Wrong Models in Ecology I

Neutral Theory: Demographic Stochasticity & Ecological Equivalence

Jacopo Grilli, Bengaluru 14/1/2025

A week ago

Yesterday

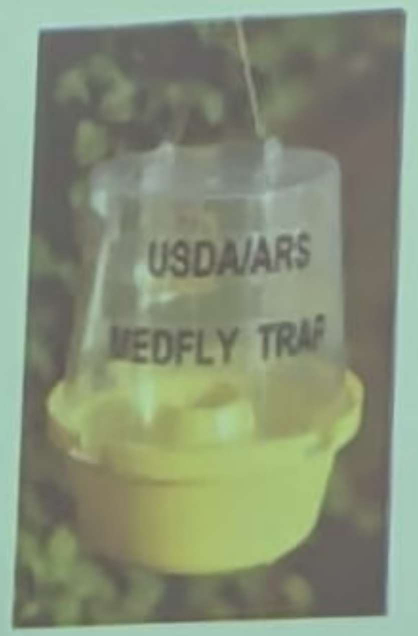
Statistical ecology

Predict species "fitness" (presence, abundance, reproduction, other measurements...) from environment & own traits

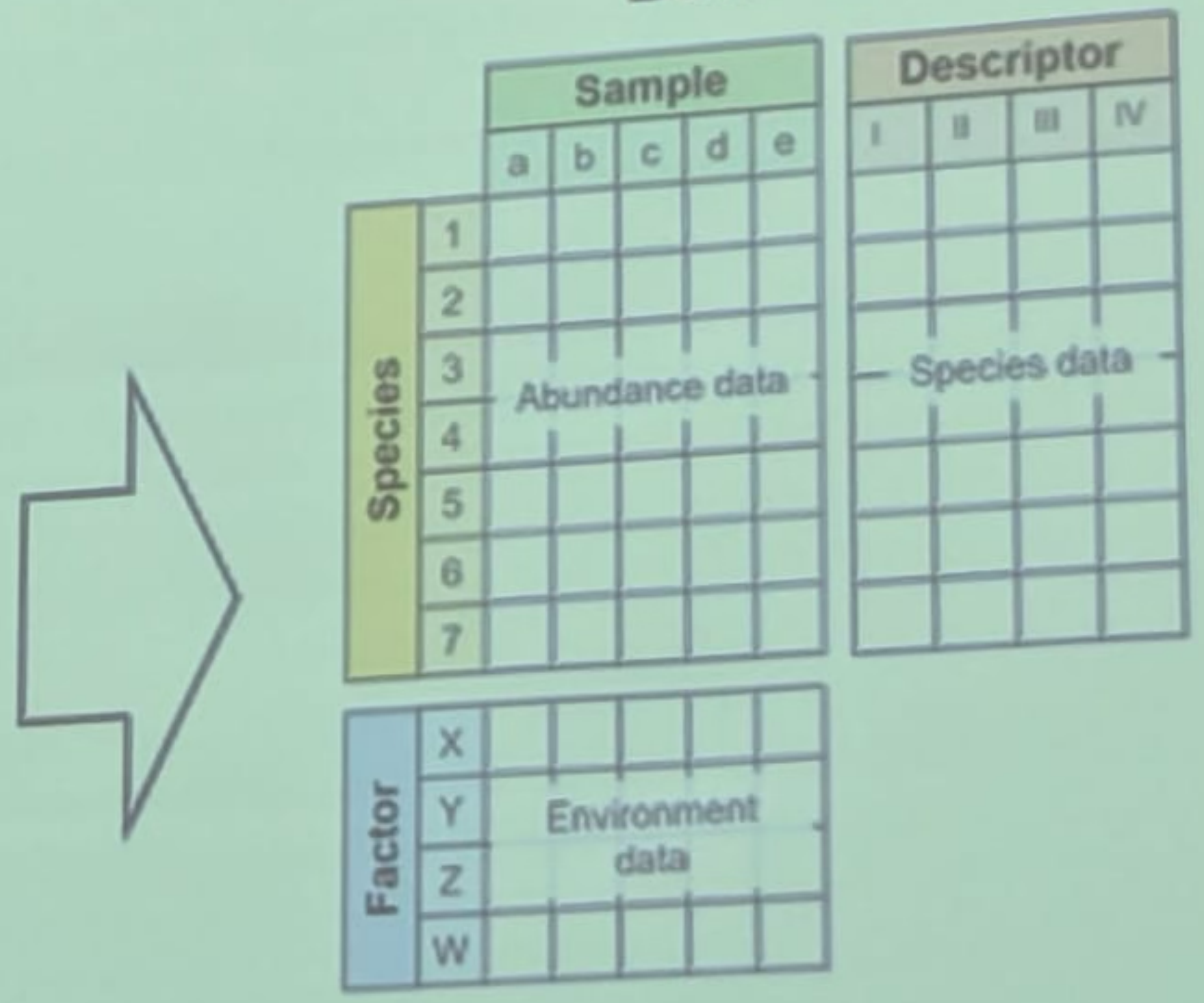
Ecological data

Controlled studies

Natural observation

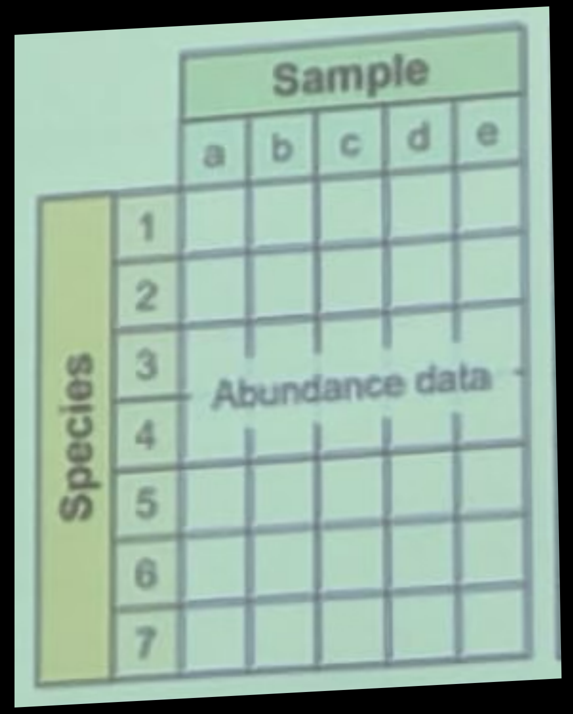


