Modeling Geographic Patterns in the Species Abundance Distribution

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and

Ethan White

$p_y = k m_y e^{-\sum \lambda_i f_i}$

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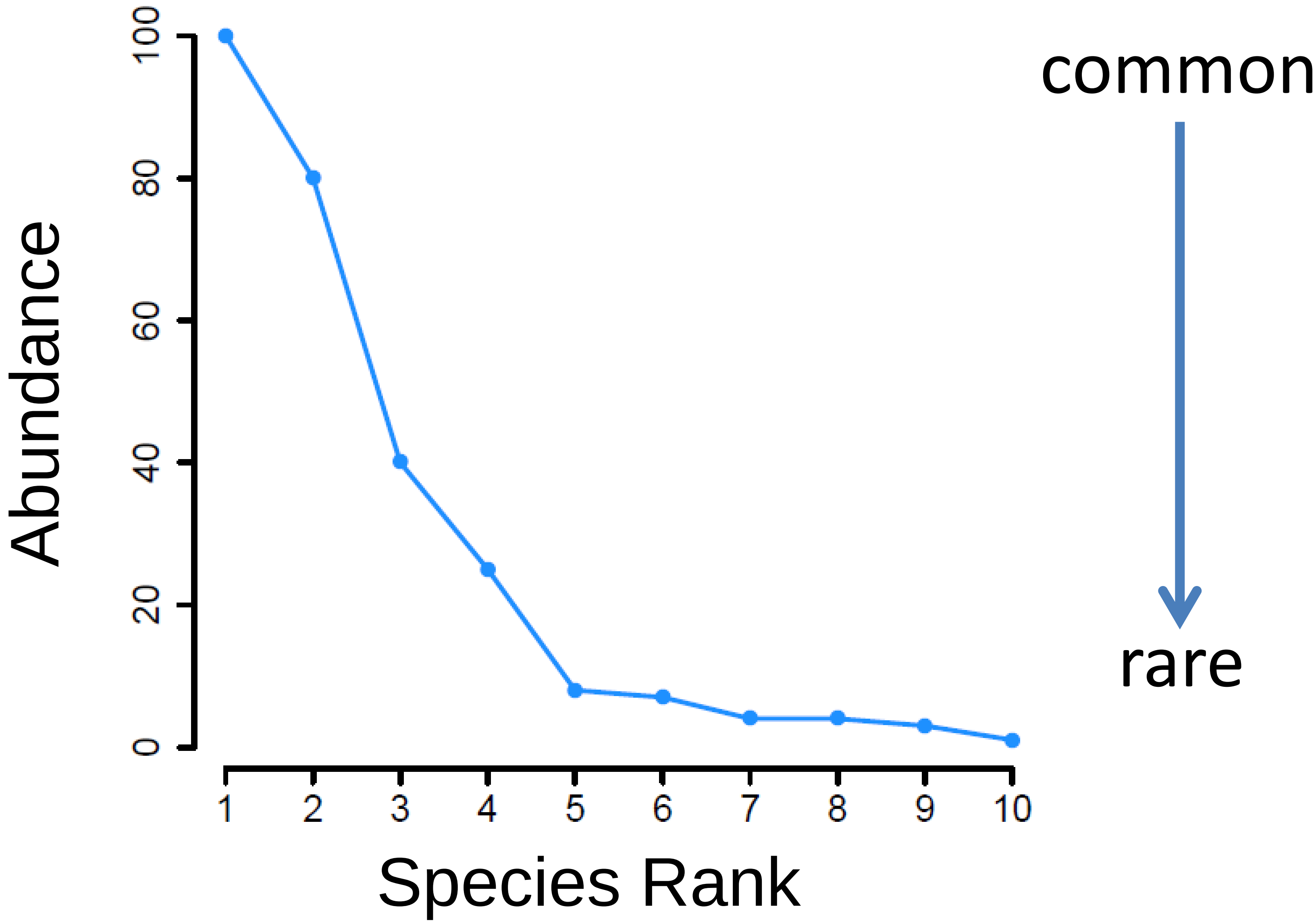
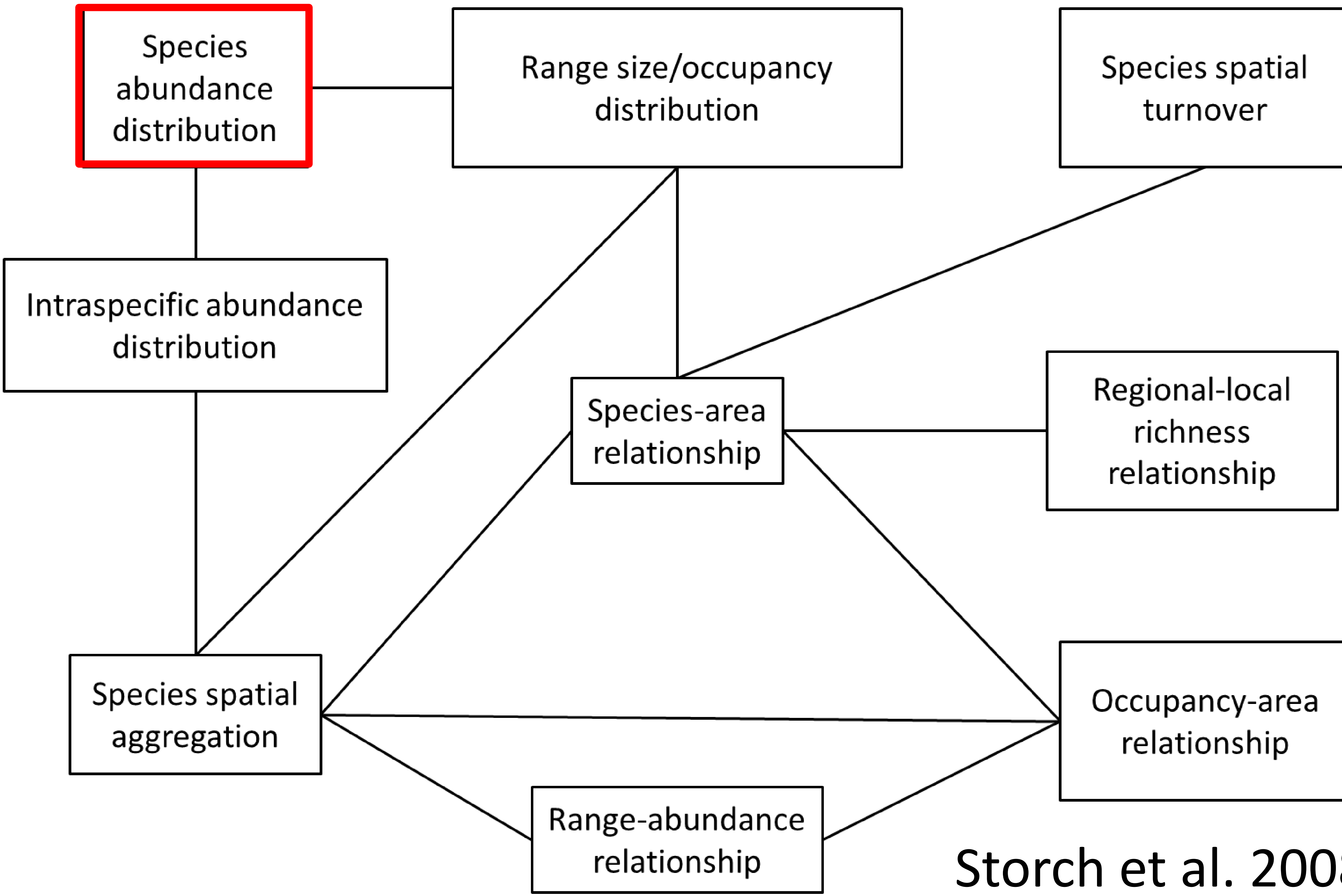
Species Abundance Distribution (SAD)

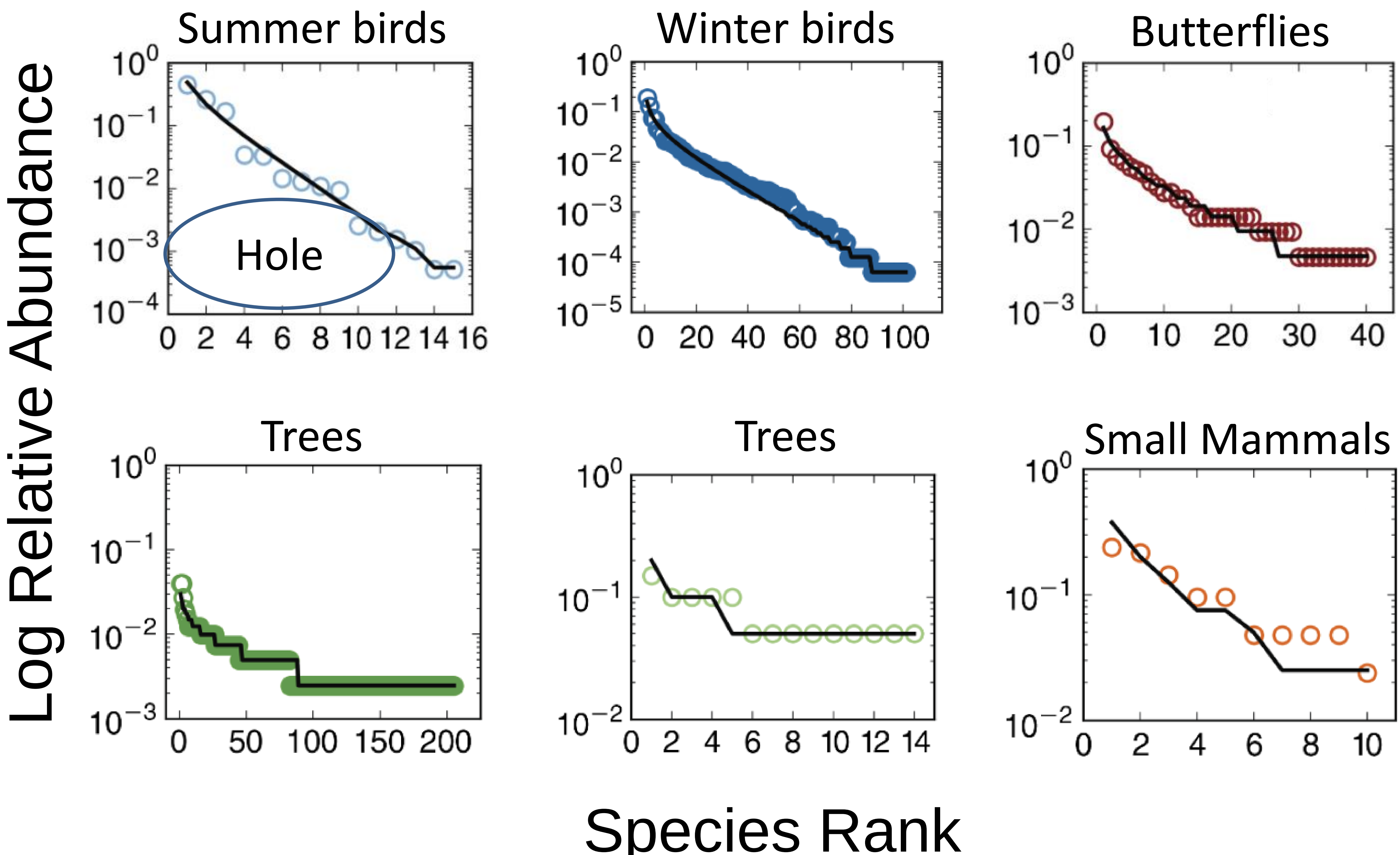


SAD is Foundational



Storch et al. 2008

Common Shape: Hollow Curve



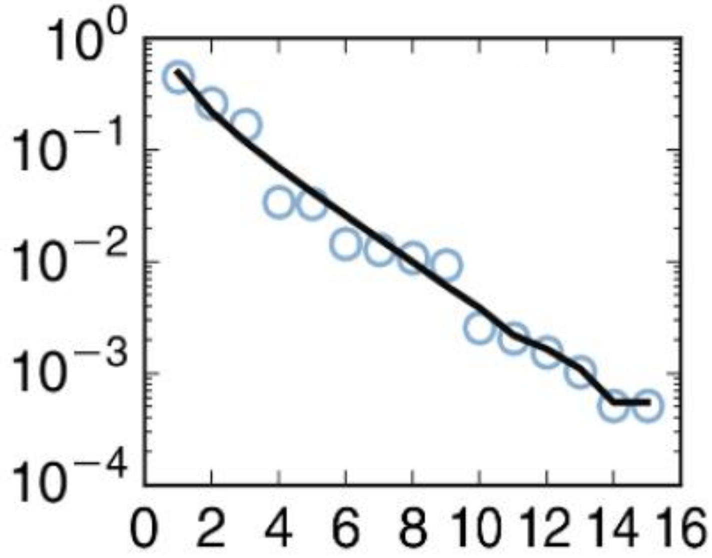
White et al. (2012)

Universal explanation for shape

- Maximum Entropy Theory of Ecology (METE)
  Harte et al. (2008), Harte (2011)

- Predicts many distributions
  species-abundance, body-size, species-area, distance-decay

- State Variables
  Total number of species (S_0)
  Total number of individuals (N_0)
  Total energy of community (E_0)
  Total area of a community (A_0)



- Predicts that a abundance follows a truncated log-series distribution

Why MaxEnt?

