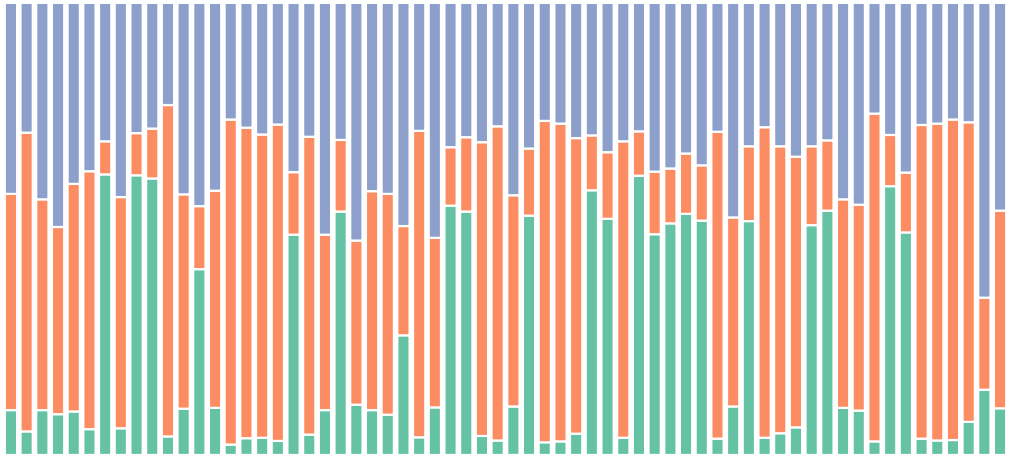
Identifying Models of Trait-Mediated Community Assembly

using random forests and approximate Bayesian computation

Megan Ruffley, Katie Peterson,
Bob Week, David C. Tank,
Luke J. Harmon



Society of Systematic Biologists

University of Idaho

SSE Society for the Study of Evolution

iDiv German Centre for Integrative Biodiversity Research

Santa Fe Institute

NSF

The Ohio State University

Botanical Society of America

FORBIO

the City College of New York

UiO : Life Science University of Oslo

ibest Institute for Bioinformatics and Evolutionary Studies

ID University of Idaho Stillinger Herbarium

Interested in identifying neutral and non-neutral processes of assembly

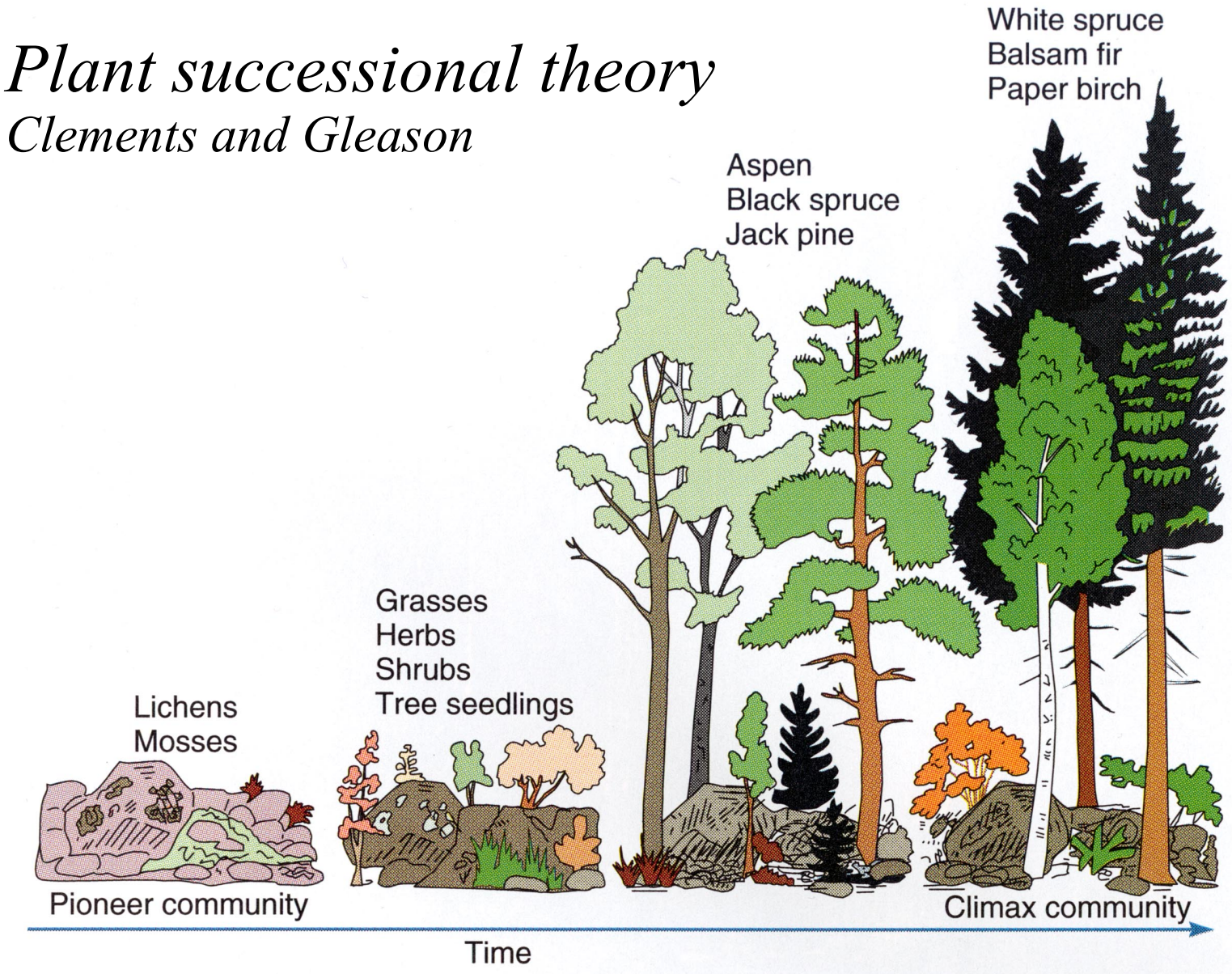
Environmental Filtering

Competitive Exclusion

Plant successional theory

Clements and Gleason

Are communities a result of deterministic (Clements 1938) or stochastic (Gleason 1927) processes



