Reconstructing species' range dynamics using SDMs

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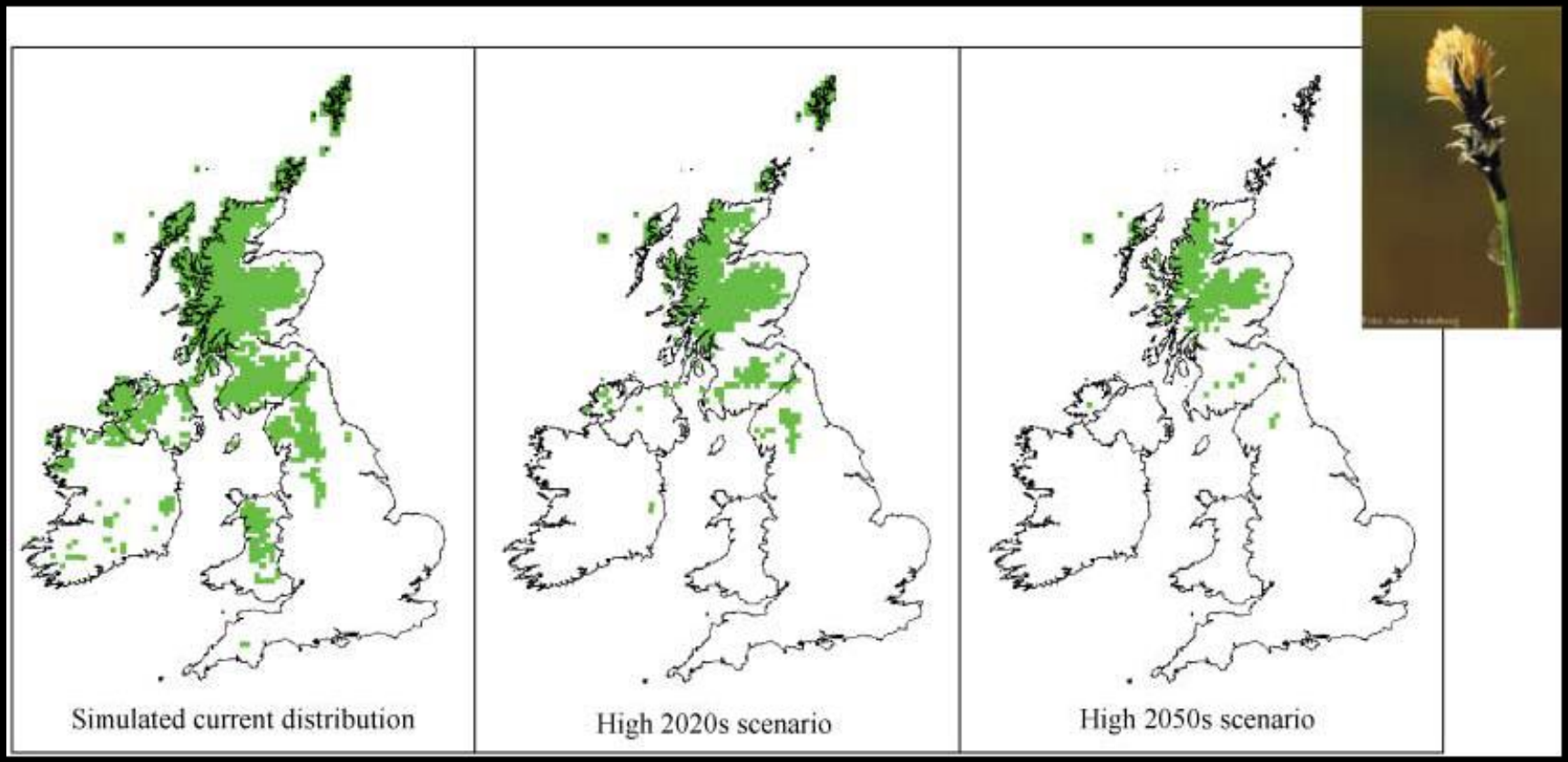
PhD Course on Species Distribution Modelling
Sandbjerg, Denmark, August 2010

Forecasting the effects of global change



Pearson & Dawson (2003) *Global Ecol & Biog*

Hindcasting past species ranges

- Species range dynamics

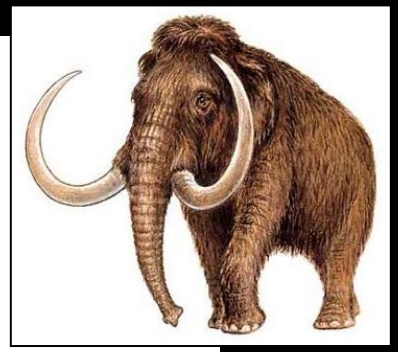
  migration, glacial refugia, range limits

- Consequences of past climate changes

  extinction, range size

- Speciation / Differentiation

The extinction of the Woolly Mammoth

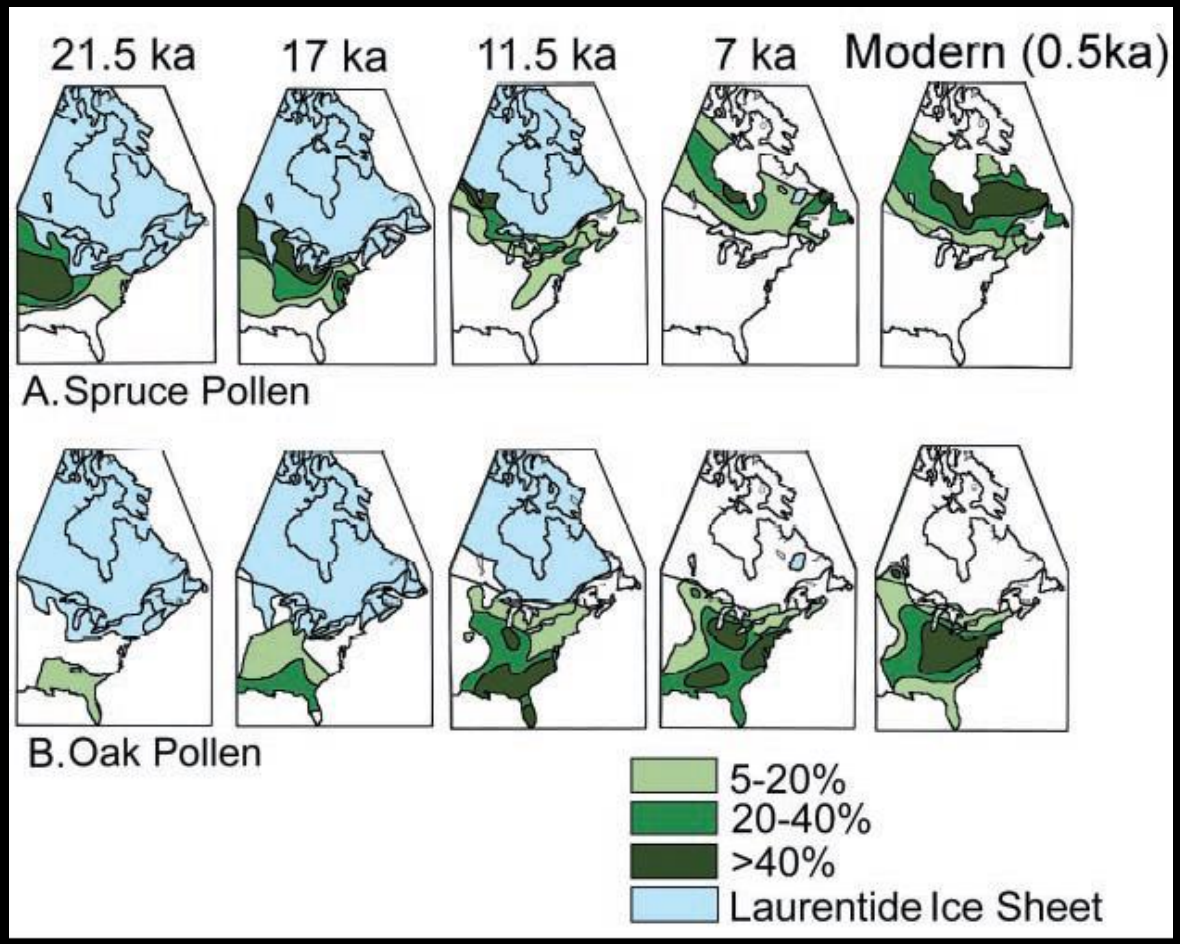


Nogués-Bravo et al. (2008) *PLoS Biol*

Main approaches to reconstruct species ranges

1. Fossil record
2. Phylogeography
3. Species Distribution Models (SDMs)

The fossil record

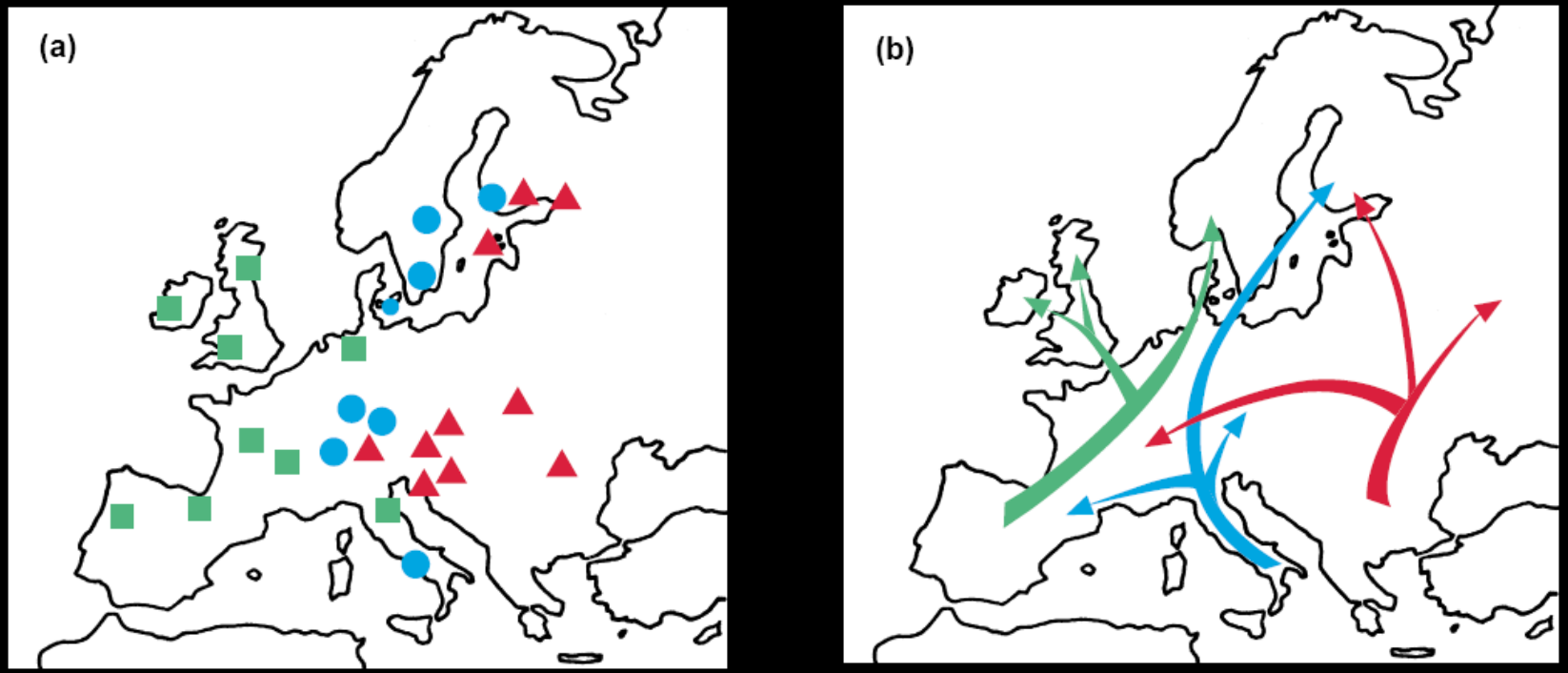


Davis & Shaw (2001) *Science*

Limitations of the fossil record

- Scarcity of data (time-space)
- Low power for rare species
- Uncertainty (spatial, temporal & taxonomic)

