Generalism drives abundance: a computational causal discovery approach

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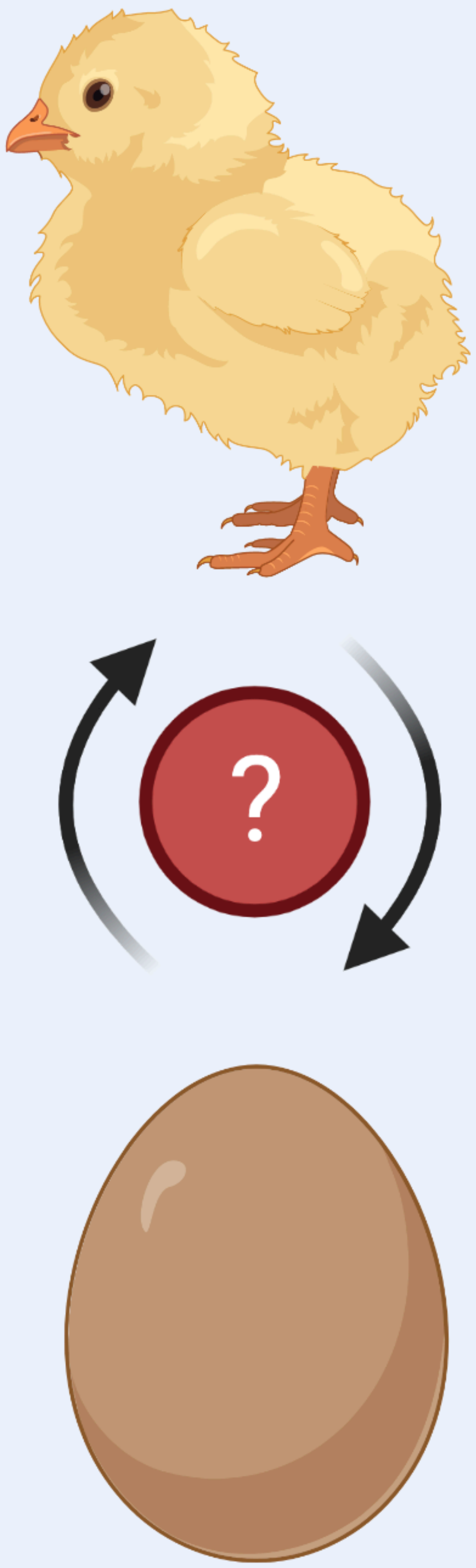
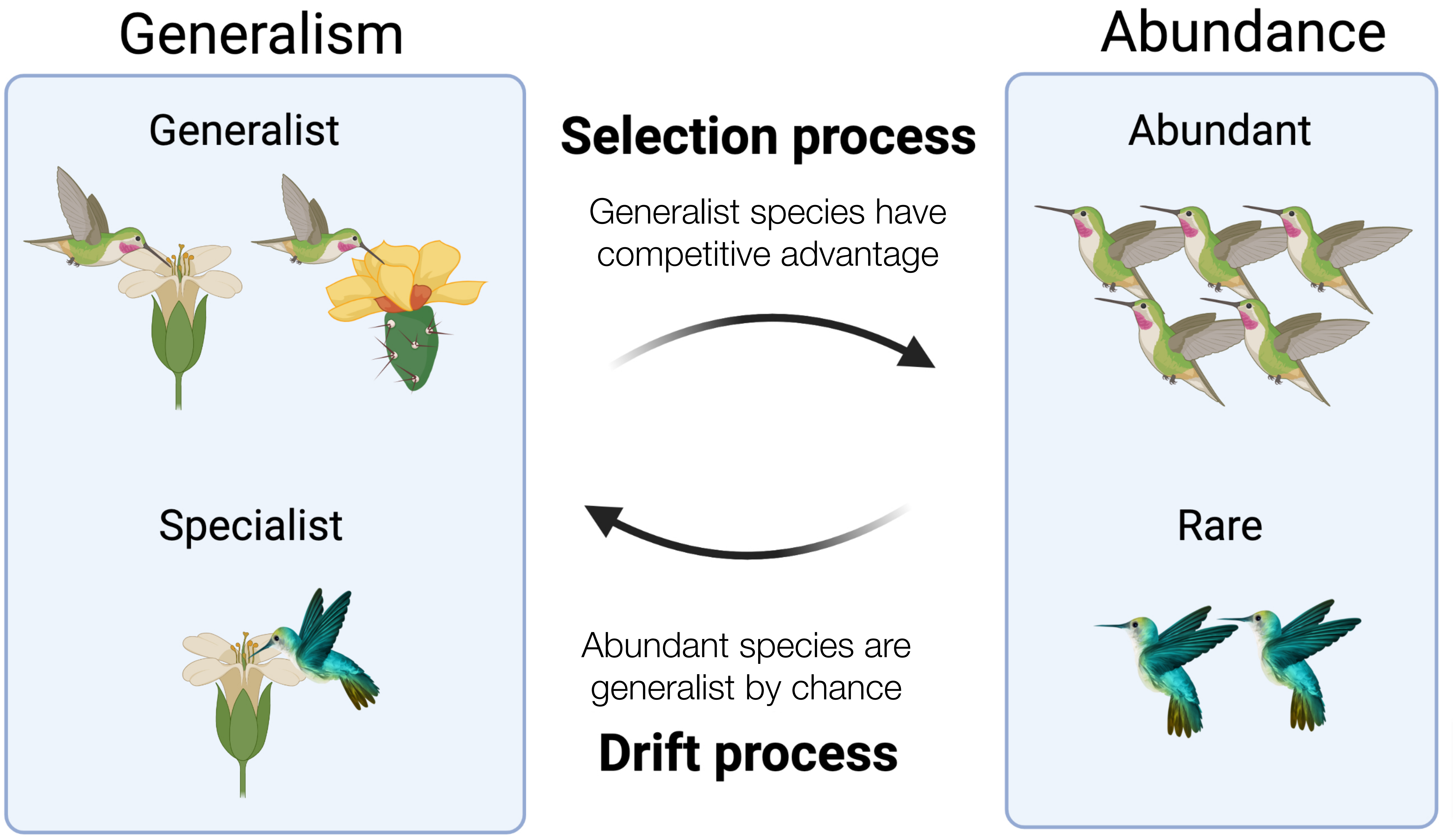