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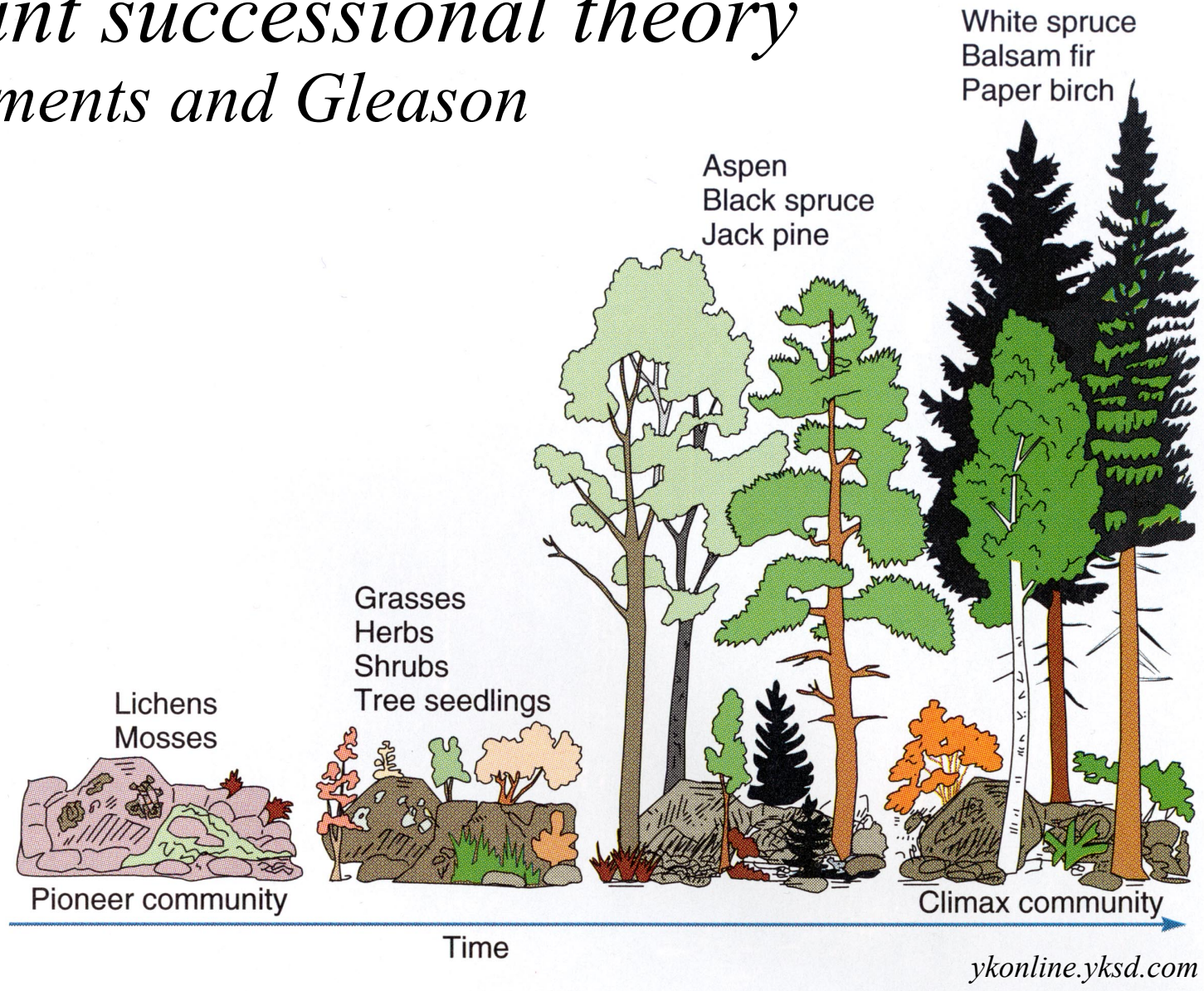


Frederic Clements (1916)

"Succession is deterministic"

-stable 'climax' community that is in perfect balance with the climate

"Communities are super-organisms"

-Communities are dependent on the species interactions among members

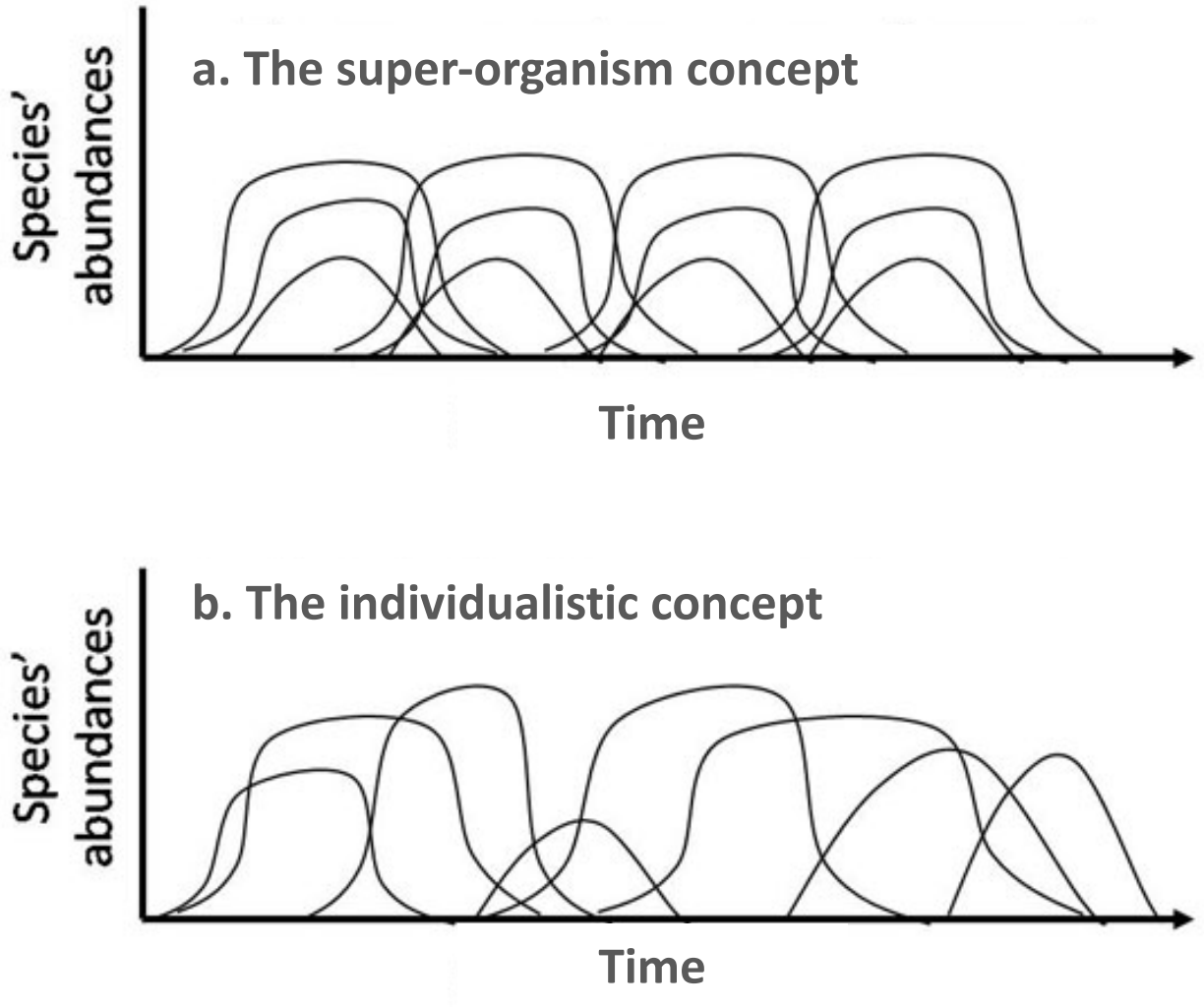
Henry Gleason (1917)

- "Each species is an independent entity"

  -distribution of each species is due to genetics, physiology, life history, and relations to abiotic and biotic factors

  -communities are just a consequence of independent interactions among species and their environment

Introduction: Clements and Gleason debate



(A) Groups of species are tightly associated, and are supplanted by other groups of tightly associated species. (B) Individual species independently respond to environmental conditions. Each curve on the graphs represents the abundance of a single species.