Data matrix



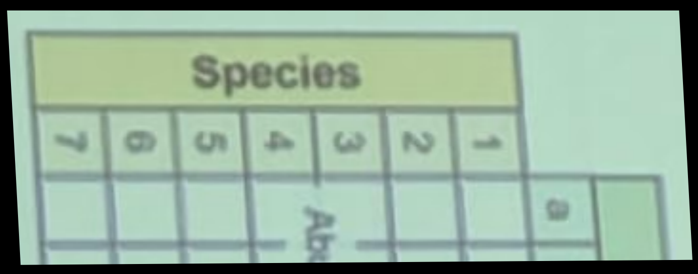
Tends to be noisy and sparse

Today and Tomorrow



Tends to be noisy and sparse

Today

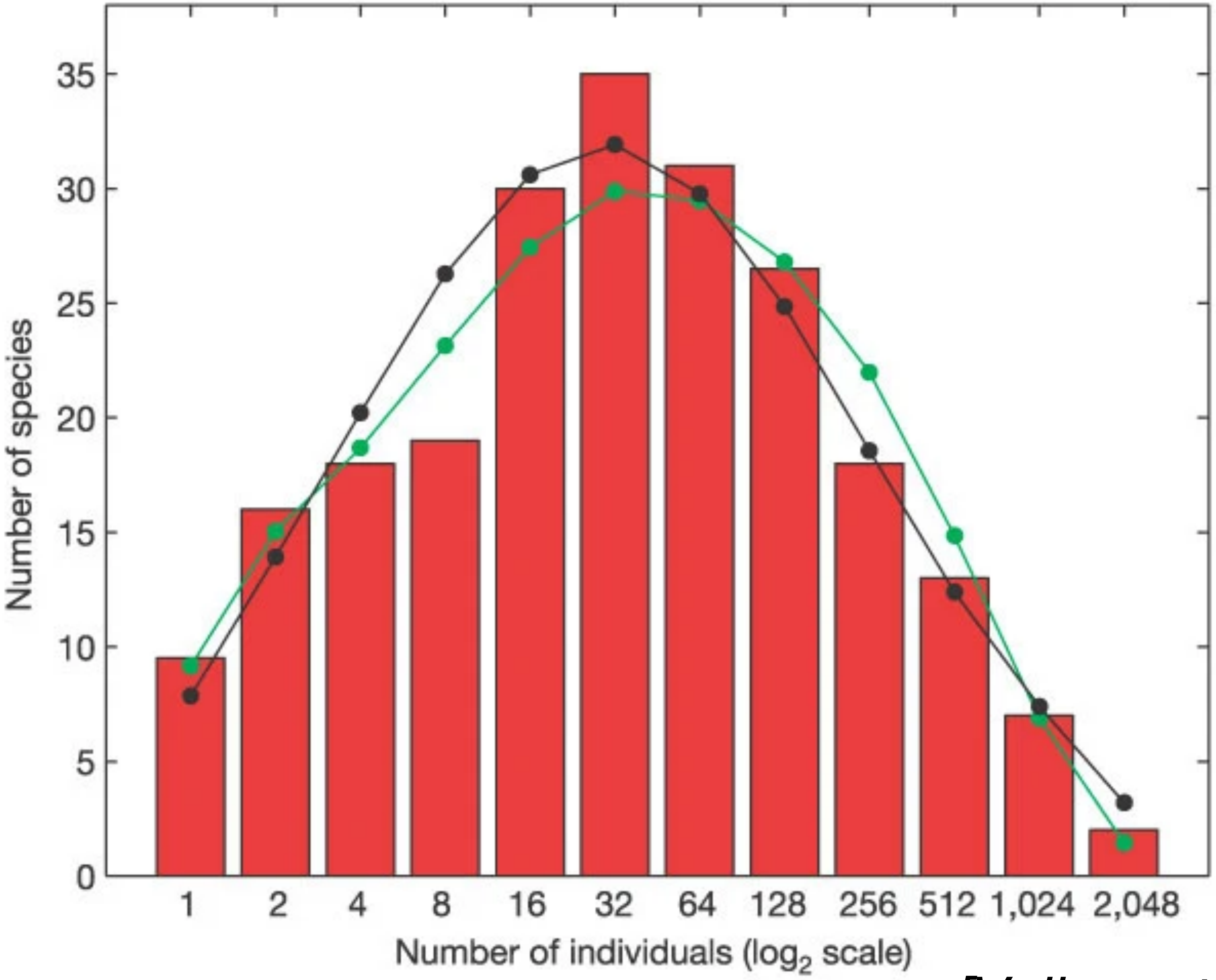


A very basic phenomenology

There are many different “things” (species/types)

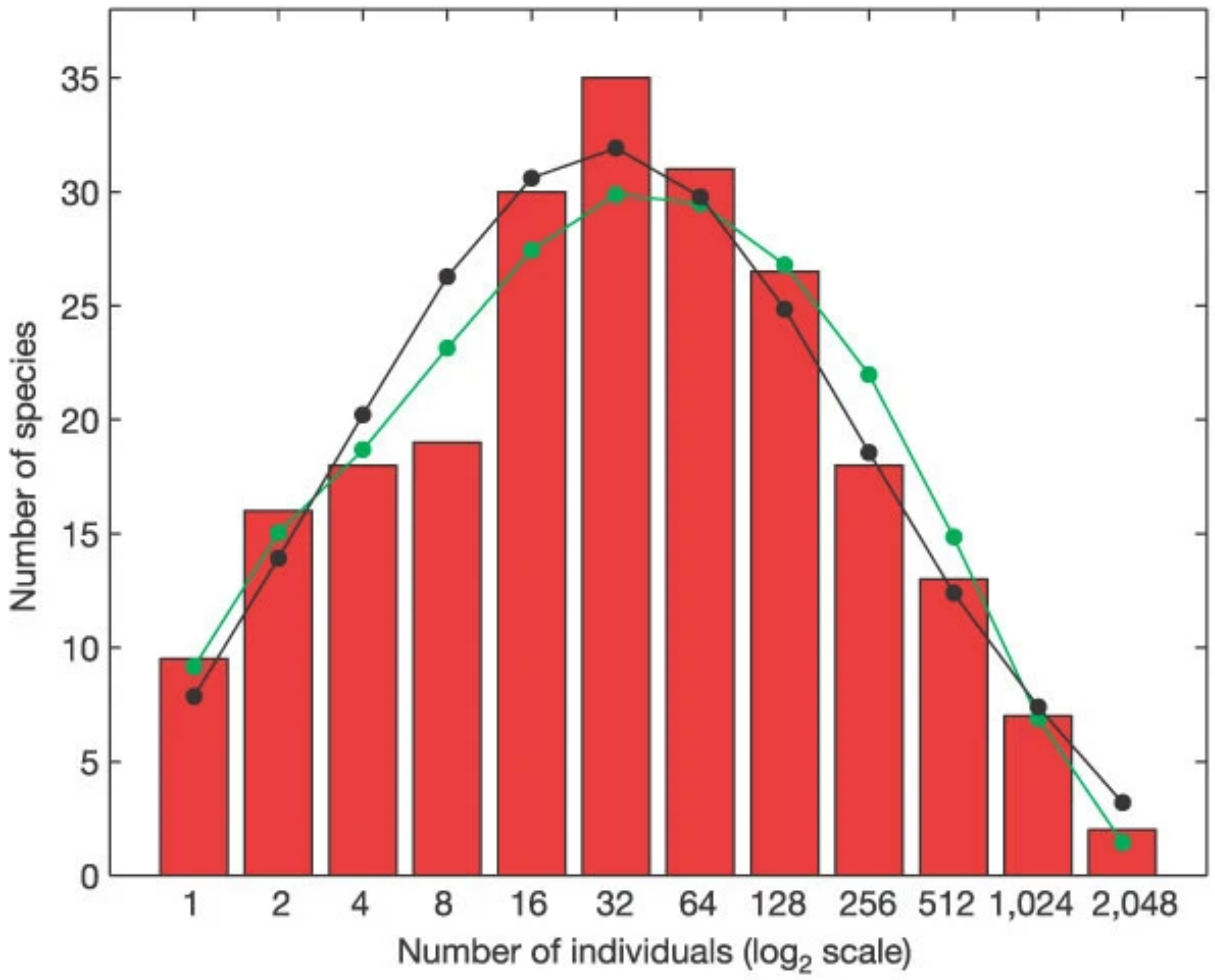
There are “common” and “rare” species

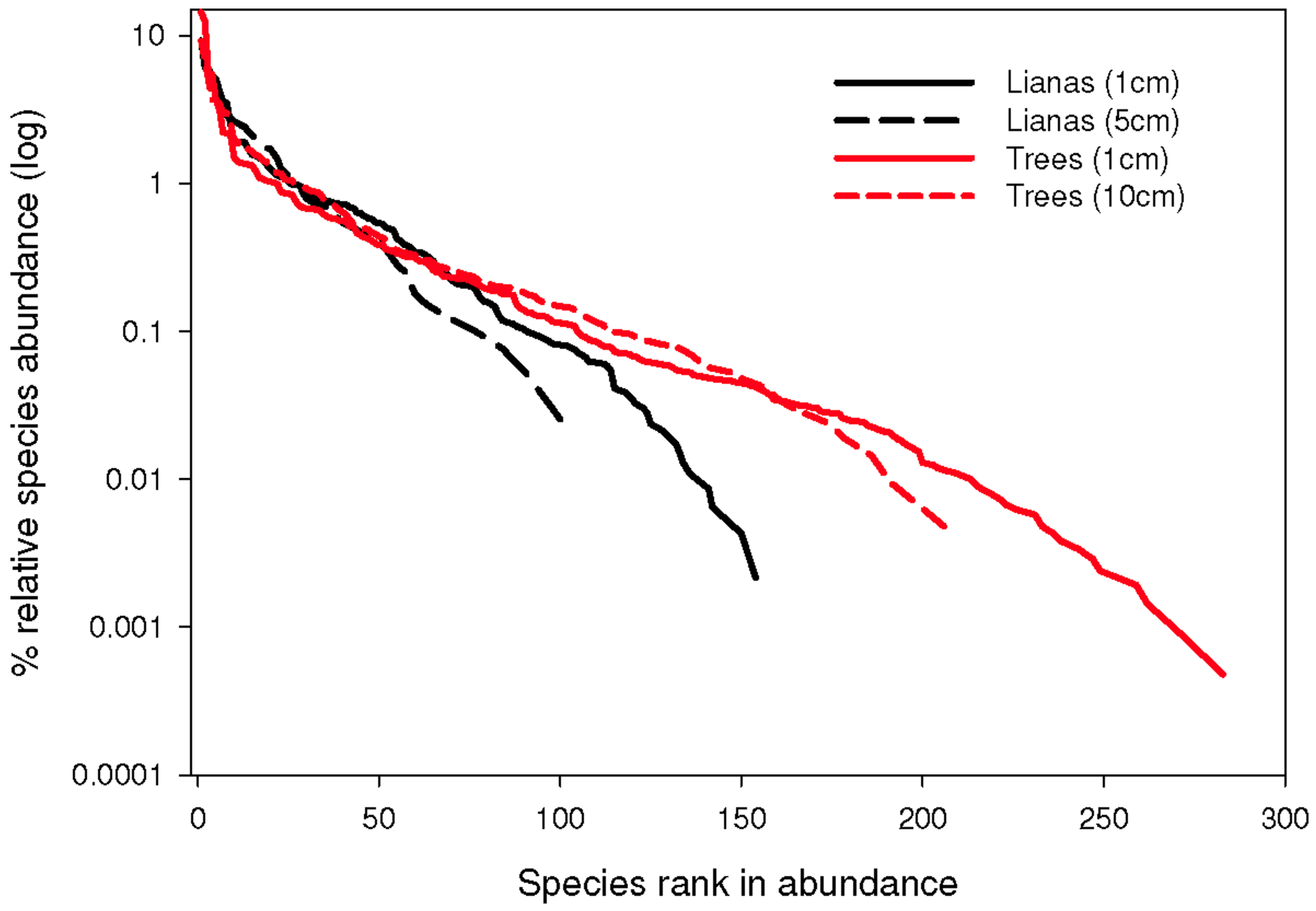
Making the observation more quantitative