Phylogeography

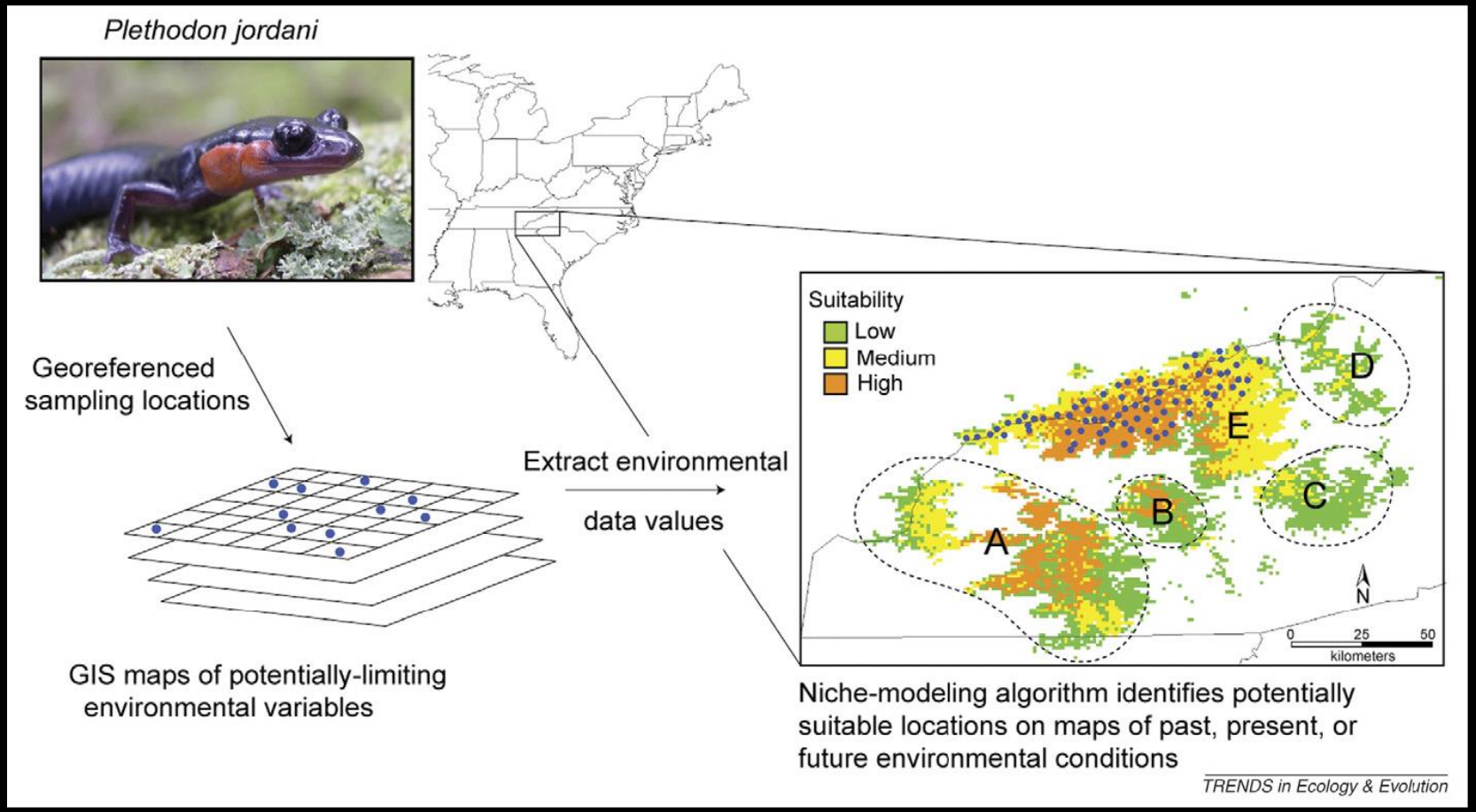


Comes & Kadereit (1998) *Trends Plant Sci.*

Limitations of phylogeographical approaches

- Costly (field sampling & lab work)
- Resolution determined by sampling effort and genetic variation
- Gene trees ≠ Species tree
- Lack of time scale (unless molecular dating)
- Patterns vs processes (but coalescence)

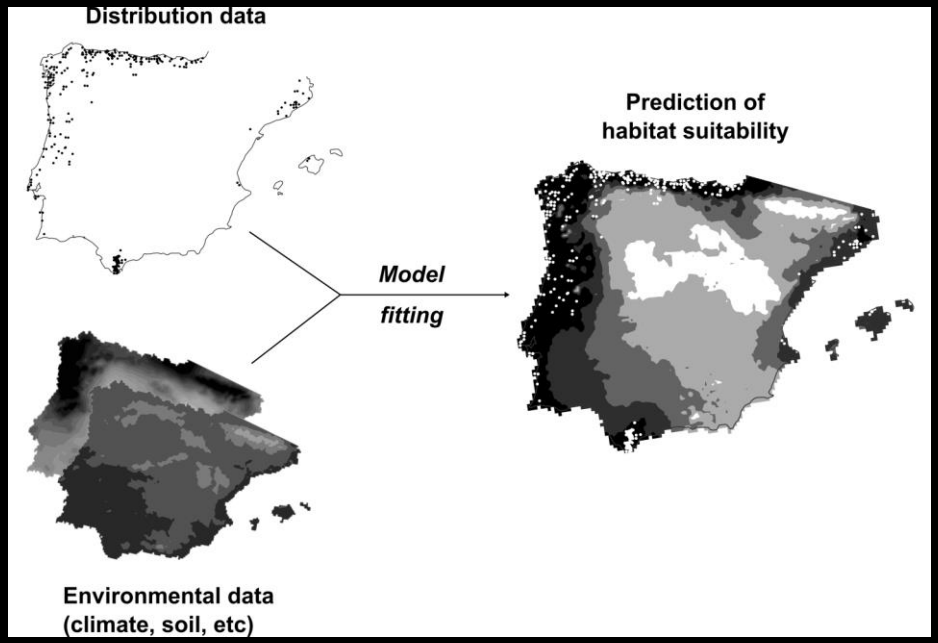
Species Distribution Models



Kozak et al. (2008) *TREE*

Projecting SDMs across time

1. Calibration: current distribution and climate
2. Projection to past or future climates

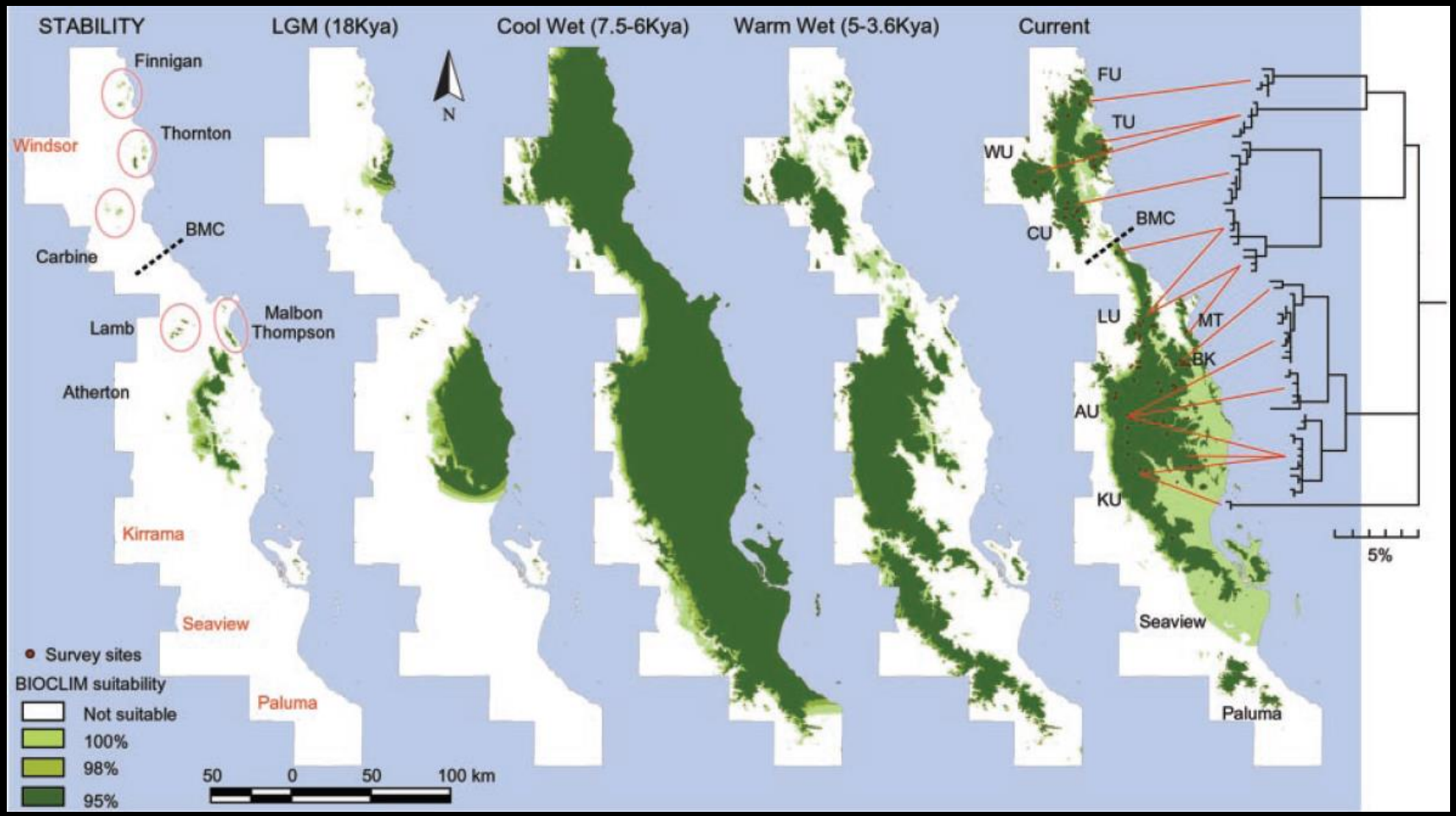


Data sources:

Future: IPCC

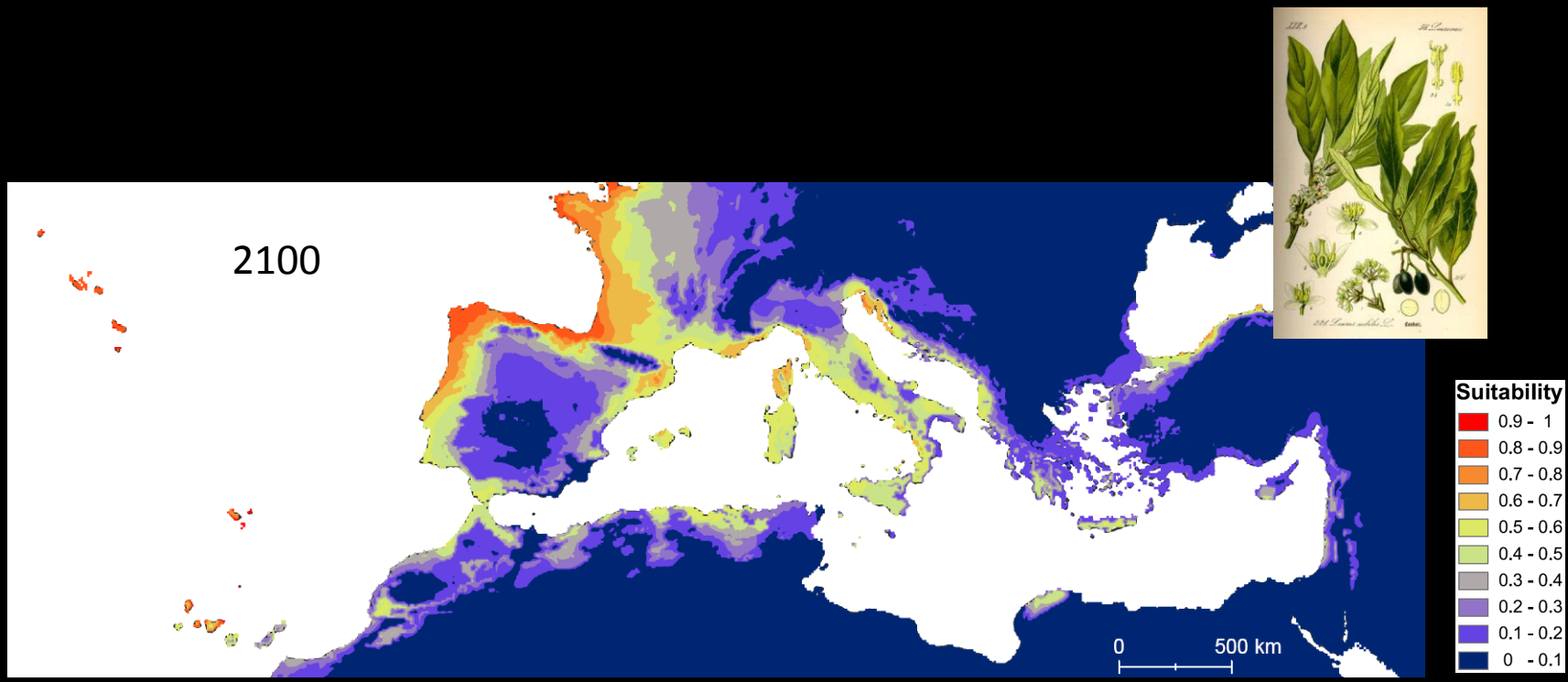
Past: PMIP2, BRIDGE, etc

Reconstructing species' range dynamics



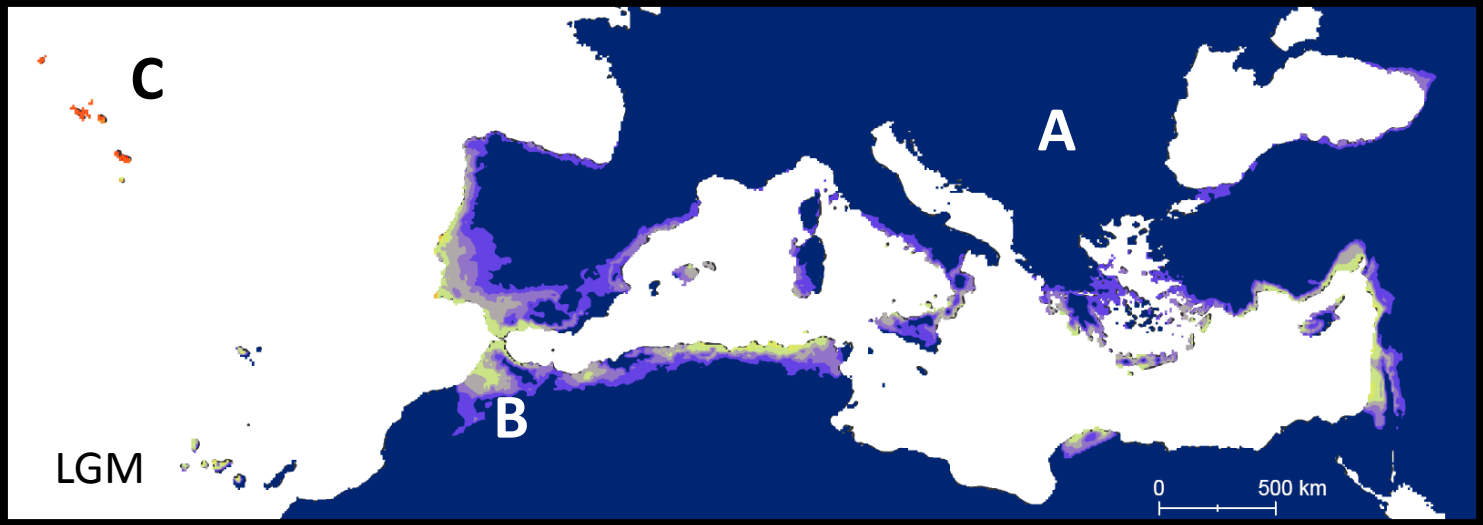
Hugall et al. (2002) *PNAS*

Laurus range dynamics over 3 Myr



Rodríguez-Sánchez & Arroyo (2008) *Global Ecol & Biog*

Interpreting projections from SDMs



1. Was the species present in A?
2. Was the species present in B?
3. Can we be more certain of species presence in C than in B?

Issues with projections of SDMs across time

First of all, we need a good model for the present

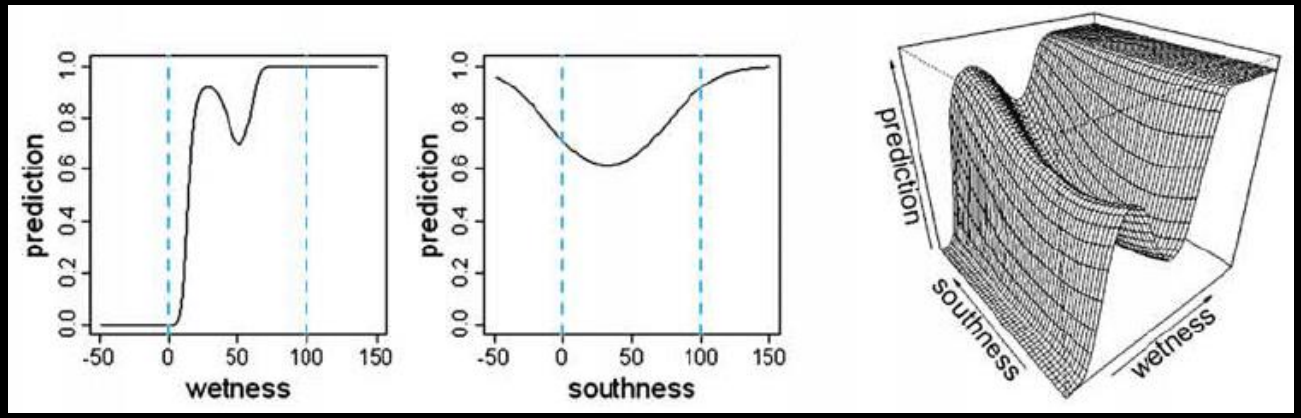
- Sample size
- Geographic coverage
- Environmental data
- Good predictive ability

Issues with projections of SDMs across time

- Choice of predictors
- Equilibrium of species distribution with climate
- Intraspecific niche differentiation
- Constancy of species-environment relationships
- Non-analog climates
- Uncertainty
- Validation

Choice of predictors

- Proximal *vs* distal predictors
  - Minimum temperature *vs* elevation, aspect…
- Check response curves

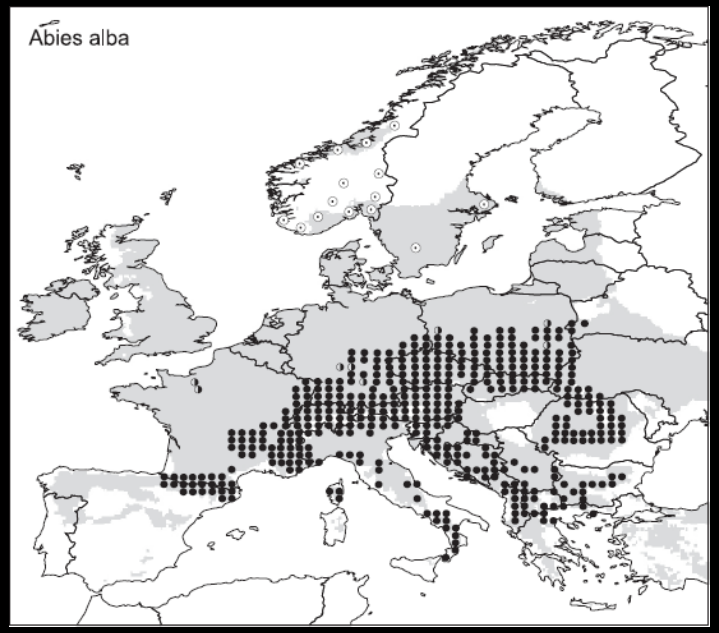


Elith & Graham (2009) *Ecography*

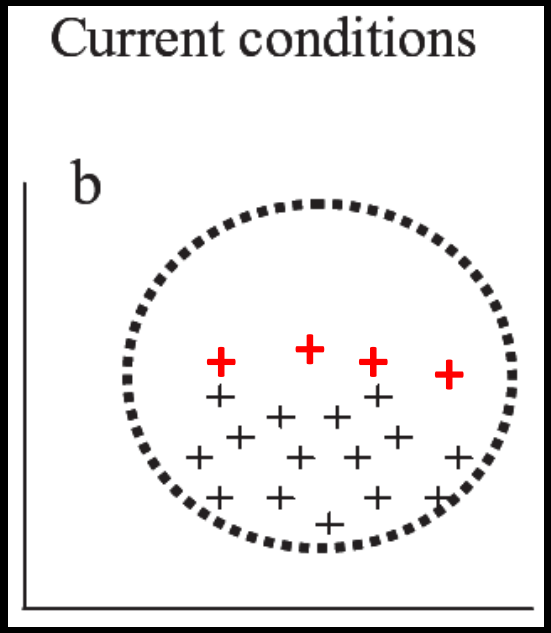
Equilibrium of species distribution with climate