Emery, S. (2010)

What influences how communities are formed?

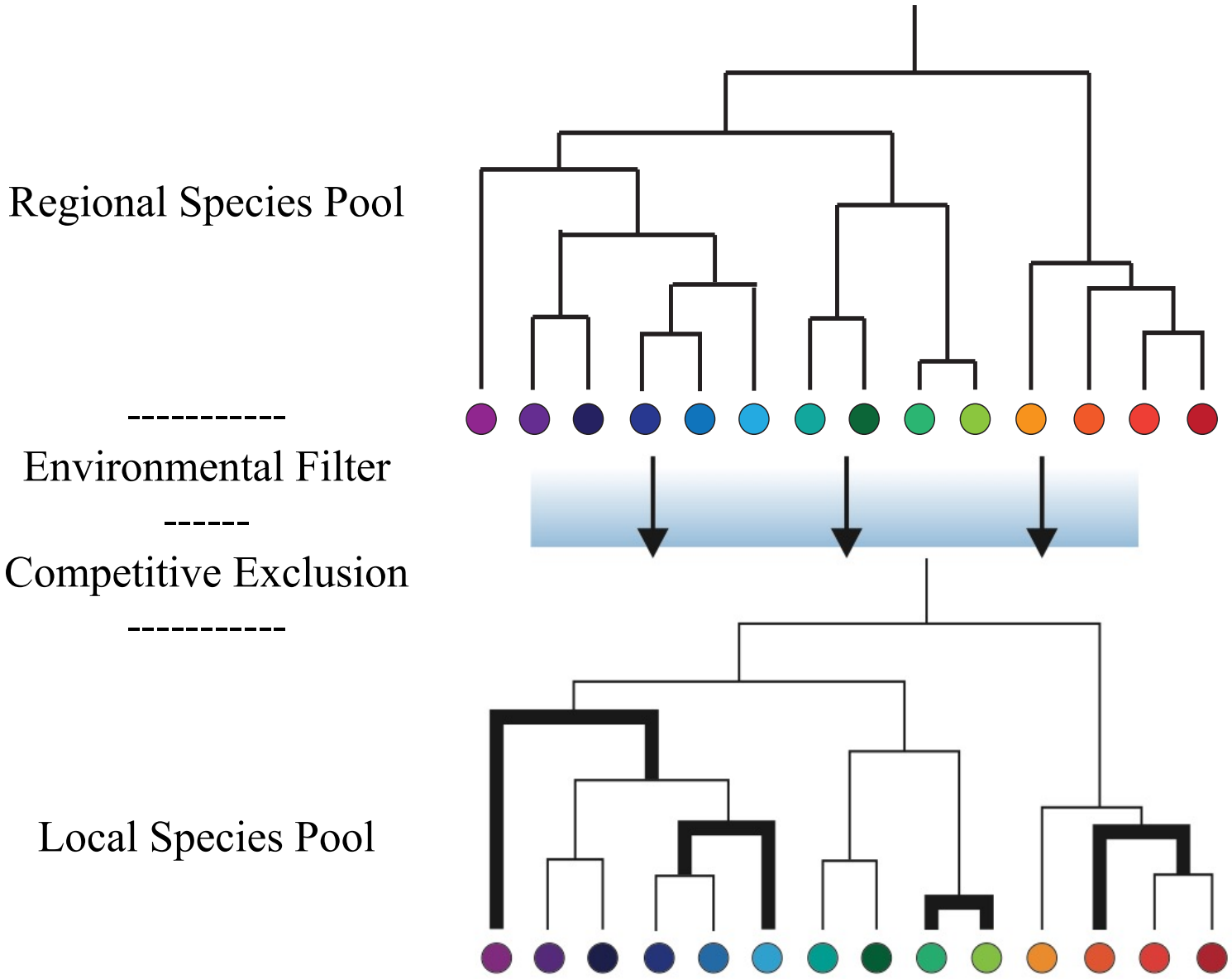
Clements – the environment

Habitat Filtering – species fail to establish in community due to incompatibility with relevant environmental factors

Gleason – the species

Competitive Exclusion – species fail to establish in a community when they cannot out-compete another species for their desired niche.

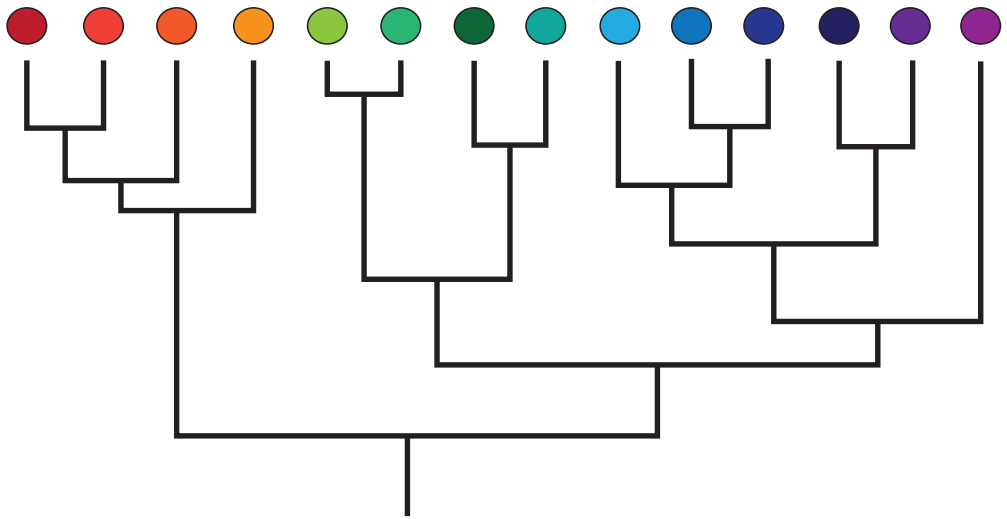
Community Assembly



How are community assembly models quantified?

Phylogenetic dispersion metrics are commonly use to detect signal for habitat filtering and competitive exclusion.