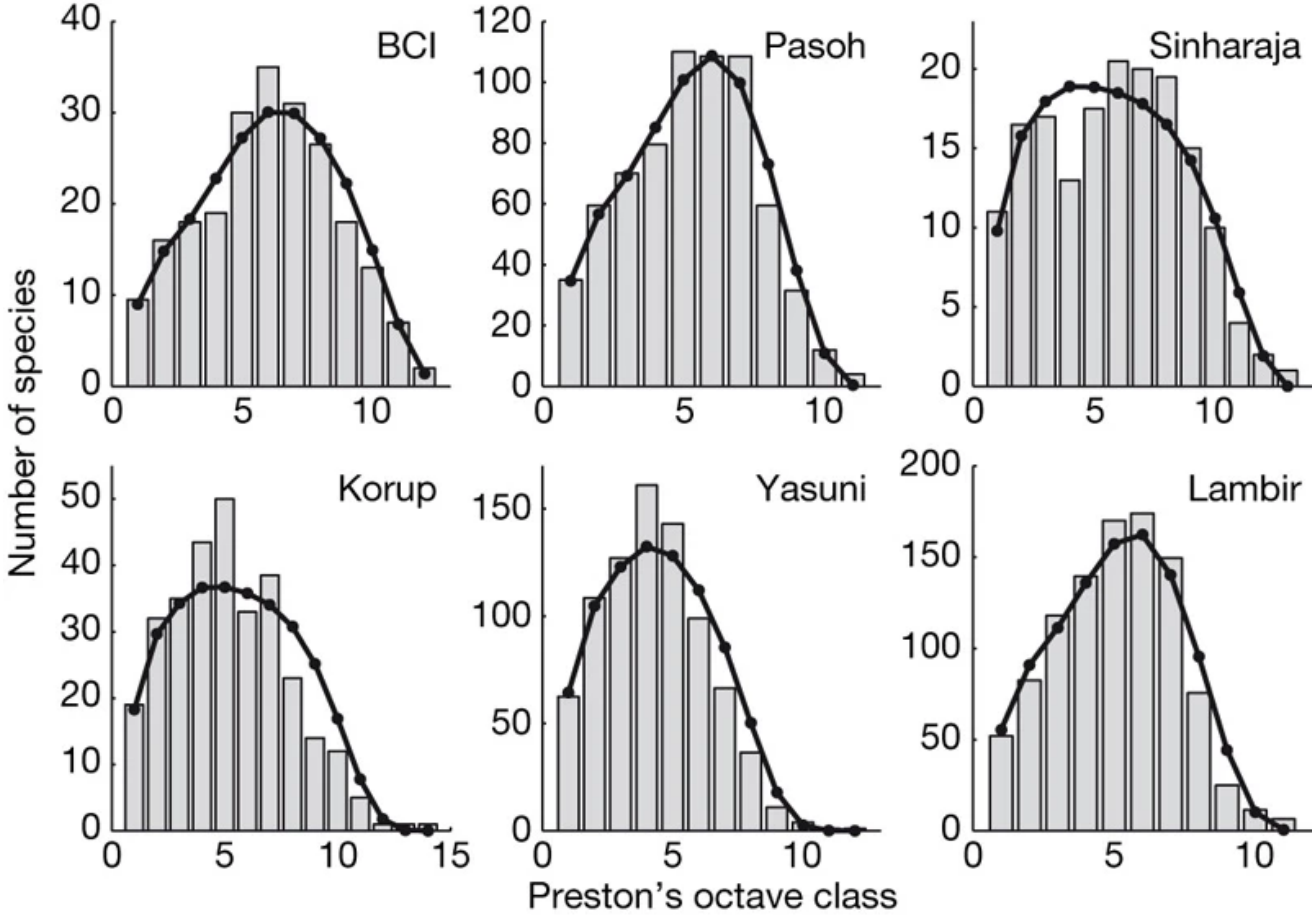
[Volkov et al., 2003]

Same observation in a different form



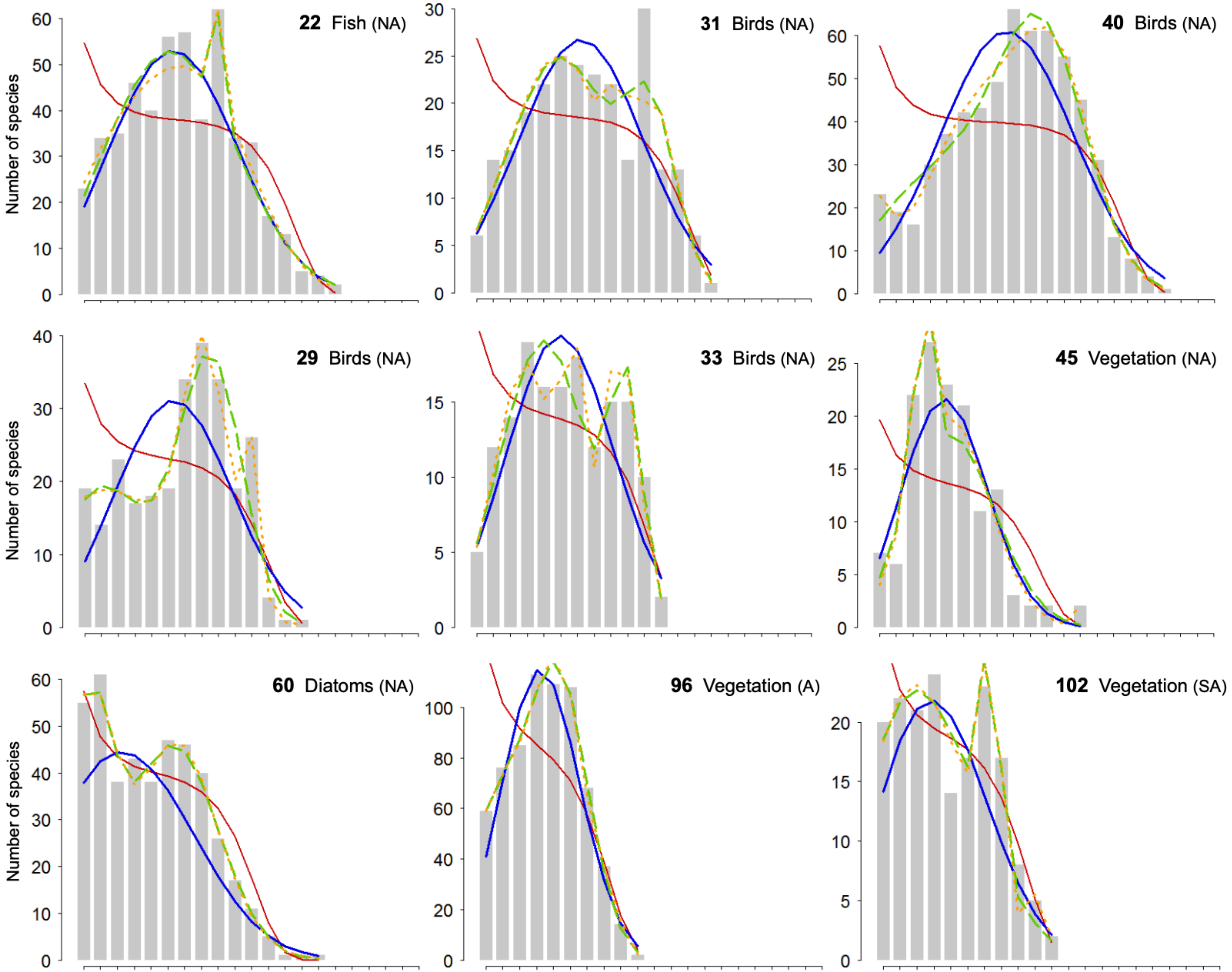


Across tropical forests



[Volkov et al., 2007]

