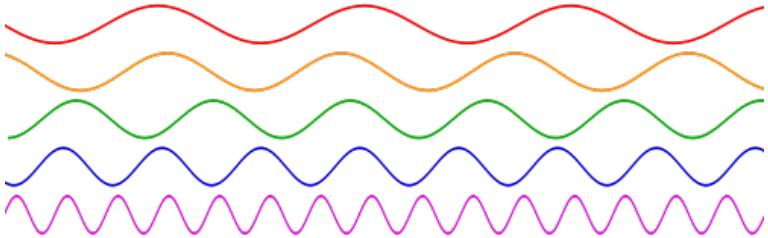


# Multi-scale models for biogeography

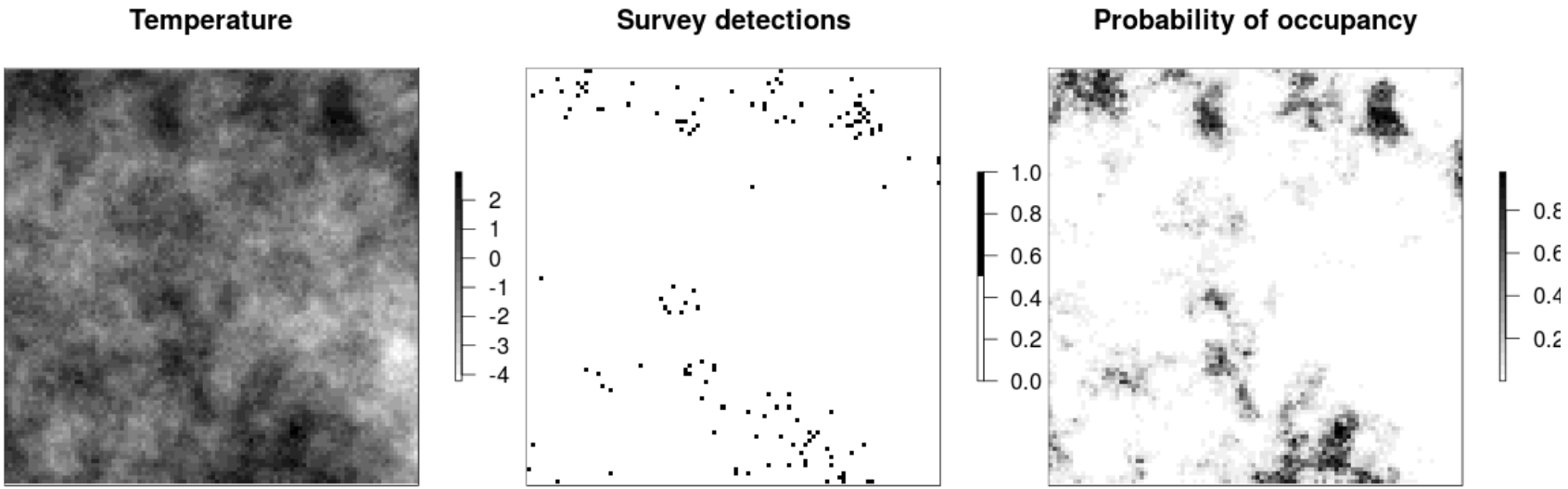
Petr Keil

Center for Theoretical Study, Charles University in Prague,
Czech Republic

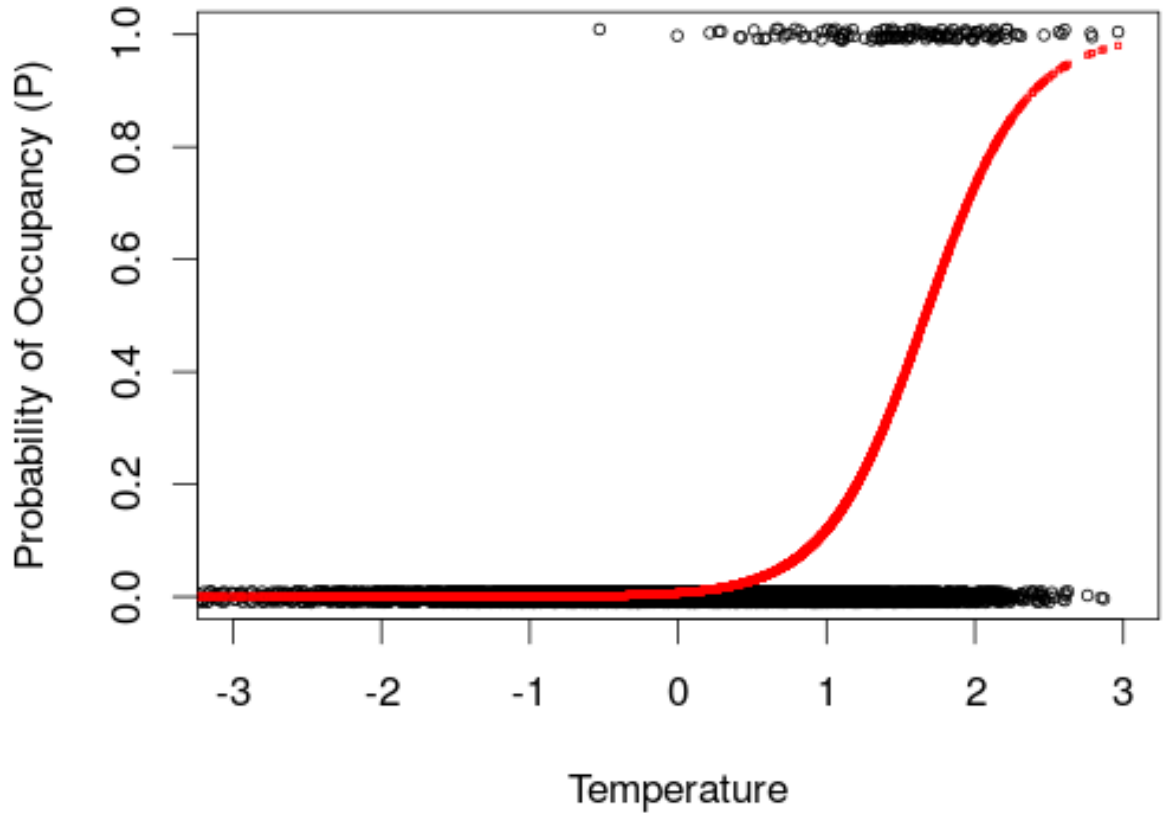
**Walter Jetz**, Yale University
**Adam M. Wilson**, Yale University
**Hugh Sturrock**, UC San Francisco
**Bob O'Hara**, Bik-F Frankfurt
**Jonathan Belmaker**, Tel Aviv University

