Integrating ecological data and patterns across spatial scales, from local plots to continents

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iDiv

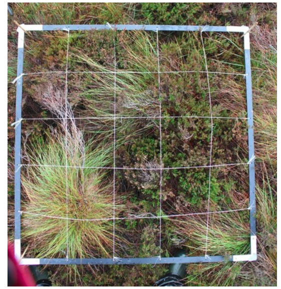
Where on Earth is biodiversity? Why? What drives it?



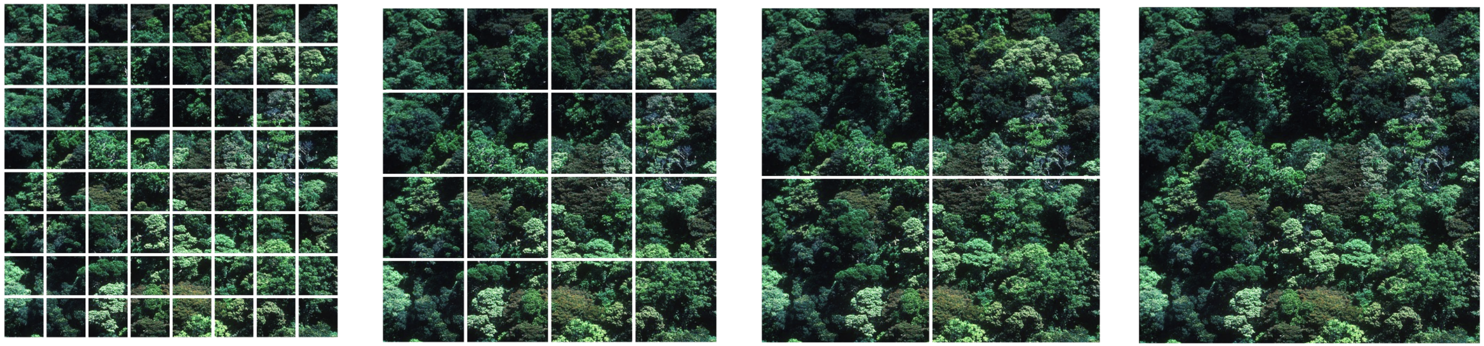



Biodiversity data and scale

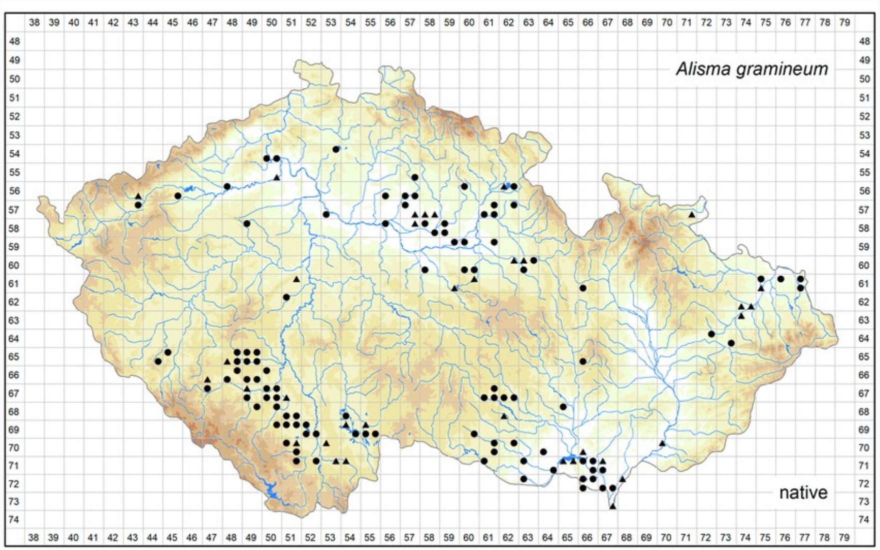
Plots, inventories, checklists

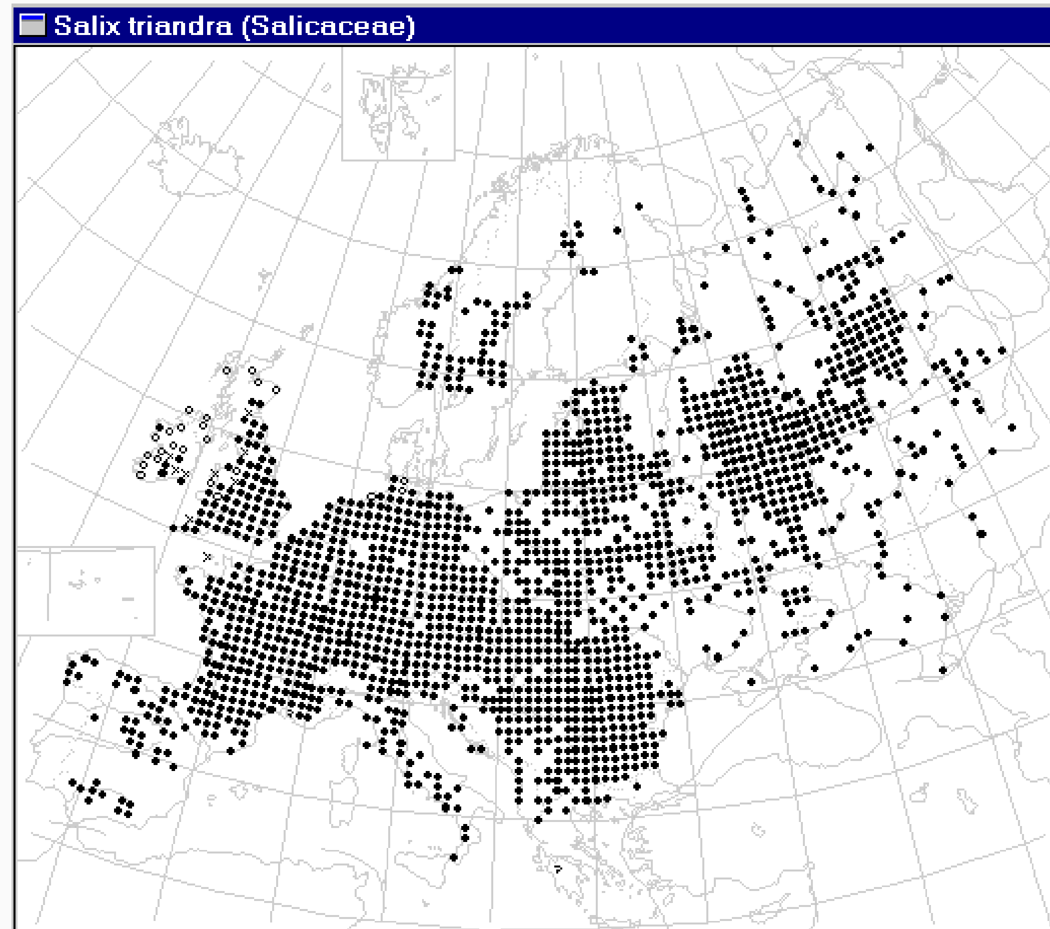


Scale = Grain = Resolution = Area of grid cell = Area



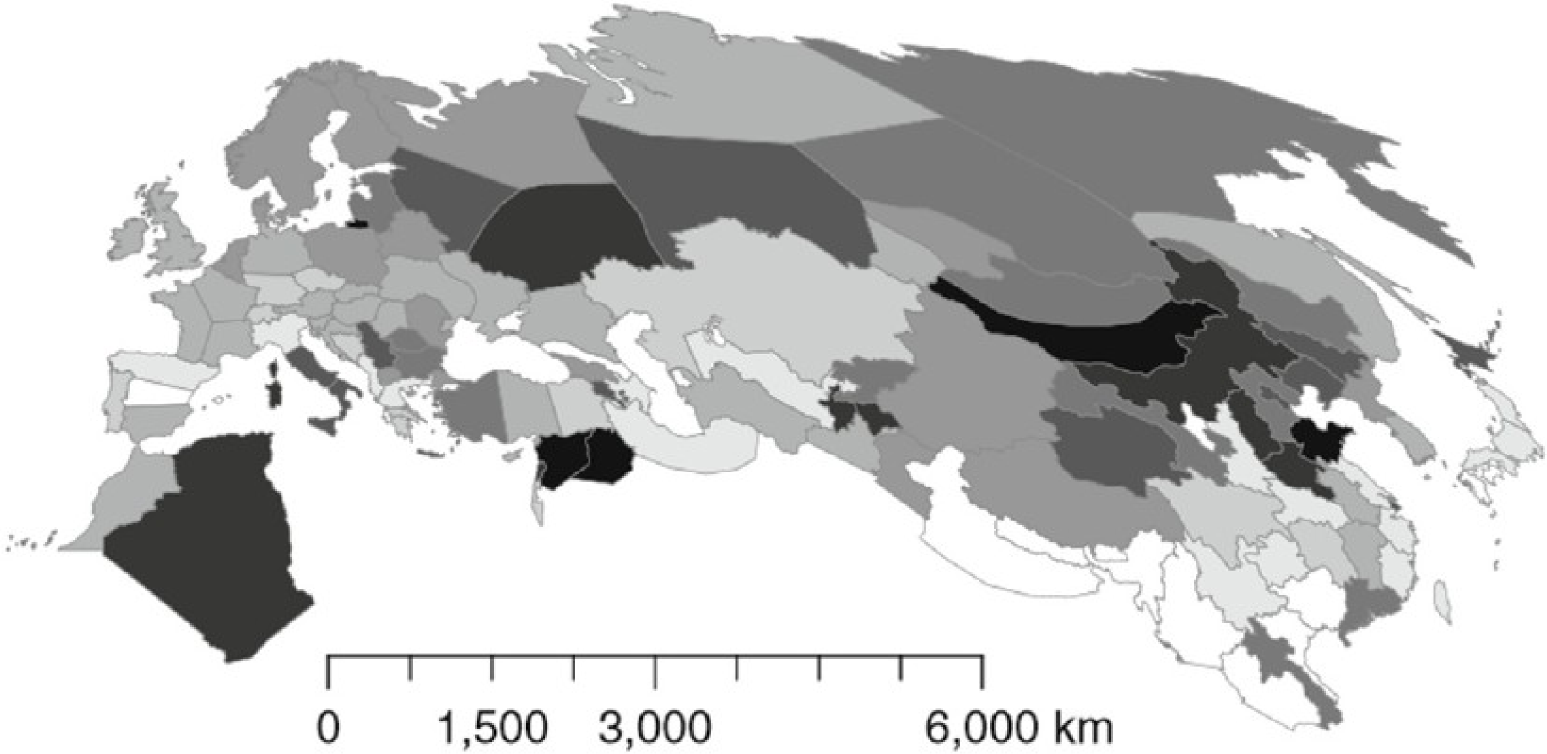
Grid atlases





Kaplan et al. (2017) *Preslia*
Jalas, Suominen, Lampinen, Kurtto: *Atlas Florae Europae*

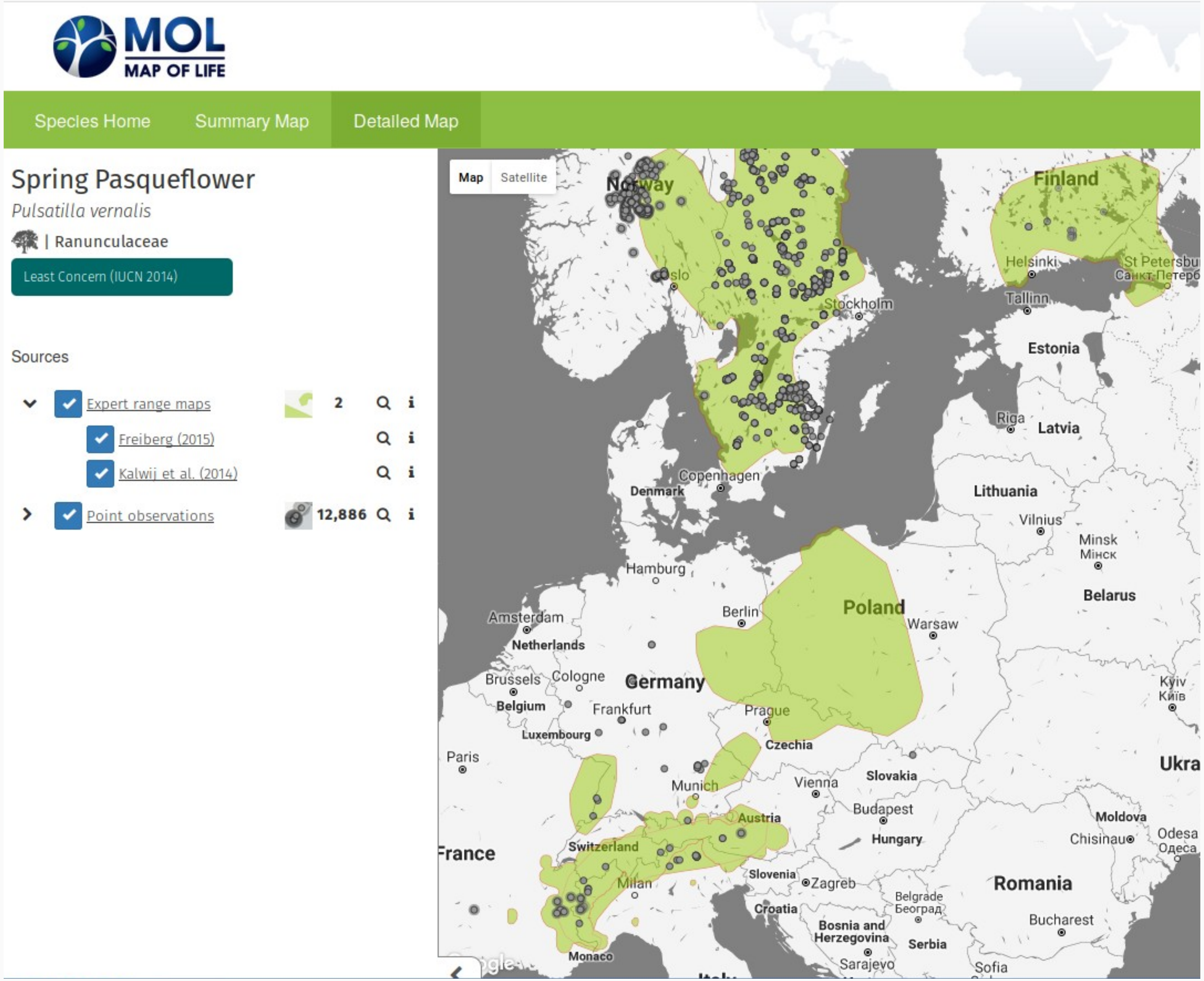
Plots, inventories, checklists



Kleisner, Keil & Jaros (2012) *Evolutionary Ecology*

Point observations, range maps – GBIF, OBIS, MoL, ...