- Dispersal limitation

- Biotic interactions (humans)

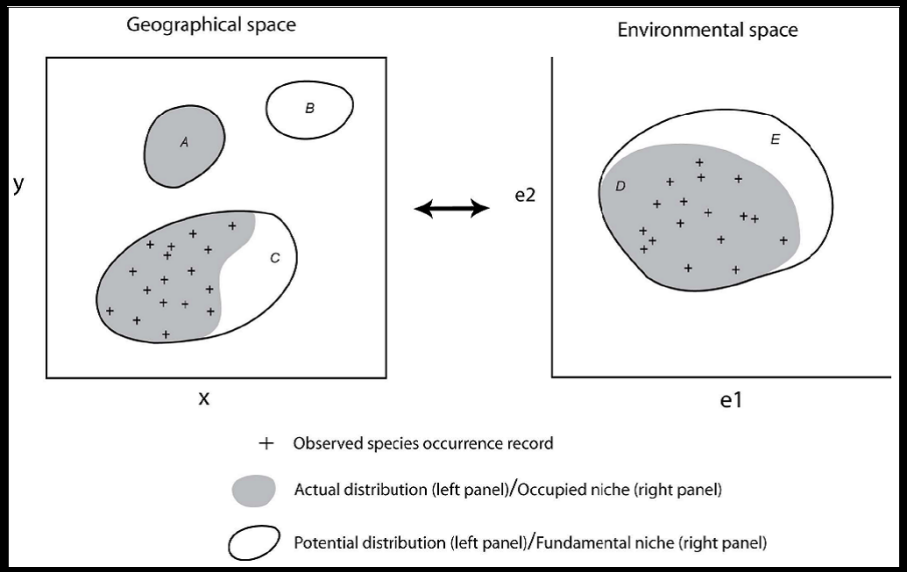


Svenning & Skov (2004) *Ecol Lett*

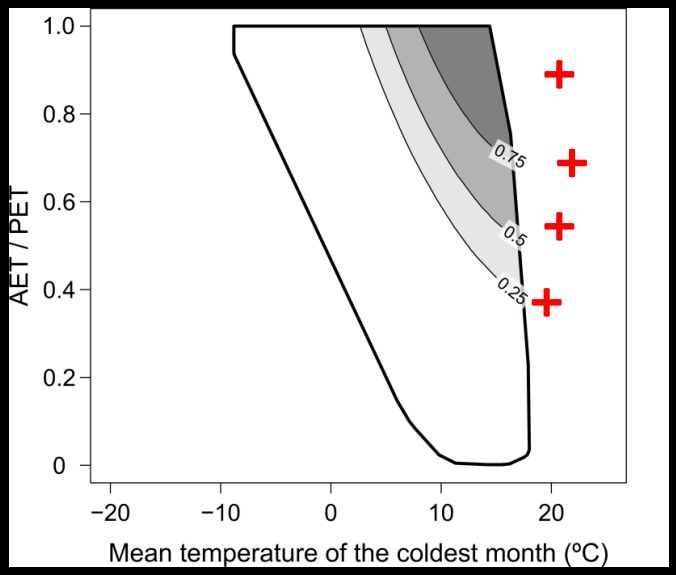


Nogués-Bravo (2009)
Global Ecol & Biog

Species' niche may be wider than available climate

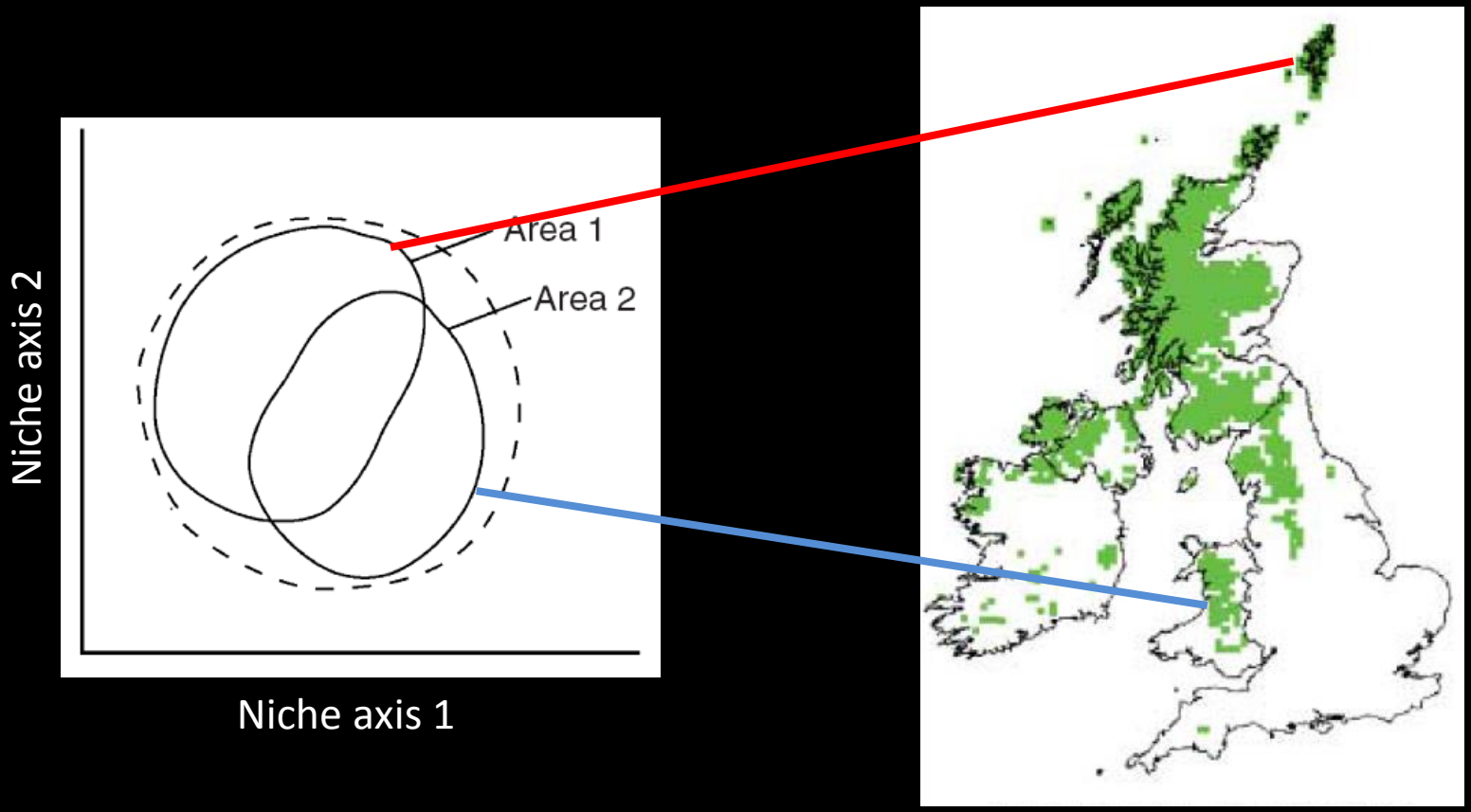


Pearson (2008)



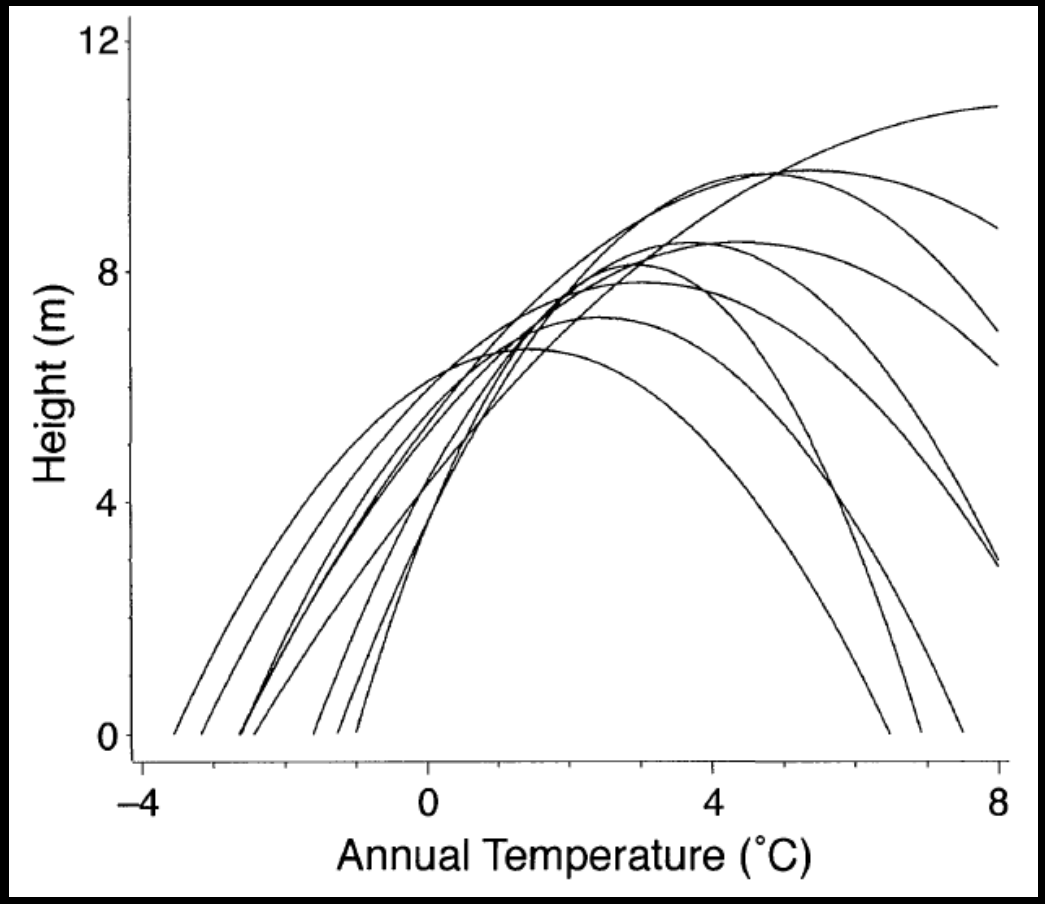
Rodríguez-Sánchez & Arroyo (2010)
Clim Ch, Ecol & Syst