not just trees

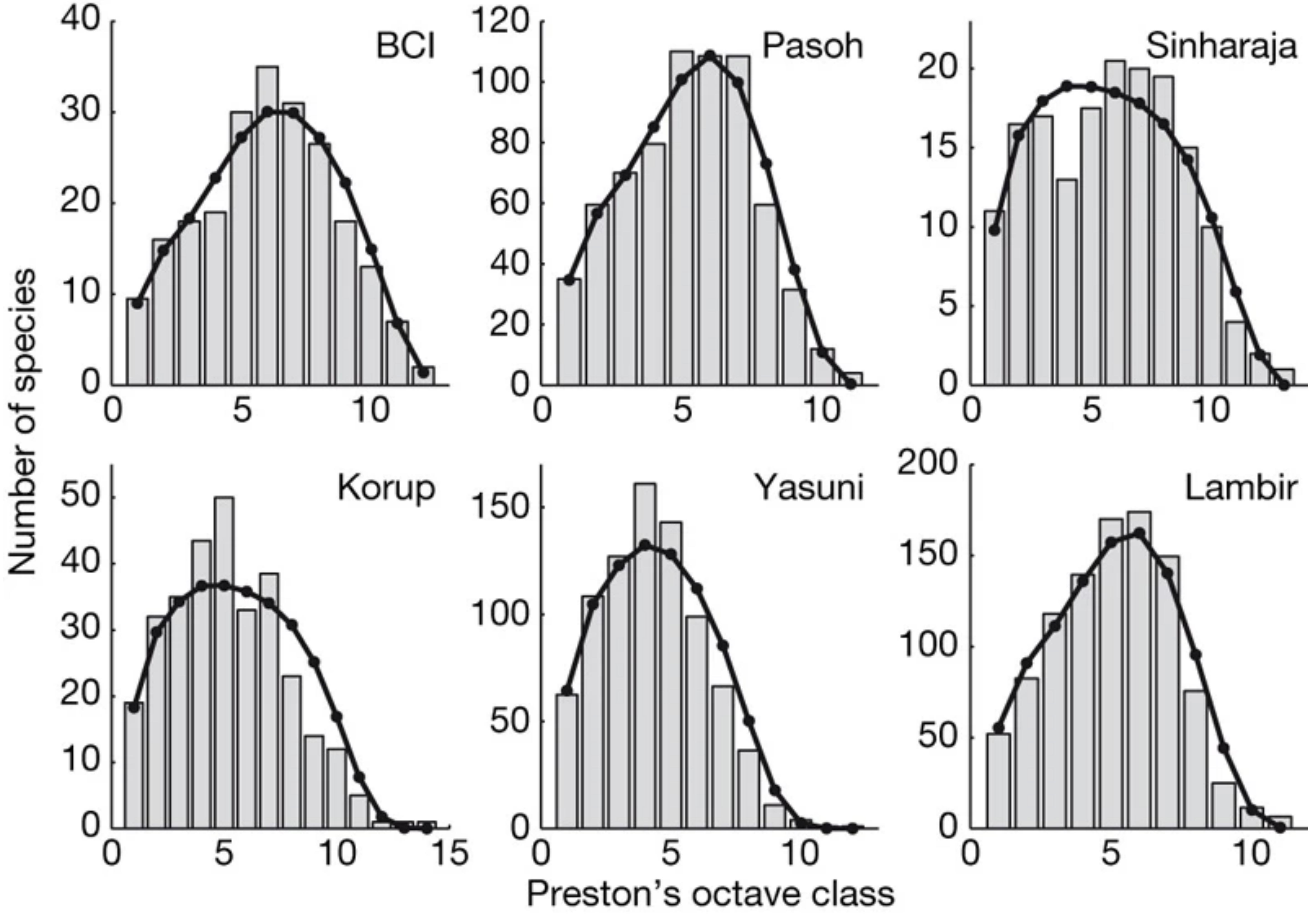


What we should expect “by chance”?
what is a minimal model?

<- board

NT reproduces species abundace distributions

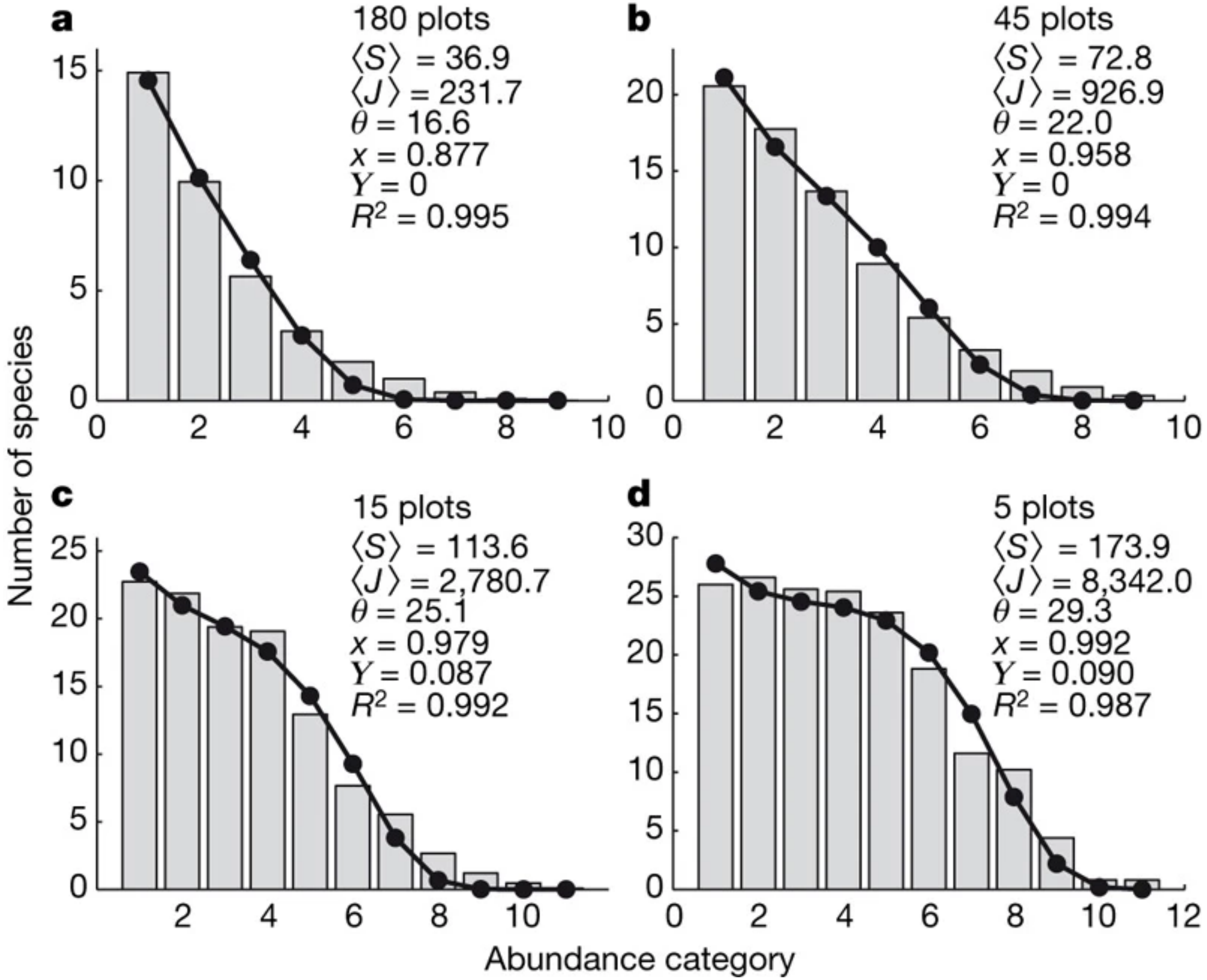
tropical forests



[Volkov et al., 2007]

NT reproduces species abundace distributions

coral reefs



[Volkov et al., 2007]

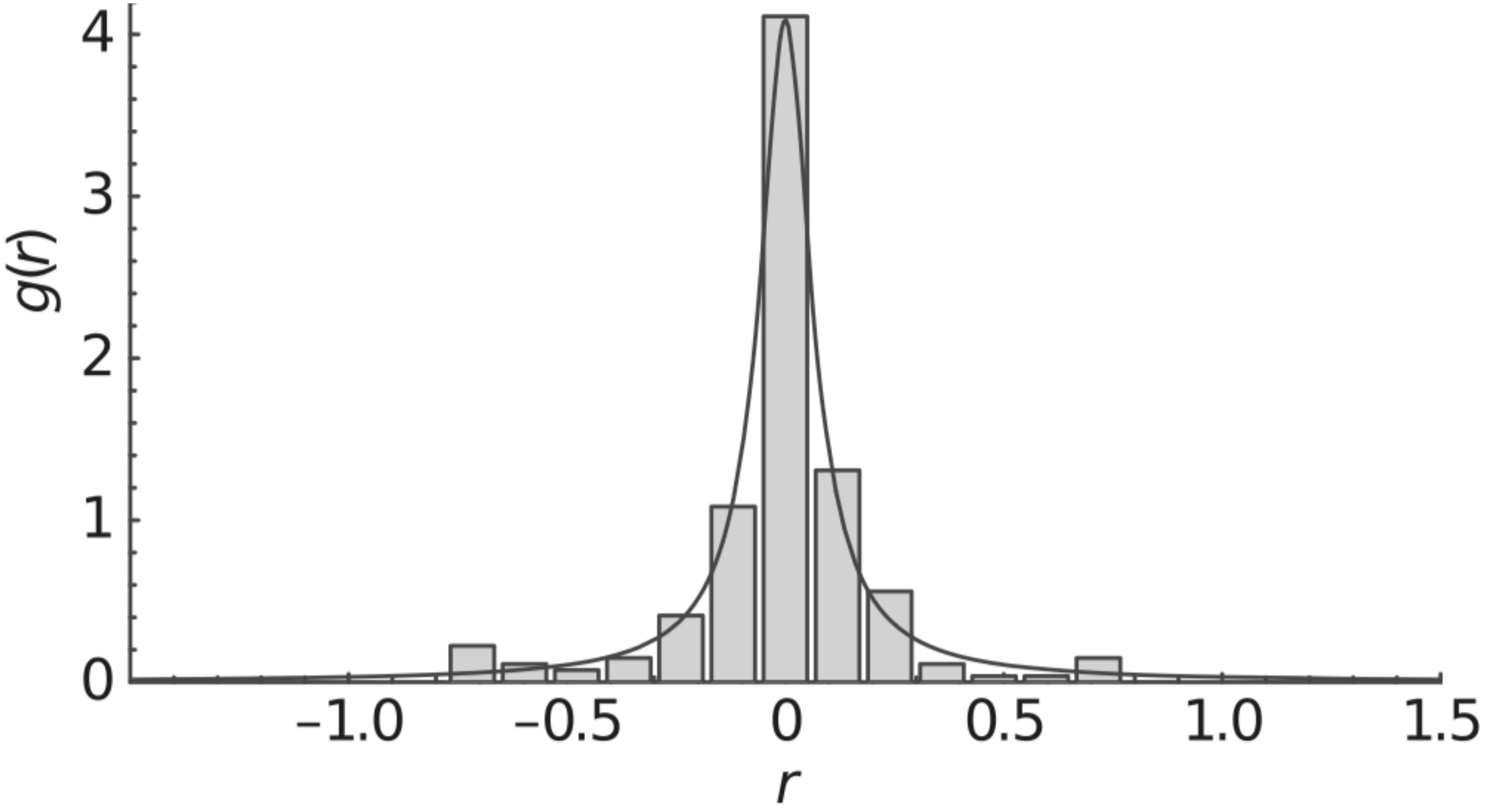
What else can you do with neutral theory?