Photo: Tinelot Wittermans

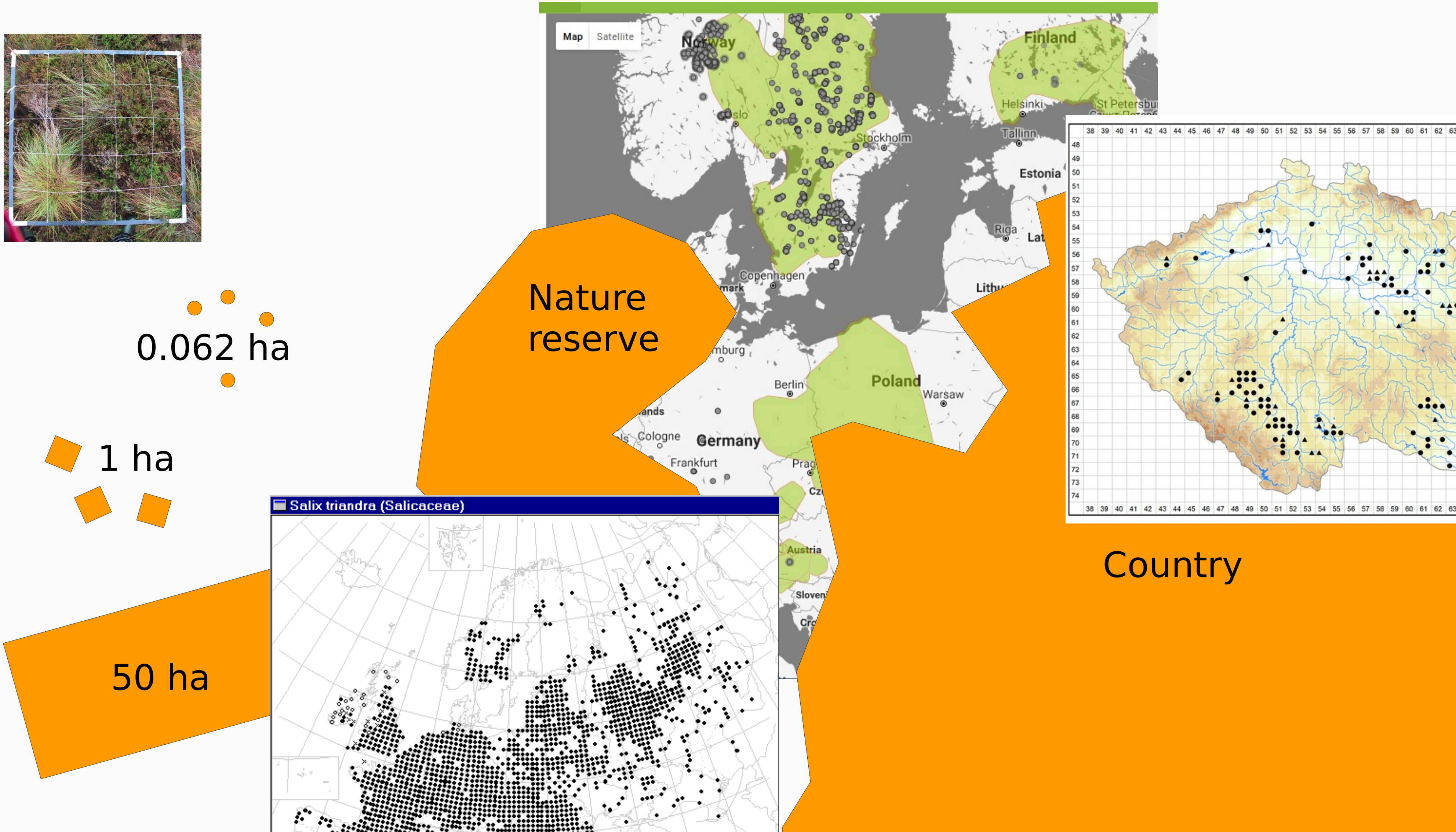


Why integrate?

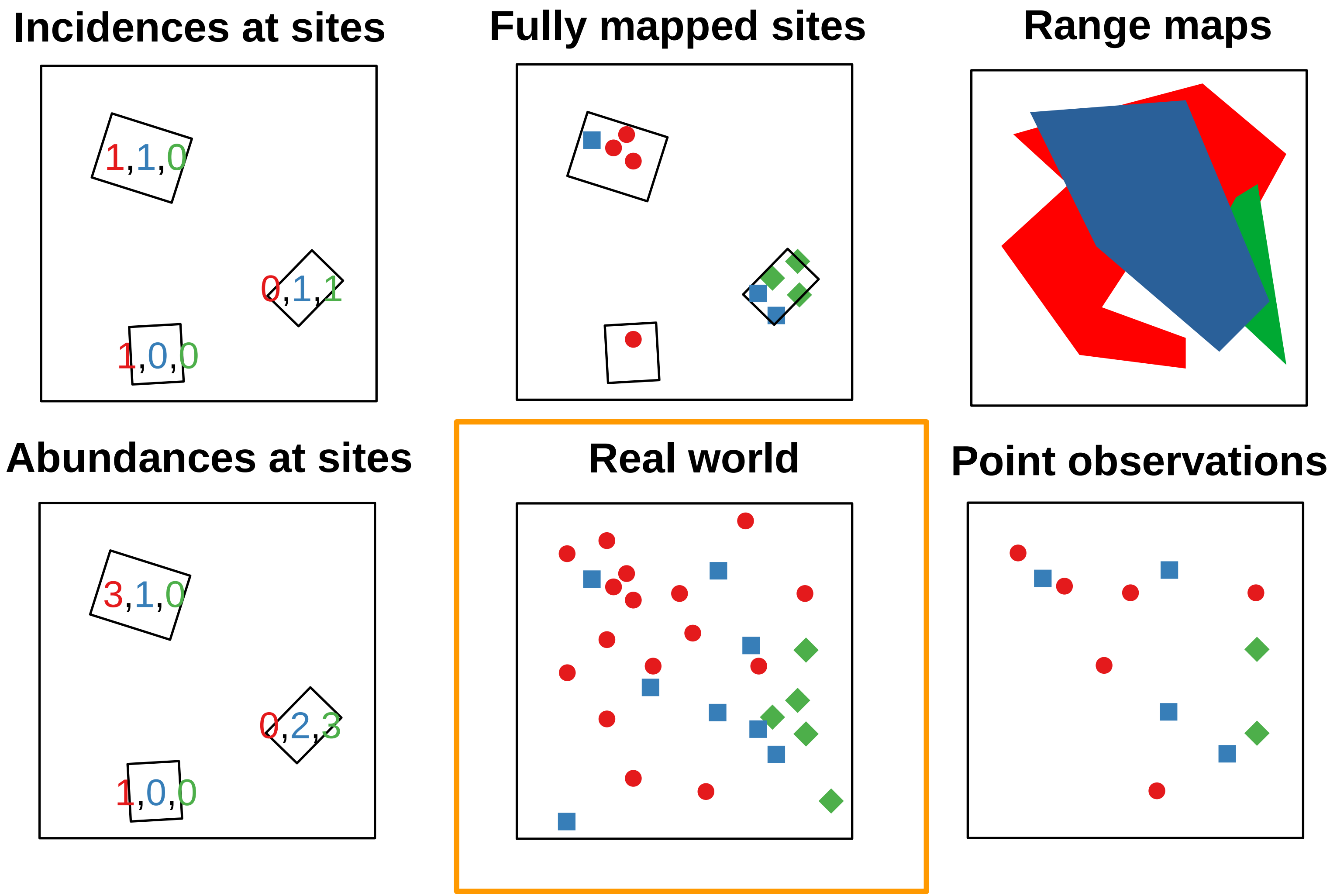
- Different data have different strengths, weaknesses, and gaps
- Larger N, geographic extent, environmental coverage
- Improved **inference**, e.g. about species niches, predictors of diversity, …
- Improved **predictions** of occurrence, abundance, diversity, and community composition, both in space and time

All is one

Can we integrate the data?

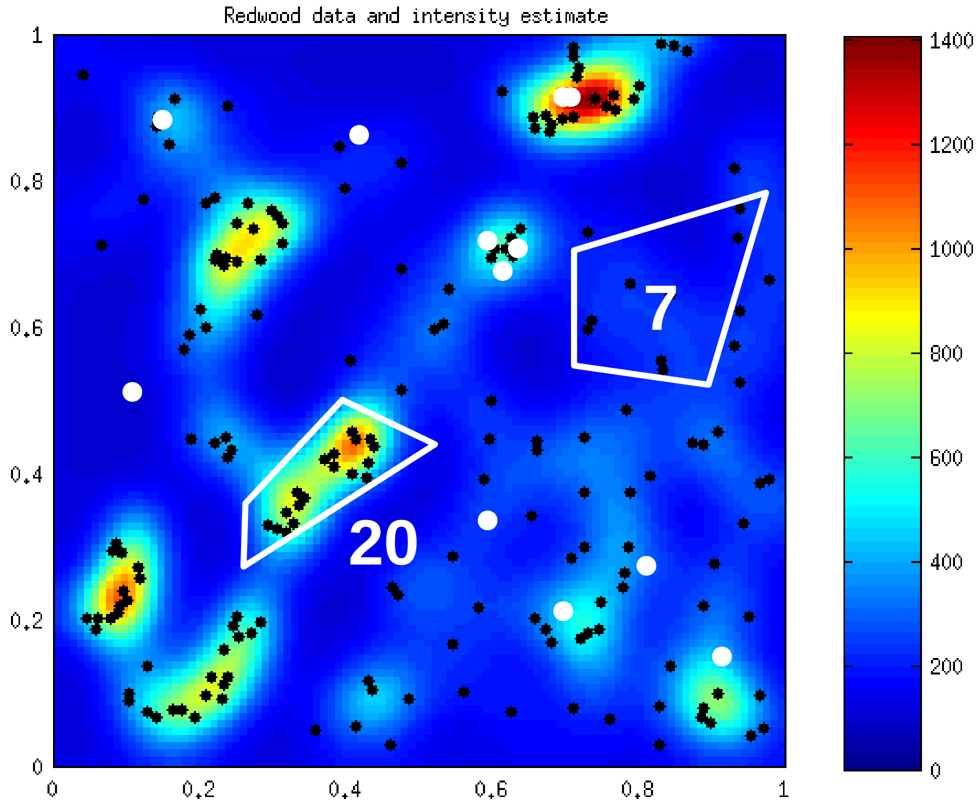


Can we integrate the data?