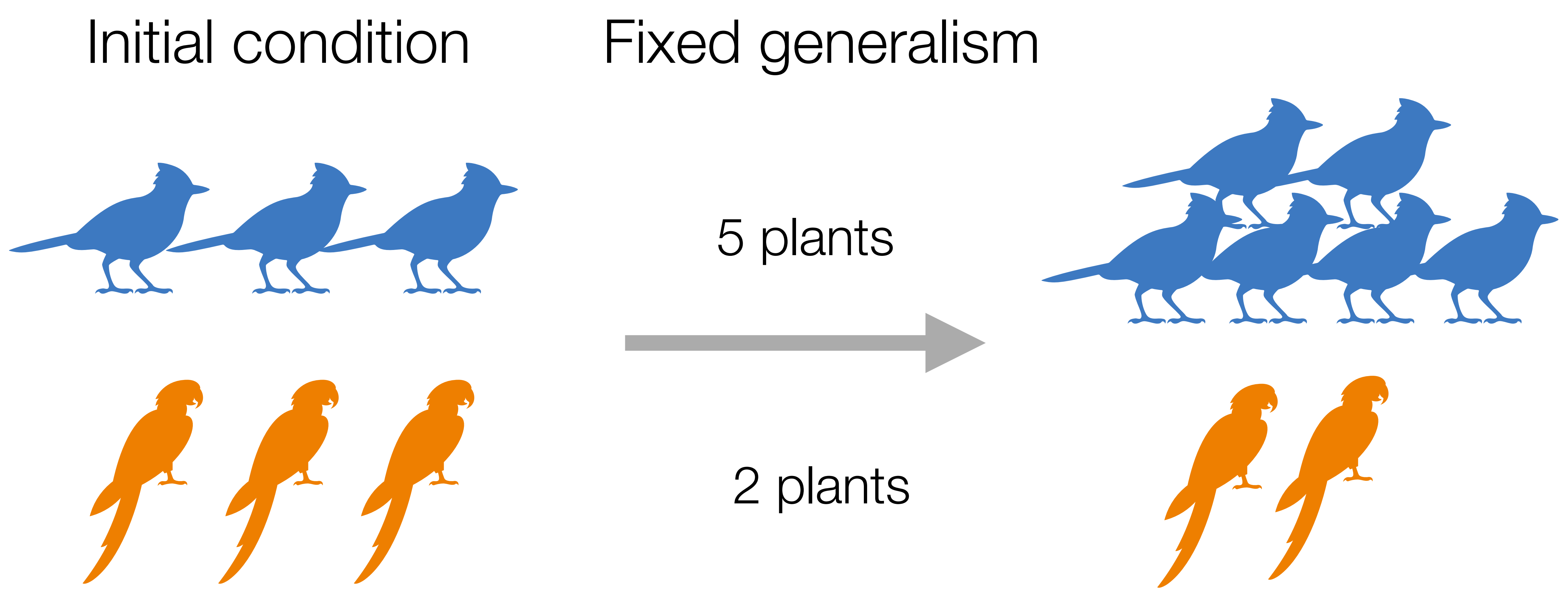
More abundant species are also more generalized