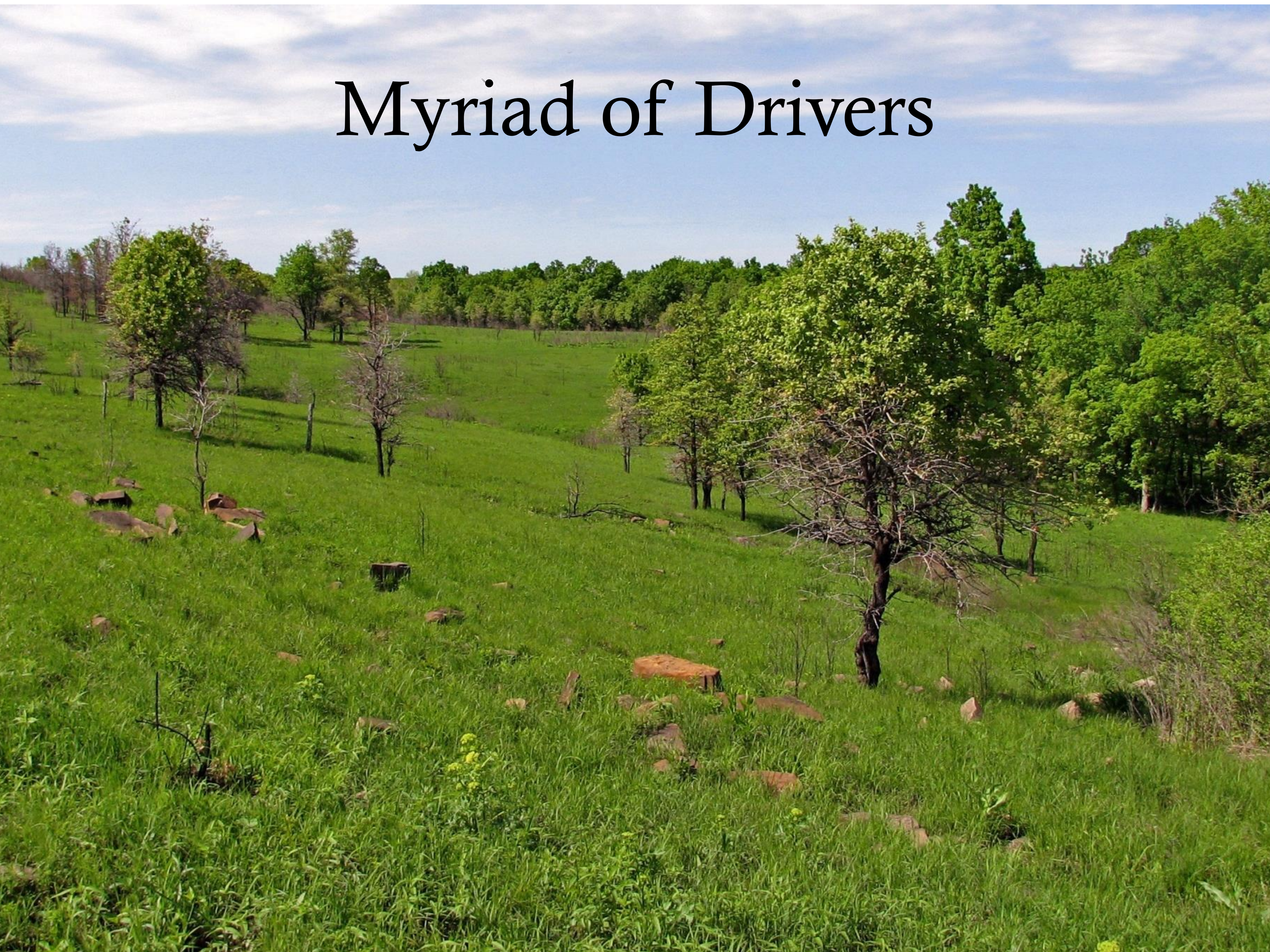
- Infers the **most likely state** of system given **constraints**

- Top-down approach to modeling

- Expected when processes cancel one another out
  - e.g., when there are many non-directional processes interacting

Haegeman and Loreau 2009

Myriad of Drivers



METE abundance distribution solution

Joint Distribution
Abundance & Metabolic Rate

$$R(n, \varepsilon \,|S_0, N_0, E_0)$$

Shannon's Entropy

$$I_R = -\sum_{n=1}^{N_0} \int_{\varepsilon=1}^{E_0} R(n,\varepsilon) \cdot \ln\left(R(n,\varepsilon)\right) \cdot d\varepsilon$$

Constraints
Average # of individuals
Average total metabolism

$$\sum_{n=1}^{N_0} \int_{\varepsilon=1}^{E_0} n \cdot R(n,\varepsilon) \cdot d\varepsilon = \frac{N_0}{S_0}$$

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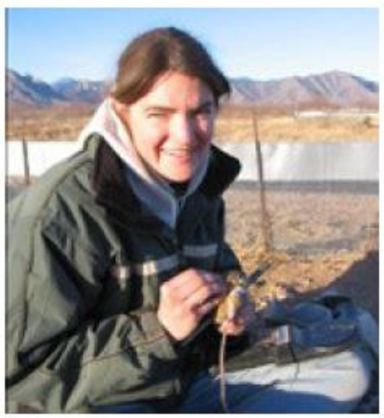
Species-abundance distribution

$$\Phi(n|S_0, N_0) \approx \frac{1}{ln(\beta^{-1})} \cdot \frac{e^{-\beta n}}{n}$$

(Harte et al. 2008, 2009; Harte 2011)

Does METE capture global variation in SAD?

Ethan White

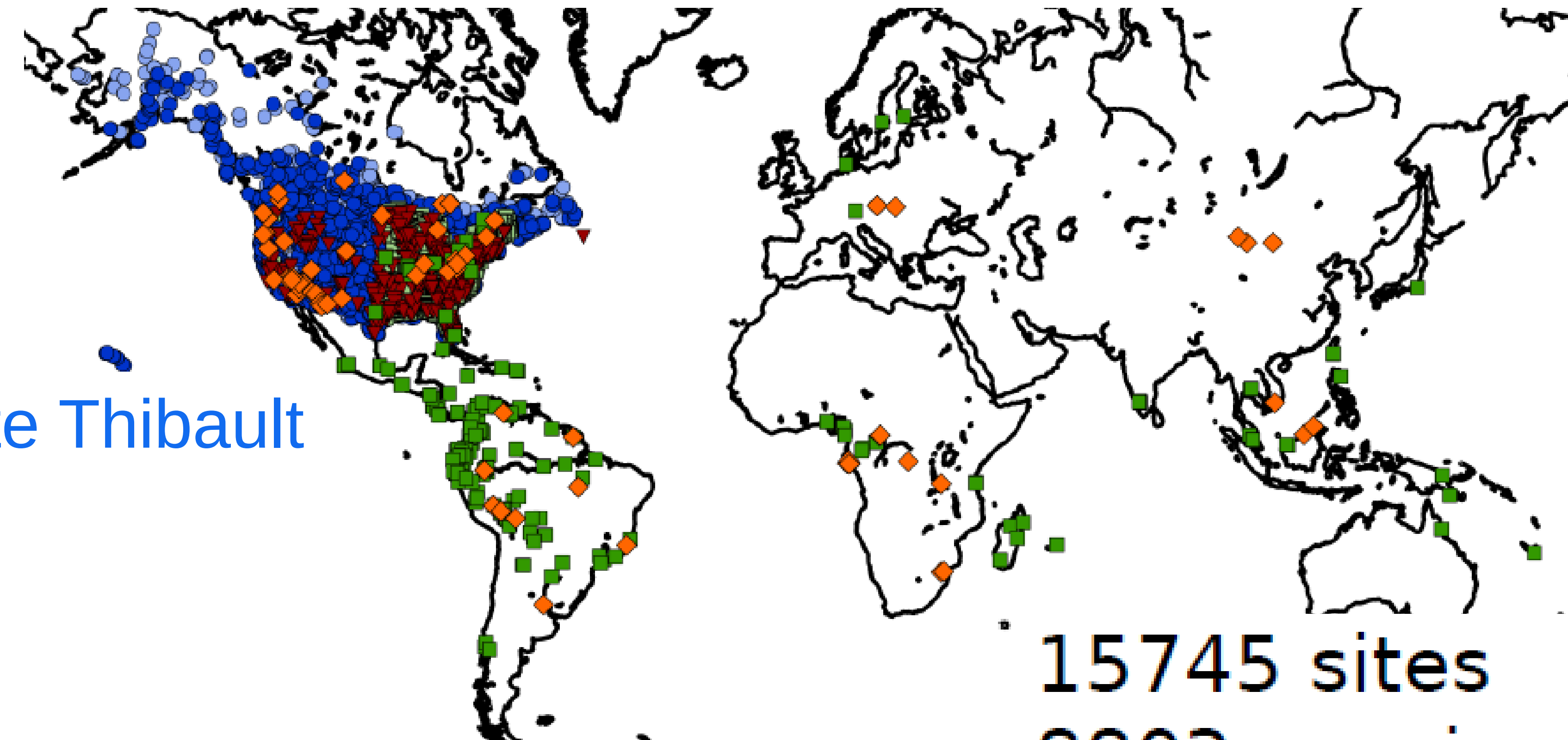


Kate Thibault

Xiao Xiao

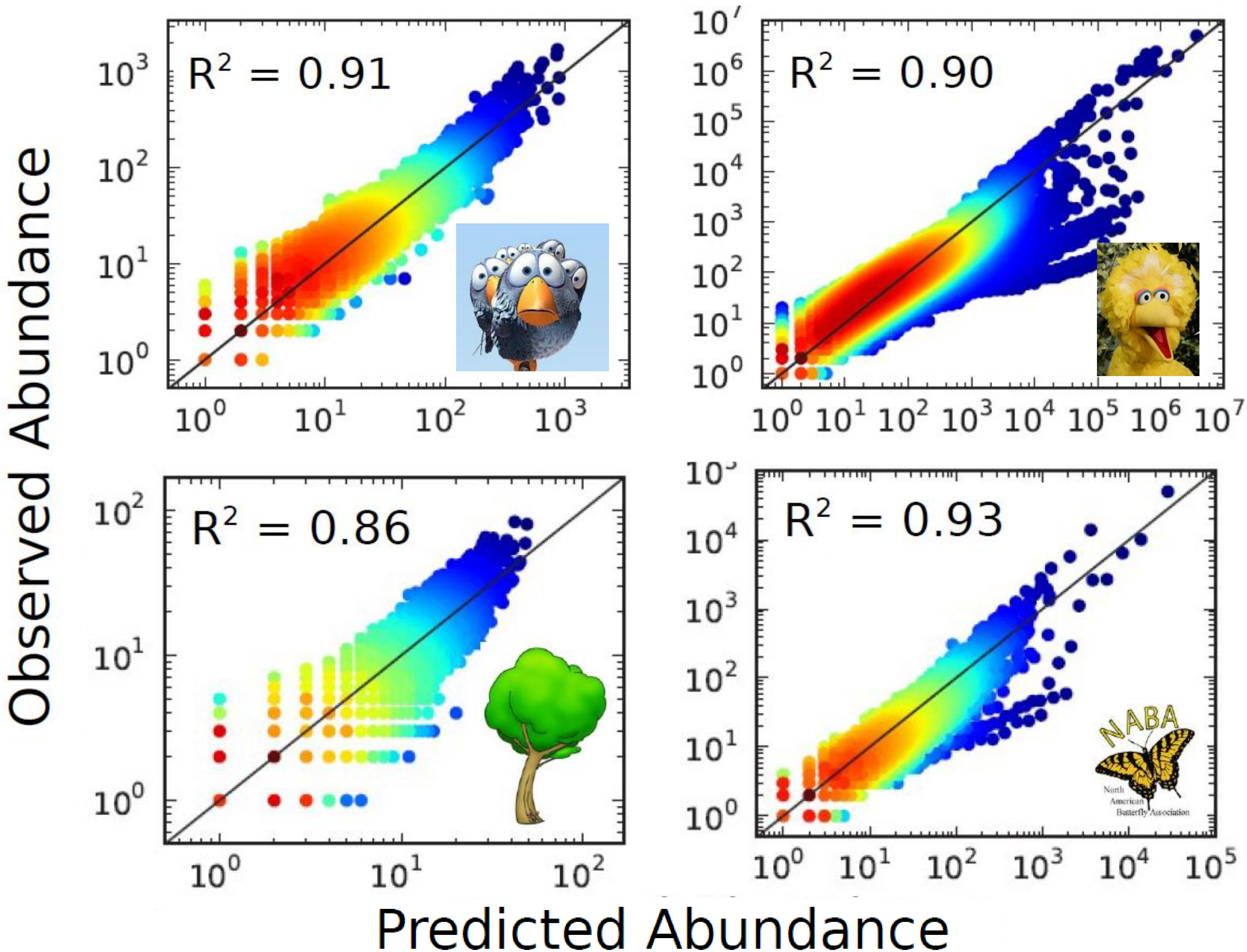
EcoData Retriever

ecodataretriever.org



- 15745 sites
- 8802 species
- 6 continents
- 4 major taxa

(White, Thibault, Xiao, 2012)



R² = 0.91
R² = 0.90
R² = 0.86
R² = 0.93
NABA
North American Butterfly Association
Observed Abundance
Predicted Abundance

The Next Challenge

- How can we predict patterns of abundance where we have no data?