Ecotypes and global change projections



Peterson & Holt (2003) *Ecol Lett*

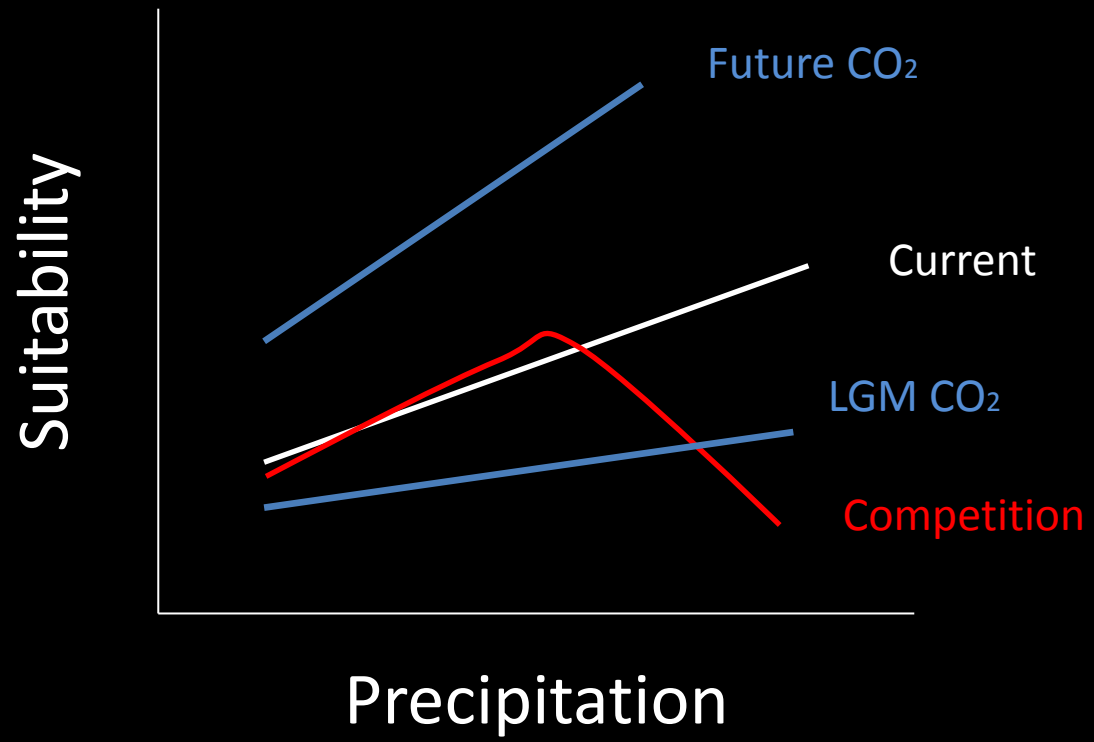
Intraspecific responses to climate in *Pinus contorta*



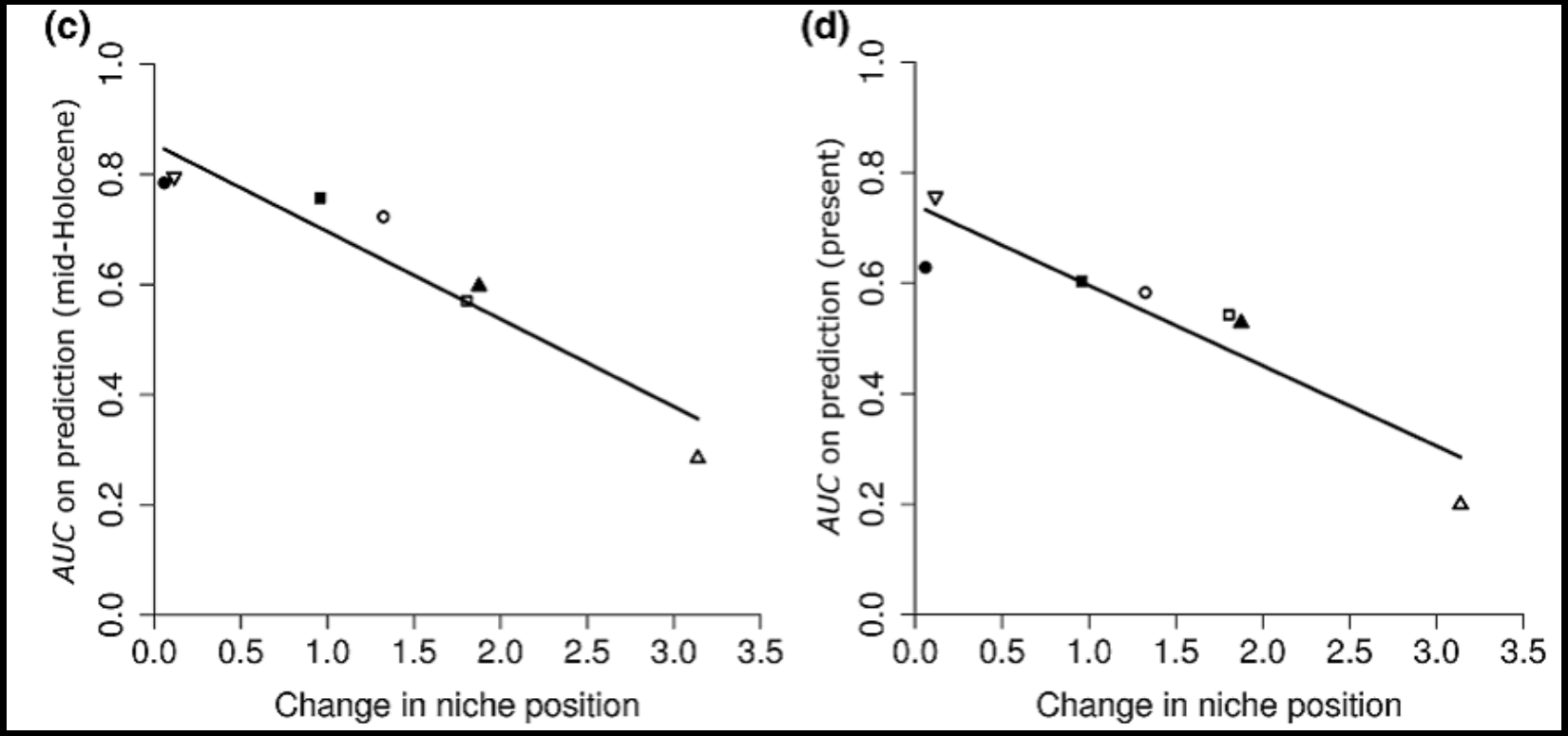
Rehfeldt et al. (1999)
Ecol Monogr

Stability of climatic niches through time

Constancy of species-environment relationships



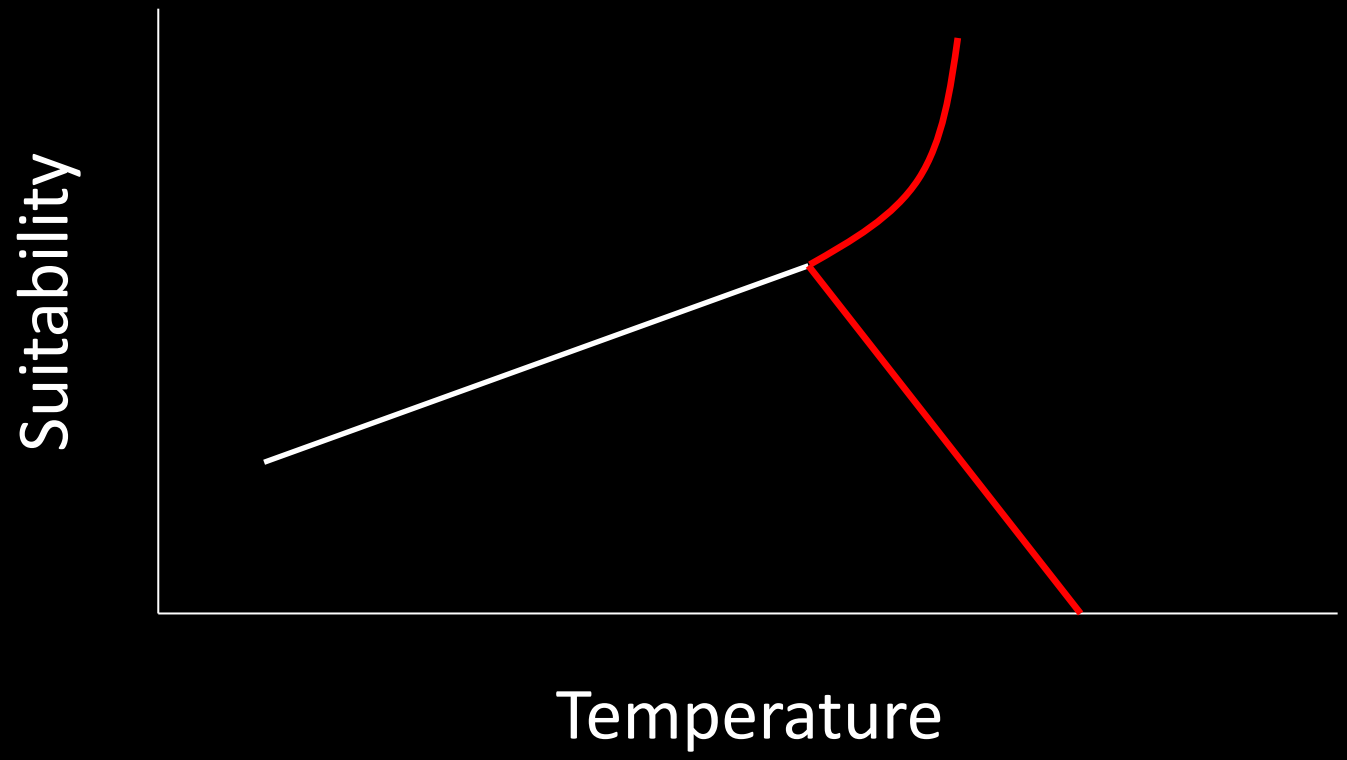
Predictive perfomance decreases with larger niche shifts