-Mean Phylogenetic Distance (MPD)
-Mean Nearest Taxon Distance (MNTD)

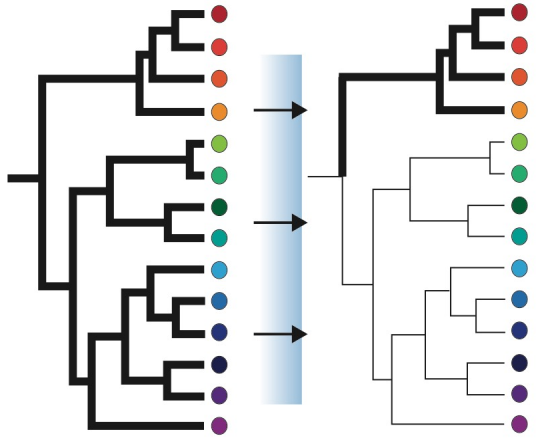


Assumption: functional traits of importance are phylogenetically conserved.

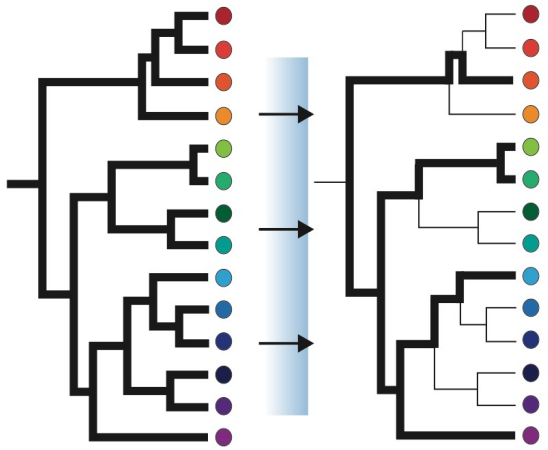
Introduction: Community Assembly

Traits are phylogenetically conserved

Habitat Filtering = phylogenetic underdispersion

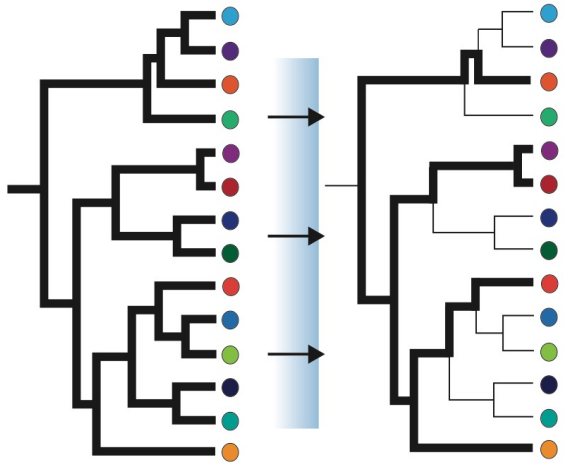


Competitive Exclusion = phylogenetic overdispersion



Traits are phylogenetically convergent

Habitat Filtering = phylogenetic overdispersion



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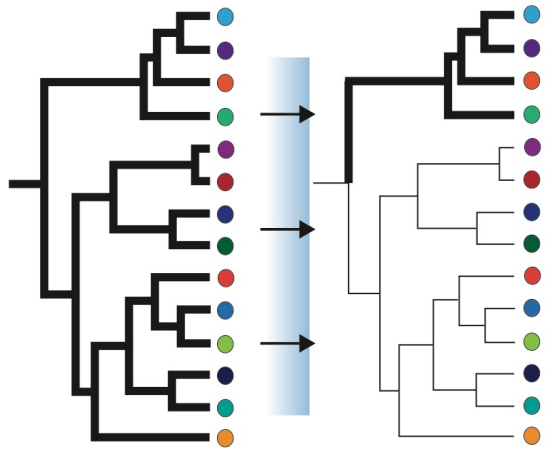


Cavender-Bares et al. 2009

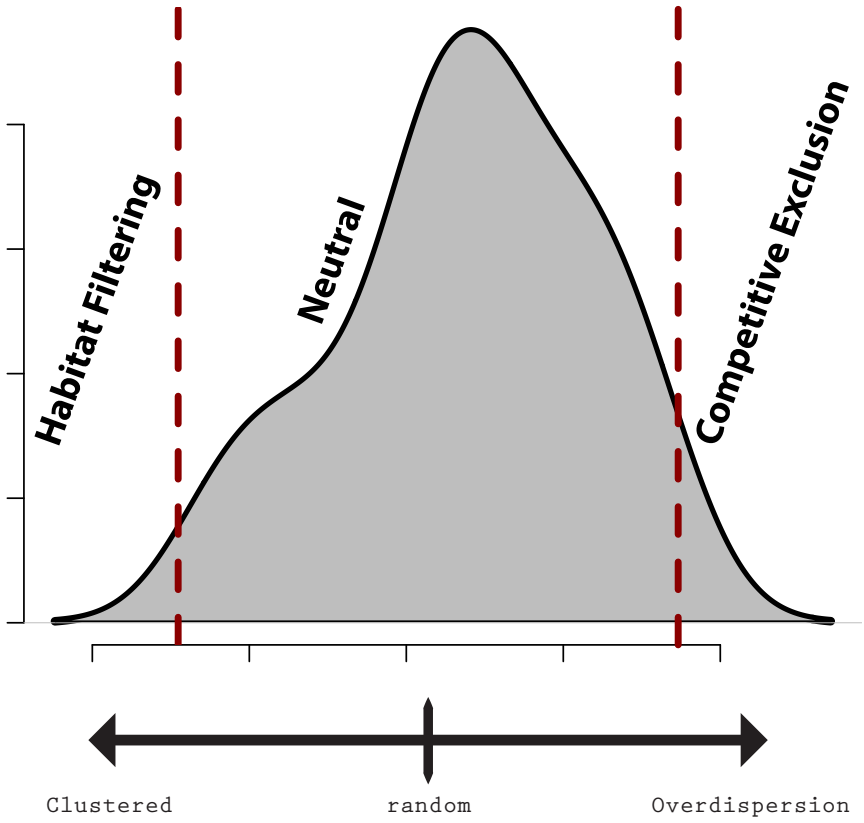
Community Assembly Inference; dispersion metrics