Dynamics

$$\mathcal{P}(\lambda, t) = \langle \delta(\lambda - x/x_0) \rangle$$
$$= \int_0^\infty dx_0 \int_0^\infty dx P(x, t | x_0, 0) P_0(x_0) \delta(\lambda - x/x_0)$$

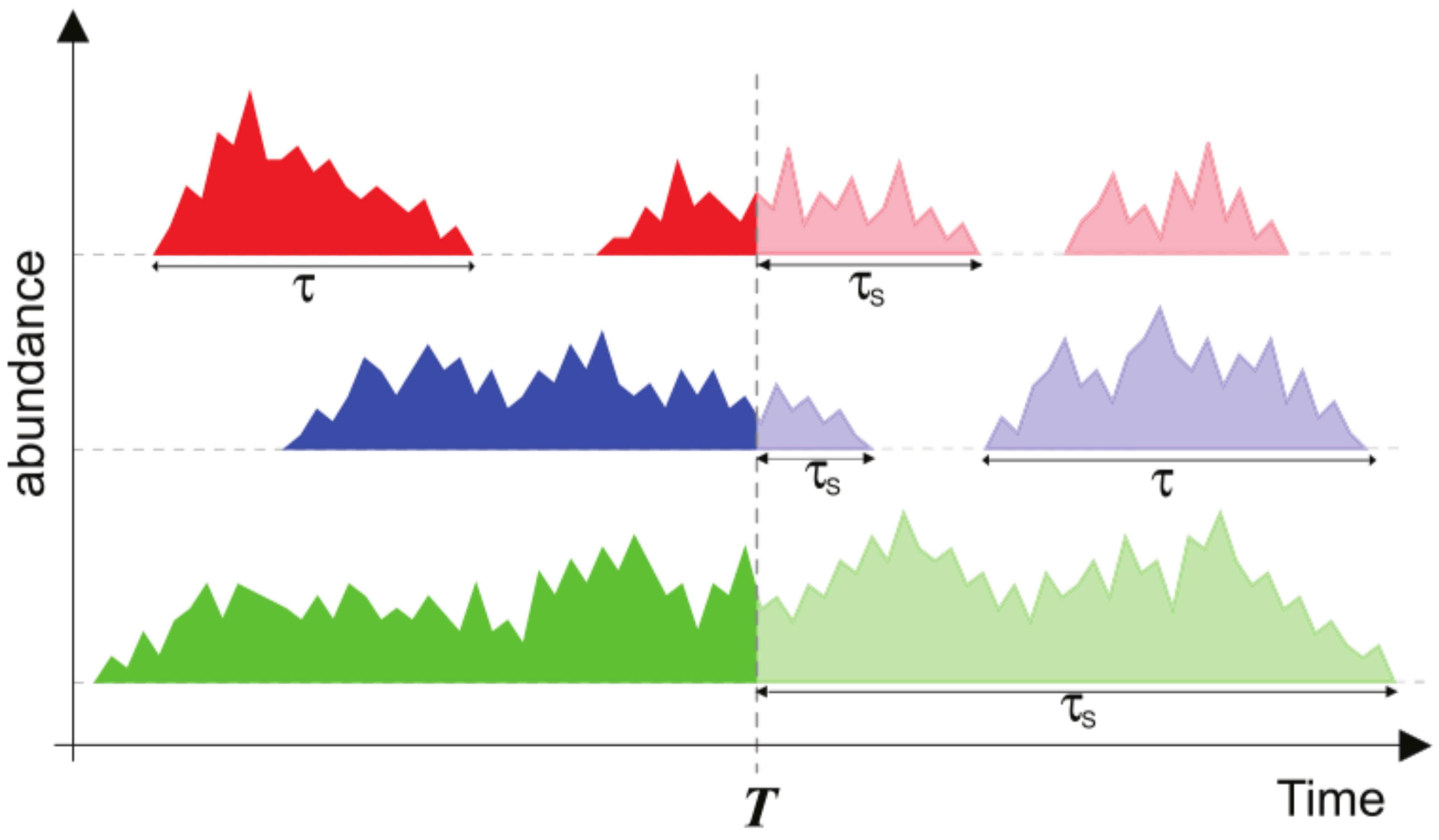
$$r = \log \lambda$$

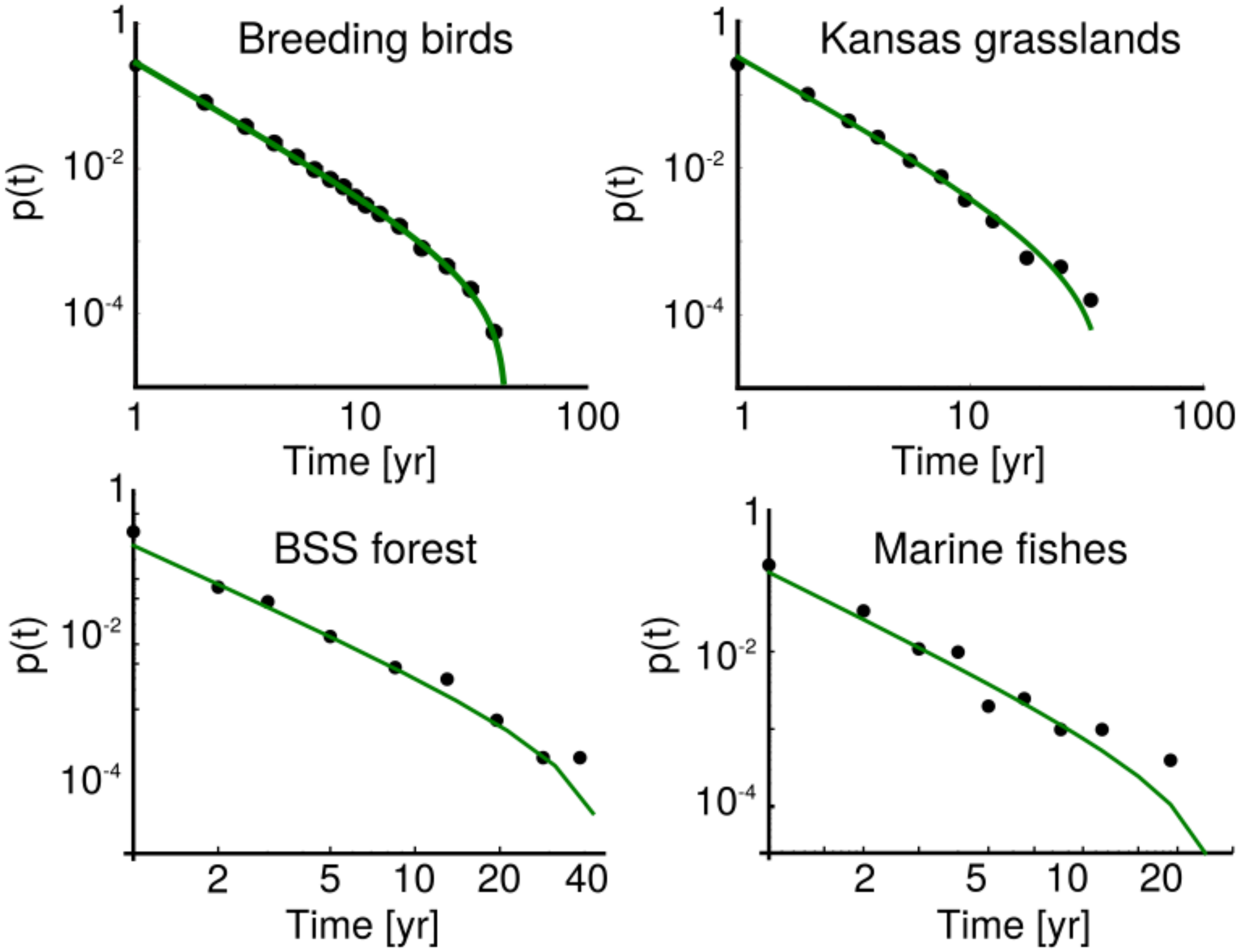
$$g(r) = e^r P(e^r, t)$$



[Azaele et al., 2006]