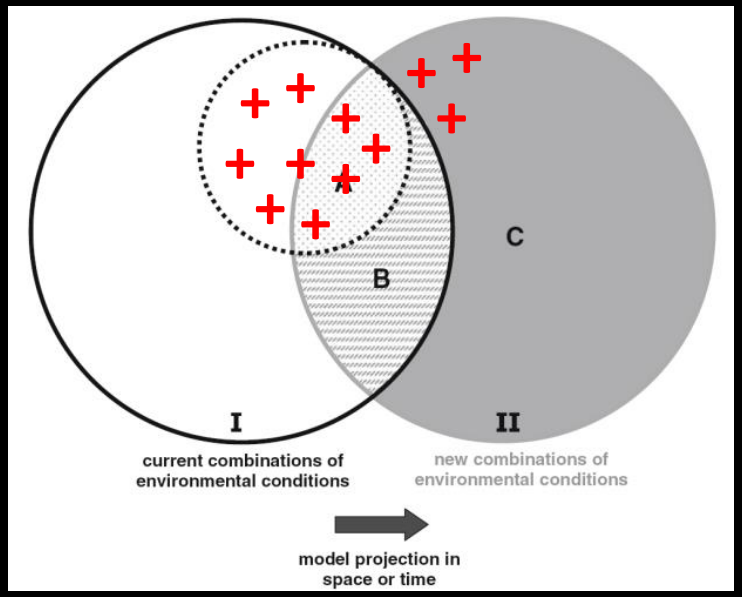
Pearman et al. (2008) *Ecol Lett*

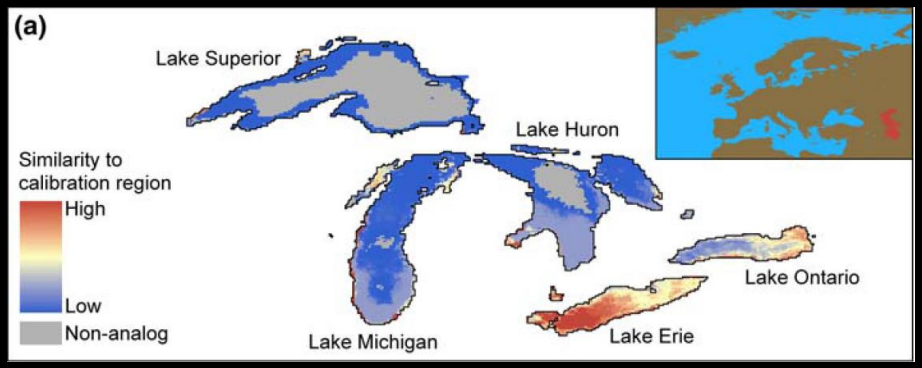
Non-analog climates

Extrapolation beyond the range of training data



Non-analog climates



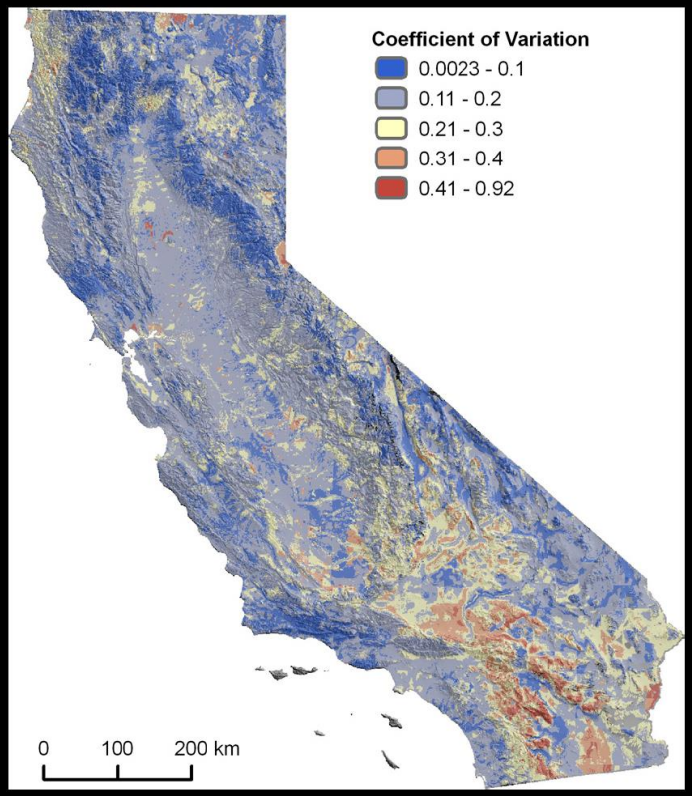


Fitzpatrick & Hargrove (2009) *Biodiv & Cons*

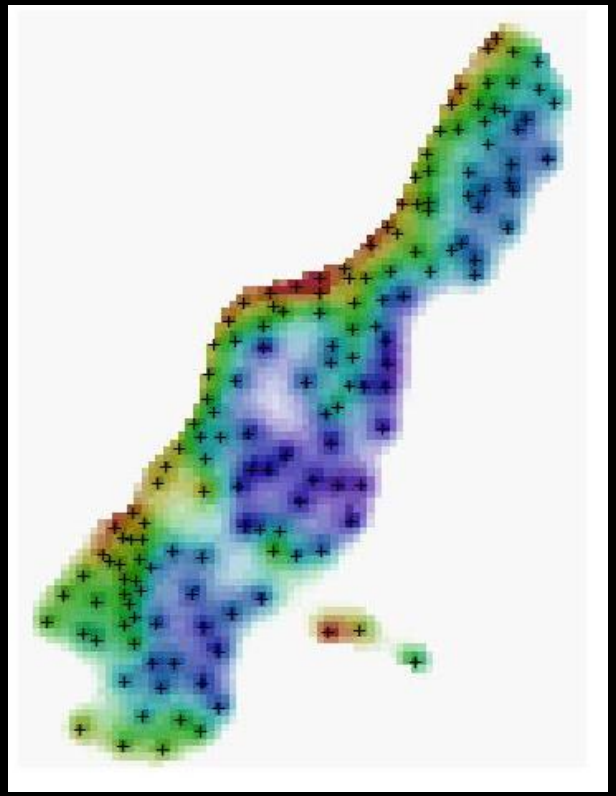
Reducing and quantifying uncertainty

- Multiple sources of uncertainty:
  - Occurrence data
  - Environmental data
  - Modelling algorithms
  - Climate scenarios
- Ensemble forecasting
  - Araújo & New (2007) *TREE*
  - BIOMOD: Thuiller et al. (2009) *Ecography*
- Bayesian approaches

Provide uncertainty estimates

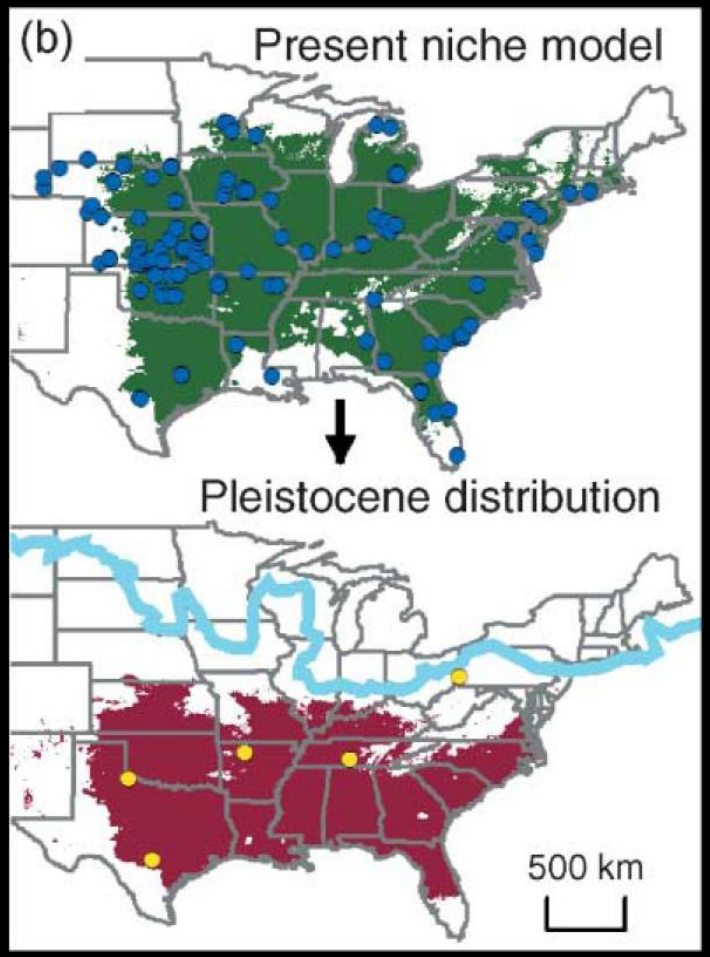


Wiens et al. (2009) *PNAS*



Hengl (2003)