# Part 1: What is a multi-scale model?

# SINGLE-SCALE STATISTICAL MODEL



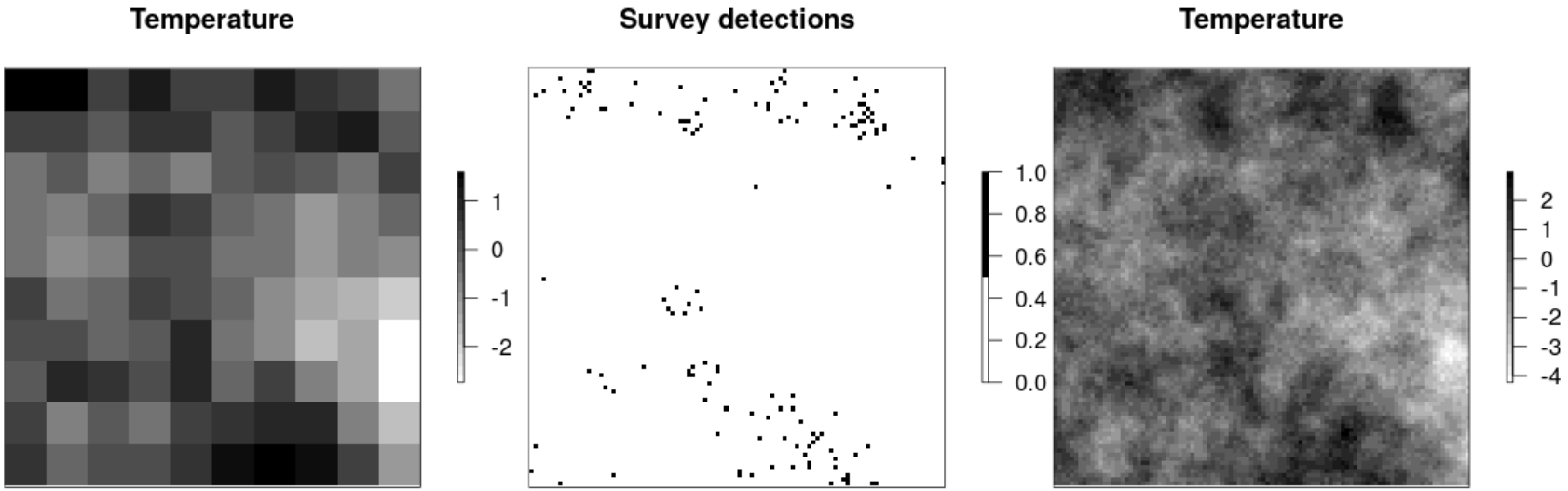
# SINGLE-SCALE STATISTICAL MODEL




$$logit(P_i) = \beta_0 + \beta_1 Temperature_i \quad (1)$$

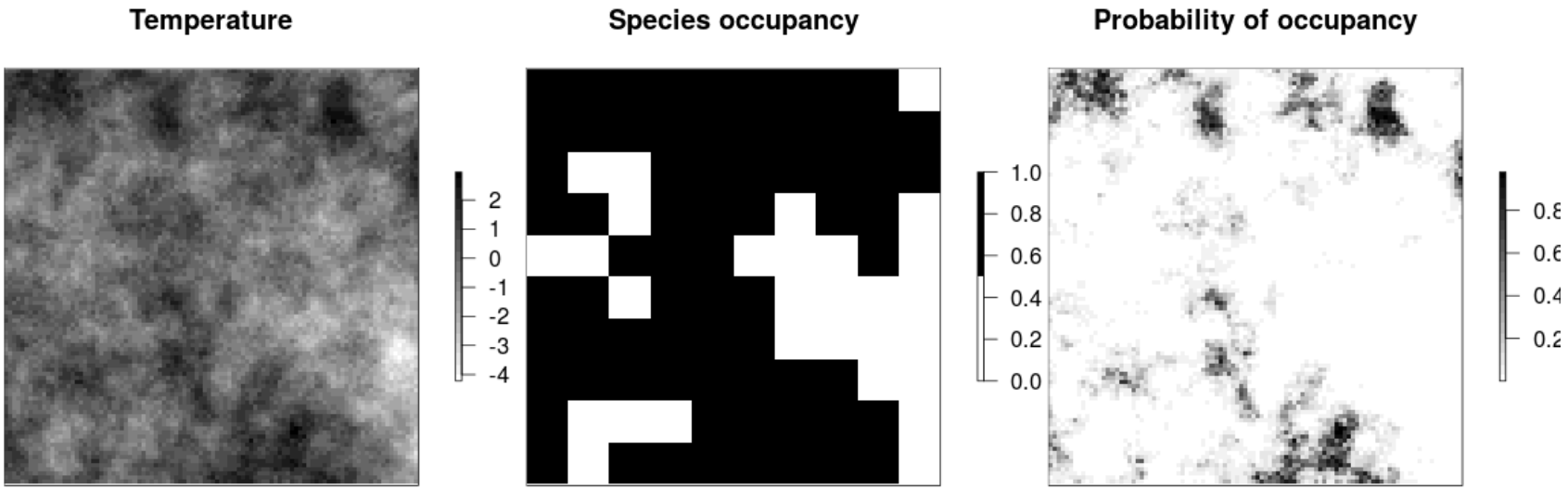
$$O_i \sim Bernoulli(P_i) \quad (2)$$