- Can we model the state variables (S and N) across the continent to plug into METE?

Multiscale Modeling Framework

Observed S_0 & N_0 + Environment

↓

Predicted
$\hat{S}_0$ & $\hat{N}_0$

↓

Maximum Entropy
Theory of Ecology

↓

Predicted
Abundance Distribution

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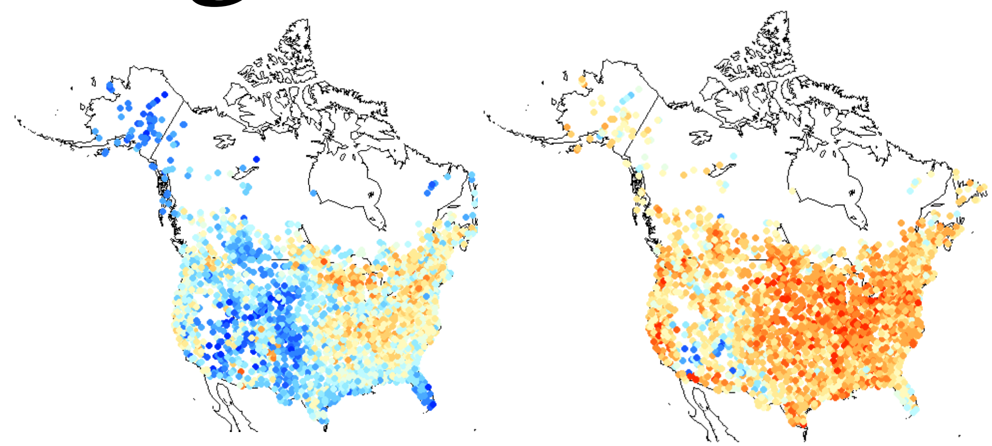

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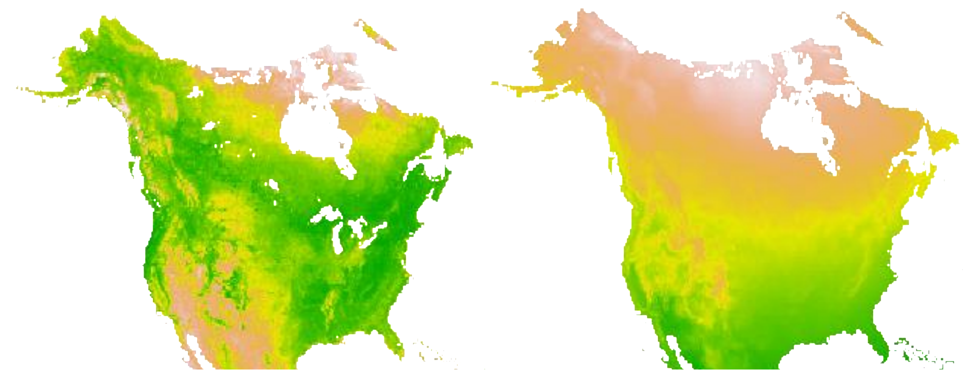

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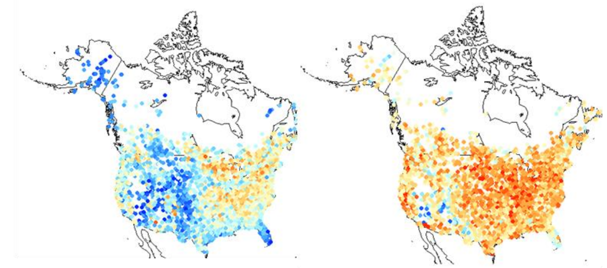
Explanatory Modeling Framework
(e.g., stepwise regression)

Multiscale Modeling Framework

Observed S_0 & N_0 + Environment



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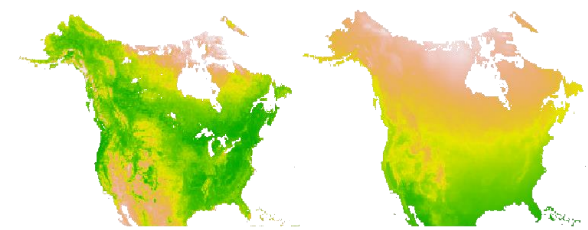

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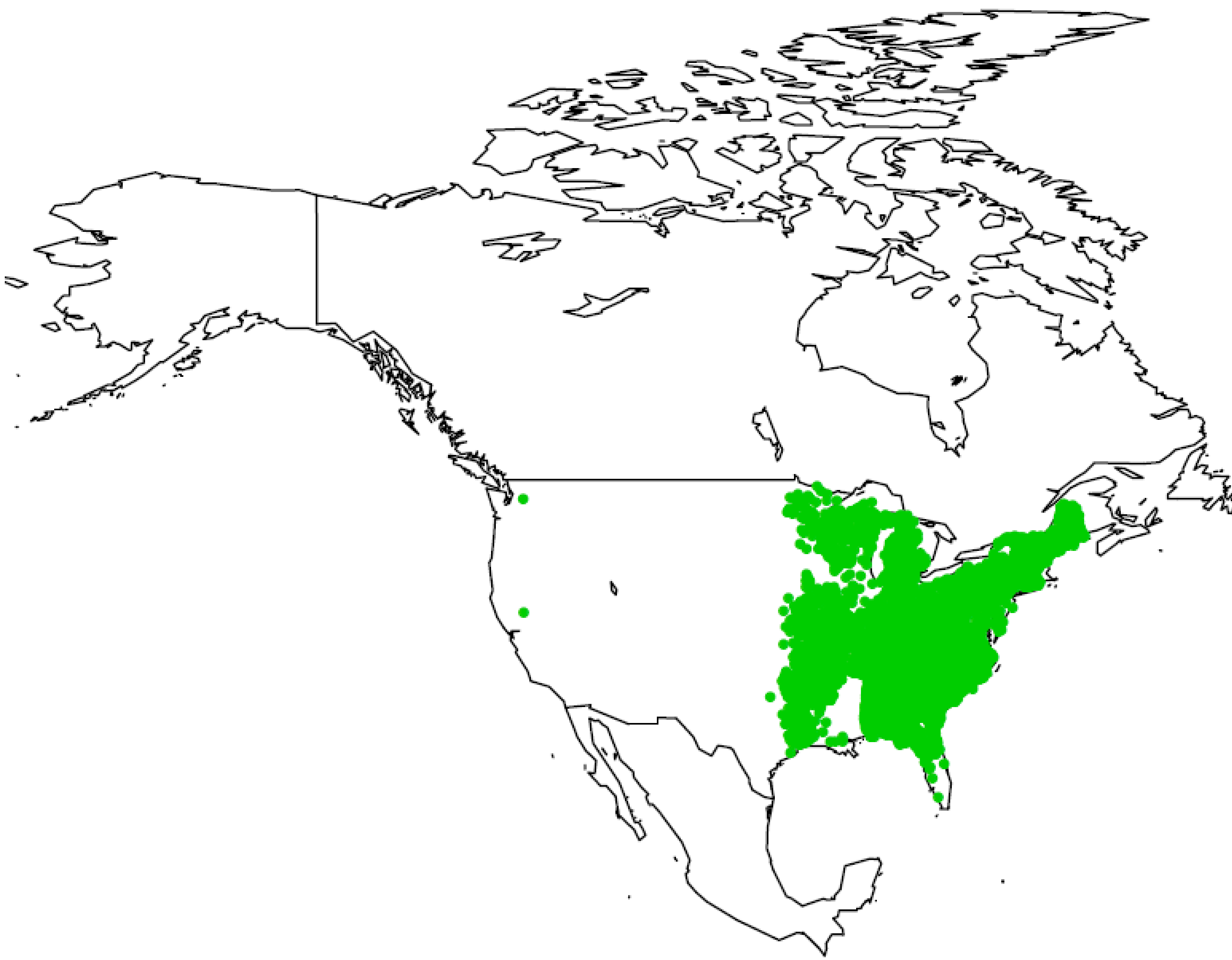
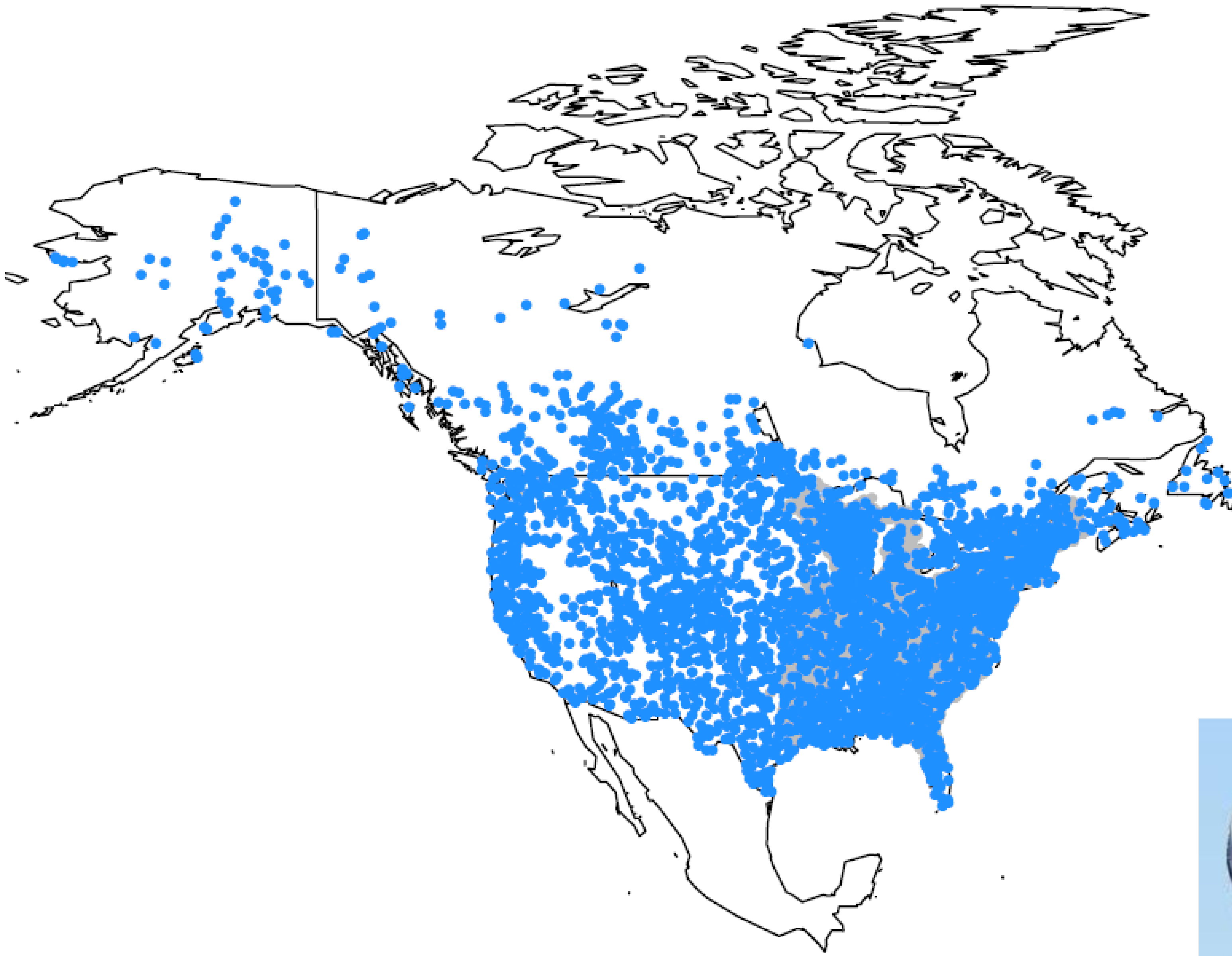
$$\Phi(n|\hat{S}_0,\hat{N}_0) \approx \frac{1}{ln(\beta^{-1})} \cdot \frac{e^{-\beta n}}{n}$$