- Phylogenetic Community Structure

  Grandcolas 1998, Webb et al. 2000, 2002, Kraft et al. 2007

- Trait Community Structure

  Weiher et al. 1999, McGill et al. 2006, Cornwell et al. 2006, Kraft et al. 2007



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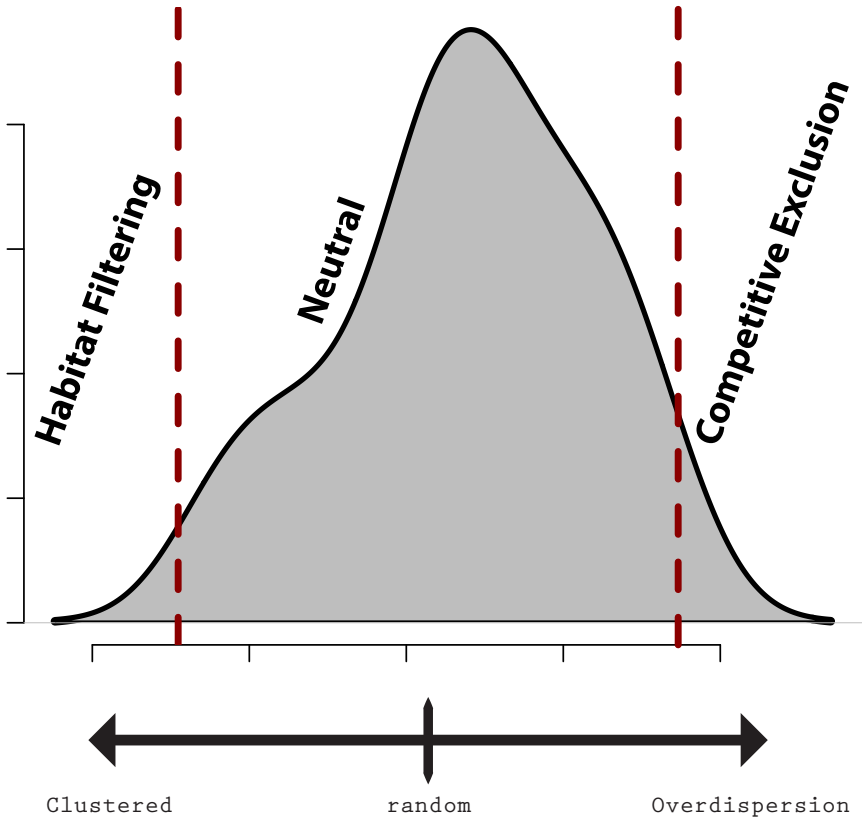
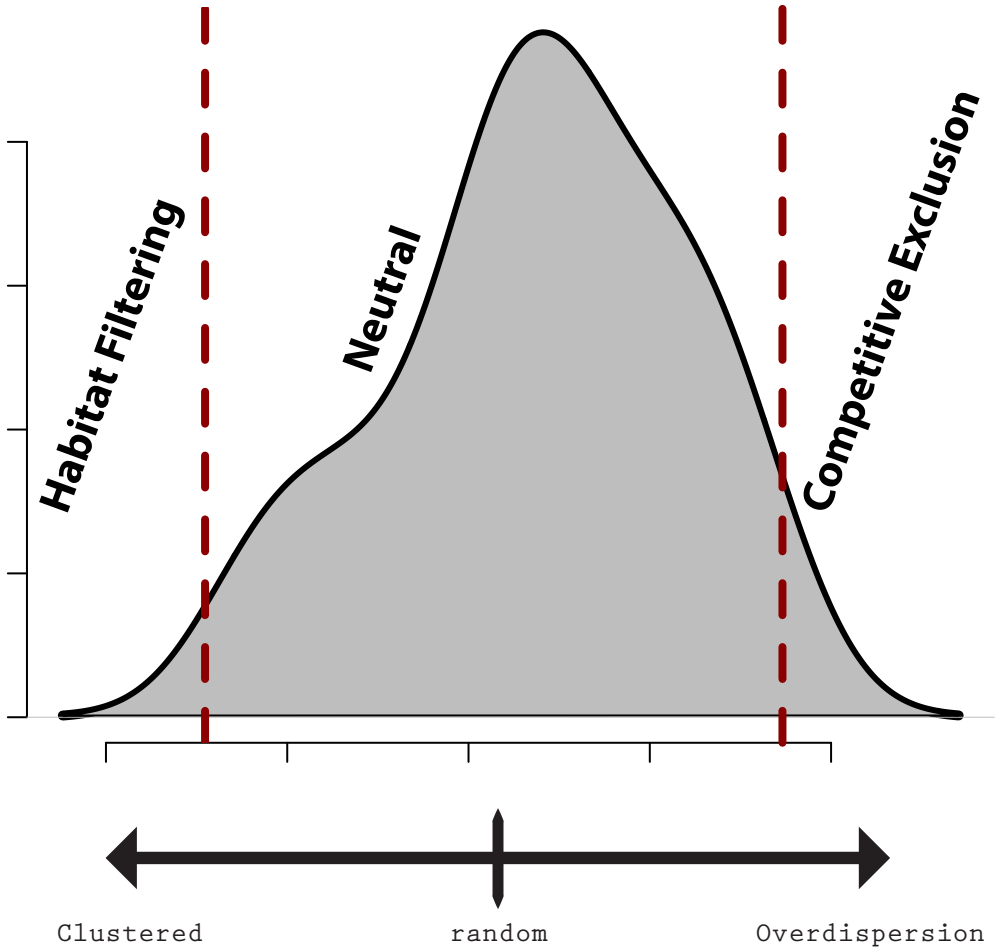


Current Community Assembly Inference Methods

- No uncertainty associated with the inference
- Not comparable across communities



CAMI development objectives

1. *Implement a model-based inference procedure*

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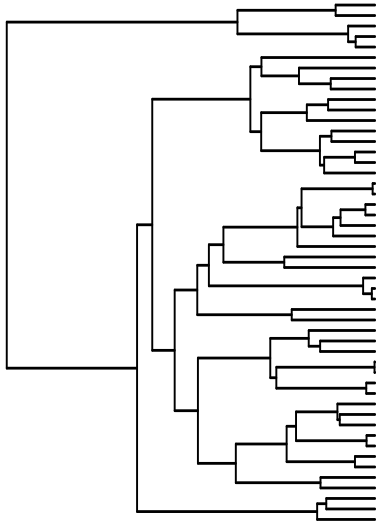
Objective 1: Implement a model-based inference procedure

1.1 Regional community phylogeny: N, λ, μ



N	regional species pool
λ	speciation rate
μ	extinction rate
σ^2	rate of character change
α	strength of constraints (OU only)
n	local species pool
t_E	effect of environmental filtering
t_C	effect of competitive exclusions

Ruffley *et al.* 2019 *Ecol. & Evol. Accepted*

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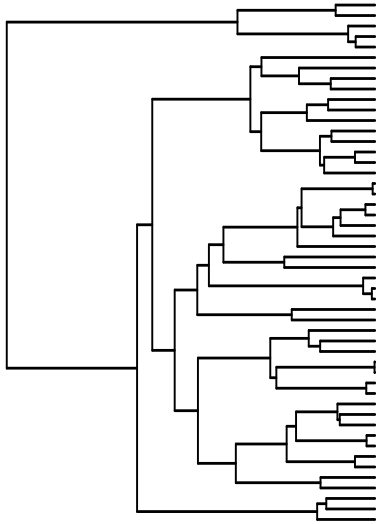
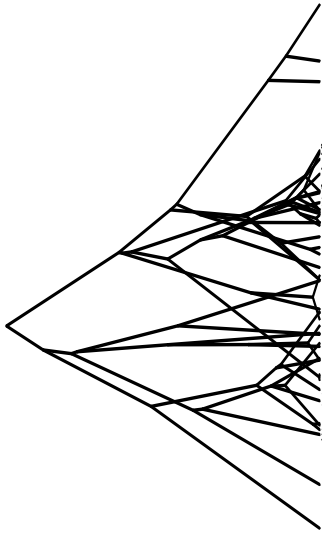


