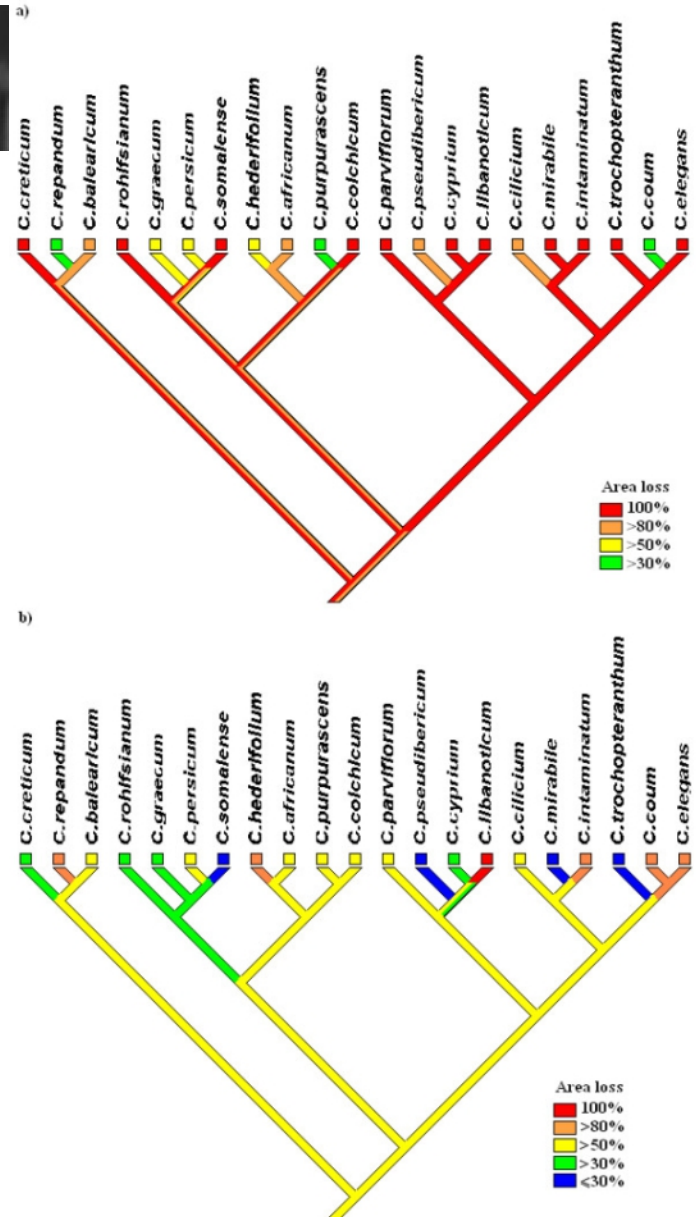
Parsimony optimisation of extinction risk for *Cyclamen*

Parsimony optimisation of extinction risk based on examination of models within 2050 scenario for:

a) BIOCLIM

b) Maxent

Characters treated as ordered, Analysis performed in Mesquite

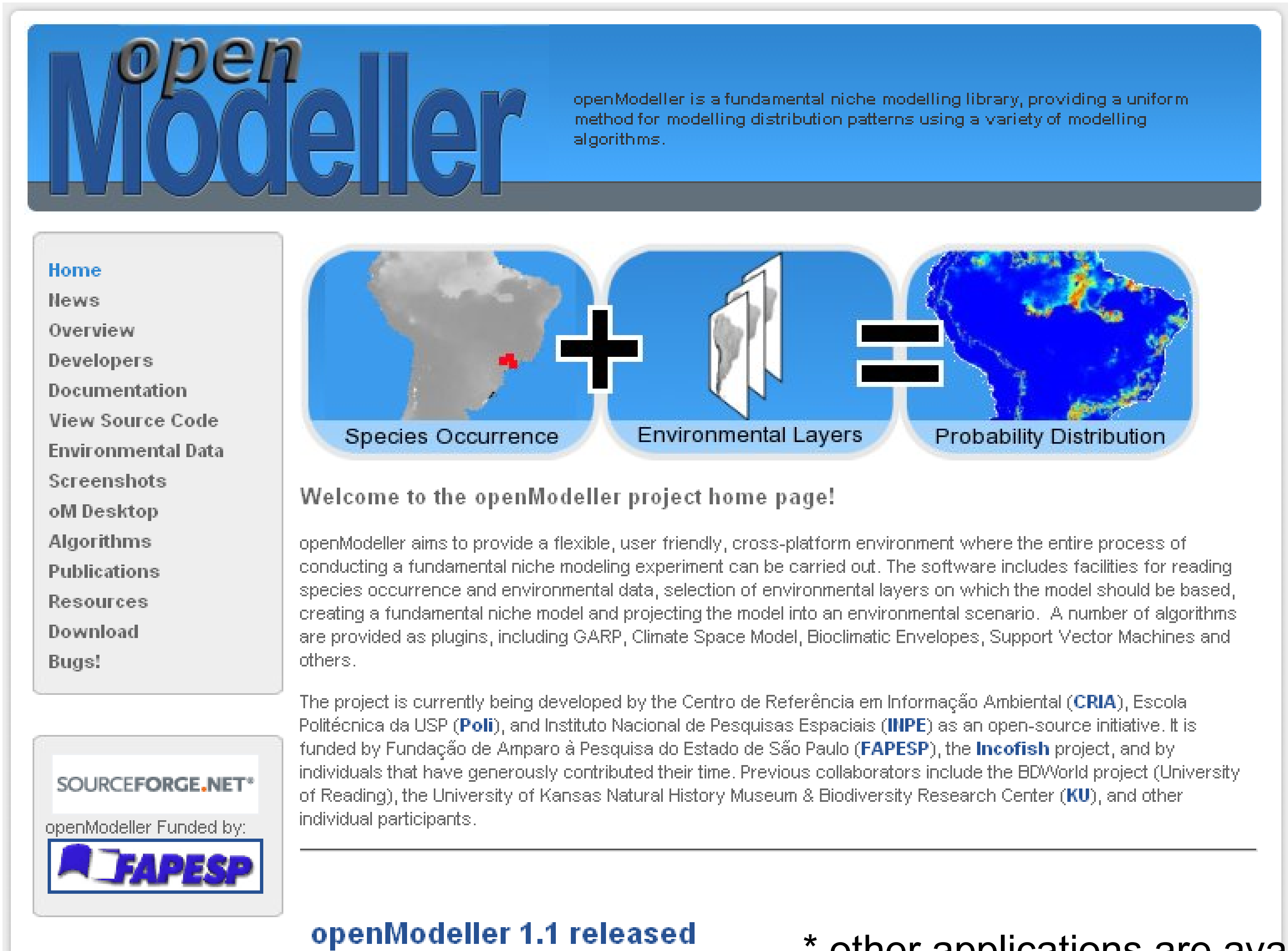


Conclusion

- Estimating distributions is useful due to a lack of data

- Estimating distributions is difficult (see left)

Many algorithms, one interface*



* other applications are available