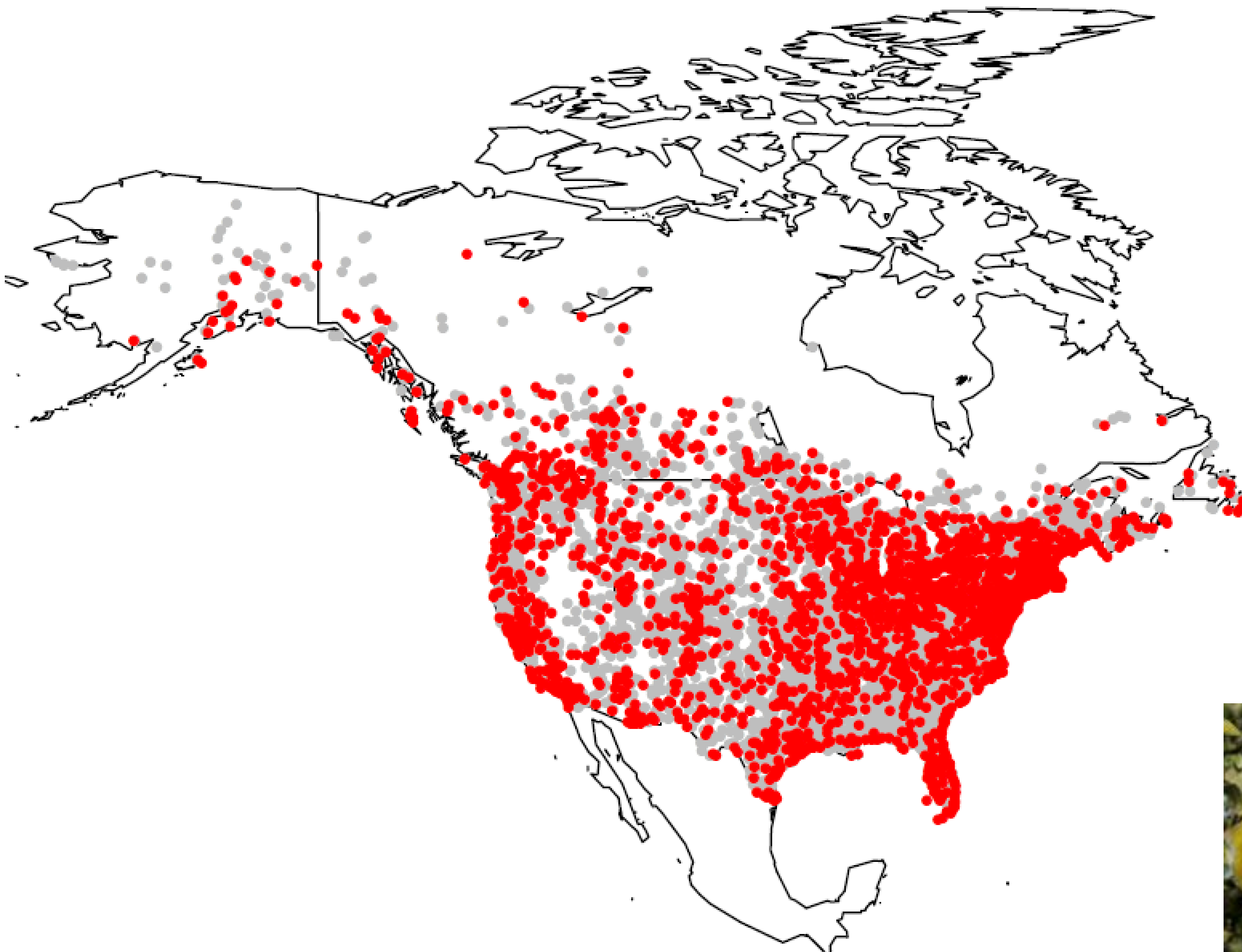
Forest Inventory Analysis (FIA)



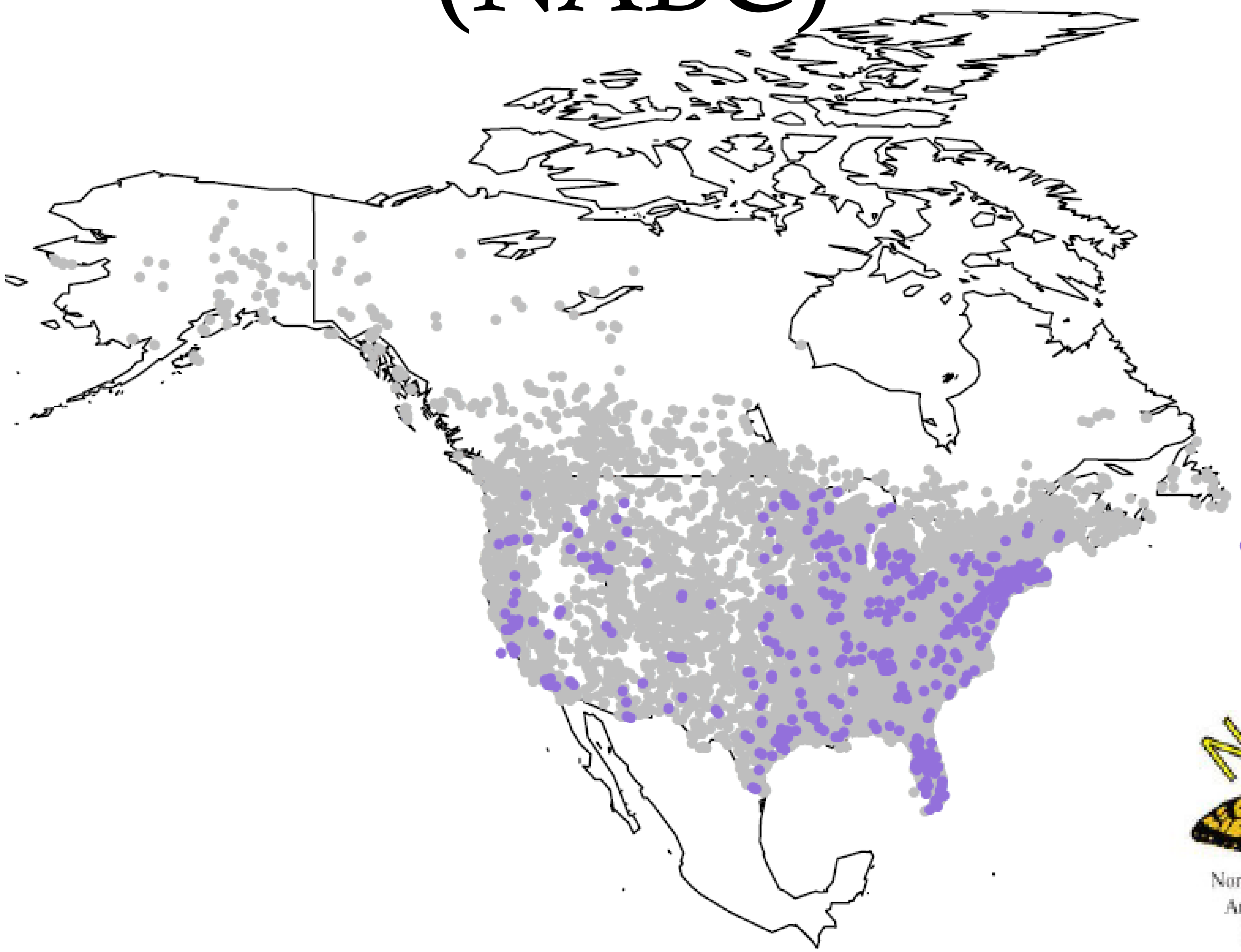
Breeding Birdy Survey (BBS)



Christmas Bird Count (CBC)

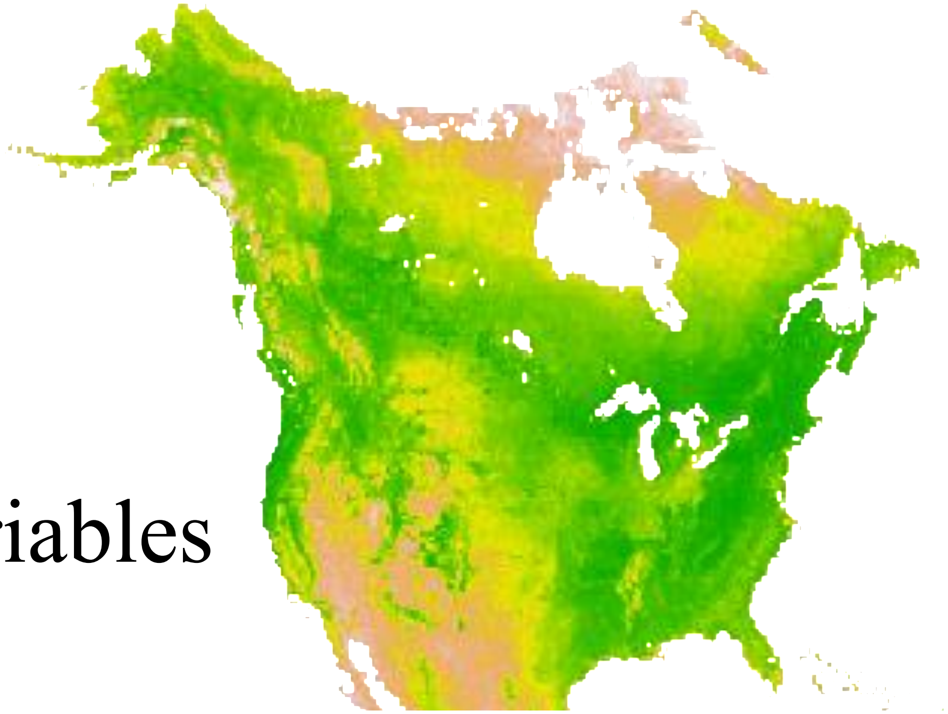


North American Butterfly Count (NABC)