Dynamics

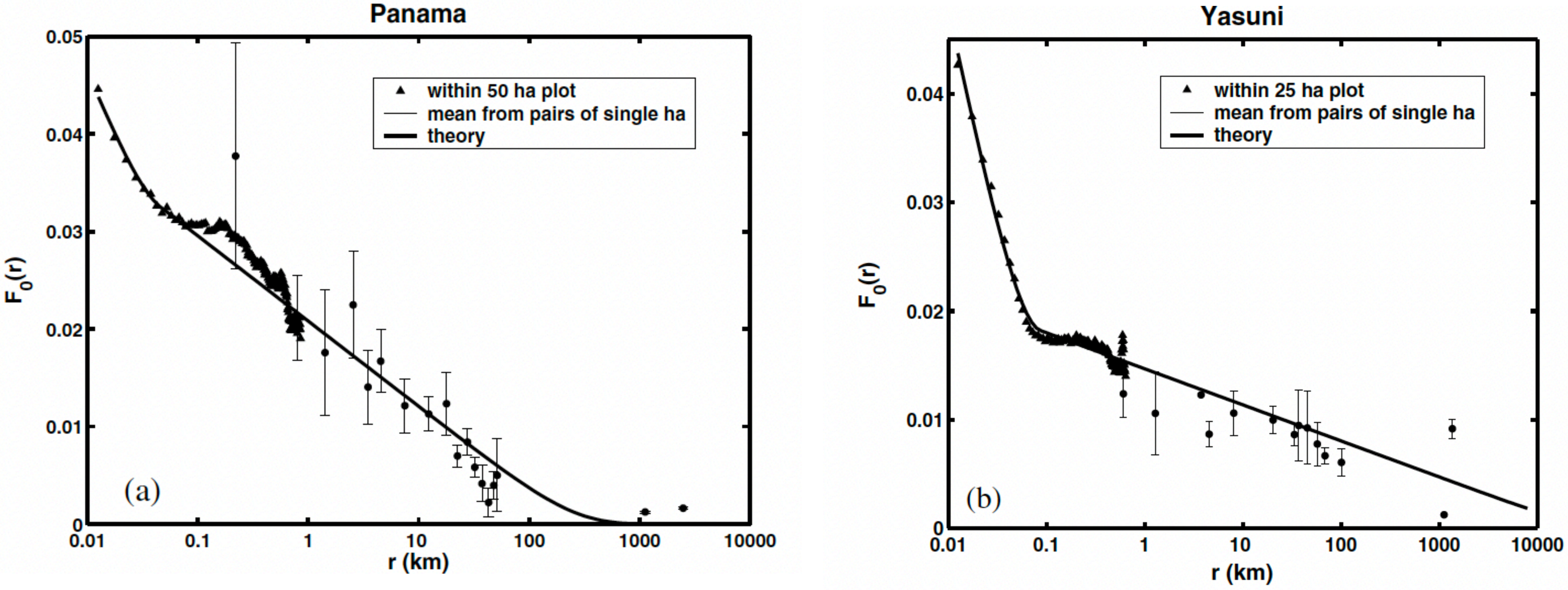




[Suweis et al., 2012]

Space

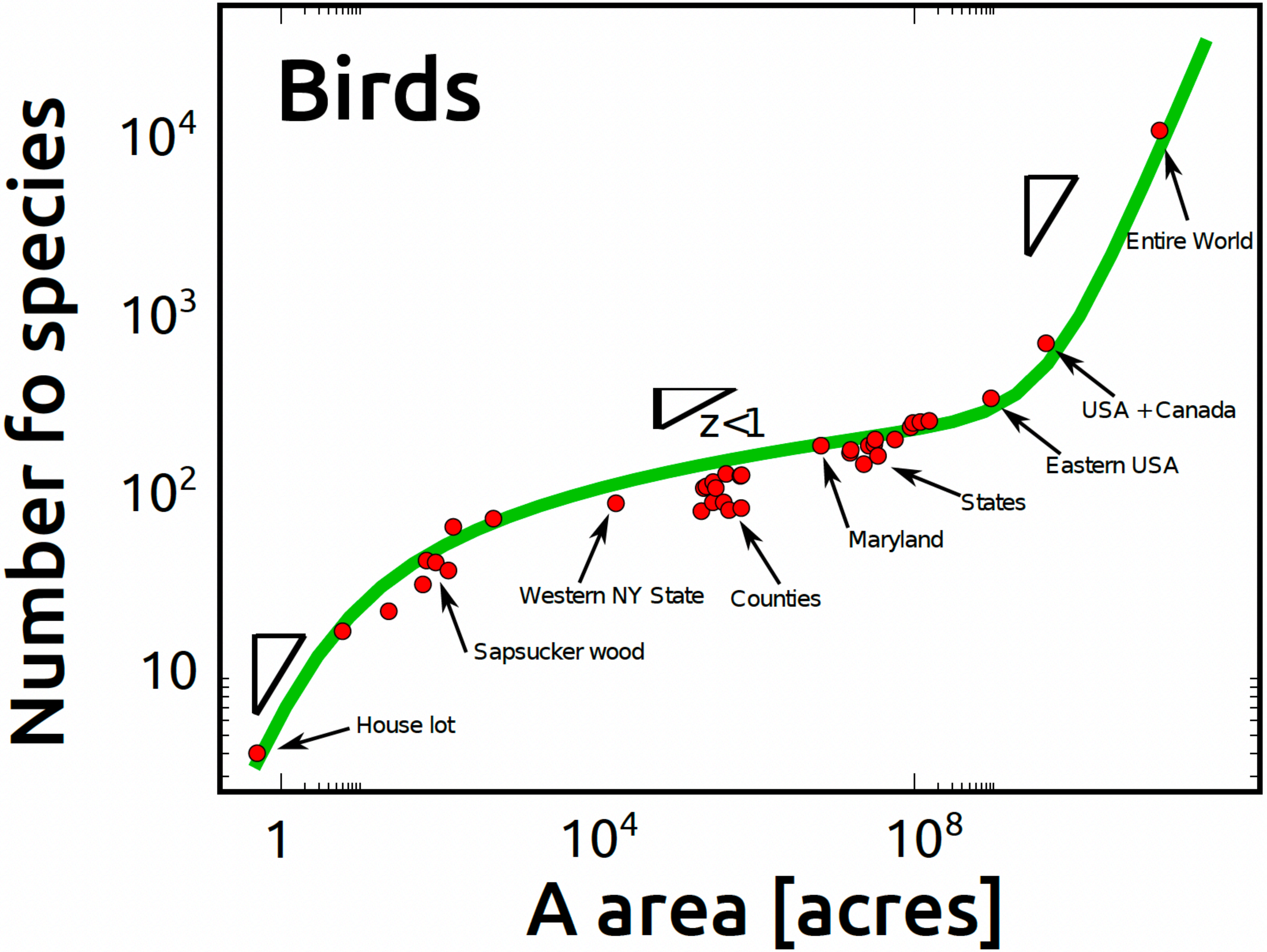
Probability that two random individuals are conspecific



[Zillio et al., 2015]