Loosely based on Isaac, O'Hara, et al., *in prep*

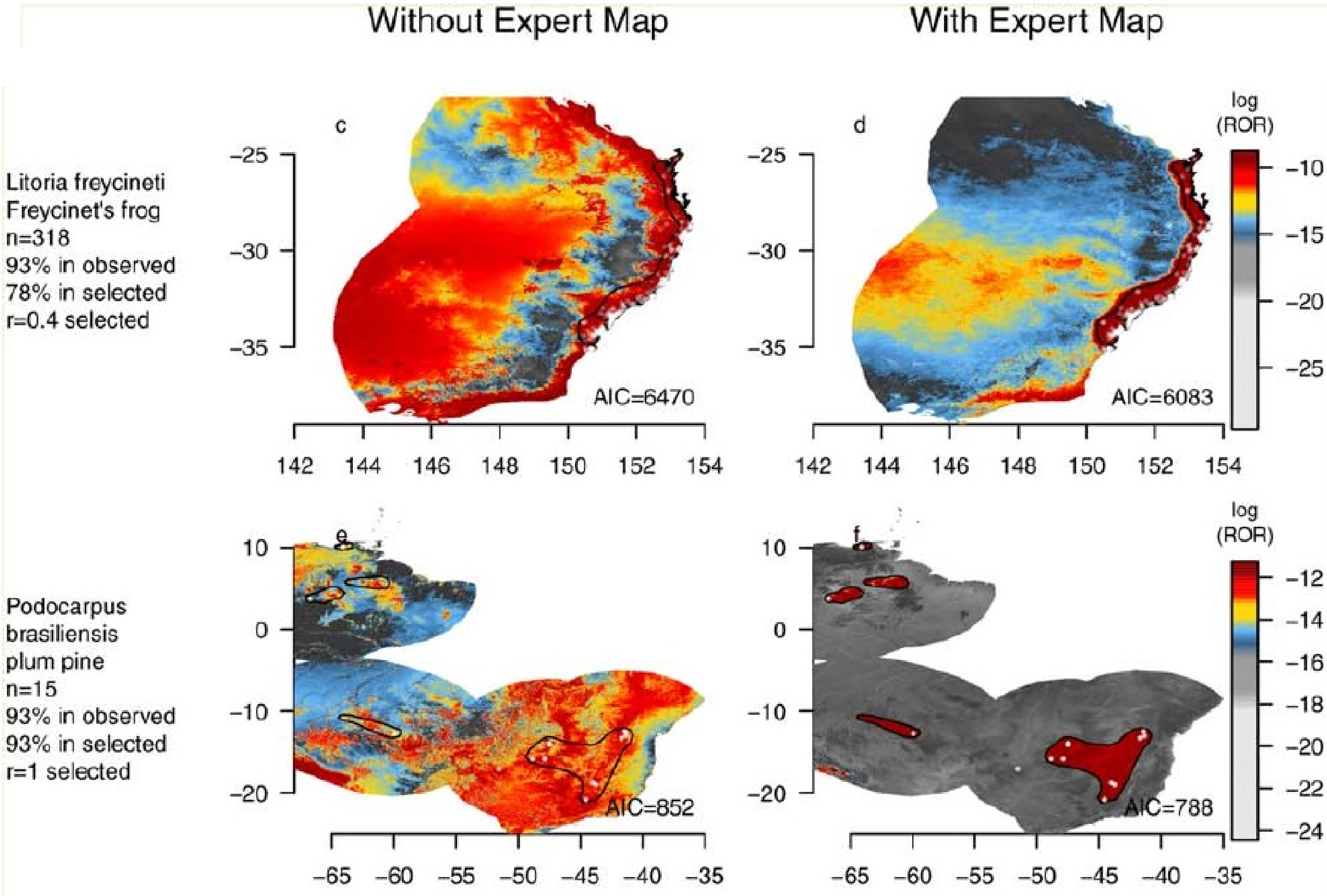
Poisson point process as a common denominator



- MaxEnt
- Poisson GLM, cloglog regression
- Occupancy models, hierarchical models
- Geostatistics
- Point pattern analysis

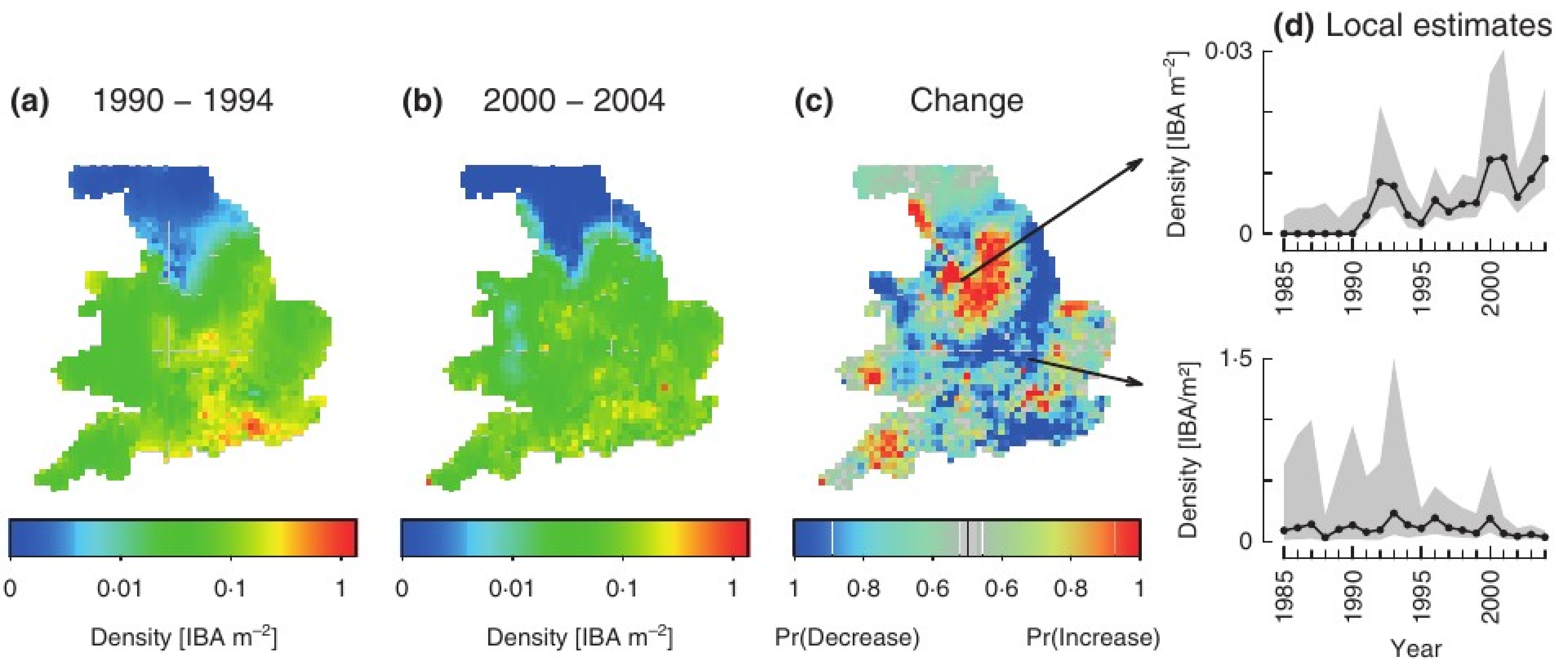
Royle & Dorazio 2008, Baddeley et al. 2010, Dorazio 2014, Thorsten Wiegand’s work

Range maps + point observations



Merow et al. (2017) *Global Ecology & Biogeography*

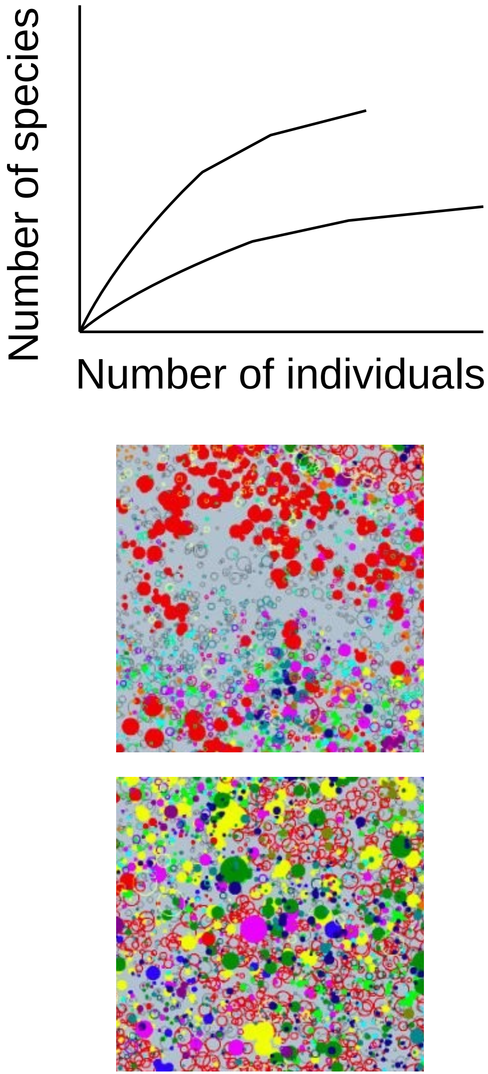
Atlas data + point observations → population trends

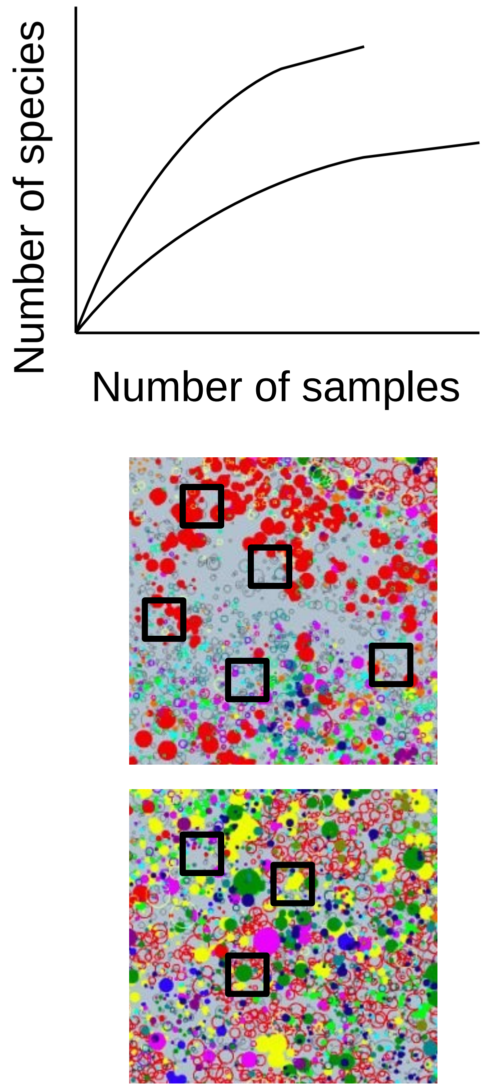


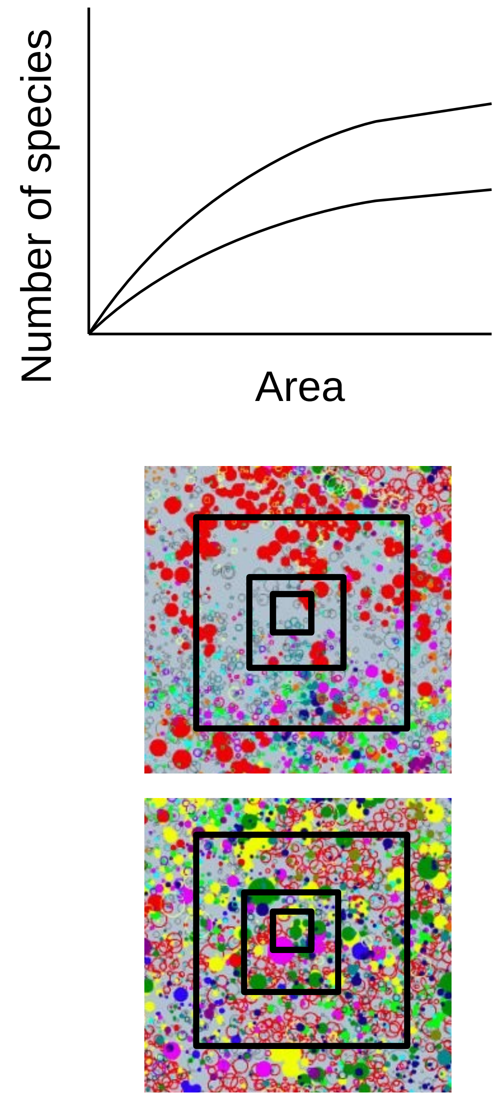
Pagel et al. (2014) *Methods in Ecology & Evolution*