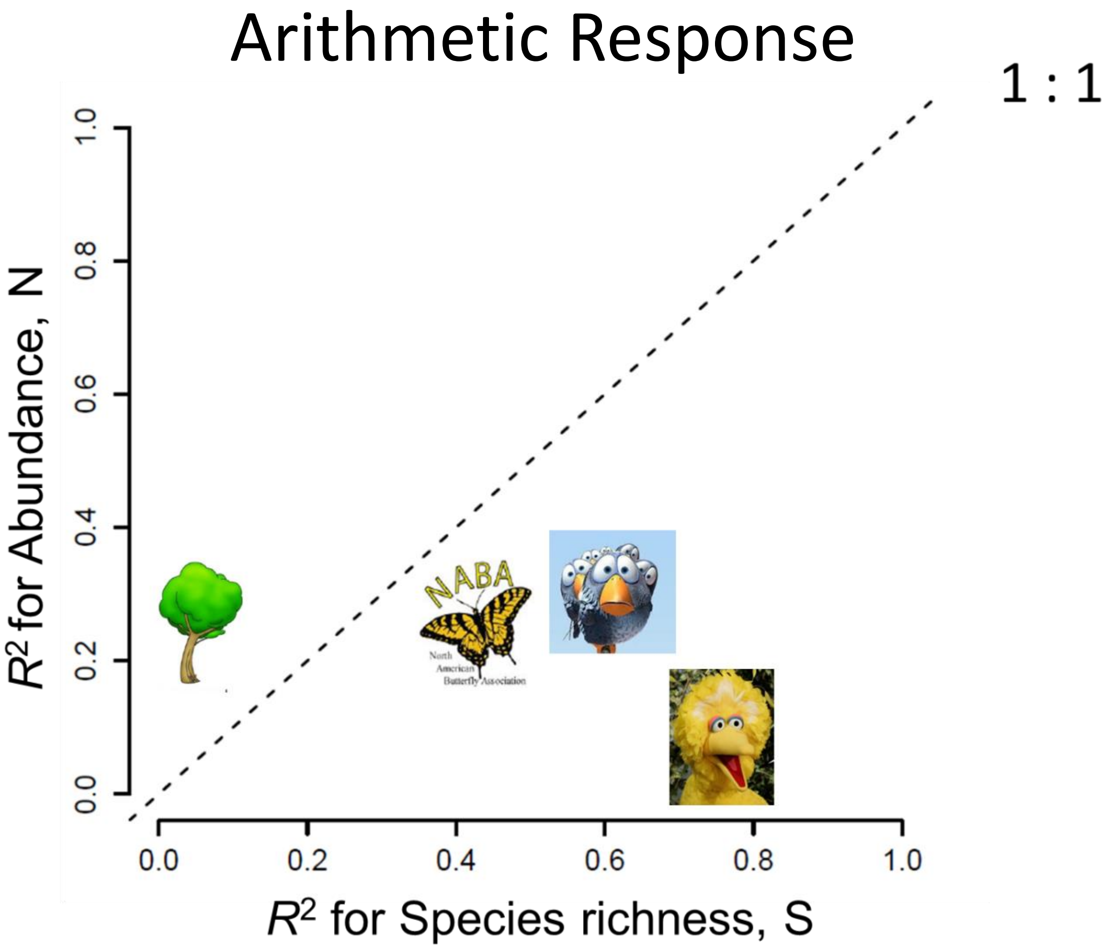
North American Butterfly Association

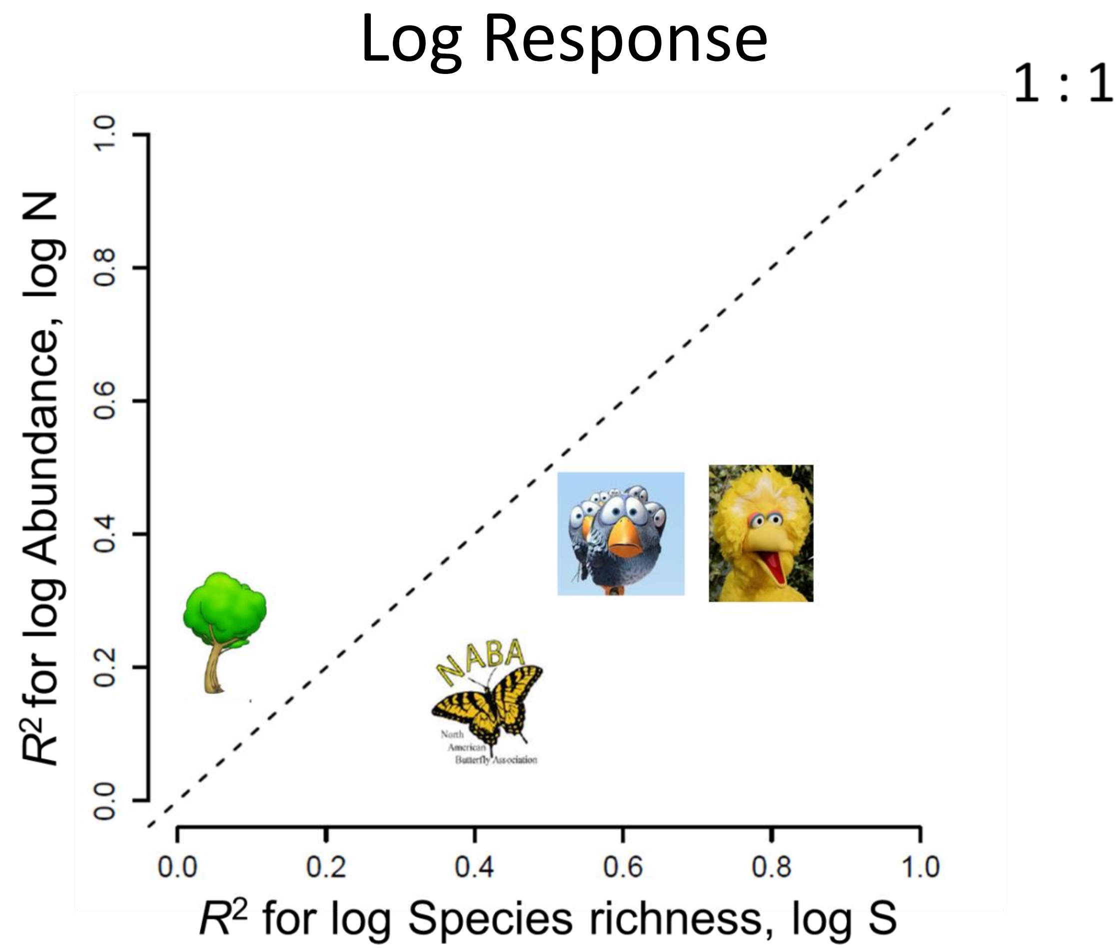
Environmental Models



- Predictor variables
  - Elevation
  - Productivity proxy (NDVI)
  - WorldClim's 19 bioclim variables
- Included averages and variance within 50 km
  - Coyle et al. (2013)
- Backward Stepwise regression