Space

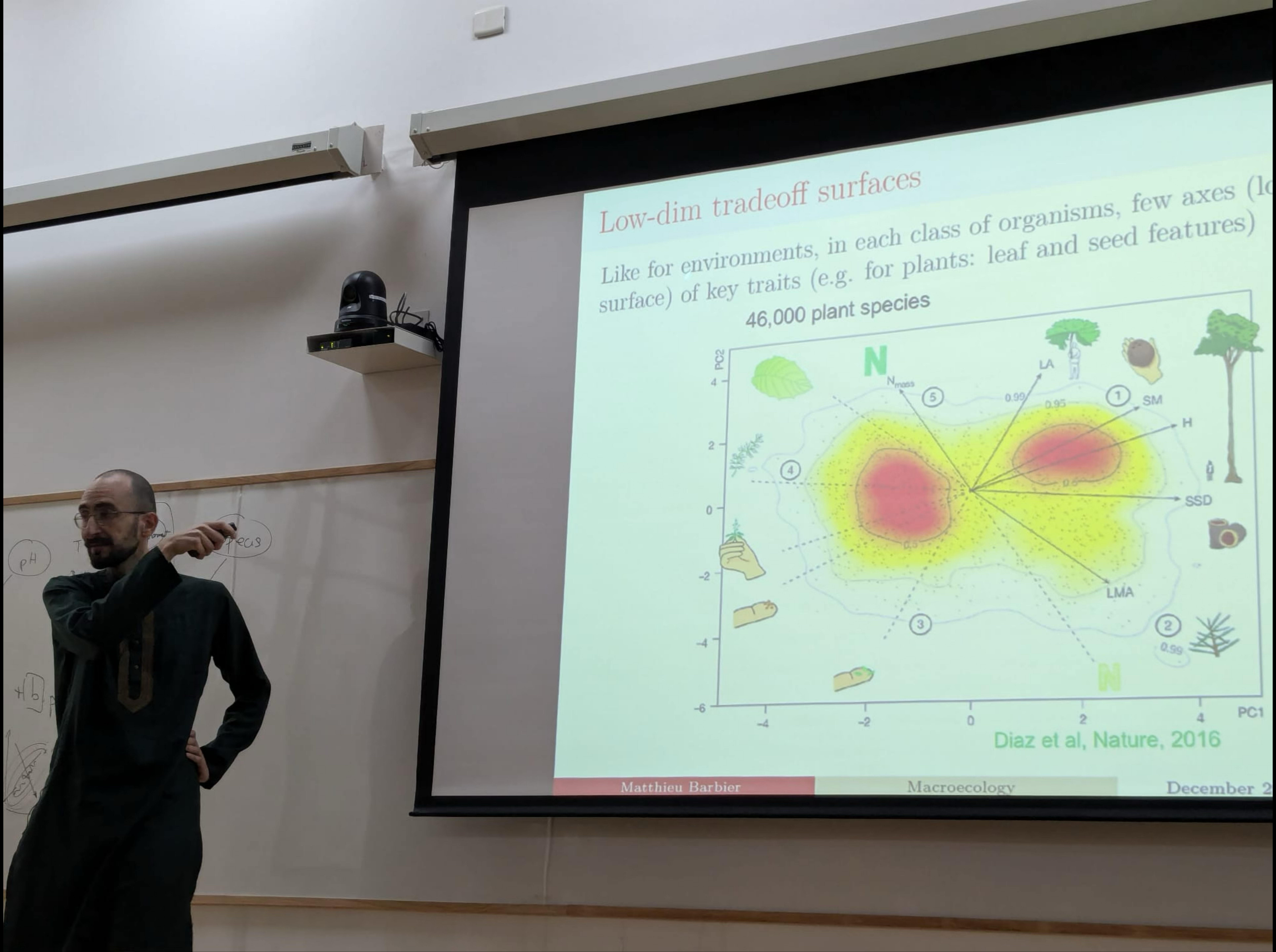
Species Area Relationship



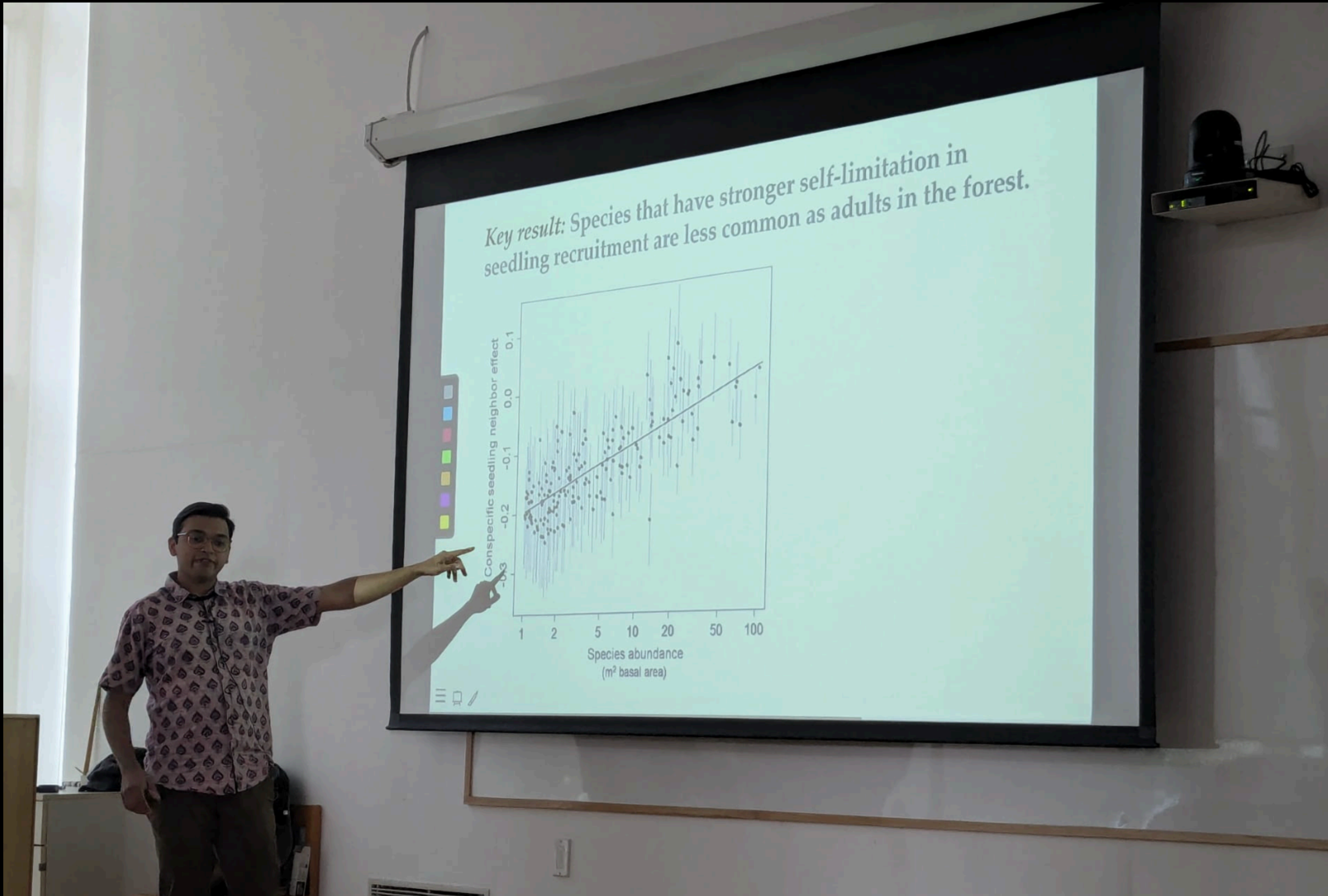
[Grilli et al., 2012]

How neutral theory fails

Species are very different



Species differences play a role



Timescales

Speciation as source of diversity
How "old" is a species with a given relative abundance x?

$$a(x) = -2N\frac{x}{1-x}\log x$$

[Kimura 1983]