Scaling

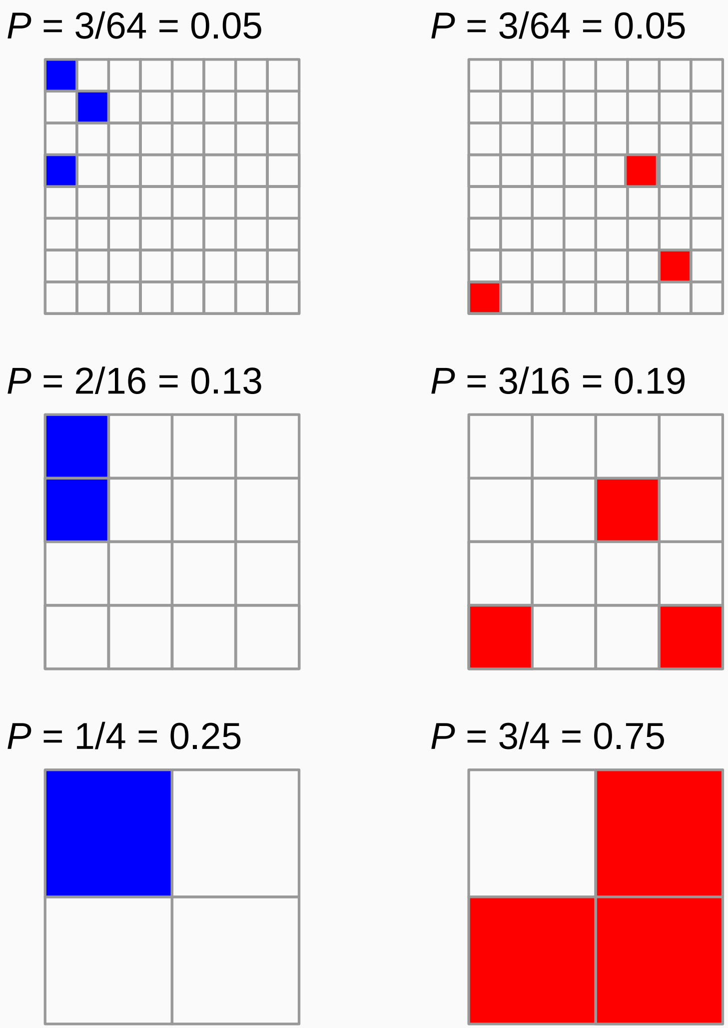
Comparing surveys with varying sampling effort

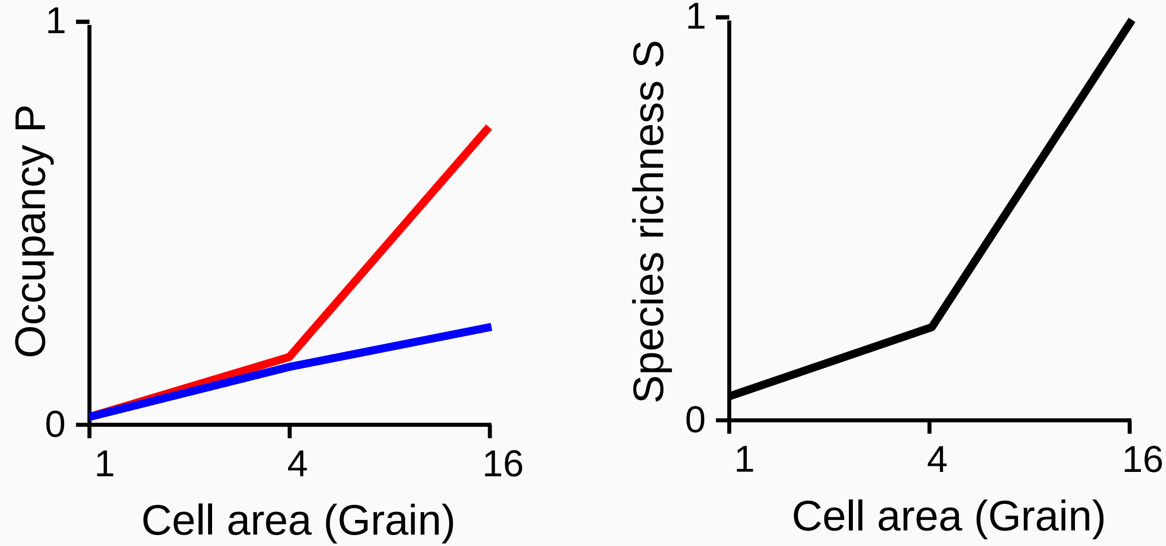






Occupancy-area and **species-area** relationships





Occupancy-area relationship (He & Condit 2007)
Scale-area relationship (Kunin 1998)
Range-area relationship (Harte et al. 2005)
Area-area curve (IUCN 2011)
Scaling pattern of occupancy (Hui et al. 209)

Downscaling occupancy

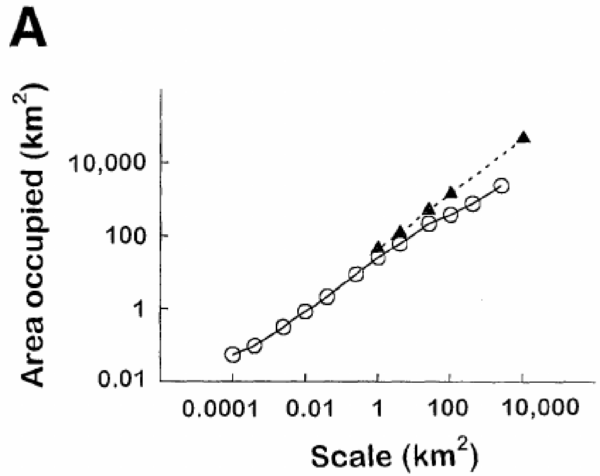
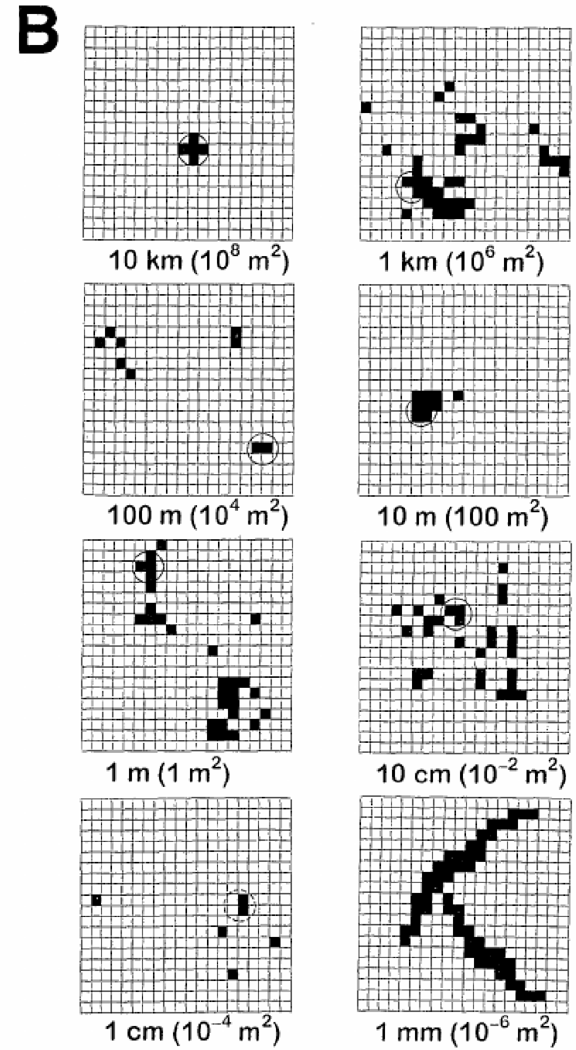
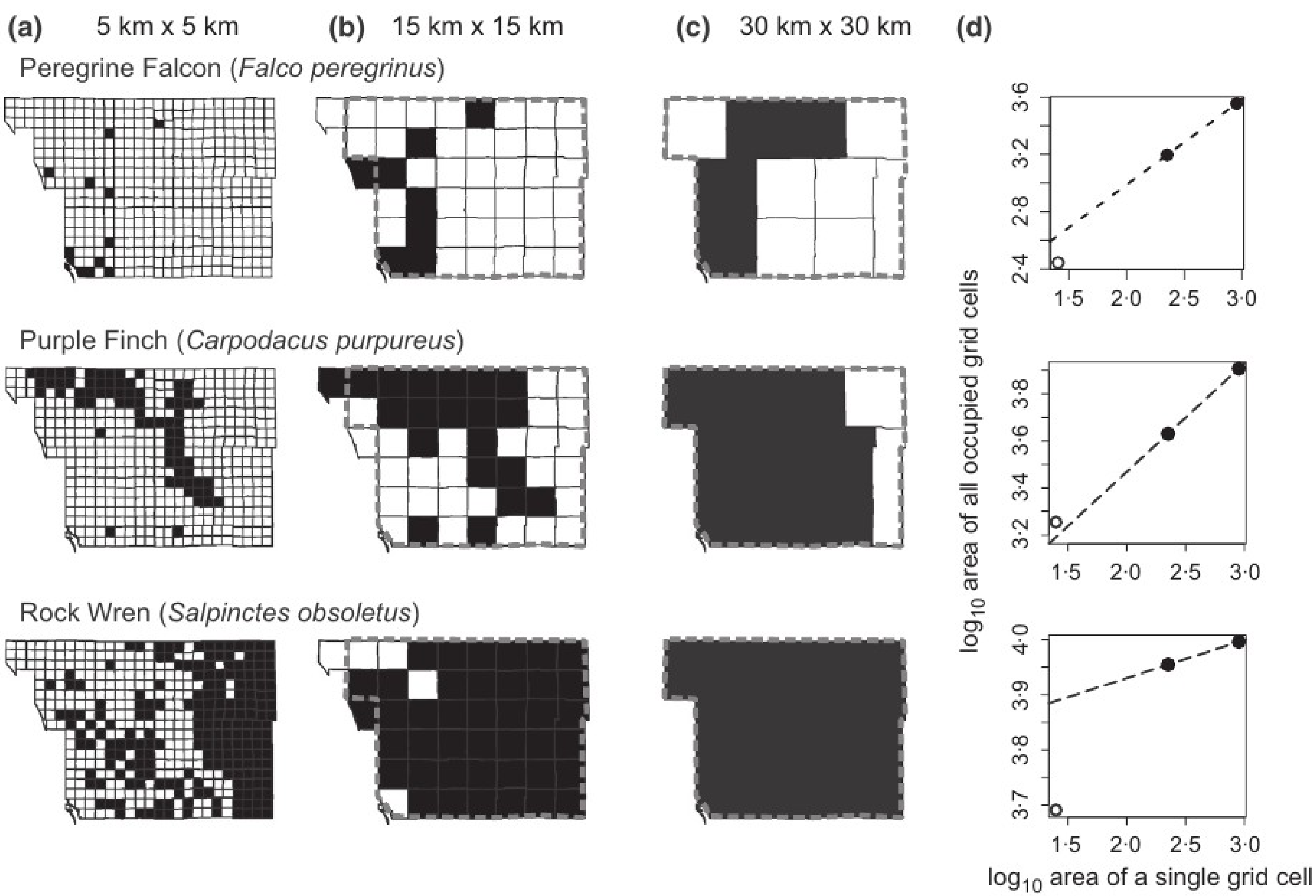


Fig. 1. (**A**) Scale-area plots for two British plant species. The circles and solid line represent *Gladiolus illyricus* (*11*); triangles and dashed line represent *Lathyrus japonica*. *Lathyrus* data are courtesy of R. Quinn; *Gladiolus* data at coarse resolutions (≥50 m) are courtesy of English Nature; finer resolutions (10 m to 1 cm) are from my field surveys of three populations. (**B**) The distribution of British *G. illyricus* populations at successively finer resolutions. Each grid displays a subset (circled) of the previous grid at 100-fold higher resolution (indicated below). The finest grid (1 mm resolution) is hypothetical, to illustrate the potential use of pixel data to represent cover.



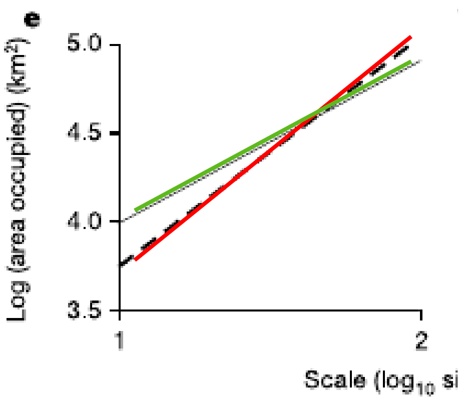
Kunin (1998) *Science*, Azaele et al. (2012) *Ecol. Appl.*,