# RESPONSE FINER THAN PREDICTORS




McInerny & Purves (2011) *Methods in Ecology and Evolution*

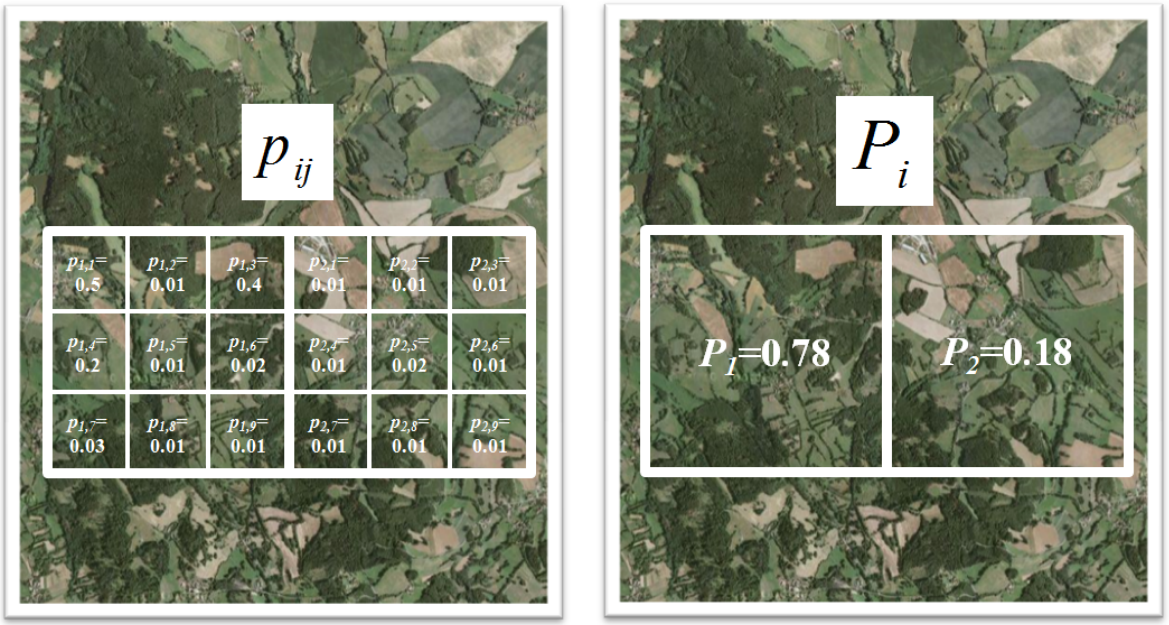
# Predictor finer than response




Keil *et al.* (2013) *Methods in Ecology and Evolution*
Keil *et al.* (2014) *Diversity & Distributions*
Keil & Jetz (2014) *Ecological Applications*
Sturrock *et al.* (2015) *Malaria Journal*