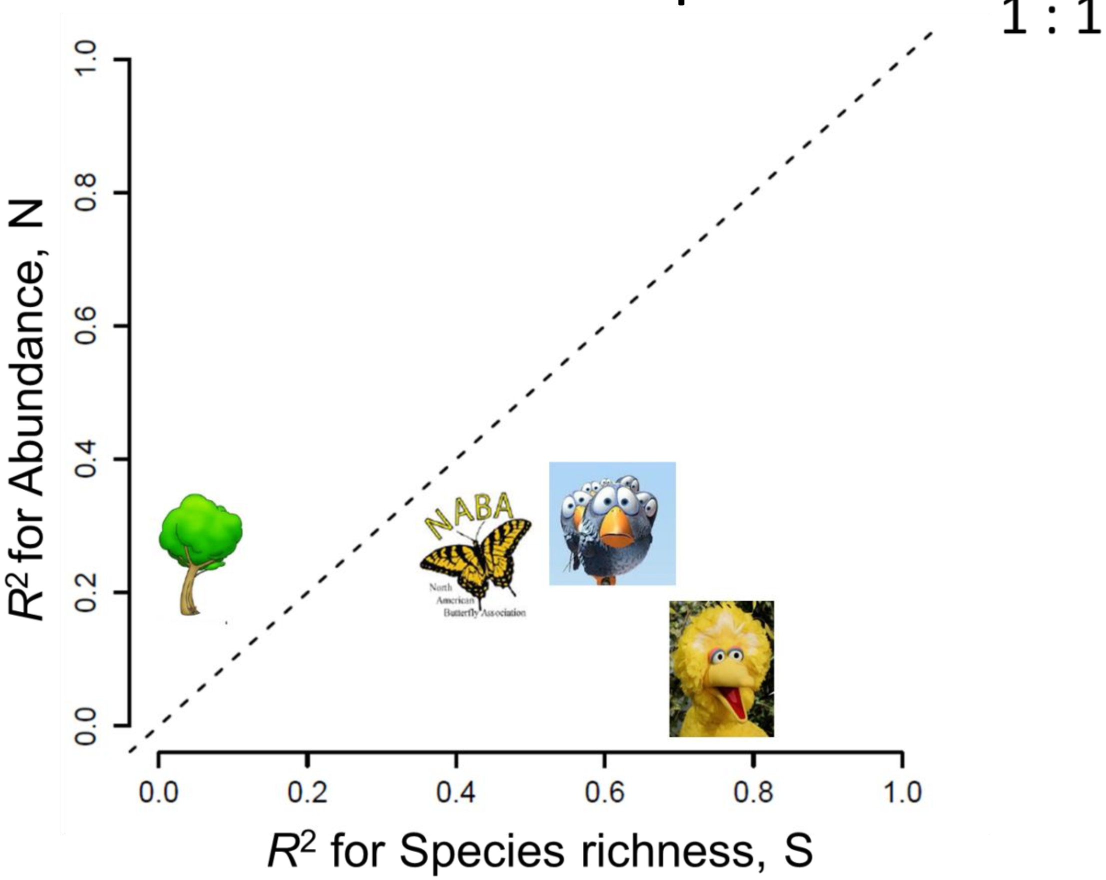
Predictability of State Variables



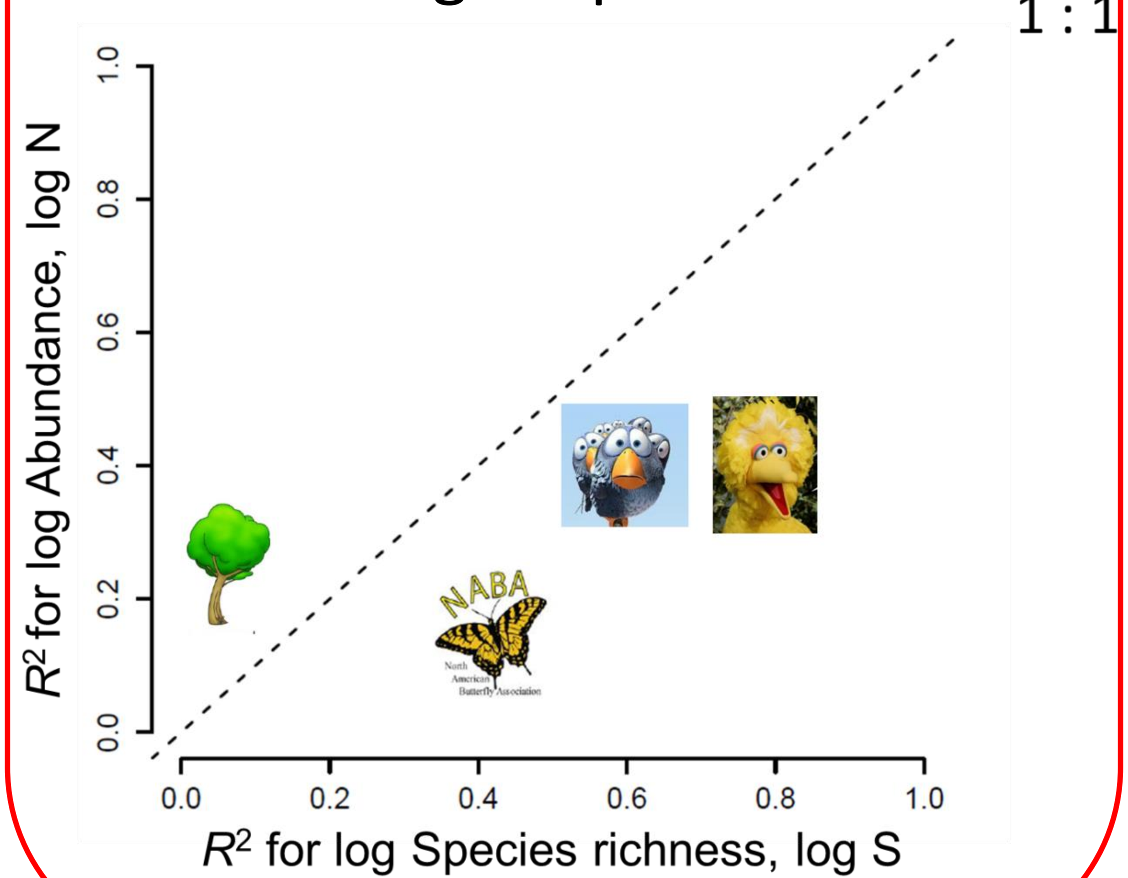


Predictability of State Variables

Arithmetic Response



Log Response

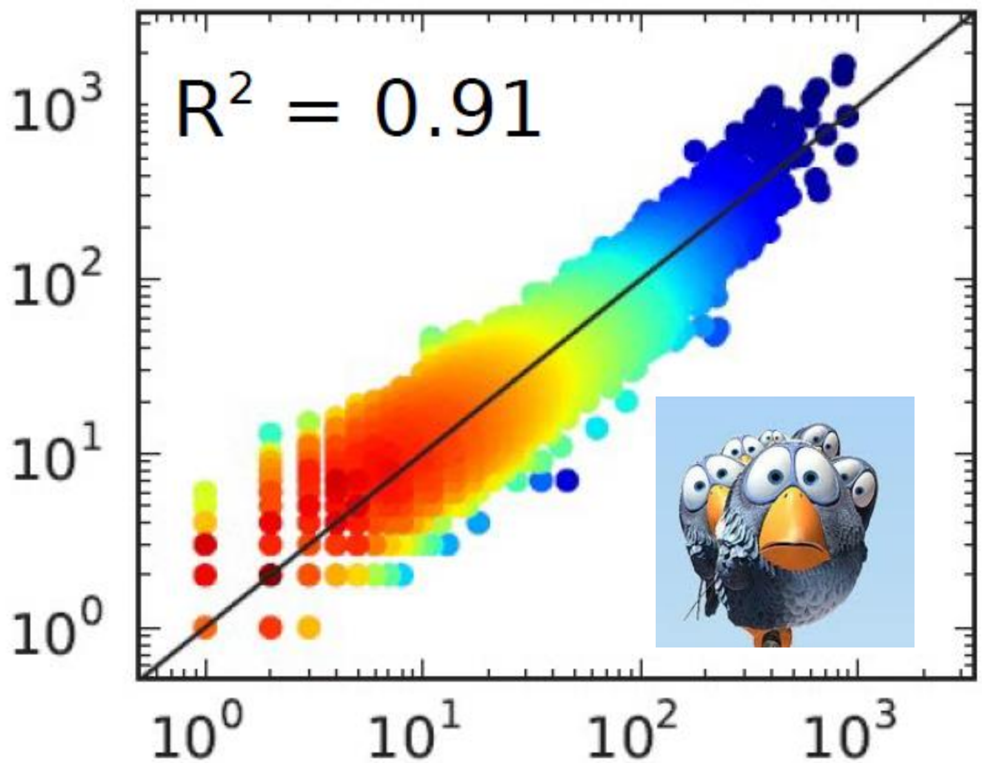


Using predicted S and N to model SAD

Observed S & N

White et al. 2012

Observed Abundance



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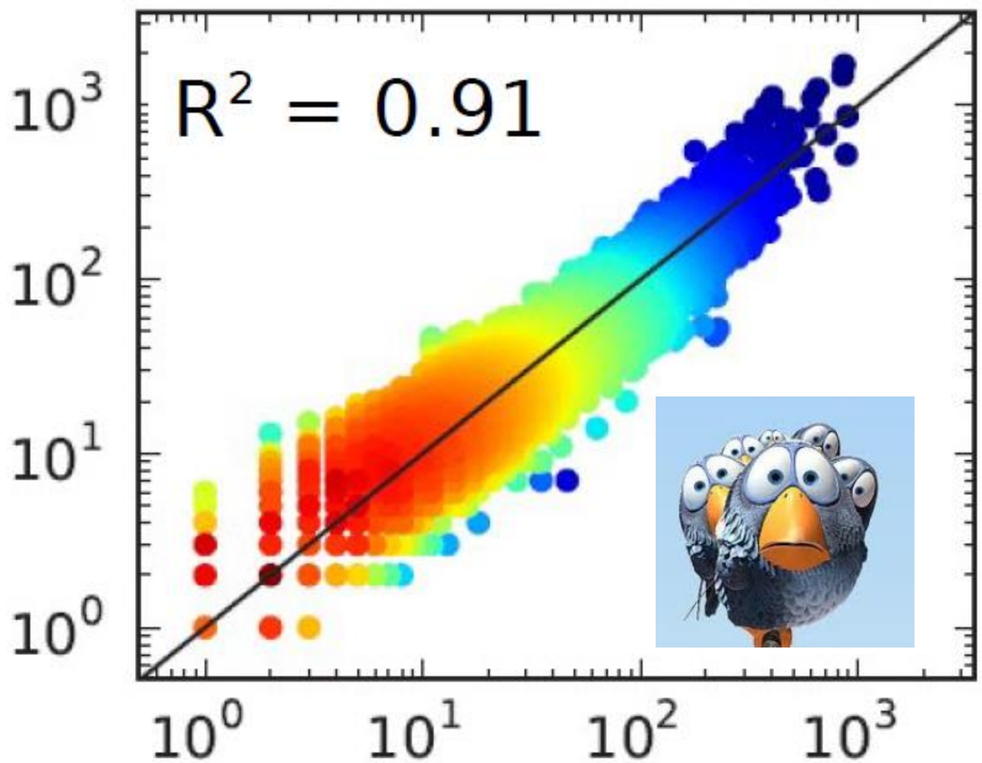

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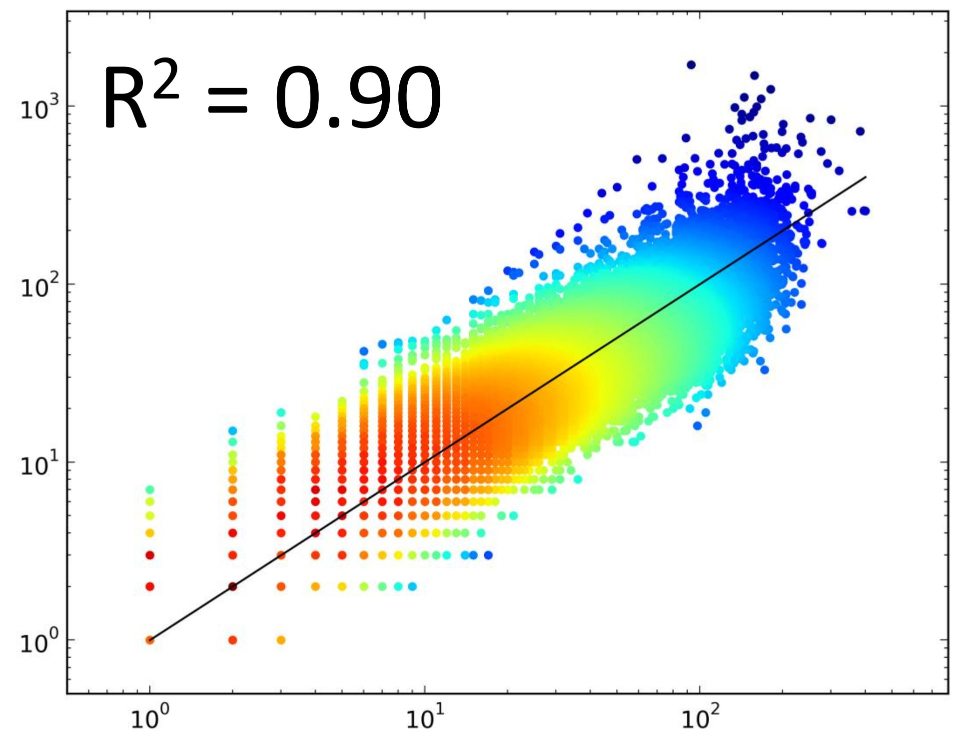

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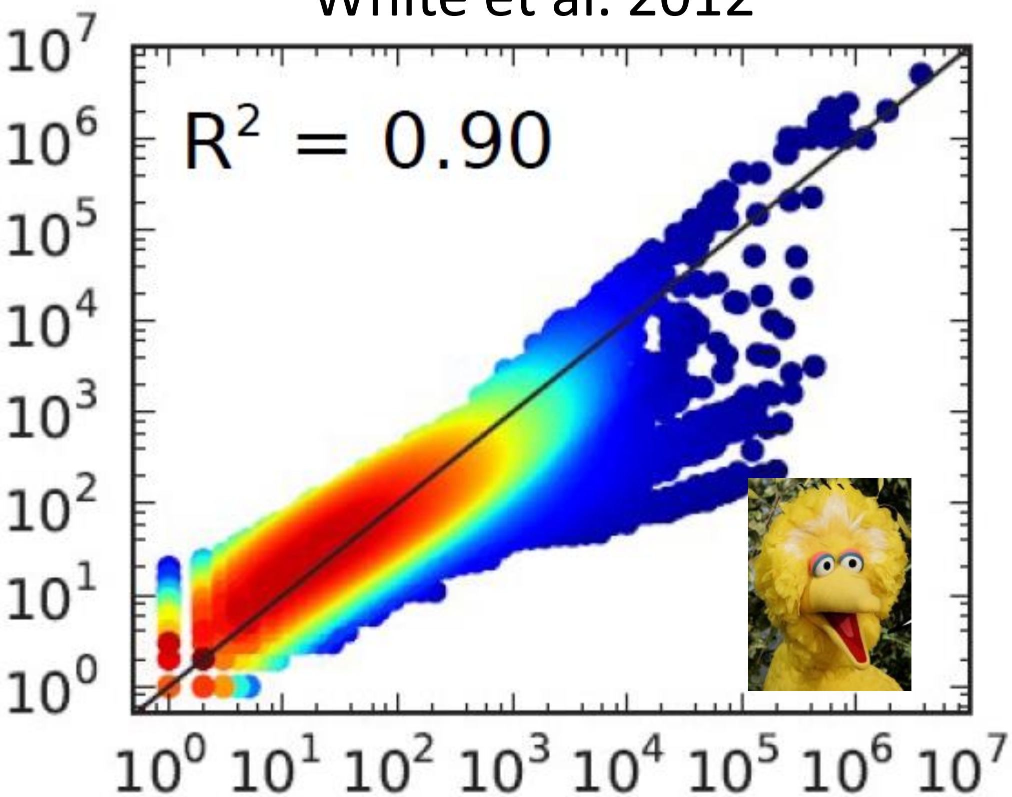

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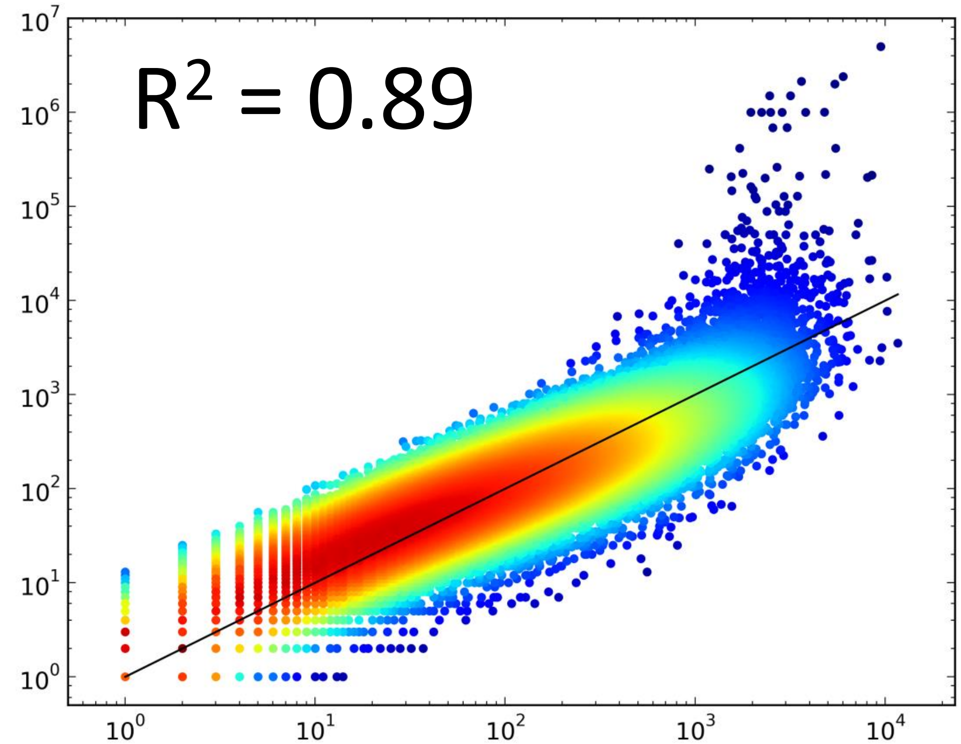

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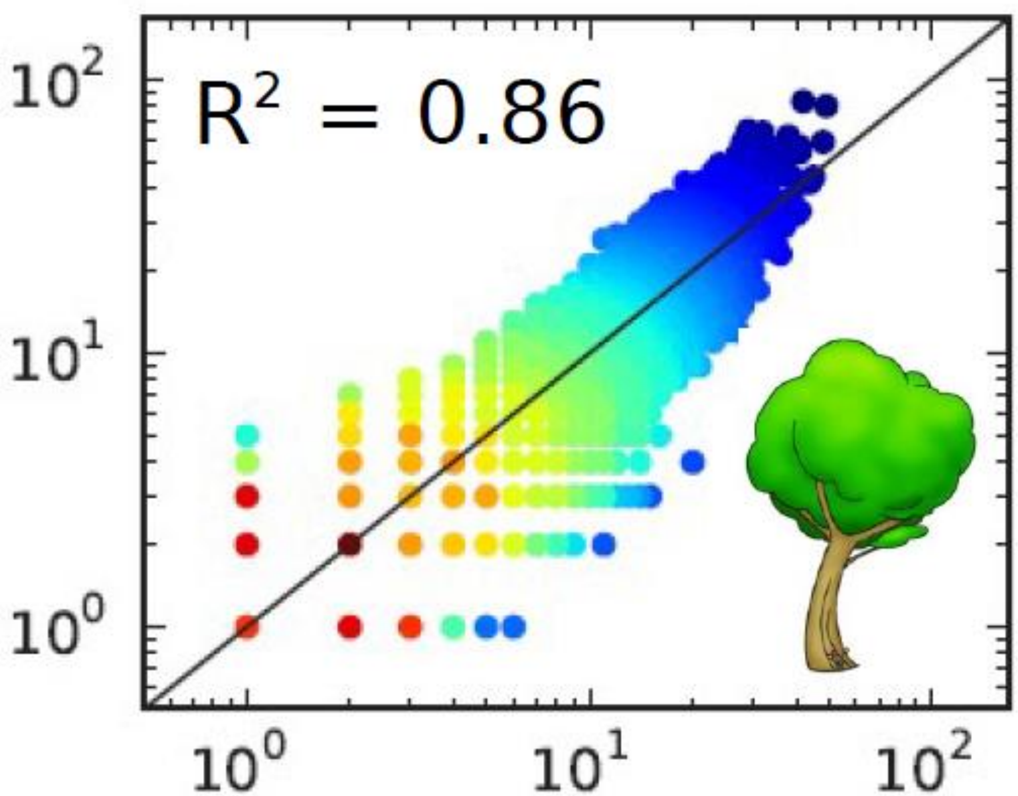