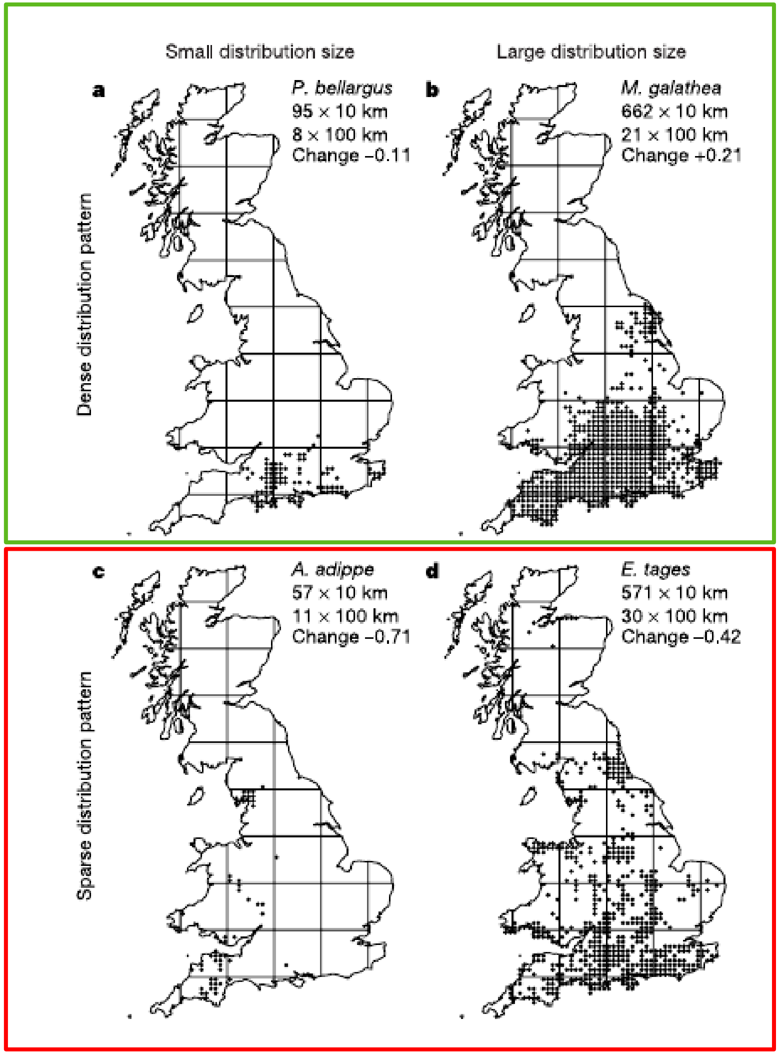
Downscaling occupancy

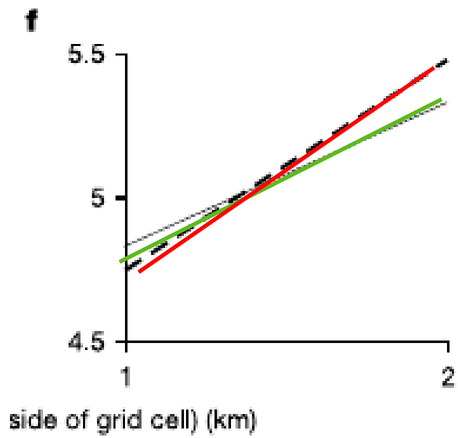


Keil et al. (2013) *Methods Ecol. Evol.*

Inferring change from static patterns

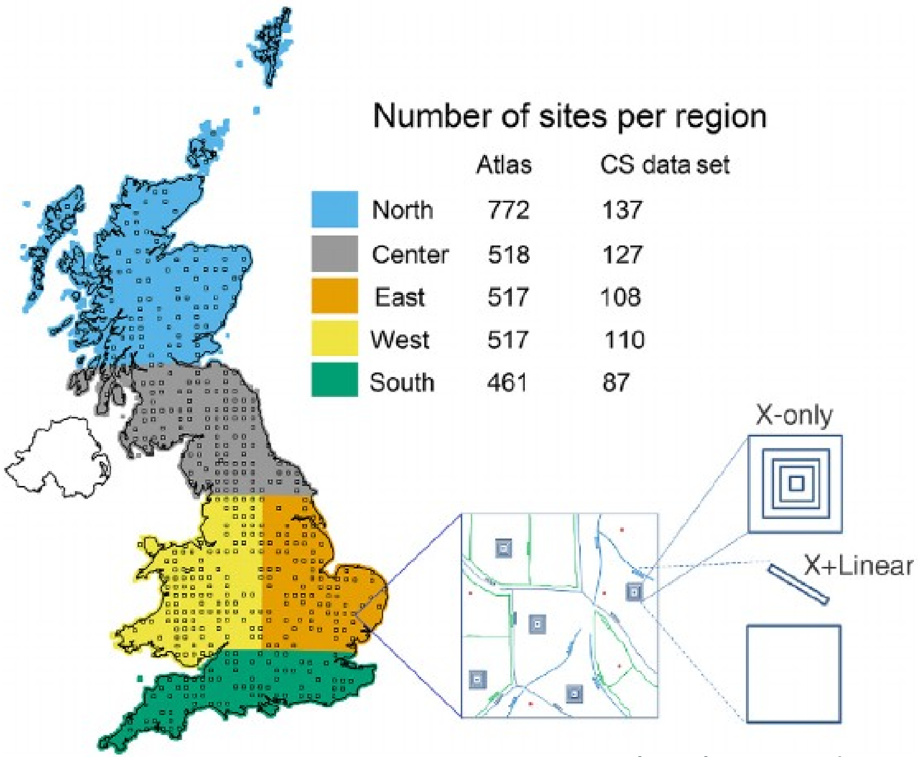




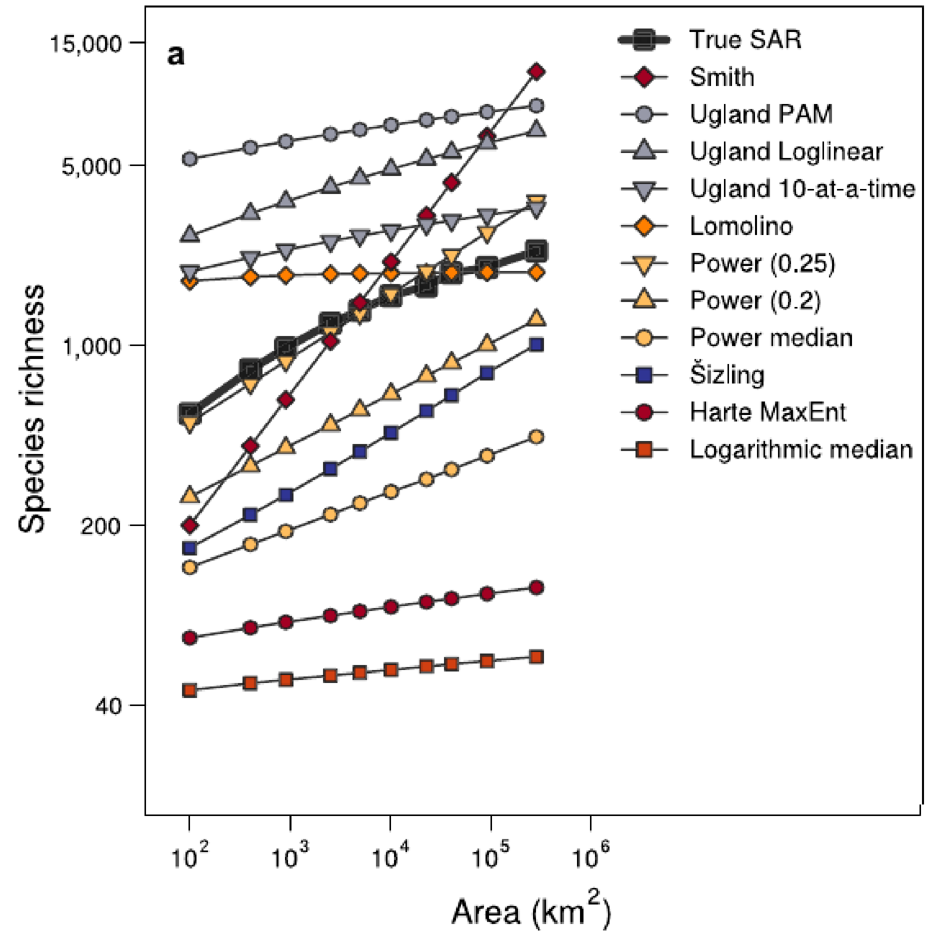


Wilson et al. (2004) *Nature*

Upscaling richness



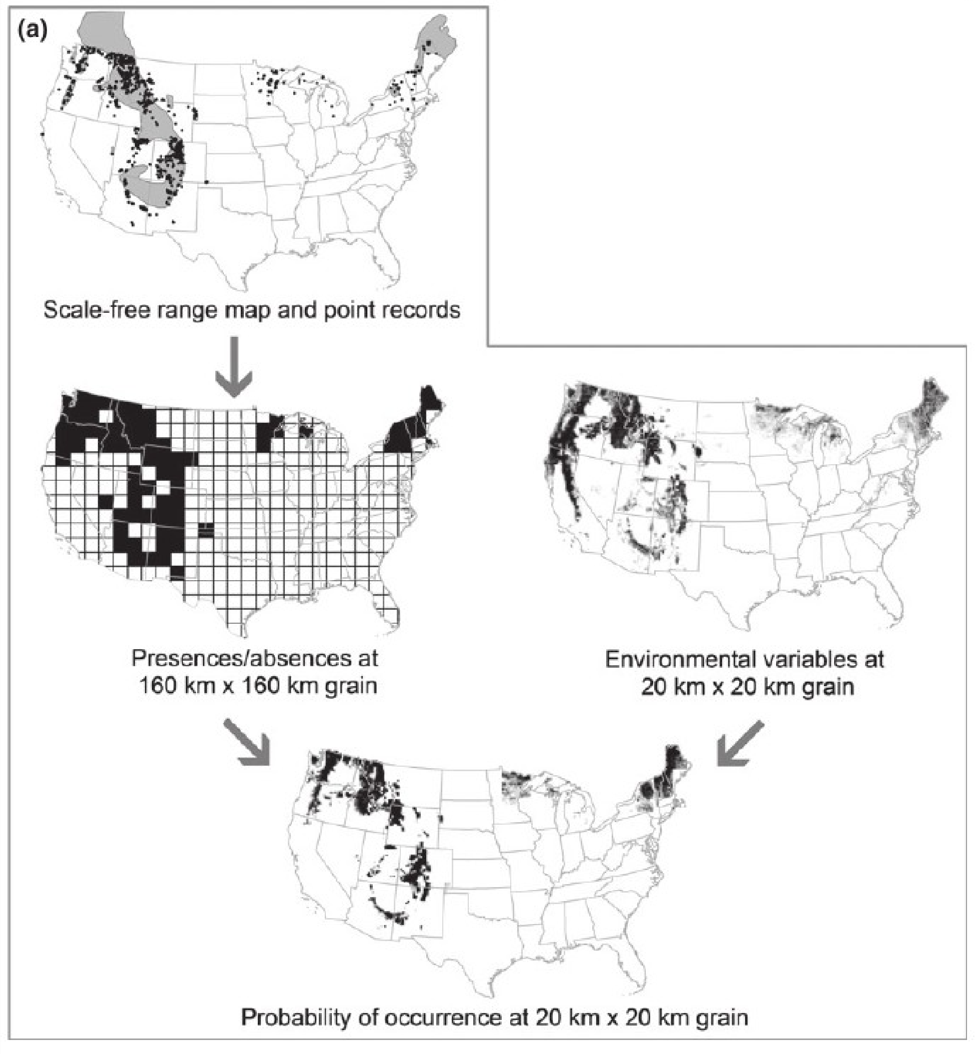
2,326 vascular plant species
2 x 2 – 14.14 x 14.14 m

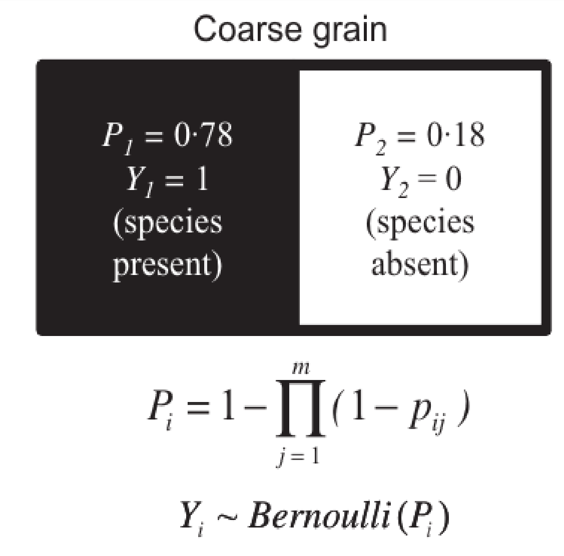


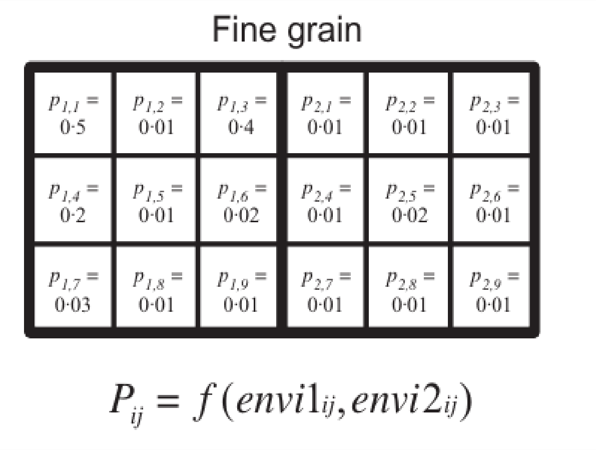
Kunin et al. (2018) *Ecological Monographs*