# Part 2: How does it work?

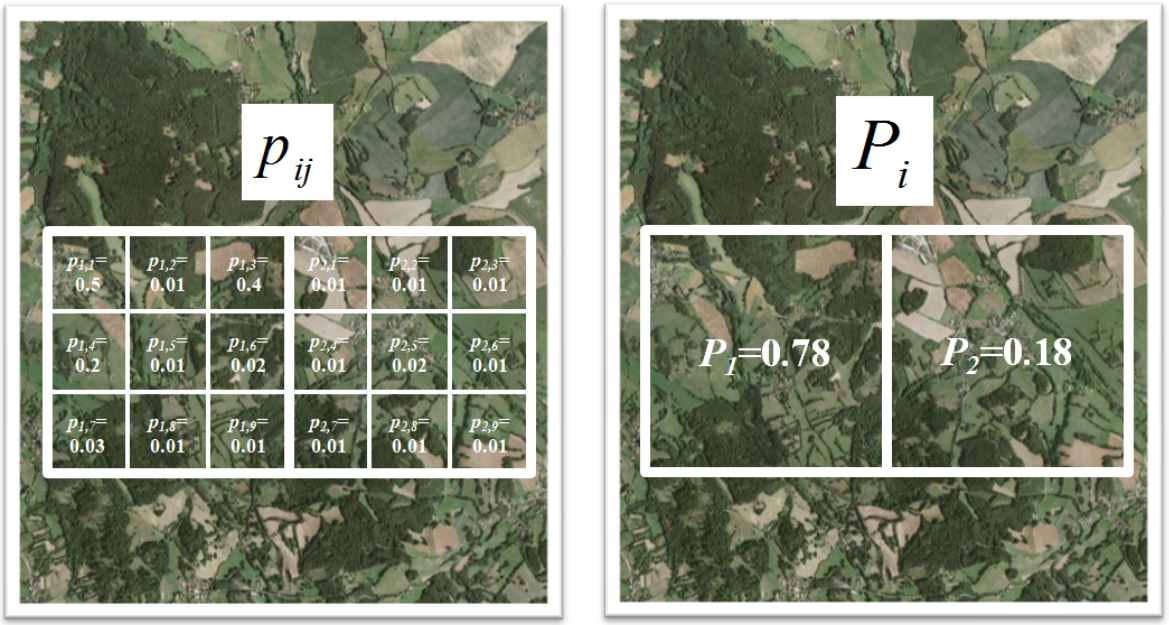
# 2-SCALE LOGISTIC MODEL FOR ONE SPECIES




$$logit(p_{ij}) = \beta_0 + \beta_1 Temperature_{ij} \quad (3)$$

Keil *et al.* 2013 *Methods in Ecology and Evolution*

# 2-SCALE LOGISTIC MODEL FOR ONE SPECIES

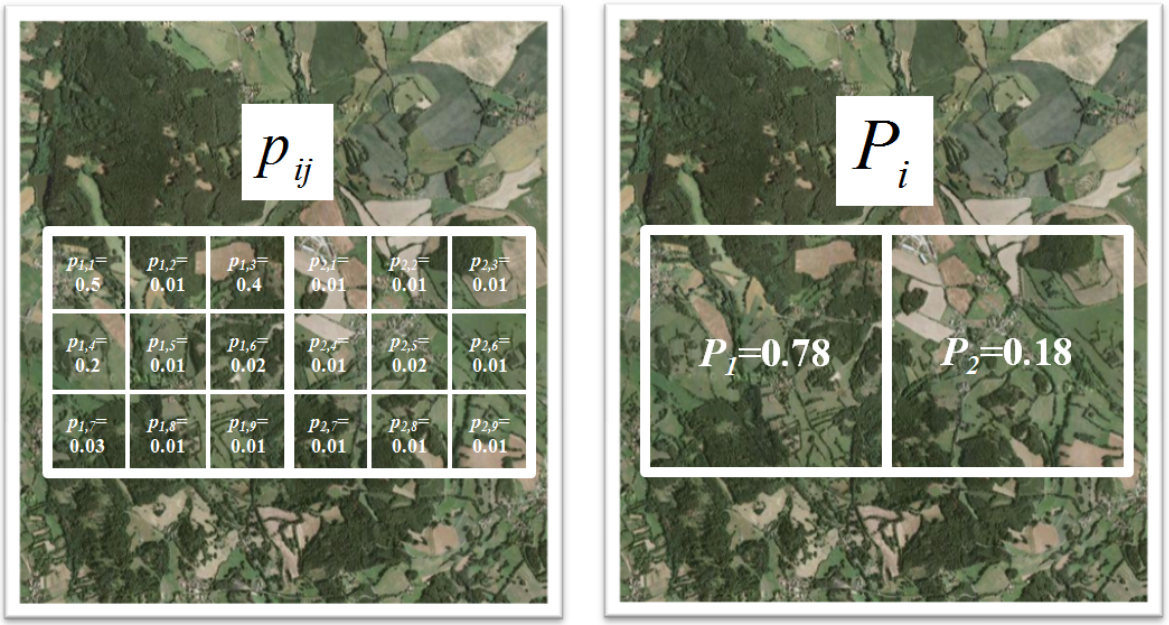



$$logit(p_{ij}) = \beta_0 + \beta_1 Temperature_{ij} \tag{3}$$

$$P_i = 1 - \prod_{j=1}^{n} (1 - p_{ij}) \tag{4}$$

Keil *et al.* 2013 *Methods in Ecology and Evolution*

# 2-SCALE LOGISTIC MODEL FOR ONE SPECIES



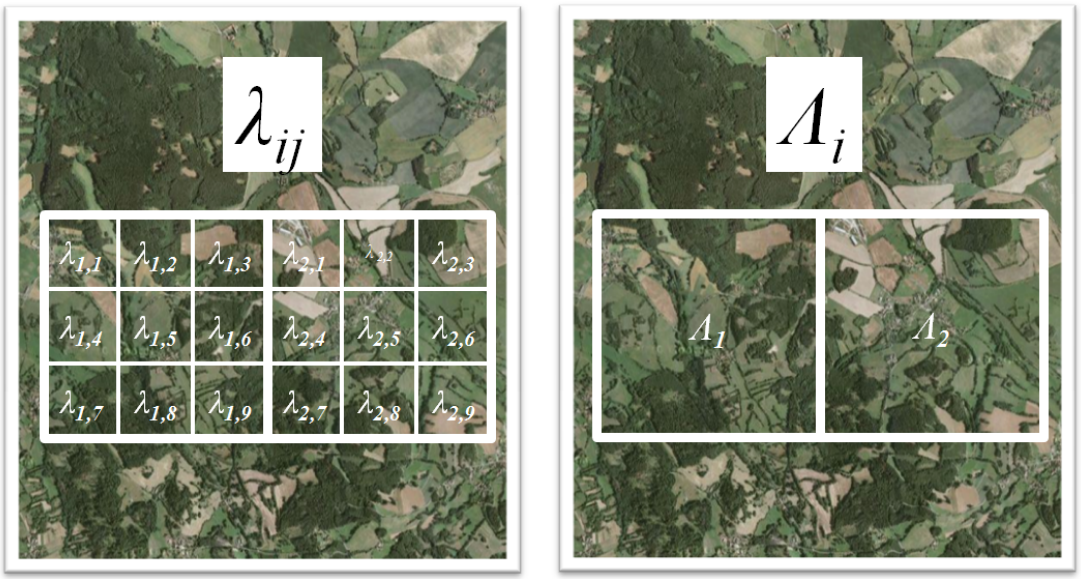

$$logit(p_{ij}) = \beta_0 + \beta_1 Temperature_{ij} \tag{3}$$

$$P_i = 1 - \prod_{j=1}^{n} (1 - p_{ij}) \tag{4}$$