1.2 Trait evolution: σ^2, α



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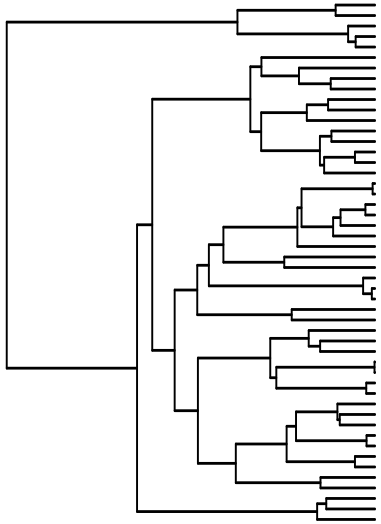

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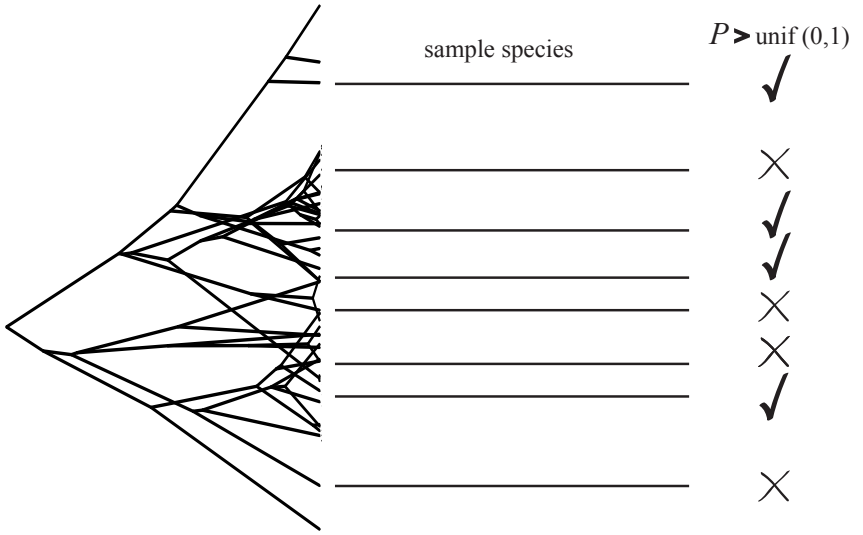
1.3 Local community assembly: n, t_E, t_C



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Objective 2: Parameterize the strength of the non-neutral assembly processes

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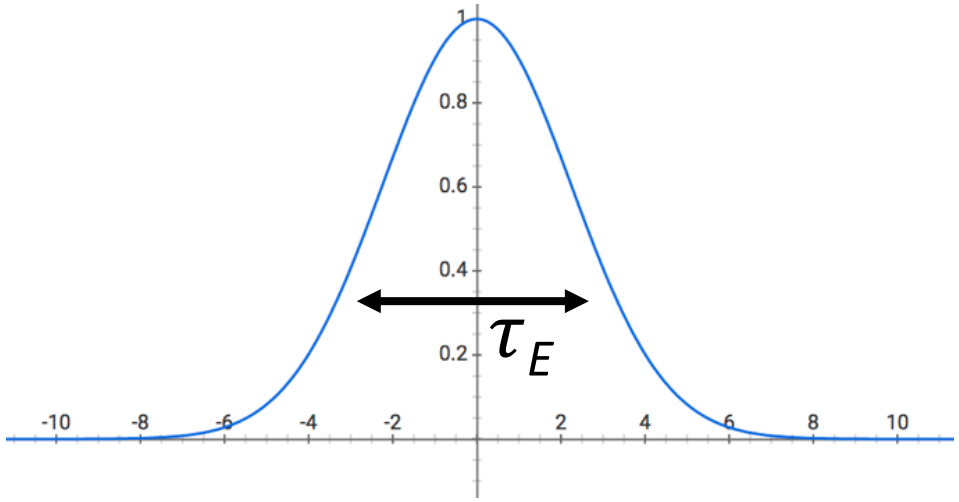
Environmental Filtering

$$P = e^{-\frac{(Zi-Zj)^2}{\tau}}$$



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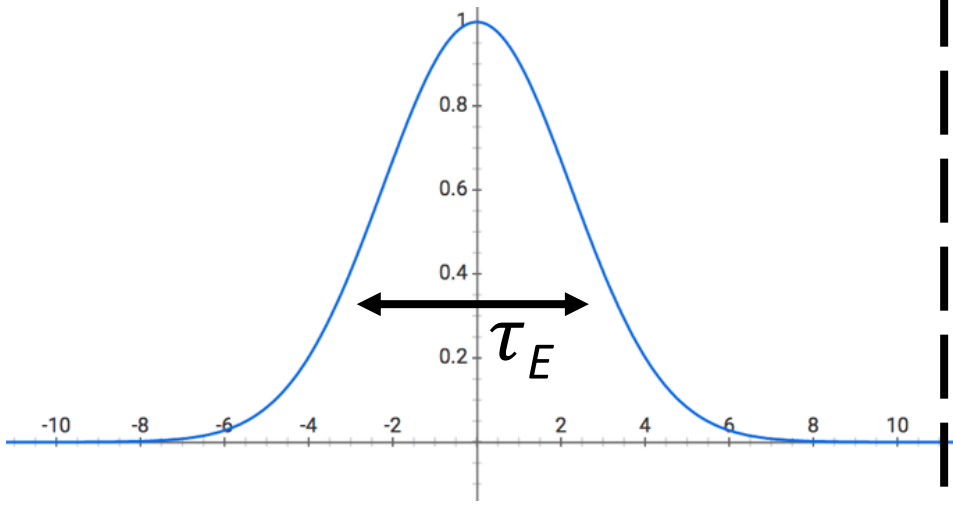
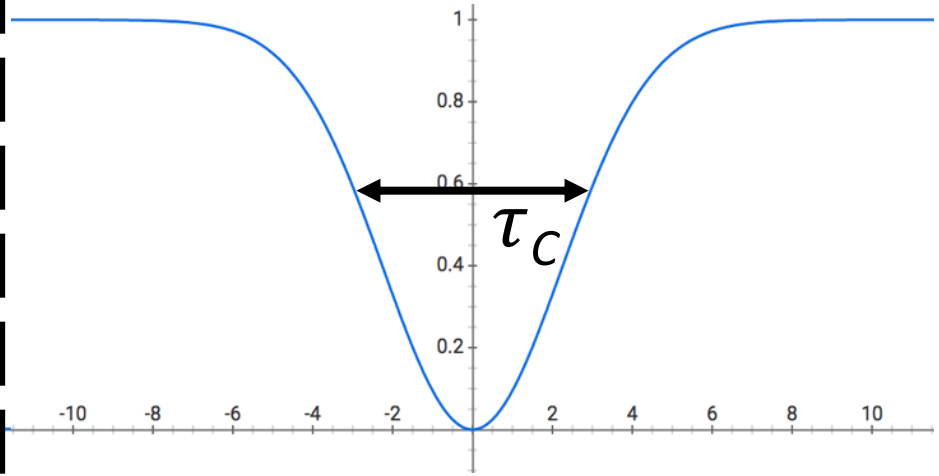