Environmental conditions

Downscaling species-distributions

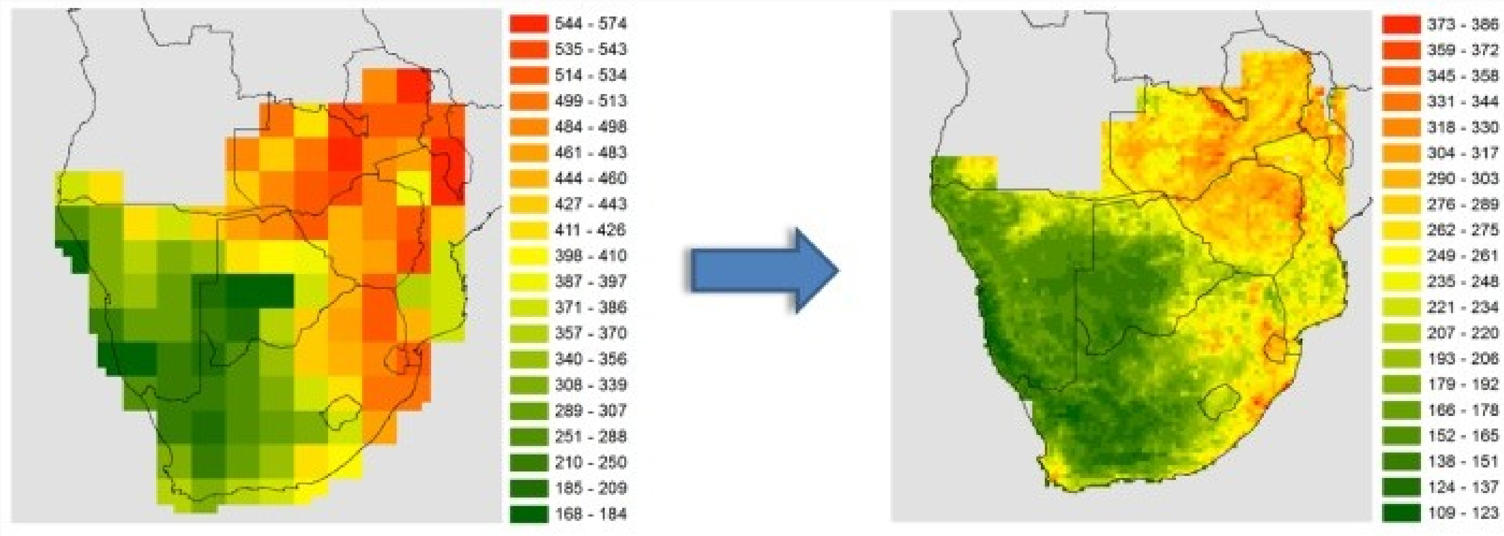


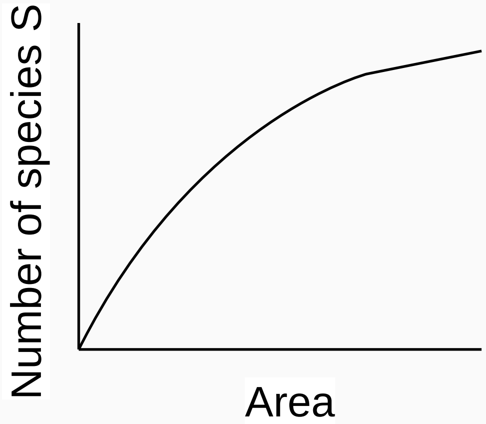




Keil et al. (2014) *Divers. Distrib.*, (2013) *MEE*

Downscaling spatial patterns of species richness





Keil & Jetz (2014) *Ecological Applications*

Scale as a statistical interaction

What drives global variation of species diversity?

Connecticut, USA

Czech Republic, Europe

Region effects, “historical” effects, dispersal limitation

Ricklefs & Schluter (1993); Map from NASA (public domain)

Environmental effects

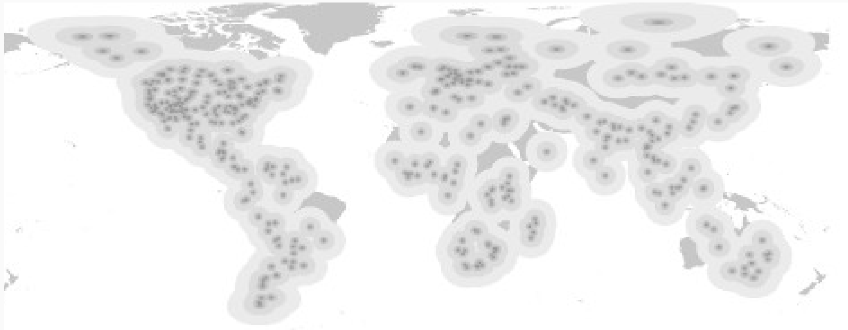
Habitat heterogeneity

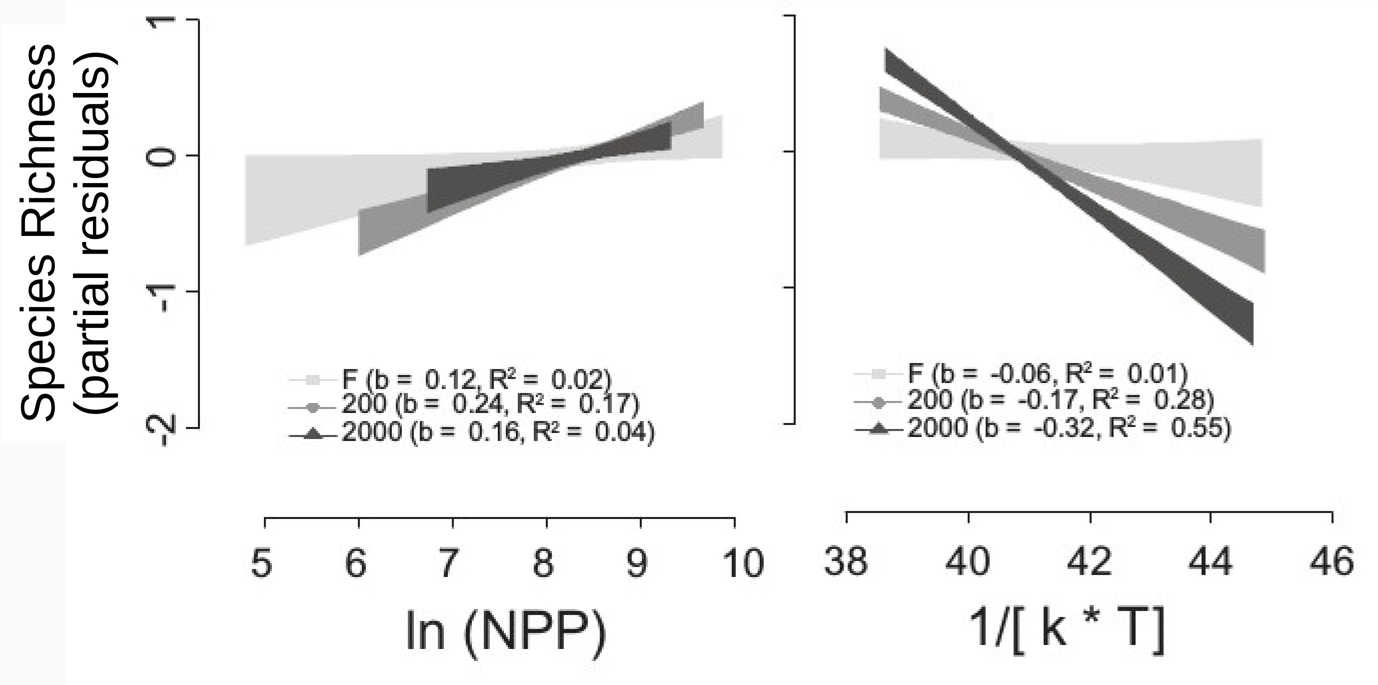
Climatic stability

Temperature

Productivity

Drivers of species diversity are grain dependent





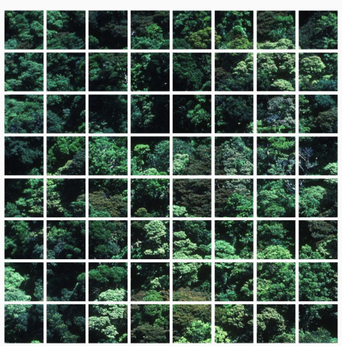
Belmaker & Jetz (2010) *Global Ecology & Biogeography*

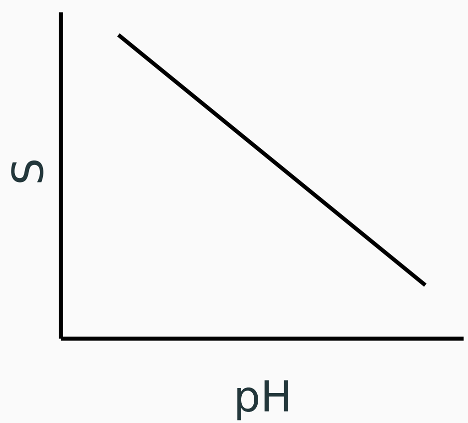
Grain dependence of an effect

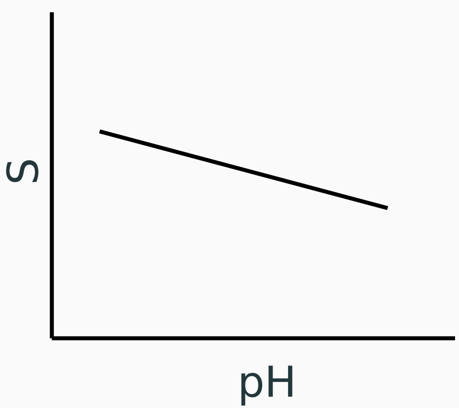
$$\log(S) = a + \mathbf{b} \cdot pH$$

$$\mathbf{b} = c + d \cdot \log(Area)$$

$$\log(S) = a + \boxed{c \cdot pH} + \boxed{d \cdot \log(Area) \cdot pH}$$







Grain dependence of an effect

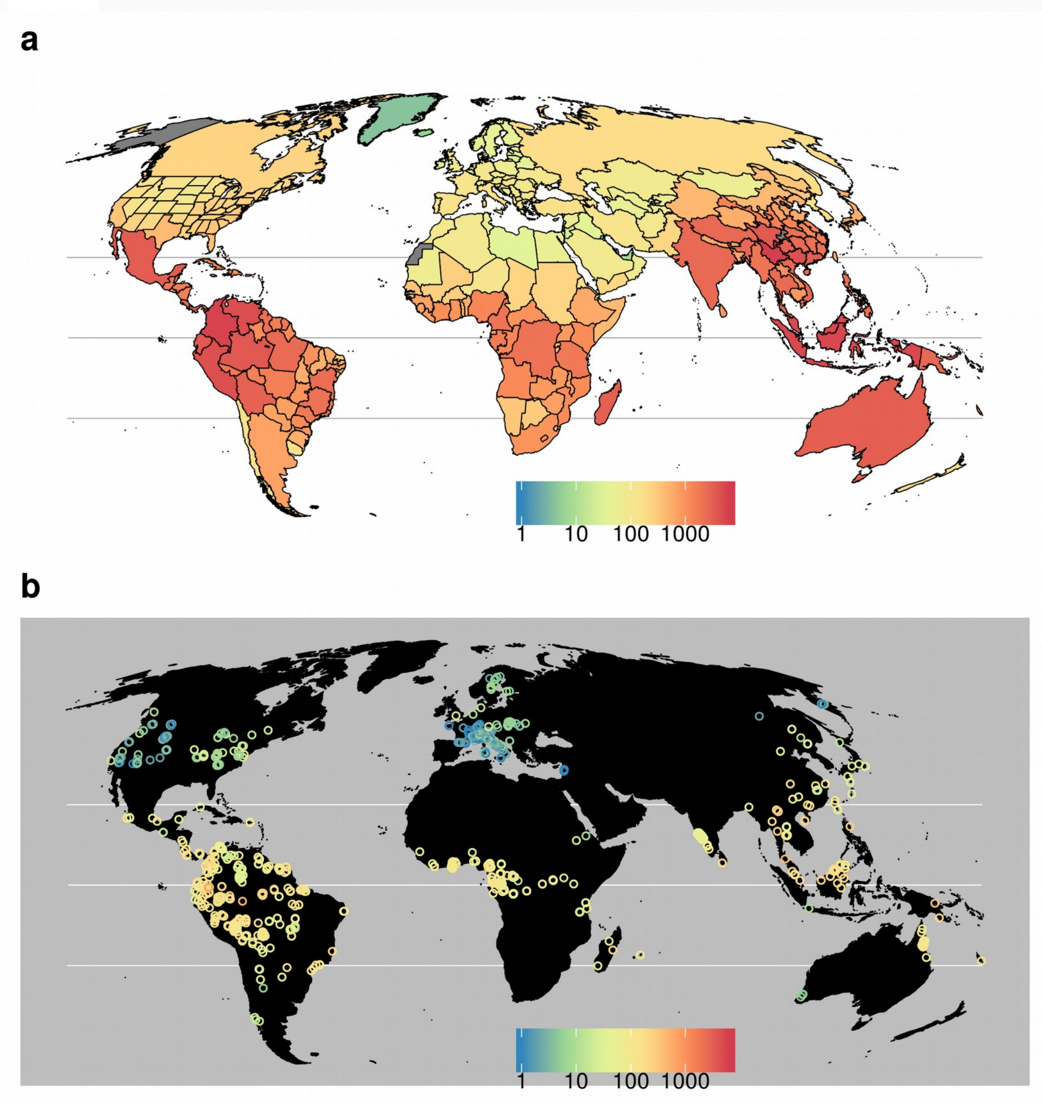
$$\log(S) = a + \boxed{c \cdot pH} + \boxed{d \cdot \log(Area) \cdot pH} + \boxed{g \cdot \log(Area)}$$