$$O_i \sim Bernoulli(P_i) \tag{5}$$

Keil *et al.* 2013 *Methods in Ecology and Evolution*

# 2-SCALE POISSON MODEL OF SPECIES RICHNESS




$$\lambda_{ij} = f(environment_{ij}) \tag{6}$$

$$\Lambda_i = \beta_w \times \hat{\lambda}_i \tag{7}$$

$$S_i \sim Poisson(\Lambda_i) \tag{8}$$

Keil & Jetz 2014 *Ecological Applications*

# How do we fit these models?

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- Likelihood maximization

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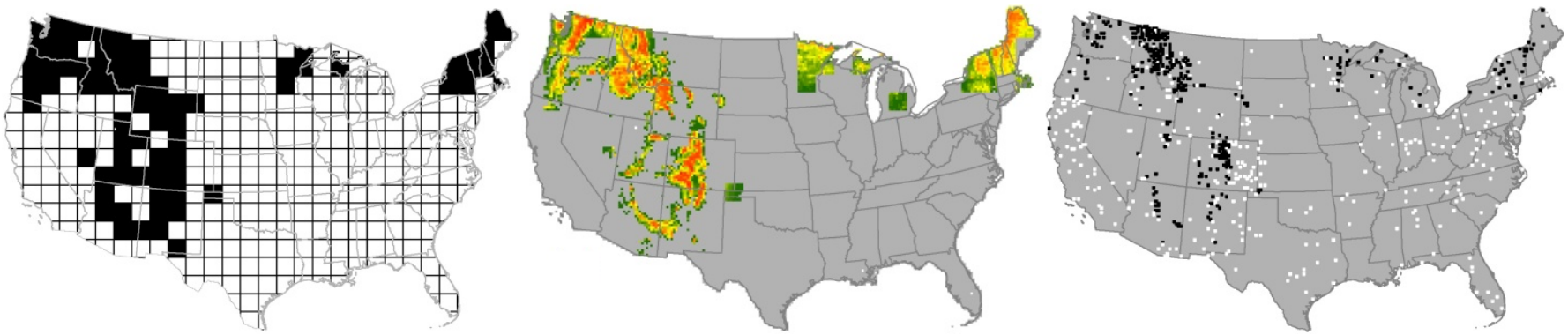
- Likelihood maximization
- MCMC (Markov Chain Monte Carlo)
- INLA (Integrated Nested Laplace Approximation)
- **Steep learning curve**