Amazon rainforest

Total number of trees: N ~ 10^{11}

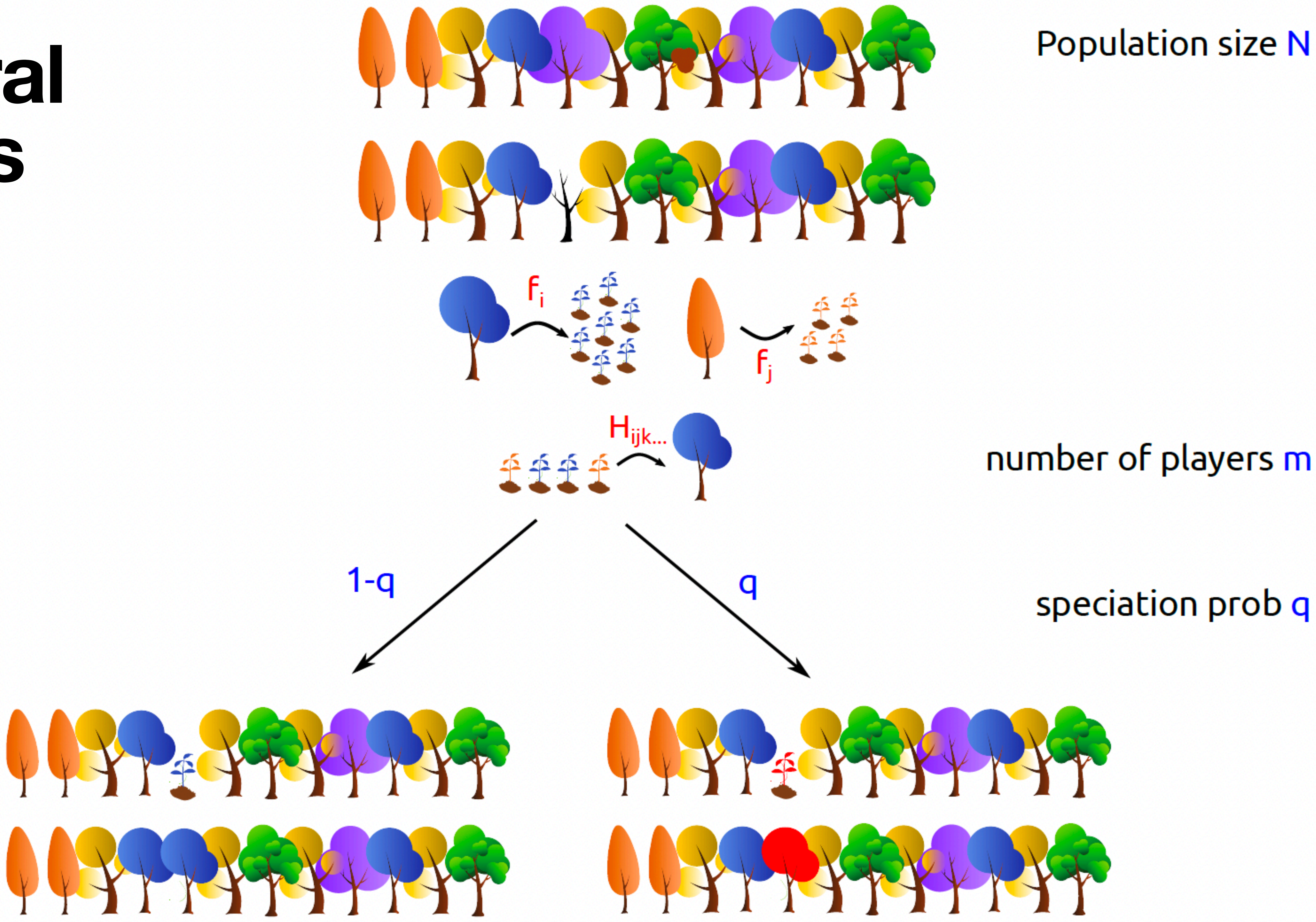
Most abundant species tree: x ~ 10^{-2}

Generation time of trees: ~ 30 years

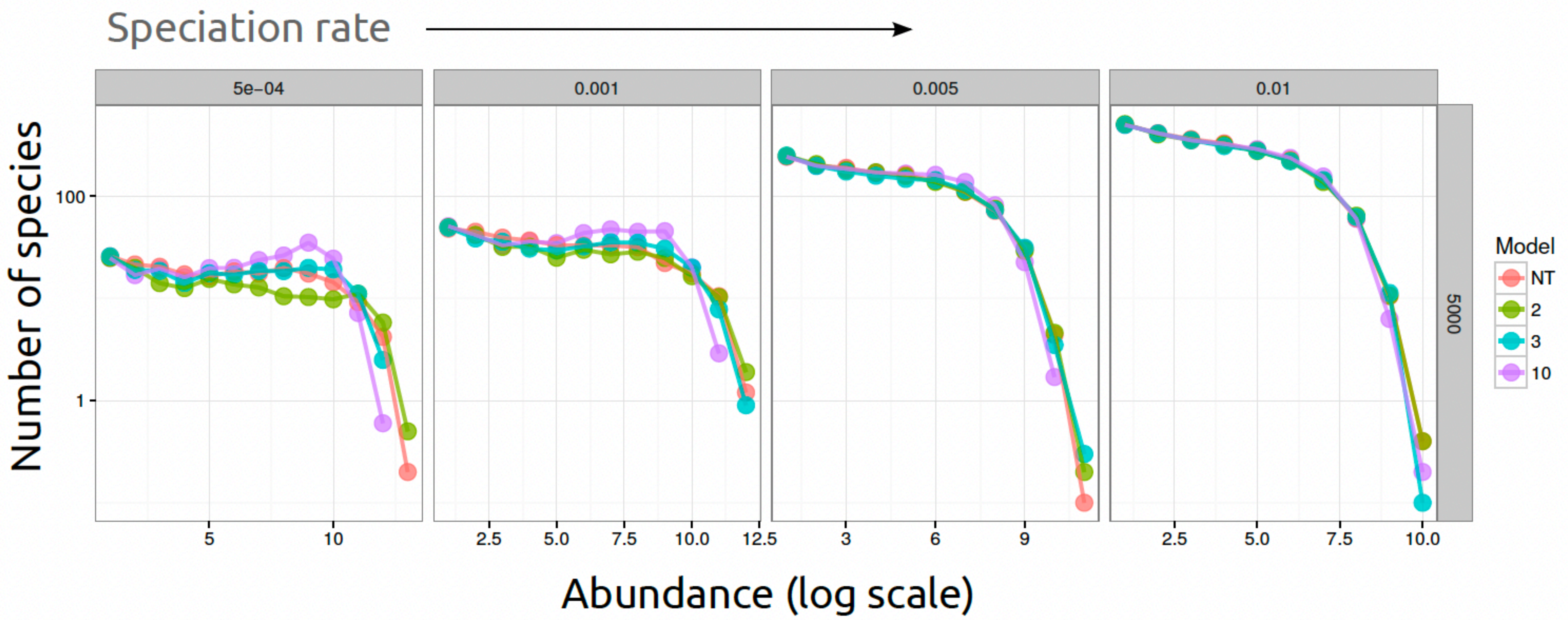
Age of the most abundant species: ~10^{11} years

Age of the universe: ~10^{10} years , First tree: ~10^{8} years ago

Non-neutral extensions

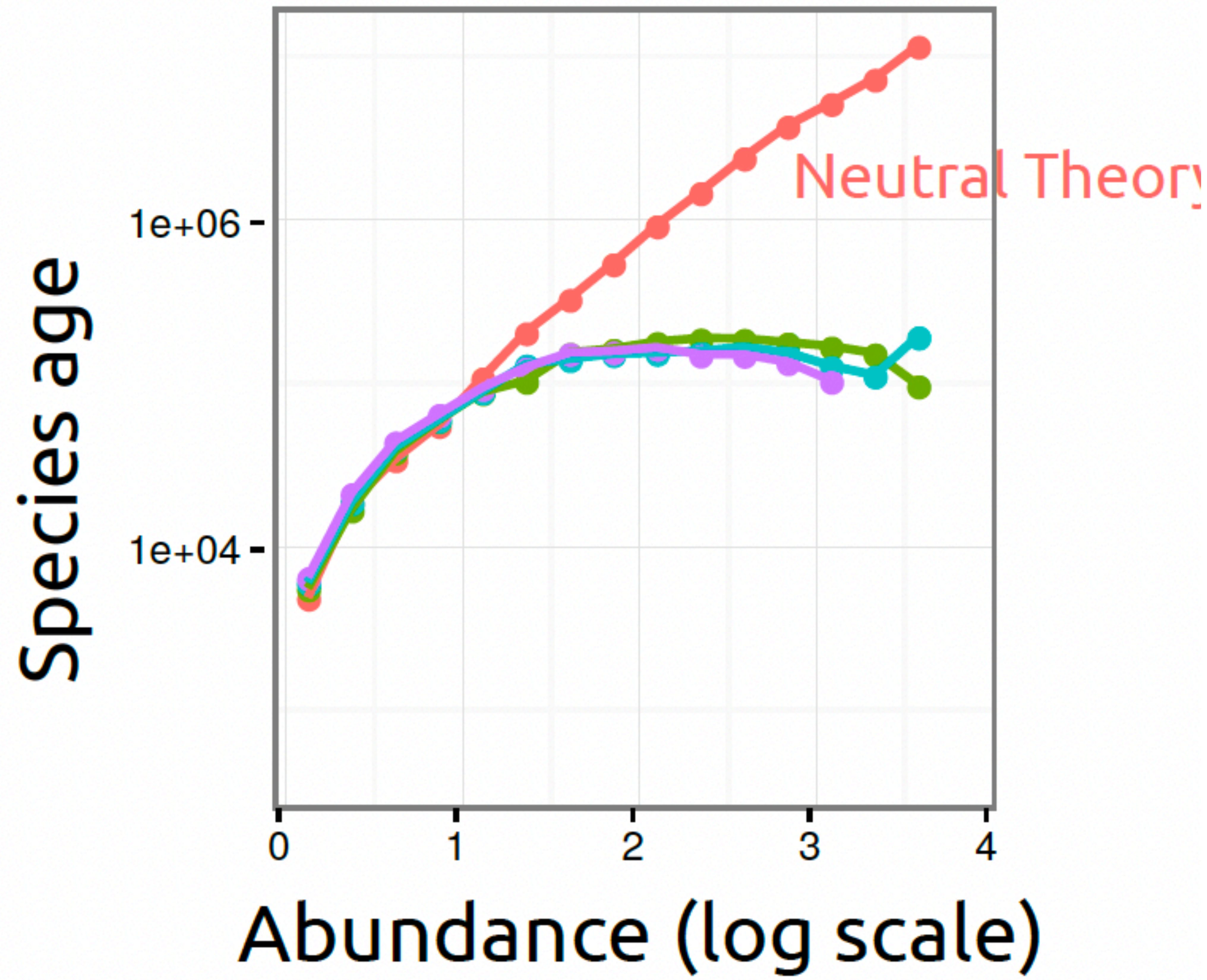


Species Abundance Distribution is insensitive to interactions



[Grilli et al., 2017]

Time to extinction is sensitive to neutrality



[Grilli et al., 2017]