Goals

- Put together global dataset of heterogeneous biodiversity data
- Fit a model estimating drivers and patterns of global species diversity across scales

Keil & Chase (2018) *BioRxiv*

Tree species richness in 286 countries and 1332 plots



Species richness

Area

Number of trees

Minimum DBH measured

Geographic coordinates

Biogeographic region

Topographic heterogeneity

Insularity

Primary productivity

Annual temperature

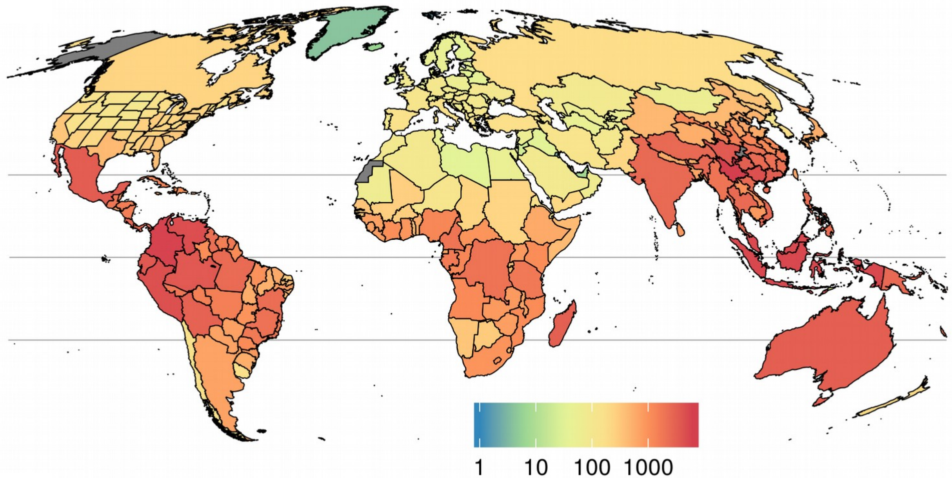
Isothermality

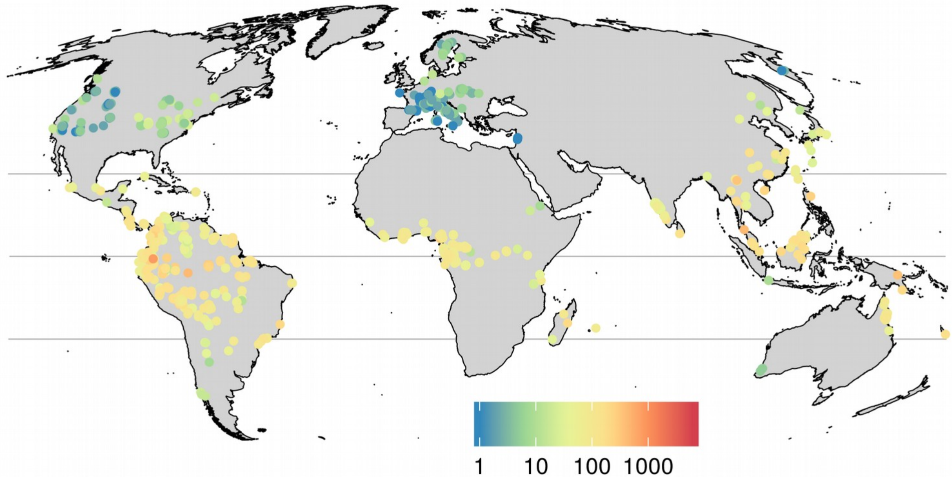
Precipitation in driest quarter

Precipitation seasonality

Keil & Chase (2018) *BioRxiv*

Models





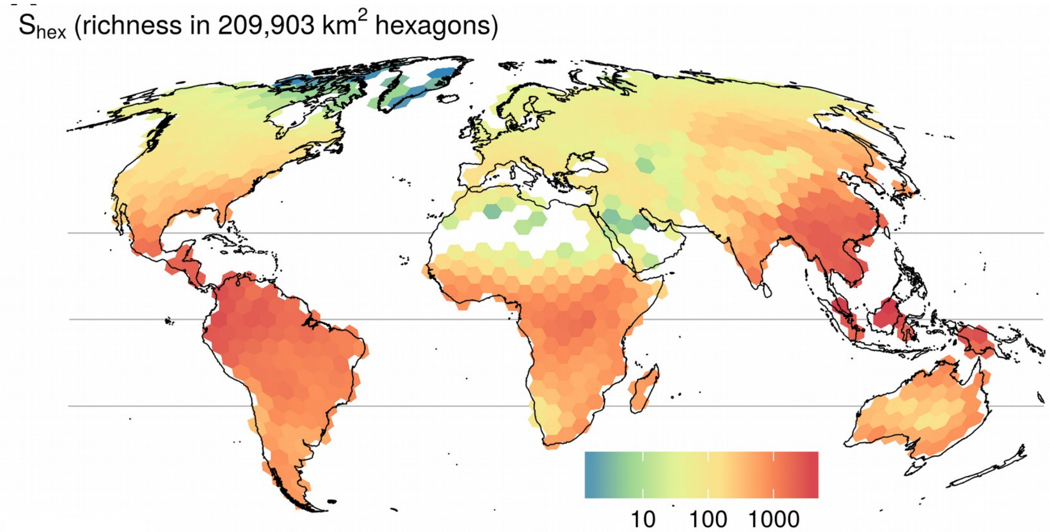
Generalized Additive Models (GAM) with Negative Binomial errors

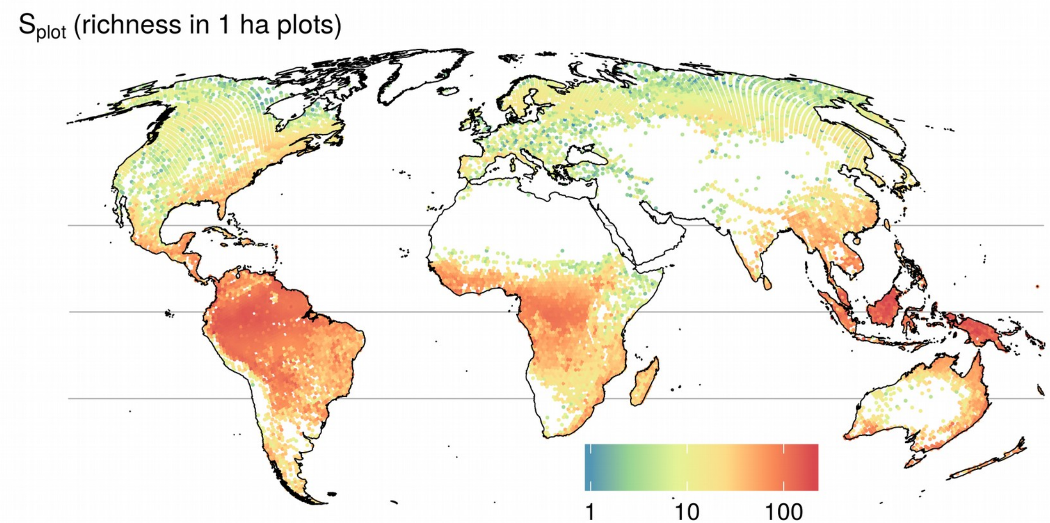
Smooth spatial term

All predictors interact with area

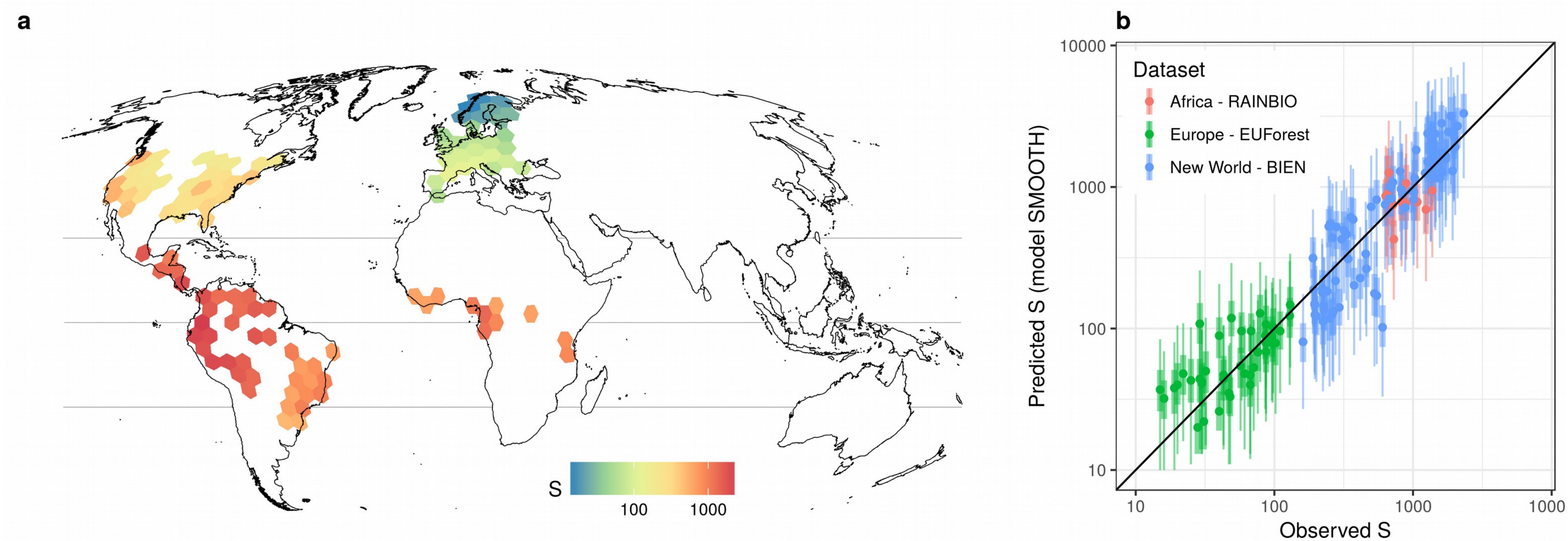
R packages `mgcv`, `brms` (interface to STAN)