A chicken-and-egg dilemma:
Generalism drives abundance, or abundance drives generalism

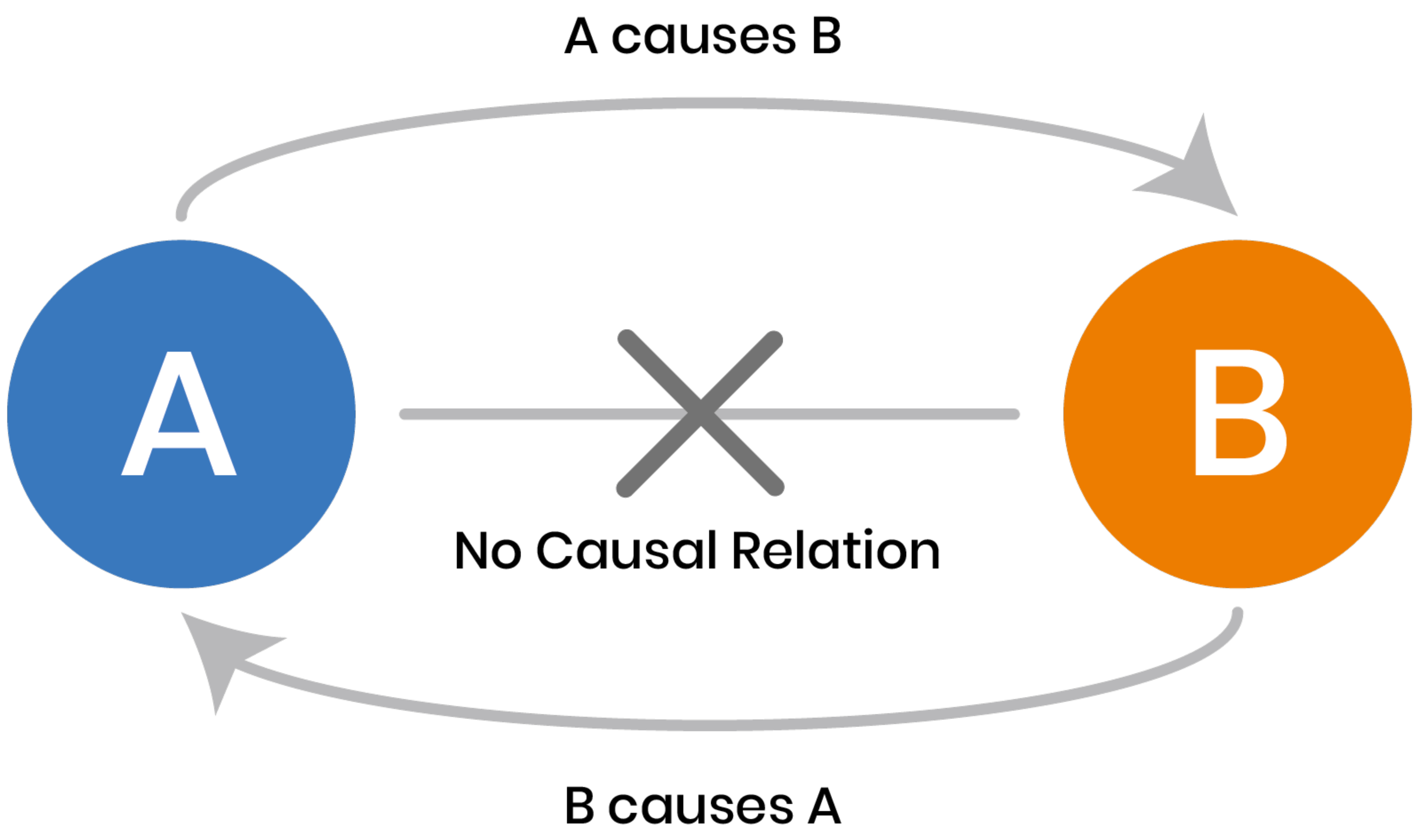


Computational causal discovery approach

Controlled experiments



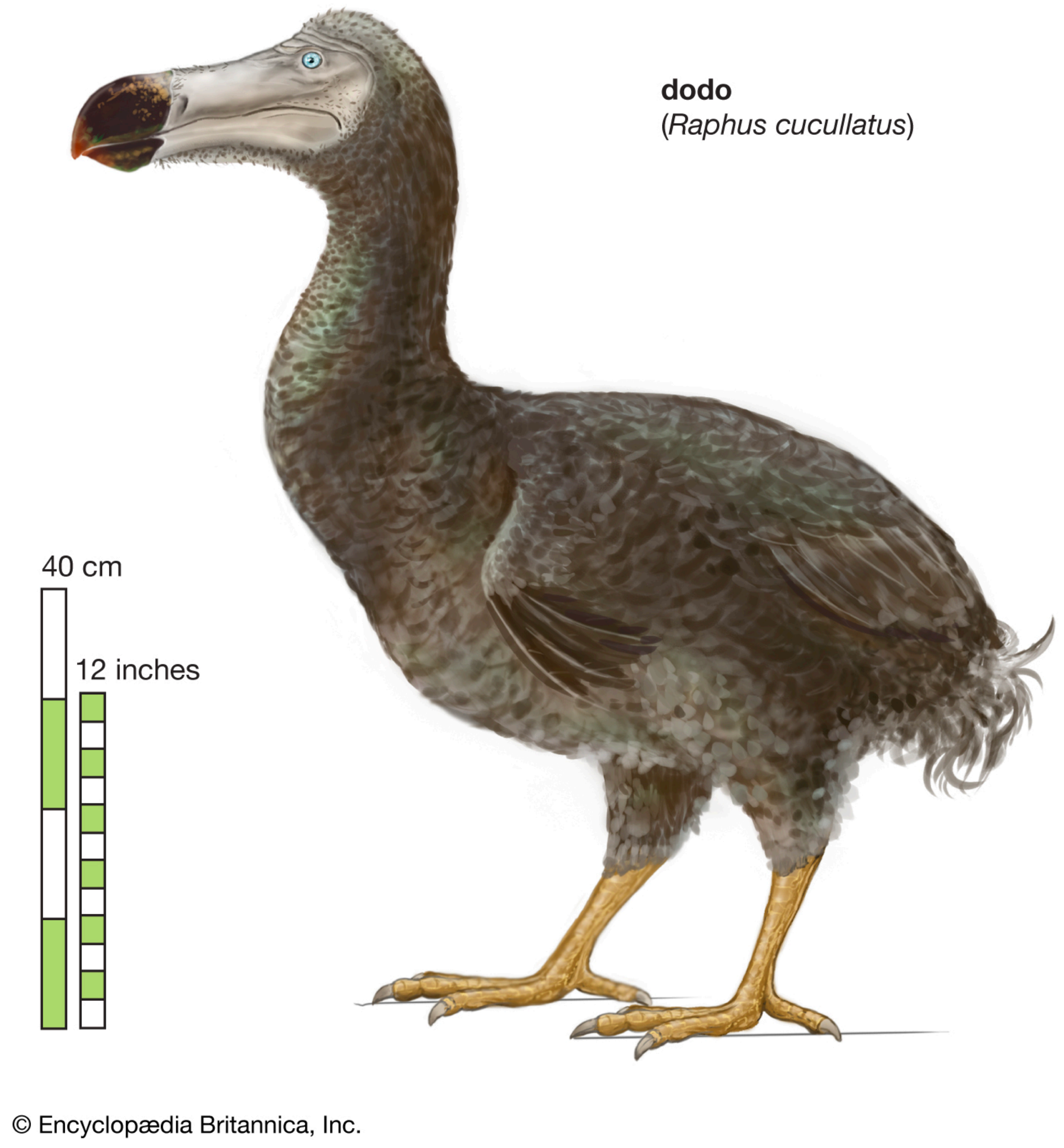
Causal discovery



https://www.inguo.io/product/causal-discovery-analysis/

Causal discovery with formal logic

Example: Detecting causal direction between dodo and extinct species



Causal discovery with formal logic

Example: Detecting causal direction between dodo and extinct species

Dodo $\longrightarrow$ Extinct species

Dodo $\not\longleftarrow$ Extinct species

it is a dodo	it is extinct	Implication	
T	T	It is a dodo and is extinct	✓
F	F	It is not a dodo and is not extinct	✓
T	F	It is a dodo and is not extinct	✗
F	T	It is not a dodo and is extinct	✓