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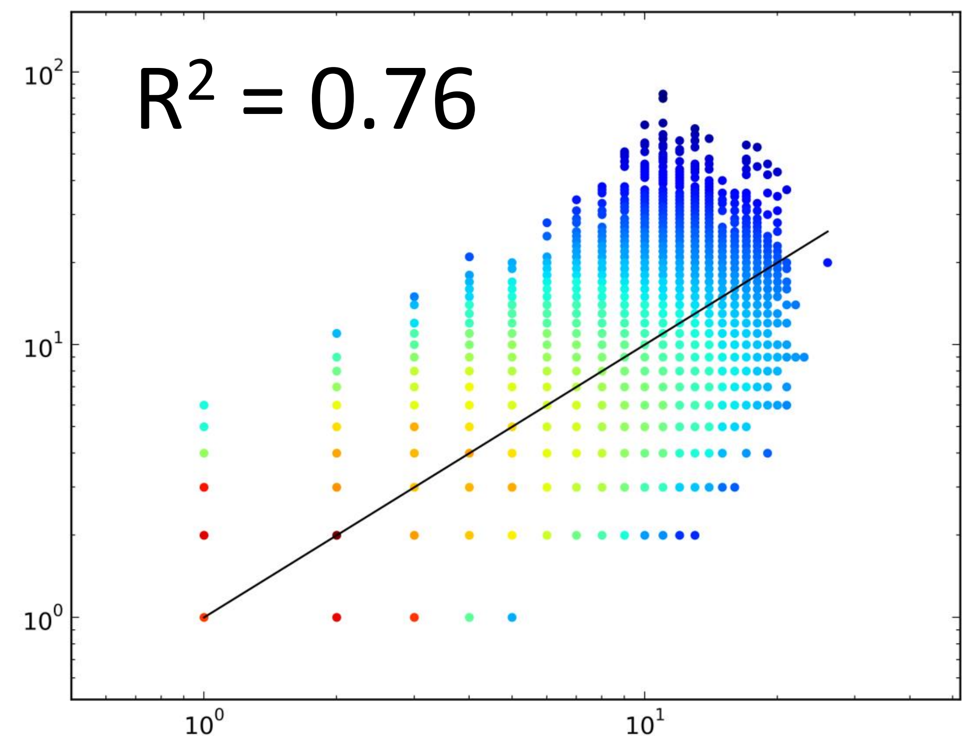

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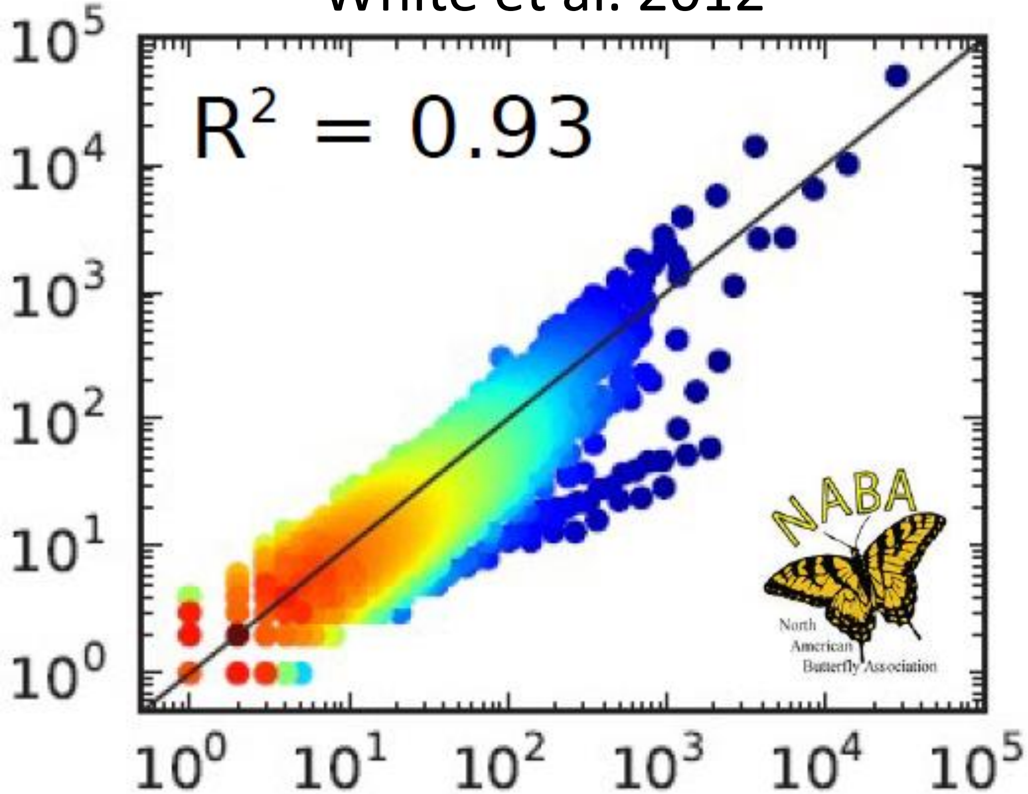

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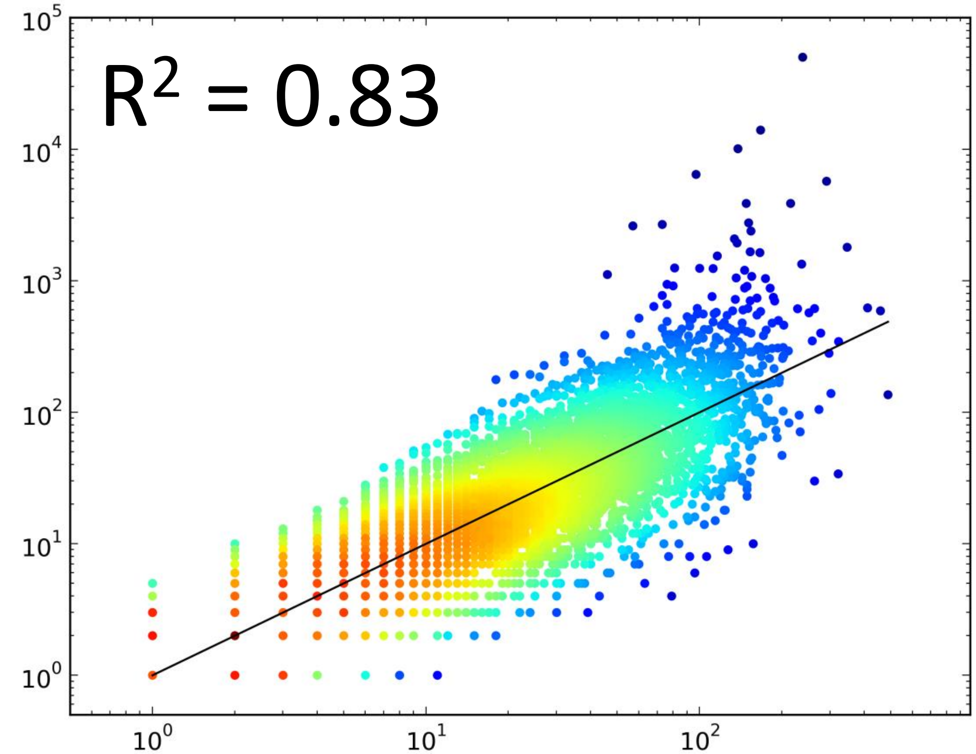
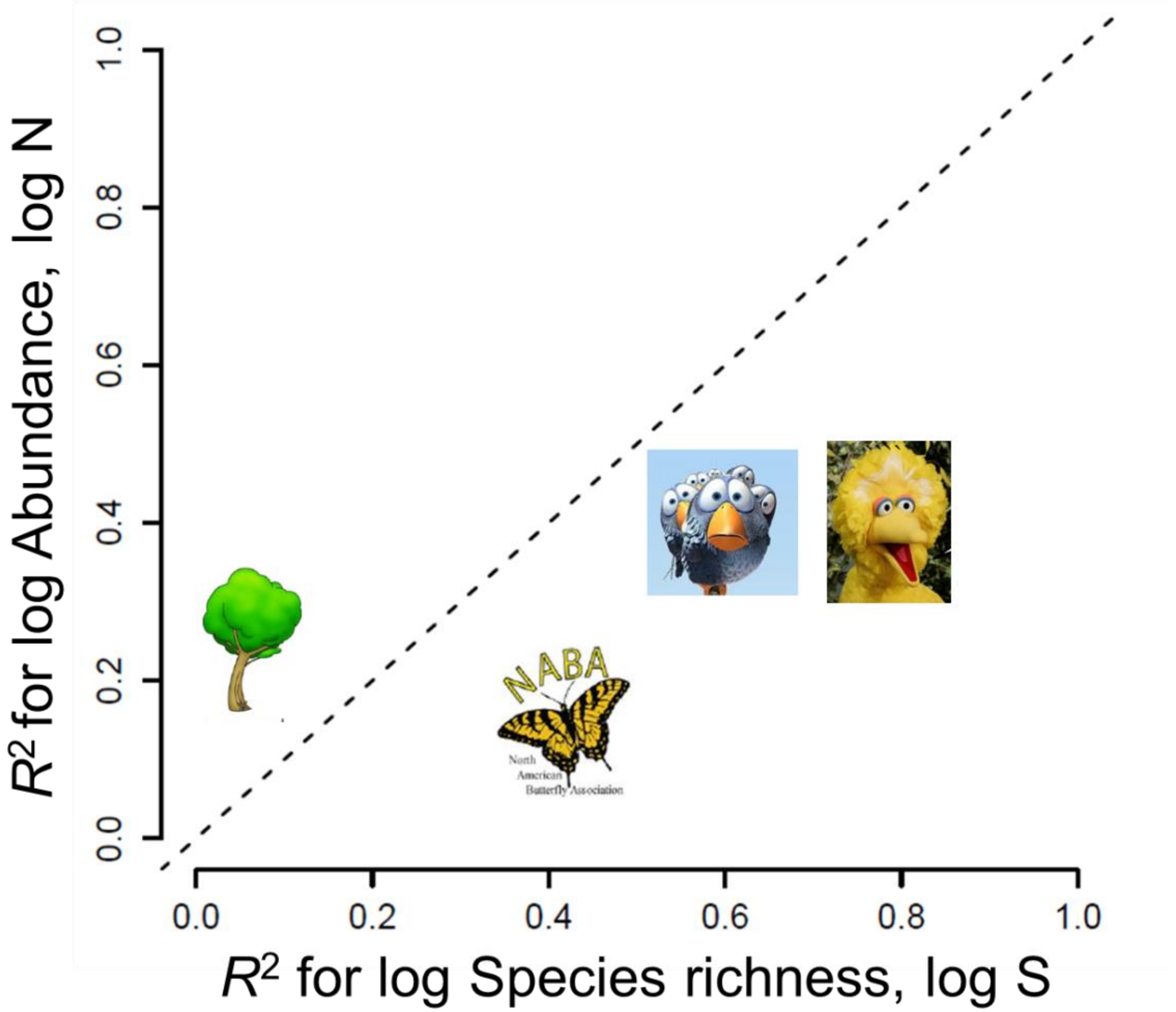