# Part 3: Case studies

# Case study 1 – Single-species

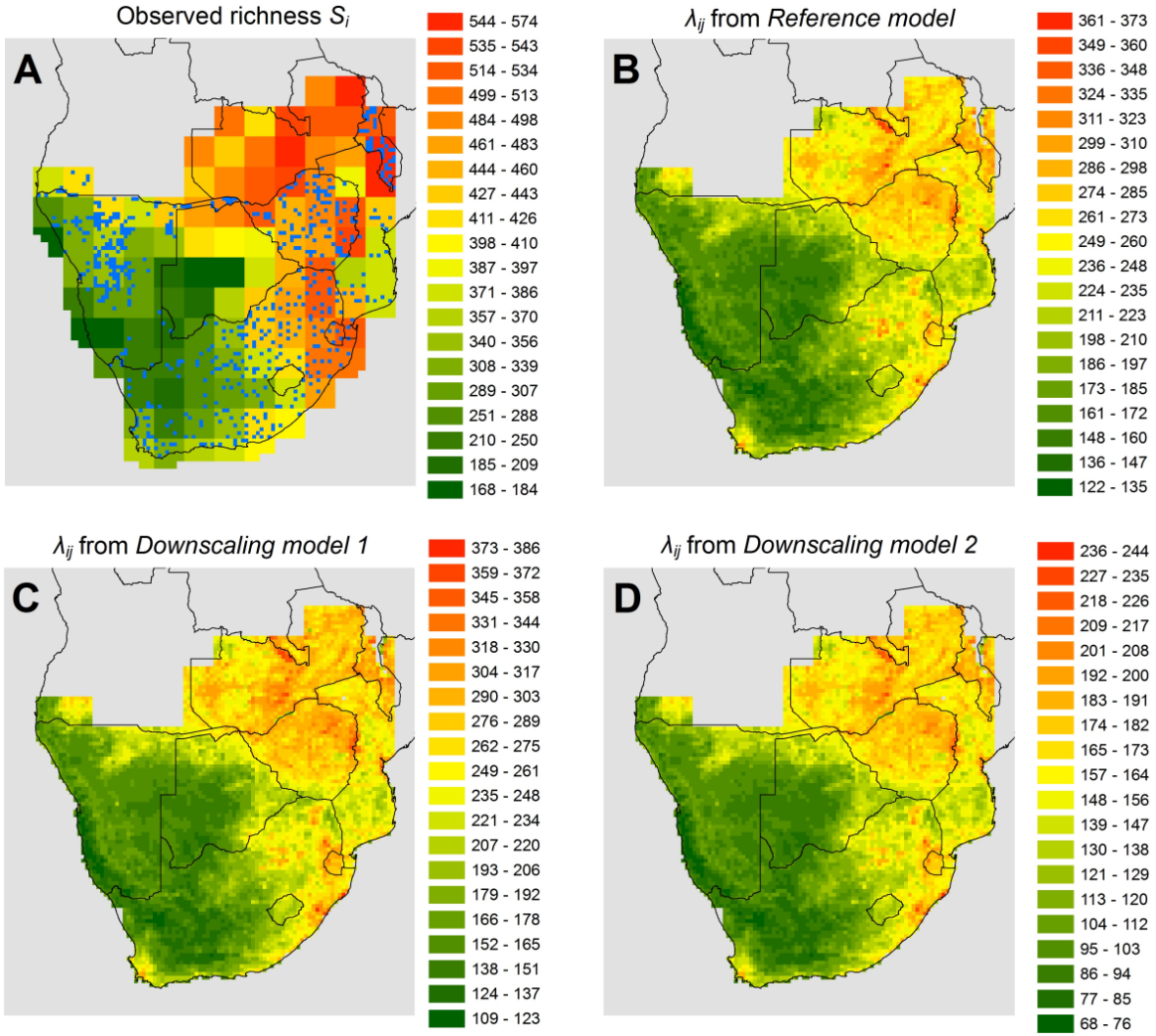
American three-toed woodpecker (*Picoides dorsalis*, Baird 1858)



*AUC*=0.93; Nagelkerke's $R^2$ = 0.69

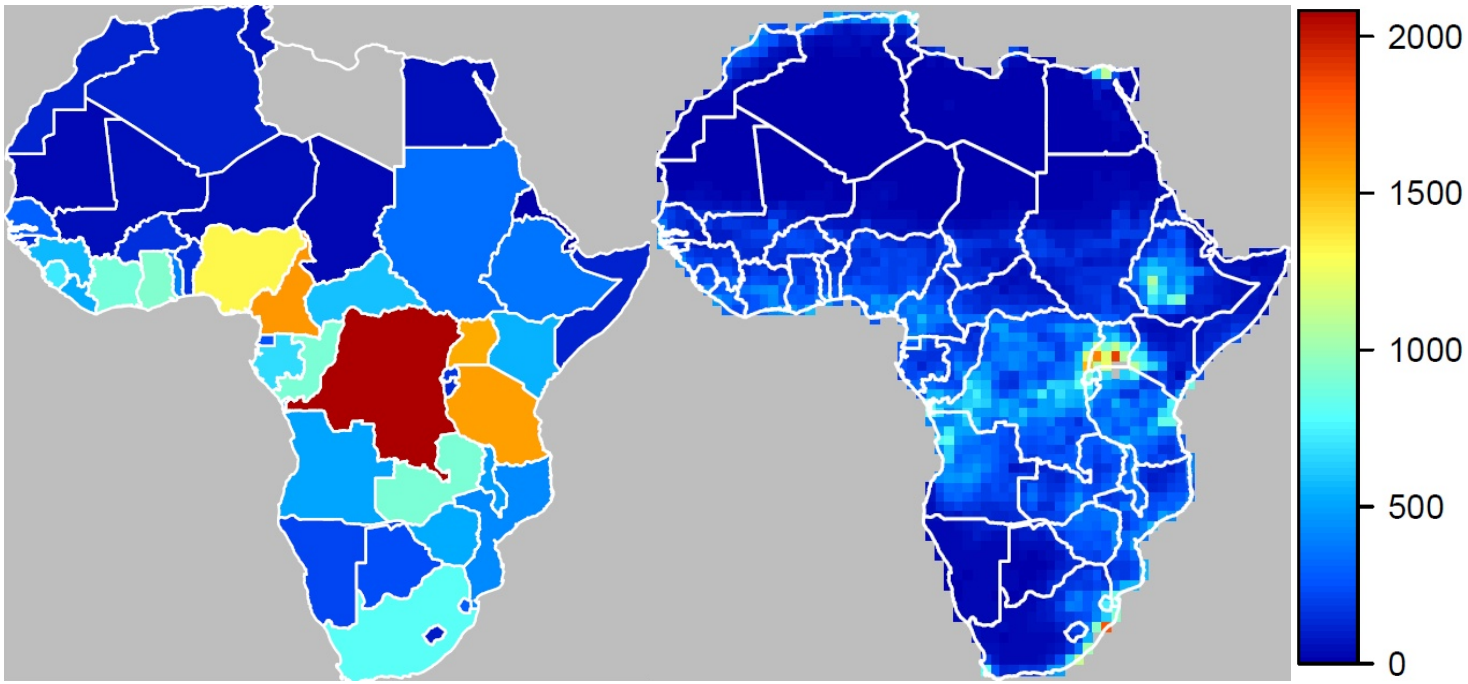
Keil *et al.* 2014 *Diversity & Distributions*