Predicted species richness



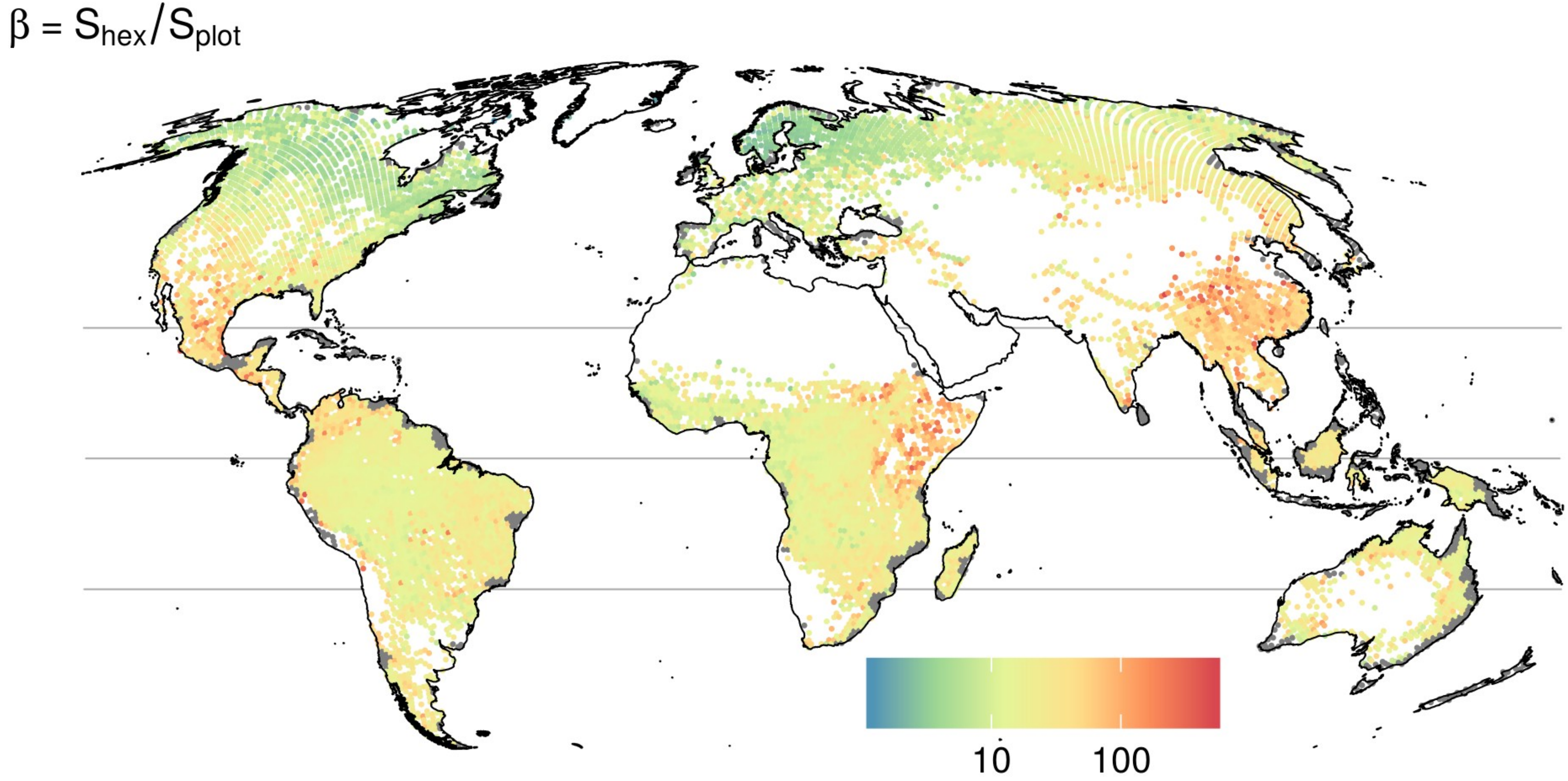


External validation

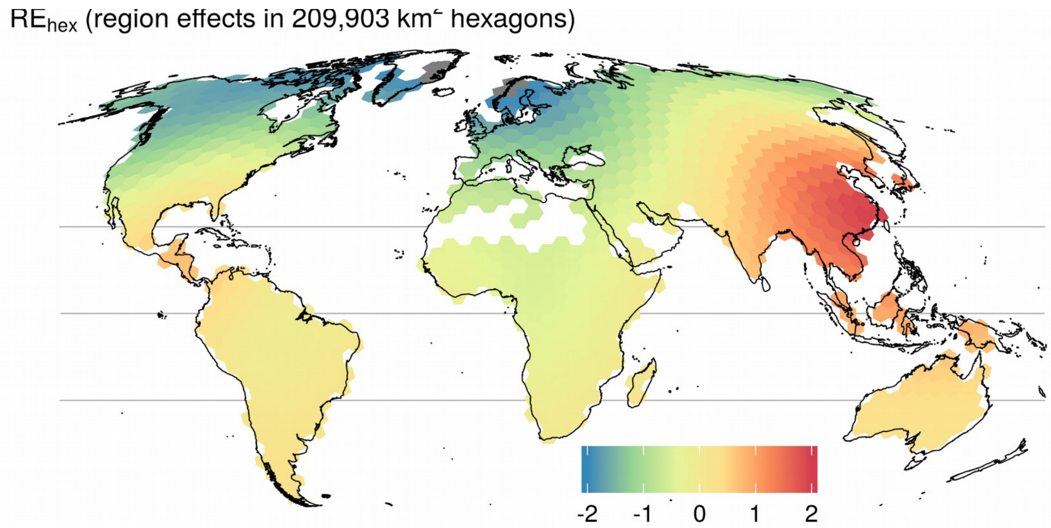


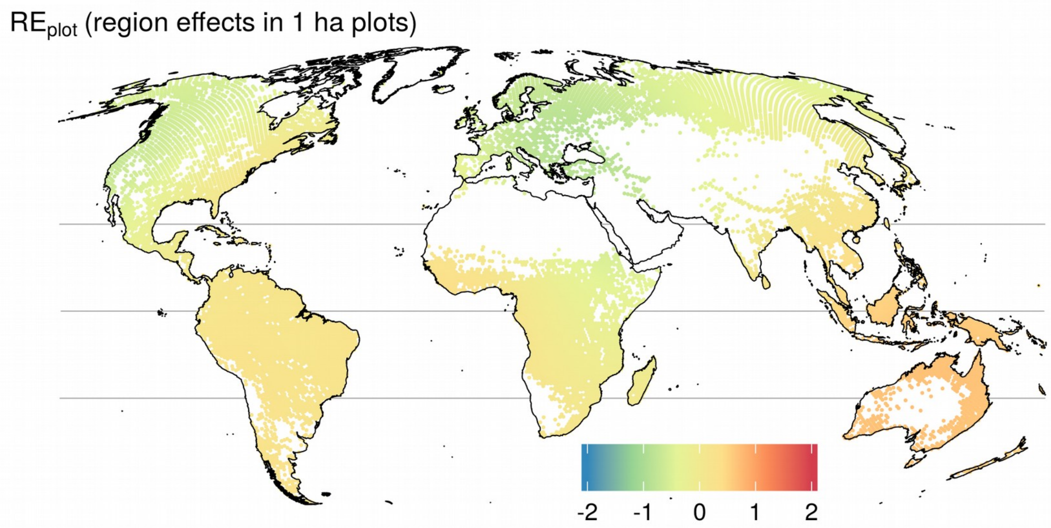
Keil & Chase (2018) *BioRxiv*

Predicted beta diversity

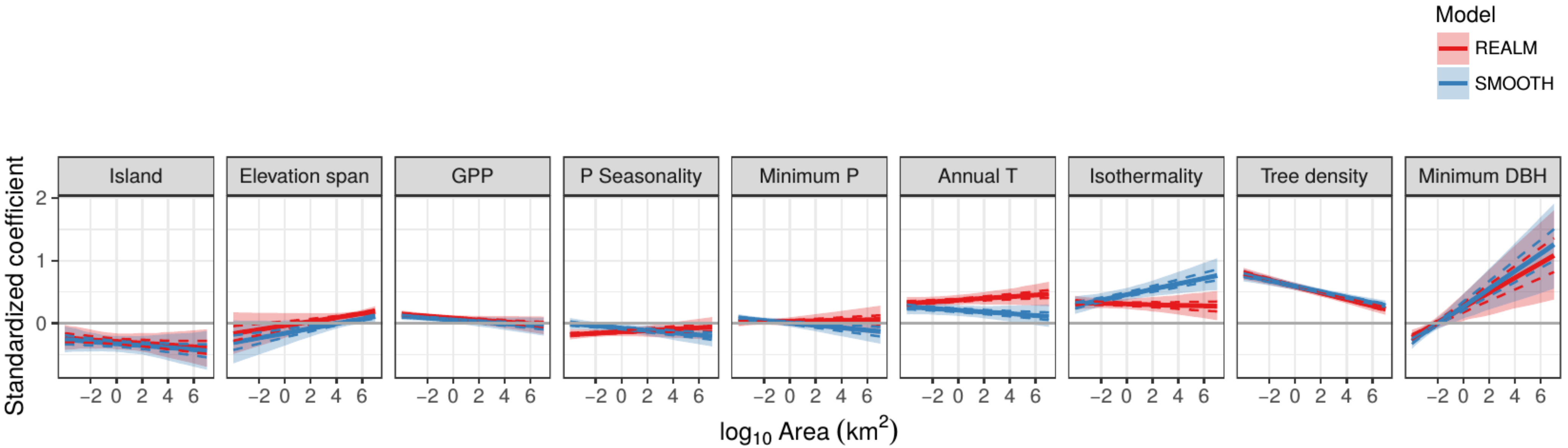


Grain-dependent effects of regions

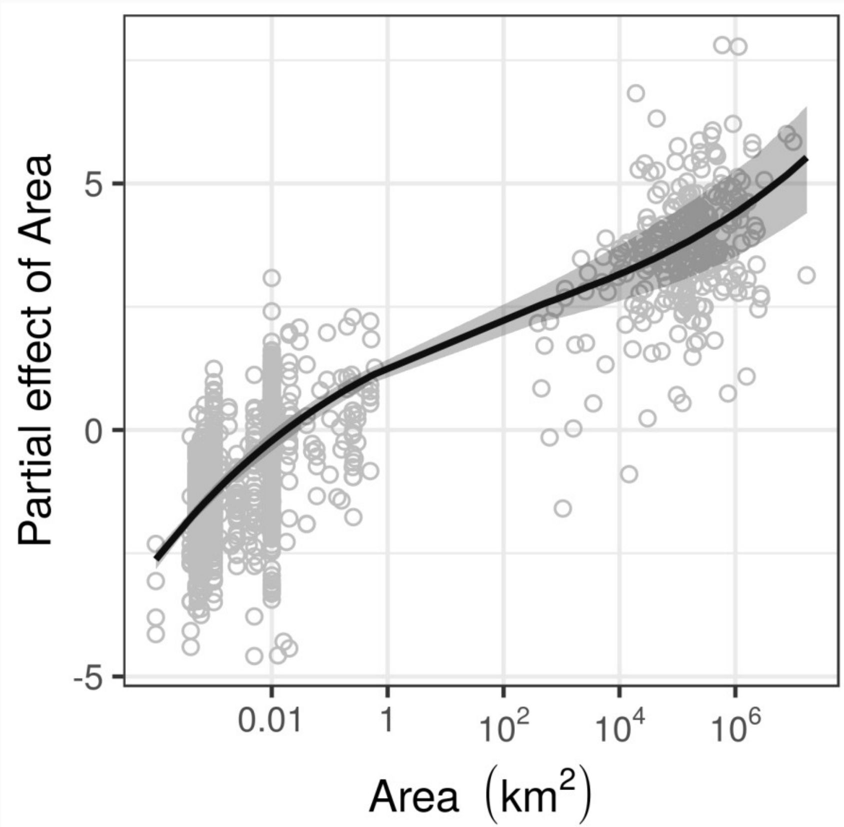


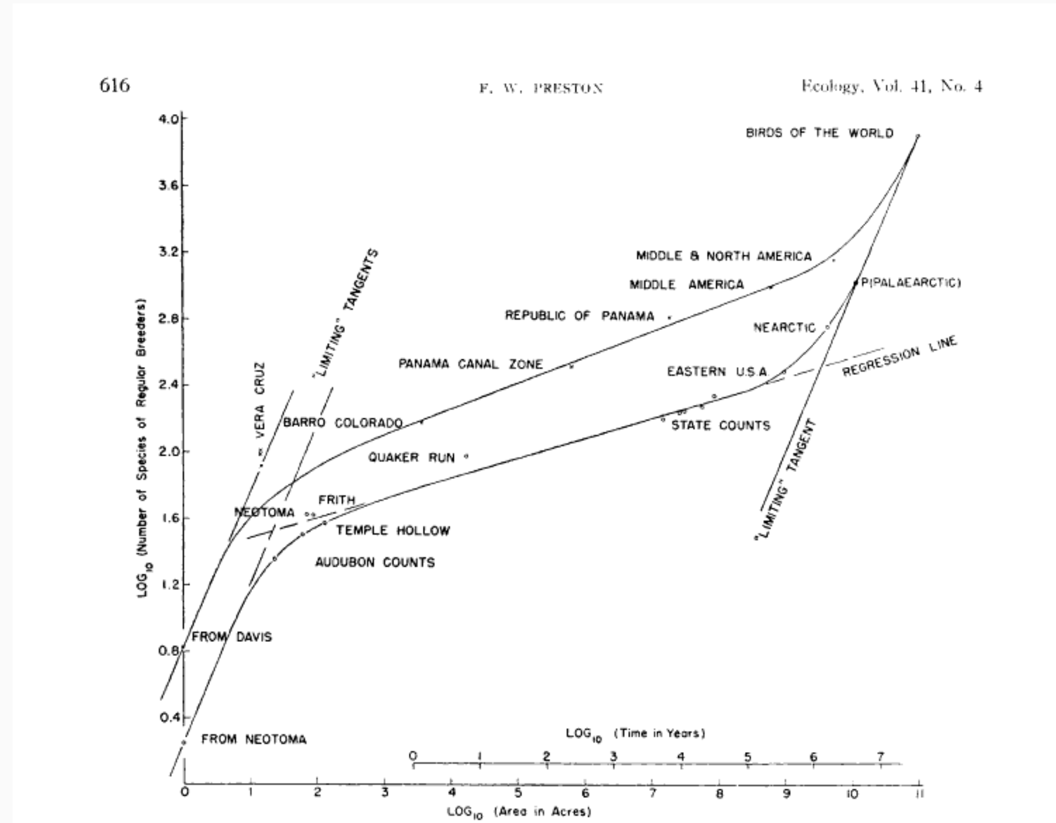


Grain-dependent effects of environment



Tri-phasic species-area relationship





Preston (1960) *Ecology*
Storch, Keil & Jetz (2012) *Nature*

Summary

Summary

- Various types of biodiversity data reflect **one thing**: Point occurrences of individuals in space, which can be seen as a point pattern.

- Abstraction to **point pattern** unifies techniques such as MaxEnt, Poisson regression, or geostatistics, and enables integration of data, patterns, and hypotheses.

- **Scaling relationships**, such as species-area or occupancy-area are a key to both data integration, and understanding of biodiversity.

- Scaling relationships can be used for **upscaling** or **downscaling.**

- Scale-dependence of “effects” can be modeled as a statistical **interaction with area**.

Deutsche
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Dylan Craven, Shane Blowes

Thank you! Questions?