Competitive Exclusion

$$P = 1 - e^{-\frac{(Zi-Zj)^2}{\tau}}$$



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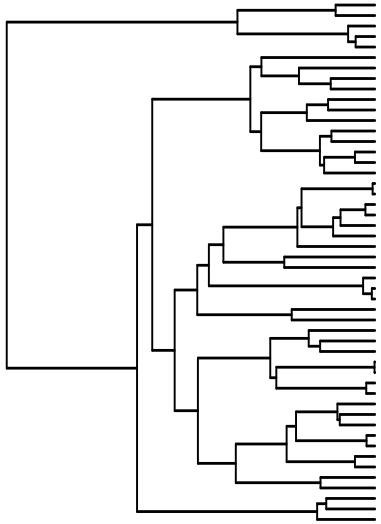

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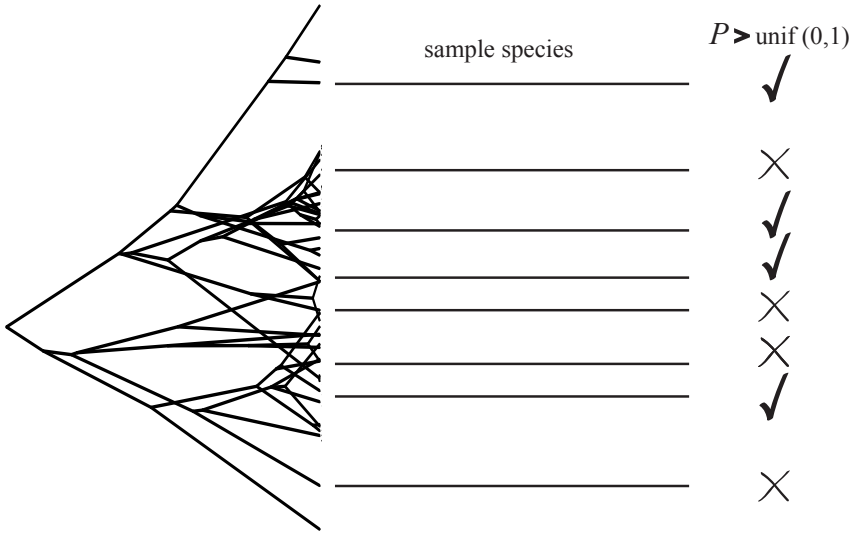

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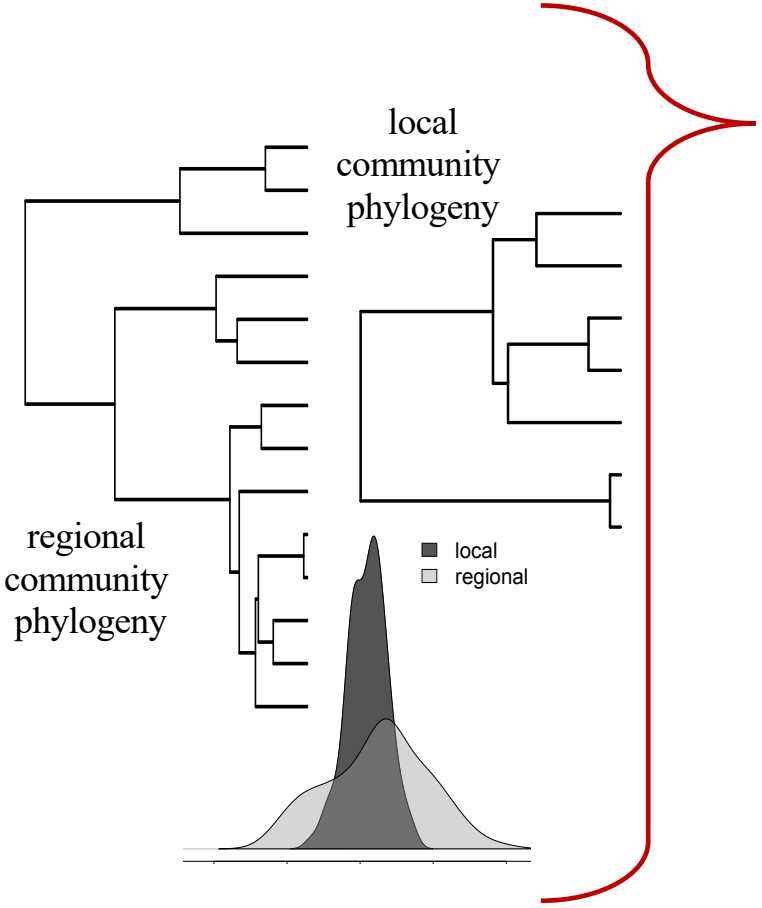

Simulation #	*SS.1*	*SS.2*	*SS.3*	*…..*	*SS.30*	*Model*
1	29.3201204	0.047795881	2.202369339	0.024039567	-0.551807157	**Neutral**
2	58.01018705	0.05683677	4.296006276	0.014001377	-0.141285853	**Neutral**
3	28.35028897	0.057748823	2.565336481	0.02472052	0.543737366	**Neutral**
4	54.4519145	0.058161893	4.462506196	0.006577184	-0.297716652	**Neutral**
5	29.52415799	0.0449925	1.332280042	-0.027307941	-0.424597011	**Neutral**
6	13.8002455	0.043015337	3.827085961	0.052868925	0.00038215	**Filtering**
7	68.51513963	0.05221236	3.773466742	0.006122832	-0.373019012	**Filtering**
8	6.409247373	0.067539483	1.27370363	0.056550081	-0.419361409	**Filtering**
9	7.869379132	0.044893904	1.621625795	0.005944114	-0.225941885	**Filtering**
10	56.74215972	0.042376631	3.870139564	-0.010551762	1.612683176	**Filtering**
11	32.21489305	0.039088122	4.436192932	-0.005017495	-0.608370405	**Competition**
12	35.31406132	0.055897014	1.802319164	0.00665565	0.575928644	**Competition**
…	15.17747744	0.052302964	2.833102254	-0.007315425	-0.343133625	**Competition**
10,000	176.8646799	0.046759559	3.404803136	0.003965272	-0.492954288	**Competition**

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Objective 1: Implement a model-based inference procedure

Model-selection using approximate approaches

- randomForests (*Breiman 2001, Breiman and Cutler 2007*)
- Approximate Bayesian Computation (ABC; *Beaumont, et al. 2002, Csilléry, et al. 2012)*