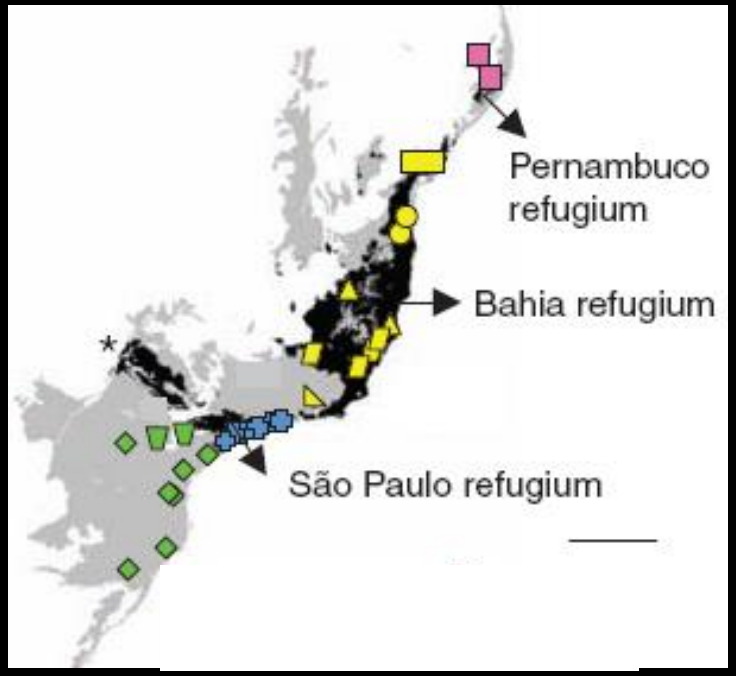
Validation with fossil records

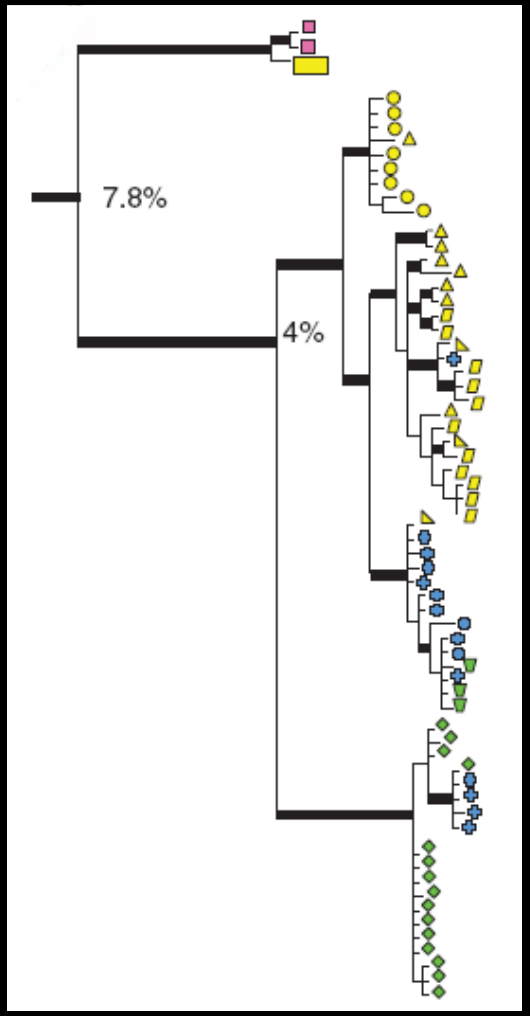


Scalopus aquaticus

Martínez-Meyer et al. (2004)
Global Ecol & Biog

Integration with phylogeography

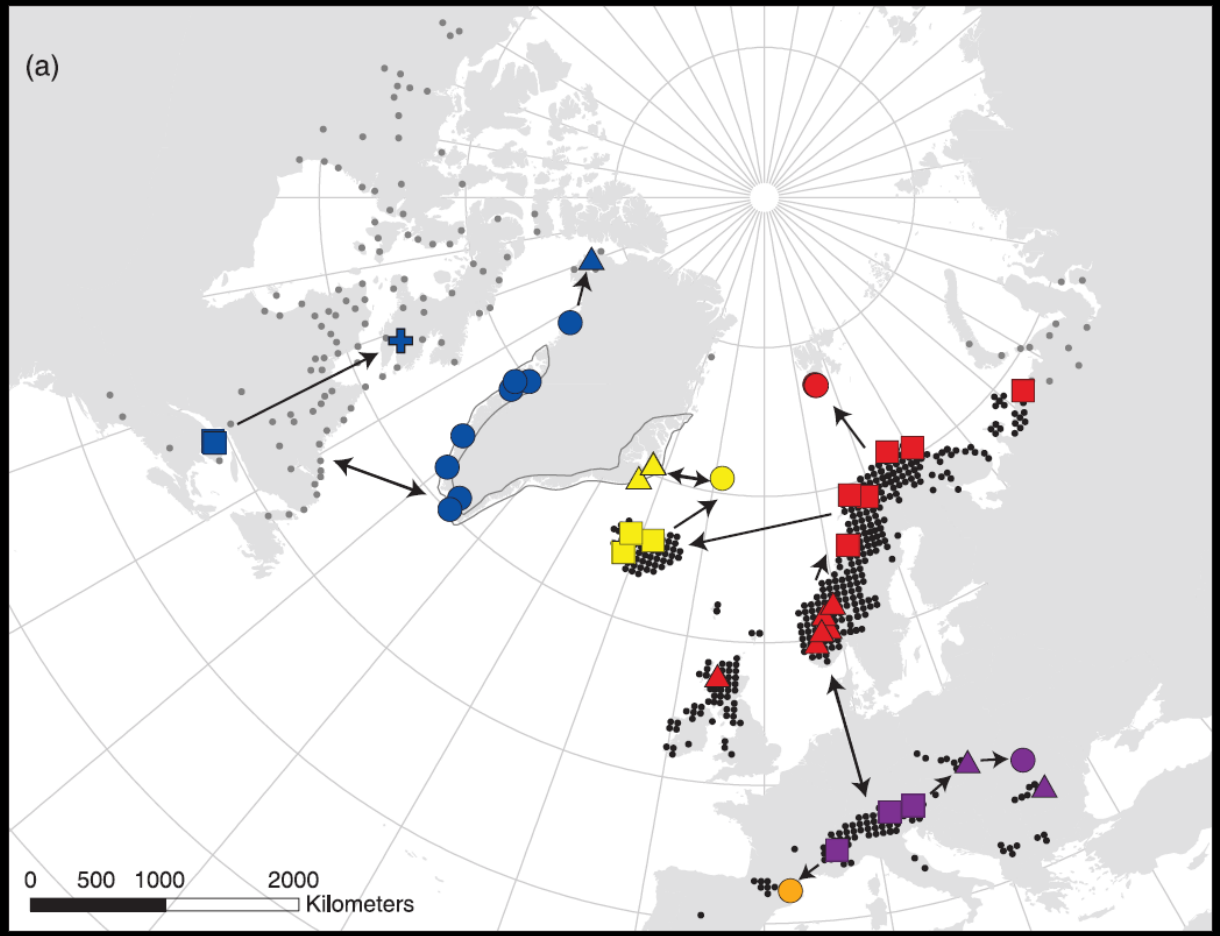




Hypsiboas faber

Carnaval et al. (2009) *Science*

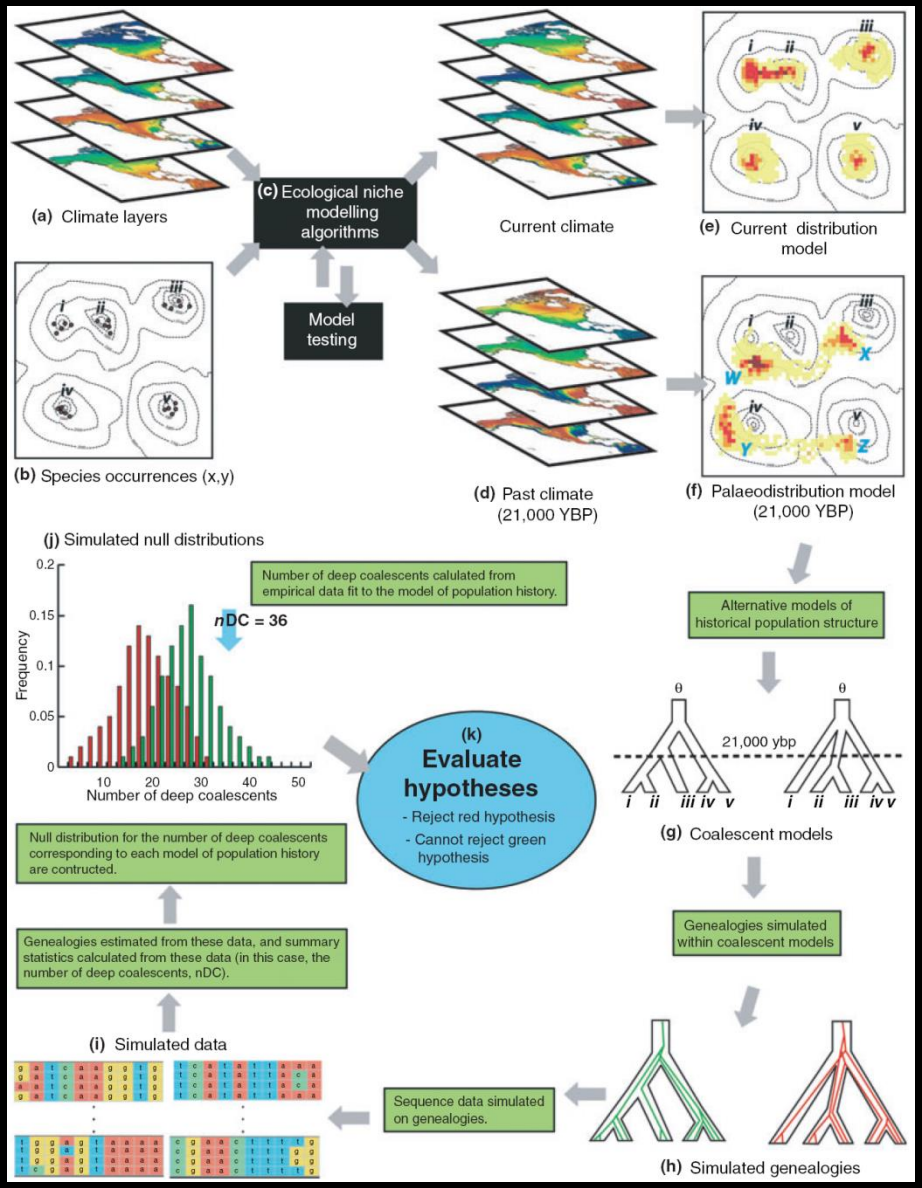
Three-way integration



Salix herbacea

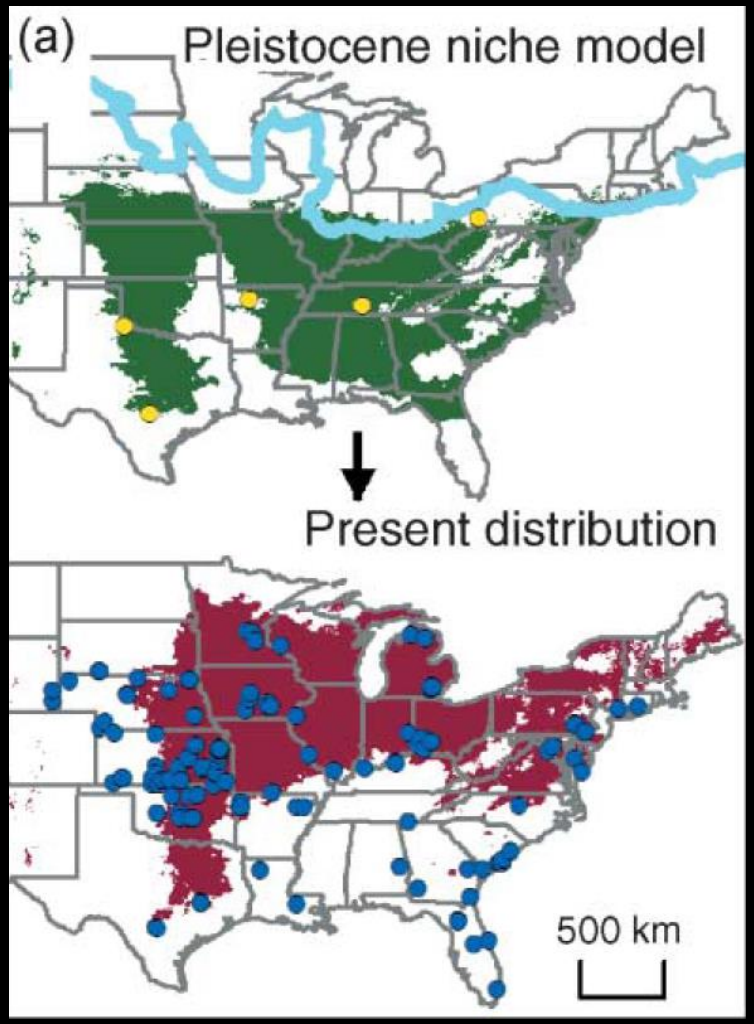
Alsos et al. (2009)
Global Ecol & Biog

Tight integration: SDMs and coalescence



Richards et al. (2007)
J Biog

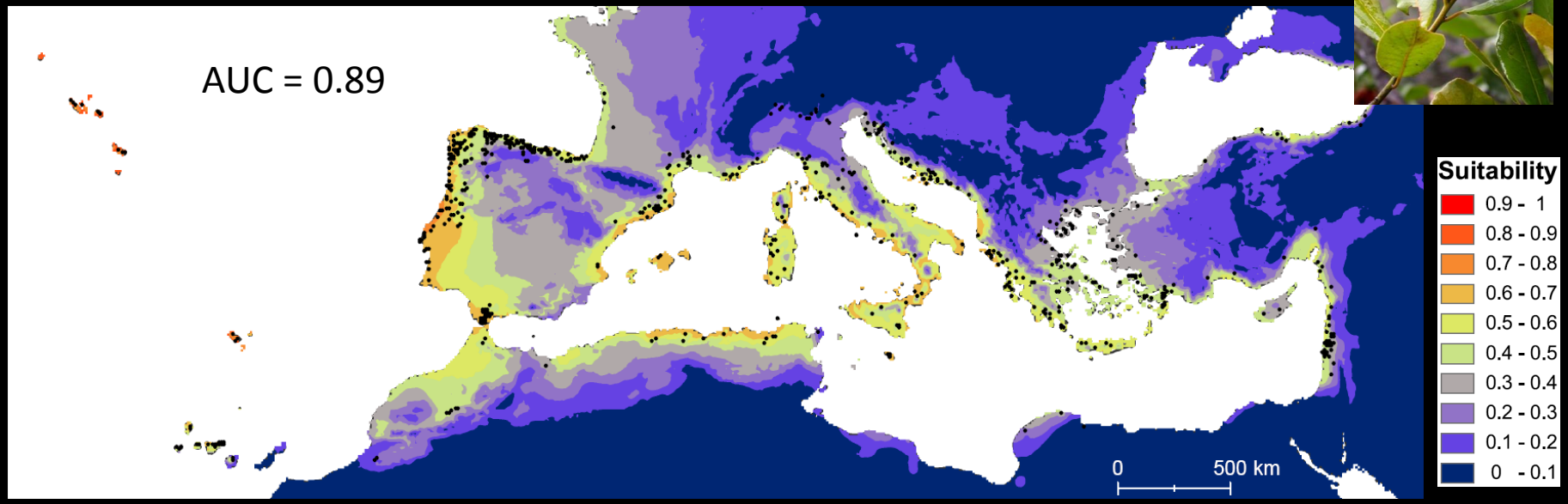
Projecting from past to present: validating SDM forecasts



Martínez-Meyer et al. (2004)
Global Ecol & Biog

Deterministic range dynamics in *Laurus*

Present suitability predicted by the model fitted to the middle Pliocene



Rodríguez-Sánchez & Arroyo (2008) *Global Ecol & Biog*

Insights from simulations

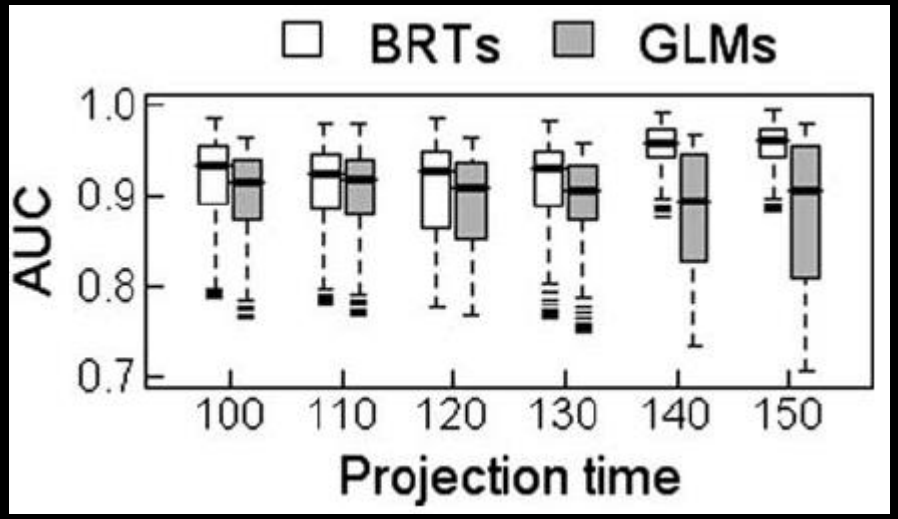
Ecography 32: 733–744, 2009
doi: 10.1111/j.1600-0587.2009.05810.x

Subject Editor: Jens-Christian Svenning. Accepted 7 March 2009

Static species distribution models in dynamically changing systems: how good can predictions really be?

Damaris Zurell, Florian Jeltsch, Carsten F. Dormann and Boris Schröder

- Climate change
- Dispersal limitation
- Parasitoid

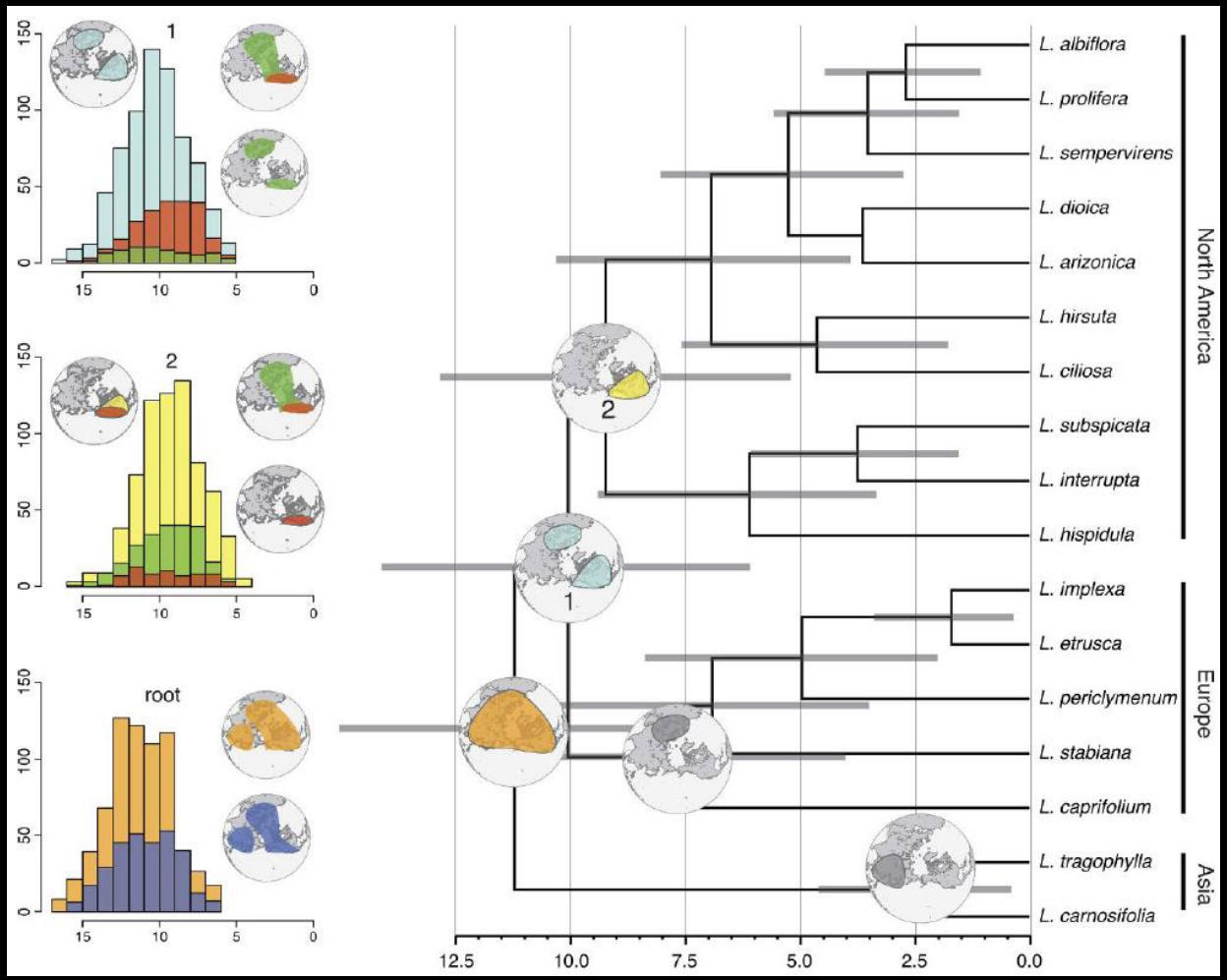


Phylogenetic approaches: geographic range evolution

Psychotria

Ree & Smith (2008) *Syst Biol*

Speciation and range dynamics in *Lonicera*



Smith & Donoghue (2010) *Syst Biol*

New modelling approaches

Diversity and Distributions, (Diversity Distrib.) (2010) **16**, 321–330