# Case study 2 – Species richness of birds



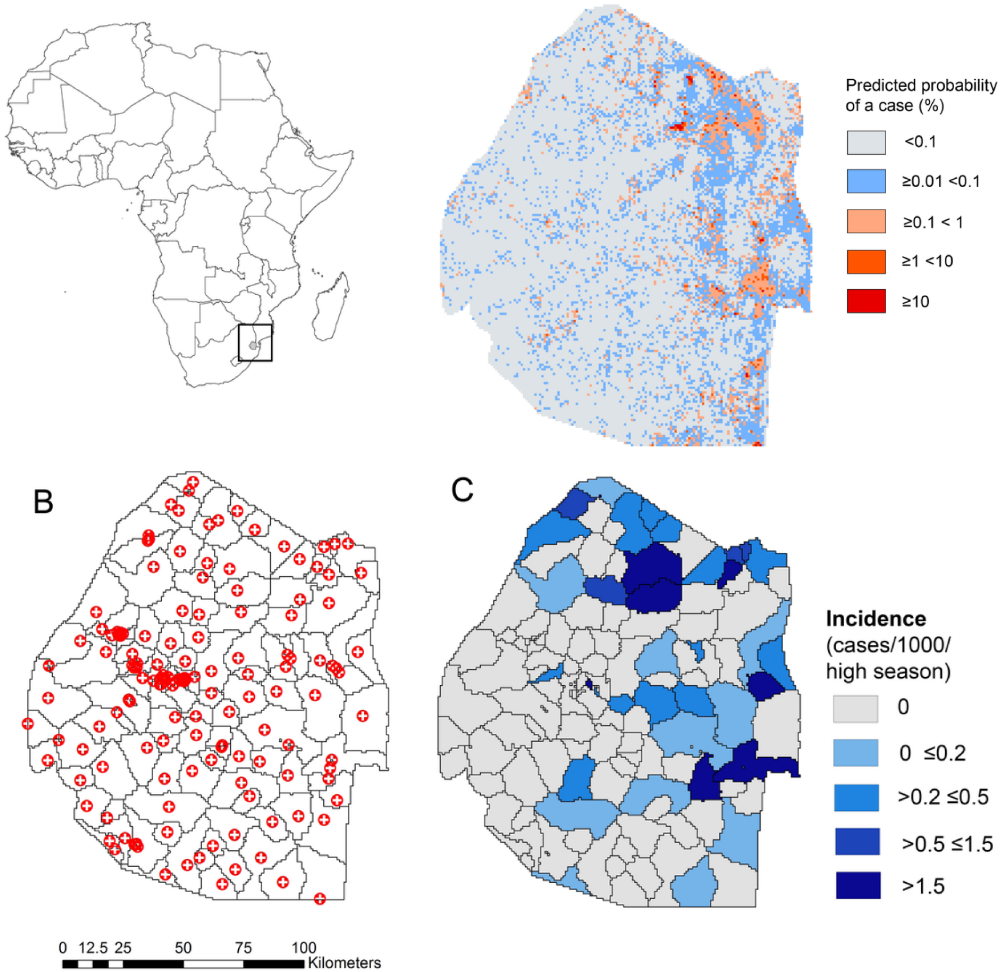

Keil *et al.* 2014 *Ecological Applications*

# Case study 3 - Species richness of butterflies




*Unpublished*

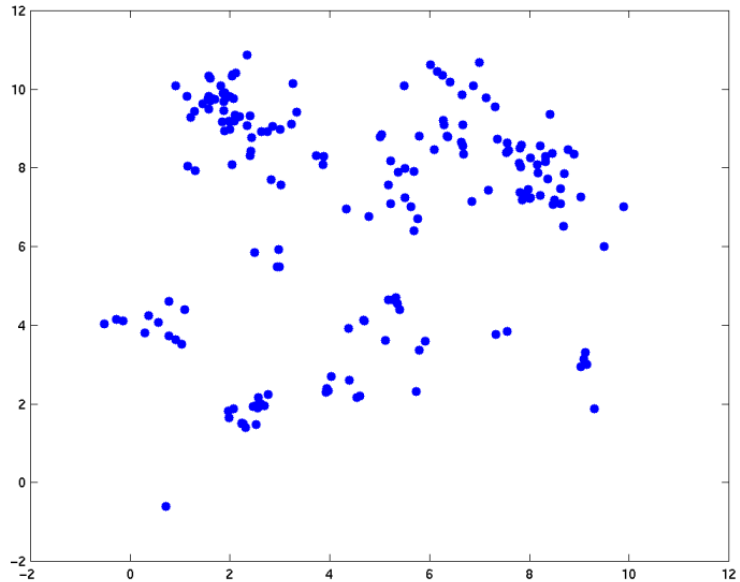
# Case study 4 – Malaria in Swaziland




Sturrock *et al.* (2015) *Malaria Journal*

# Part 4: Future prospects

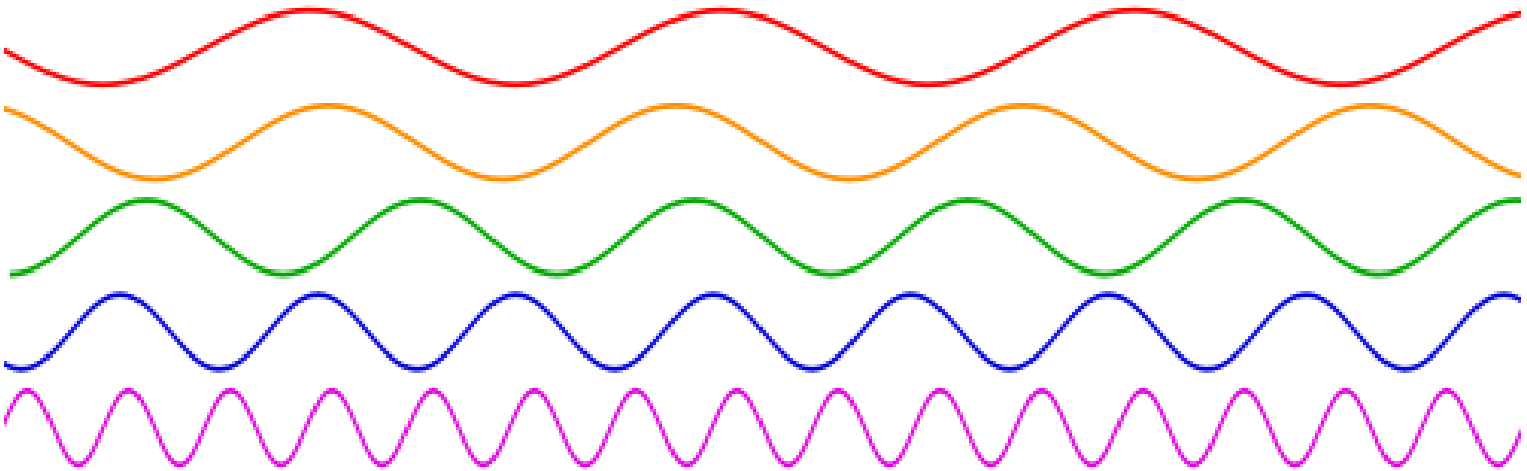
# Linking GLM, point processes and MaxEnt




Bob O'Hara

Renner & Warton (2013) *Biometrics*

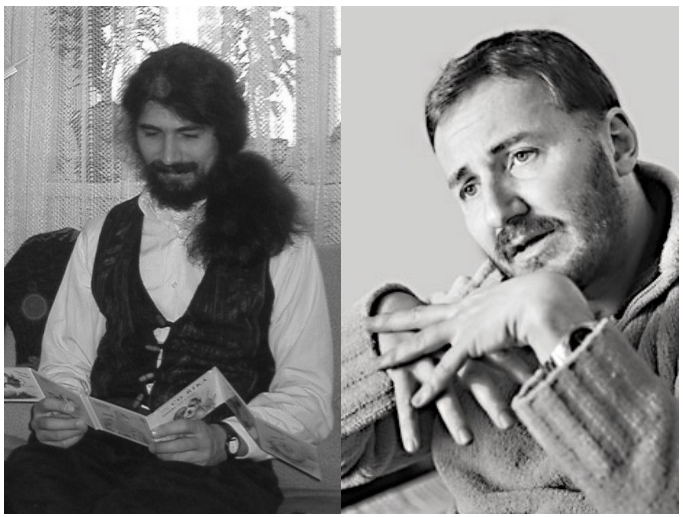
# FROM GRIDS TO **CONTINUOUS SCALE**



Keywords: Fourirer transform, Wavelets, eigenvector maps, ...

Sandel (2015) *Ecography*

# THE IDEA OF **FUNDAMENTAL SCALE**



Arnost L. Sizling, David Storch

Sizling *et al.* (2009) *PNAS*; Storch & Sizling (2008) *Folia Geobotanica*

# Summary

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- We can fit models using data from disparate grains without having to loose data.
- We can downscale maps.
- We can derive fine-scale niche using coarse-scale environmental data.
- There are exciting opportunities for research projects.
- The tools need to be made more accessible.

# Acknowledgements

Walter Jetz, Adam M. Wilson, Hugh Sturrock, Bob O'Hara, Jonathan Belmaker

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# Thank you!

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