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Results

1. *Power Analysis*

2. *Parameter Estimation*

3. *Empirical study*

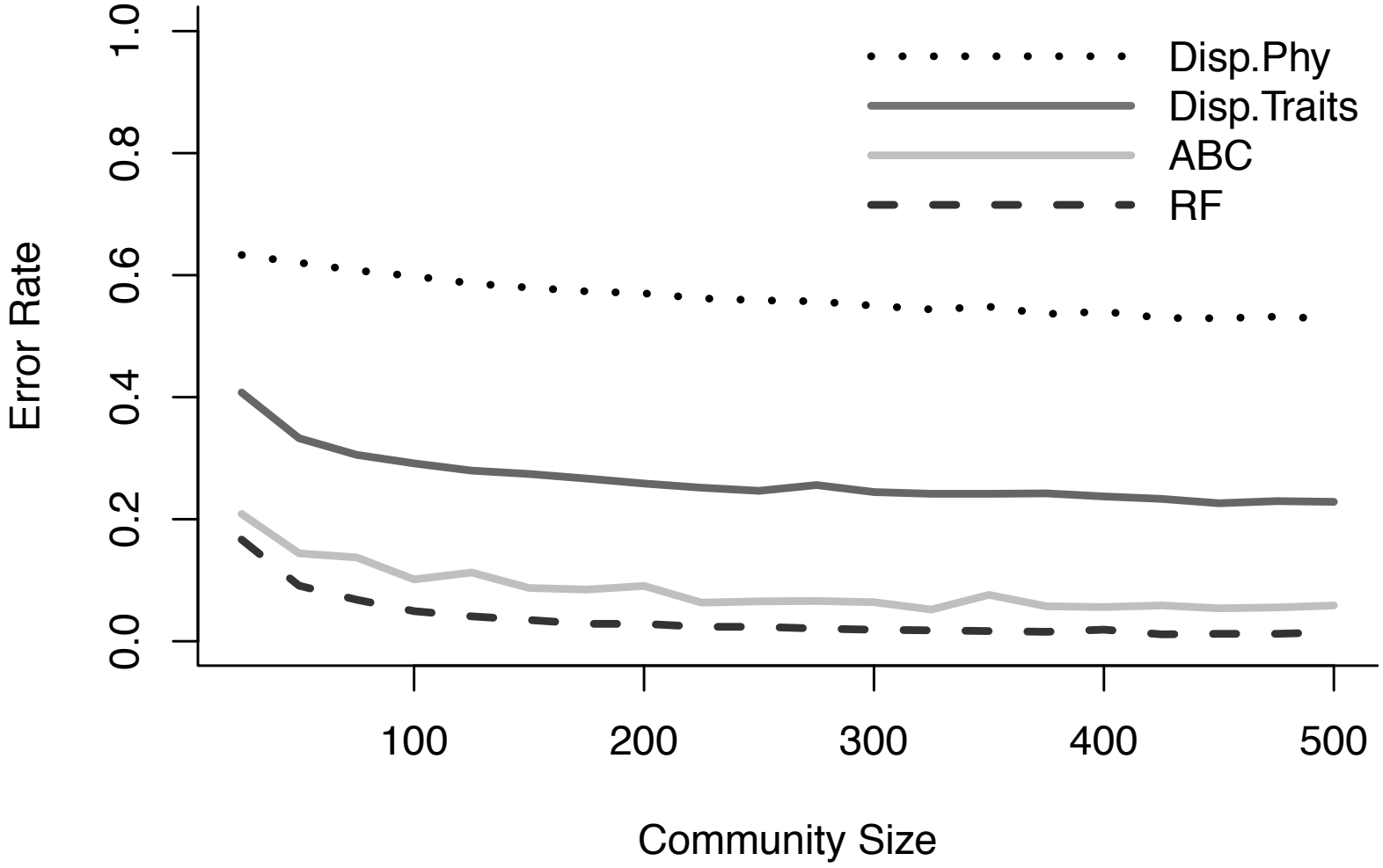
Results

1. Power Analysis

- ***Dispersion Metrics***
  - *Phylogenetic data*
  - *Functional trait data*

- ***randomForest (RF)***
- ***ABC***

Results: Power Analysis



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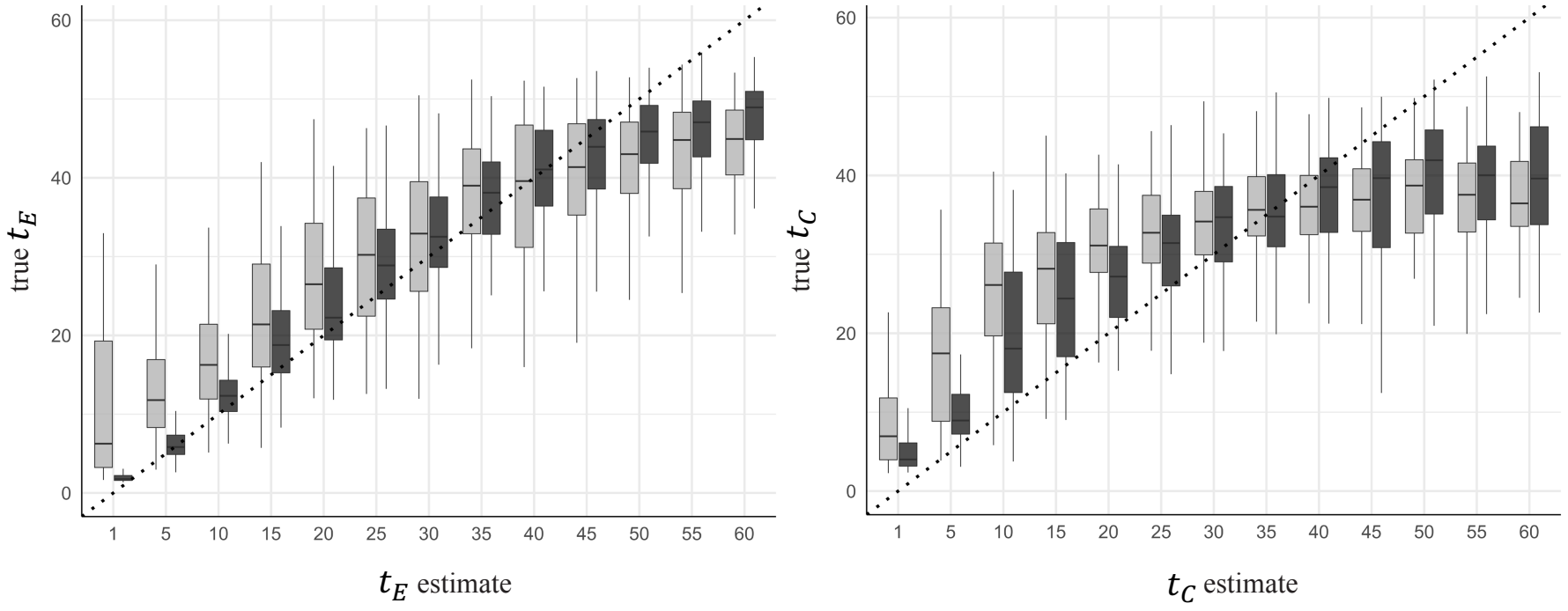
Results

1. *Power Analysis*

2. ***Parameter Estimation***
   -Estimate τ_E and t_C

3. *Empirical studies*

Results: Parameter Estimation



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- DO first tutorial and introduction to CAMI,
    - Load it
    - Simlate some data
    - Build and RF