Observed Abundance

Predicted Abundance

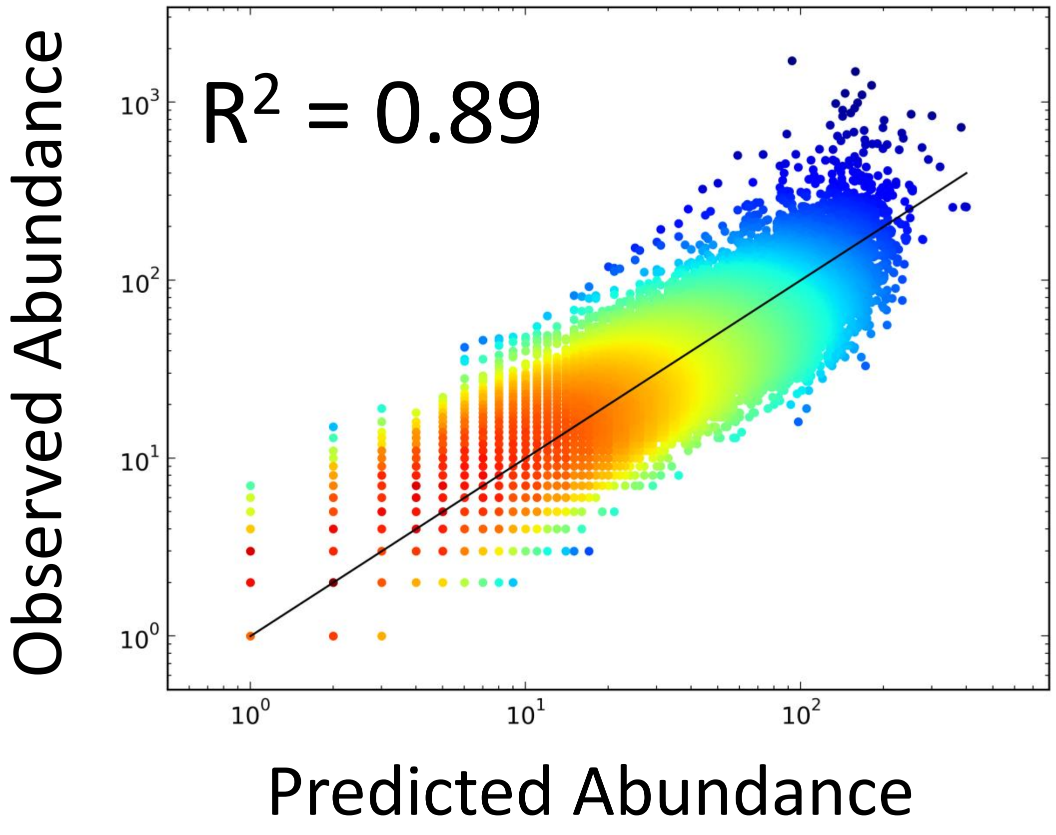
Summary of Results

- S and N can be difficult to predict



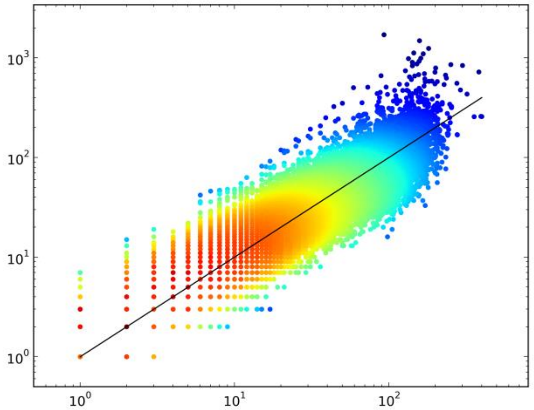
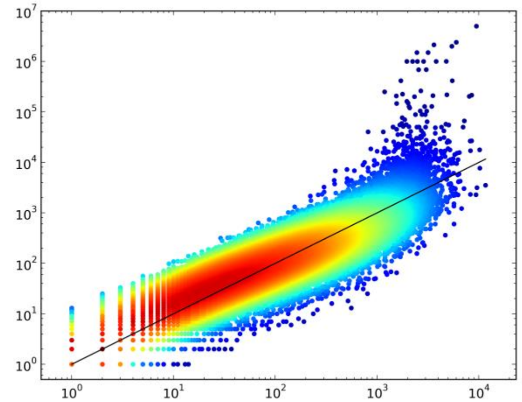
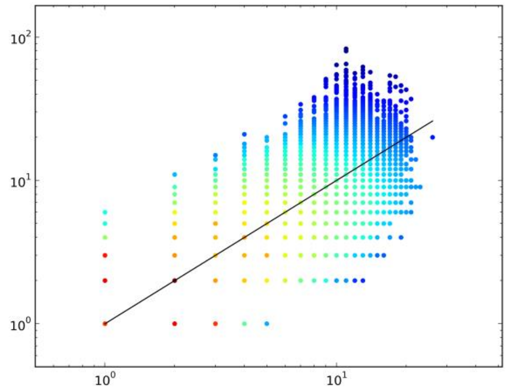
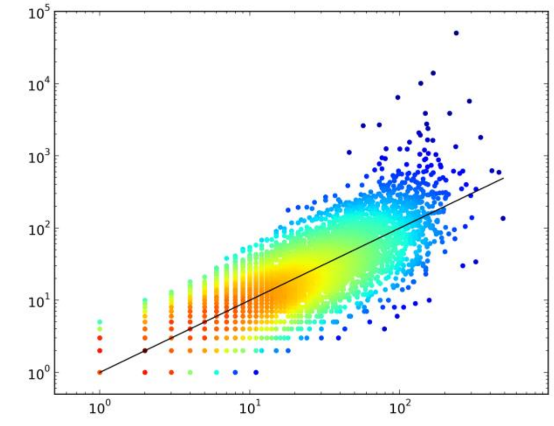
Summary of Results

- S and N can be difficult to predict
- but still yield accurate SAD predictions



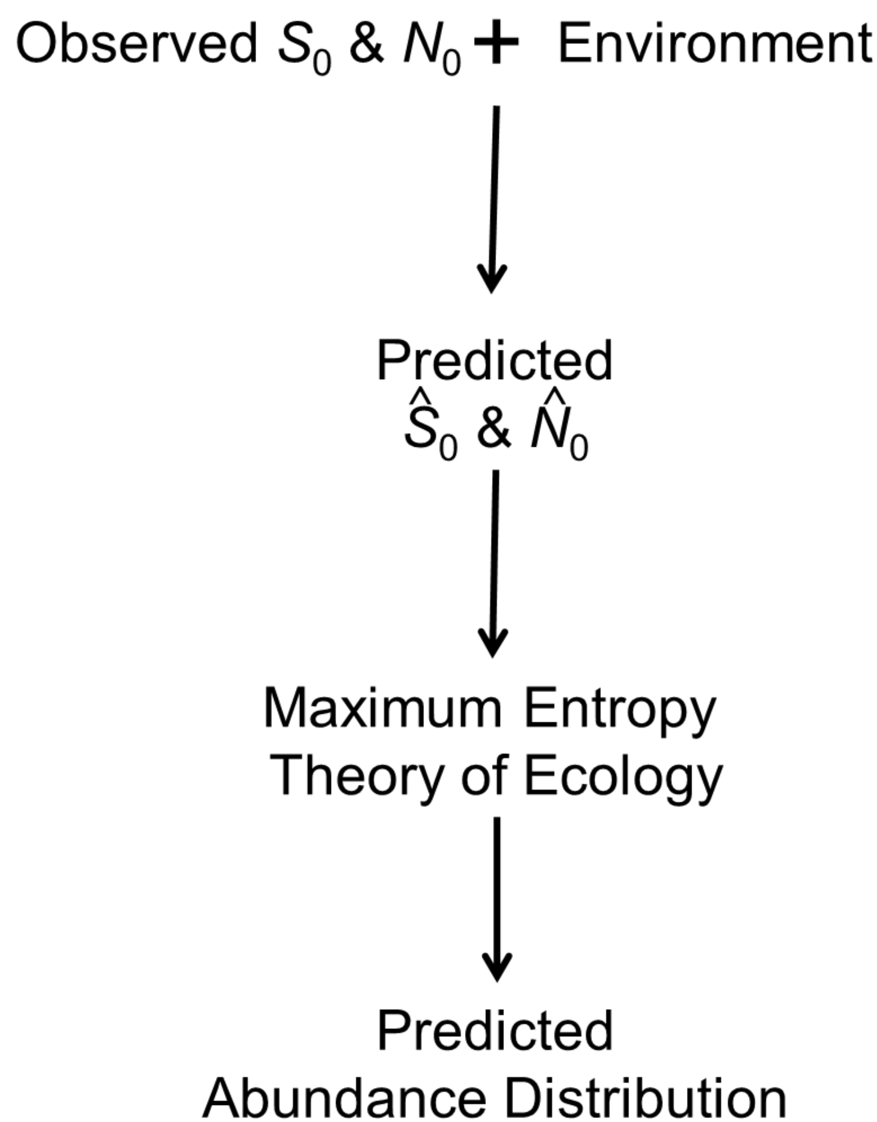
Summary of Results

- S and N can be difficult to predict
- but still yield accurate SAD predictions
- Large divergences were due to very large observed abundances

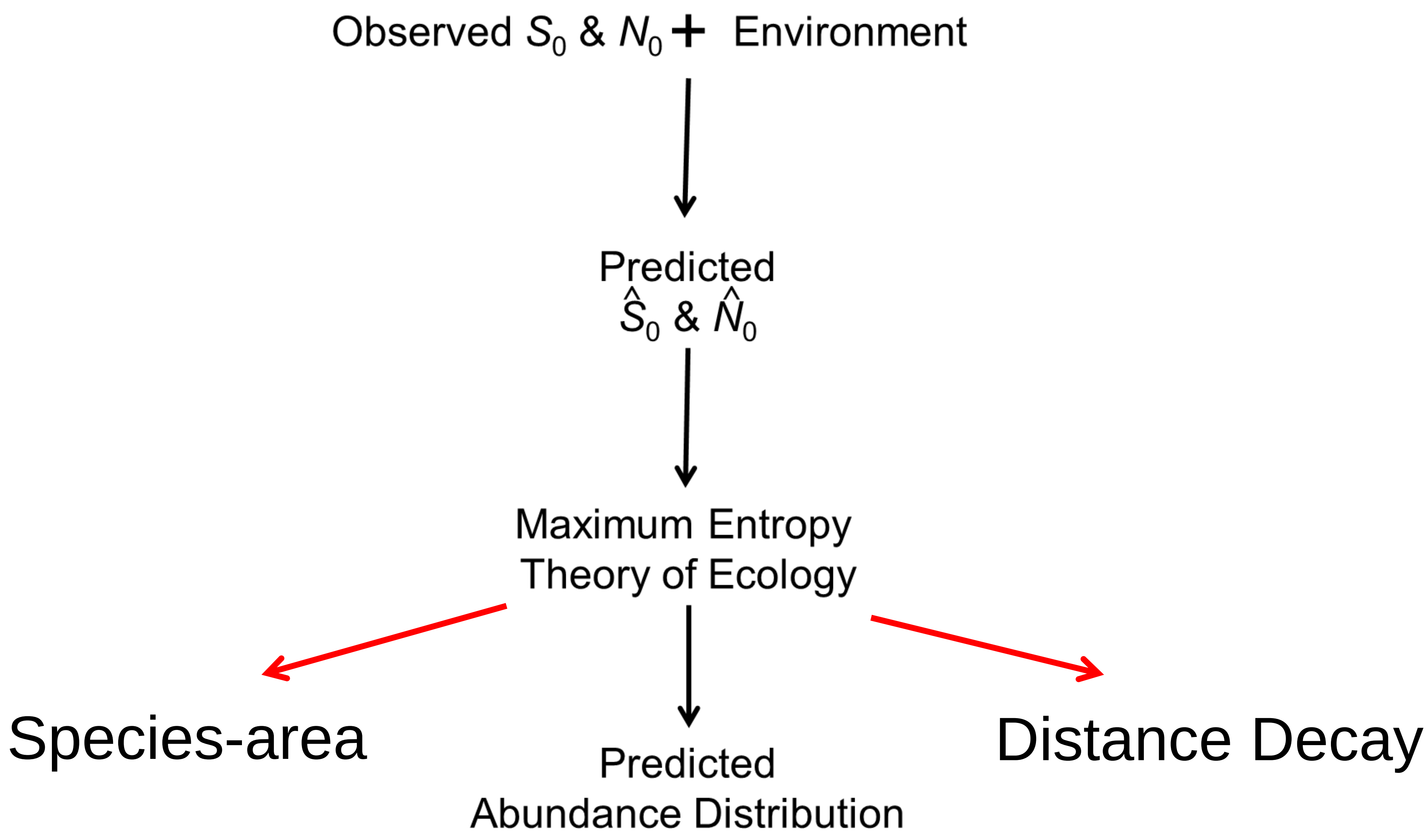
Take Home Message

- Multiscale modeling holds promise for predicting fine-scale community structure



Future Direction

- Simultaneous prediction of several aspects of internal community structure



Thank you!

- The volunteer data collectors
- The data providers
- NSF Career Award to E.P. White
- Utah State Ecology Center
- Weecology Lab