BIODIVERSITY VIEWPOINT

Moving beyond static species distribution models in support of conservation biogeography

Janet Franklin

Ecography 33: 621–626, 2010

Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change

Brian Huntley, Phoebe Barnard, Res Altwegg, Lynda Chambers, Bernard W. T. Coetzee, Lesley Gibson, Philip A. R. Hockey, David G. Hole, Guy F. Midgley, Les G. Underhill and Stephen G. Willis

Diversity and Distributions, (Diversity Distrib.) (2009) **15**, 590–601

BIODIVERSITY RESEARCH

MigClim: Predicting plant distribution and dispersal in a changing climate

Robin Engler and Antoine Guisan*

BioMove – an integrated platform simulating the dynamic response of species to environmental change

Guy F. Midgley, Ian D. Davies, Cécile H. Albert, Res Altwegg, Lee Hannah, Gregory O. Hughes, Lydia R. O'Halloran, Changwan Seo, James H. Thorne and Wilfried Thuiller

biology letters

Biol. Lett.
doi:10.1098/rsbl.2008.0049
Published online

Global change biology

Predicting extinction risks under climate change: coupling stochastic population models with dynamic bioclimatic habitat models

David A. Keith[1,*], H. Resit Akçakaya[2], Wilfried Thuiller[3], Guy F. Midgley[4], Richard G. Pearson[5], Steven J. Phillips[6], Helen M. Regan[7], Miguel B. Araújo[8] and Tony G. Rebelo[4]

Conclusions

- SDMs can have good predictive ability across time and provide useful insights to ecological & evolutionary questions
- Careful modelling & cautious interpretation (uncertainty). Validate whenever possible
- Keep an eye on developing approaches