Fort et al., *Ecol. Lett.* (2015)
Simmons et. al., *Oikos* (2019)

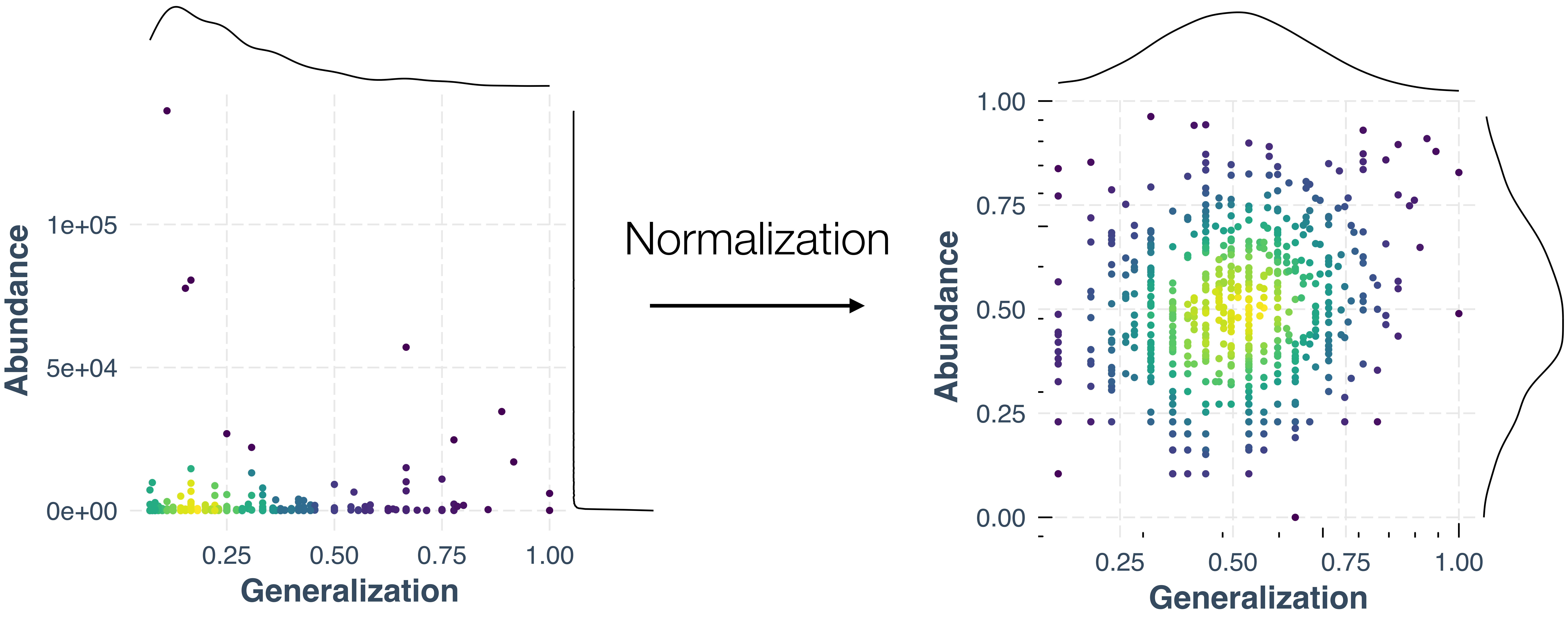
Causal discovery with formal logic

Detection of causal direction in abundance and generalism

dodo/ abundant	extinct/ generalist		
T	T	**Abundant-Generalist**	✓
F	F	**Rare-Specialist**	✓
T	F	**Abundant-Specialist**	If generalism drives abundance
F	T	**Rare-Generalist**	If abundance drives generalism

Fort et al., *Ecol. Lett.* (2015)
Simmons et. al., *Oikos* (2019)

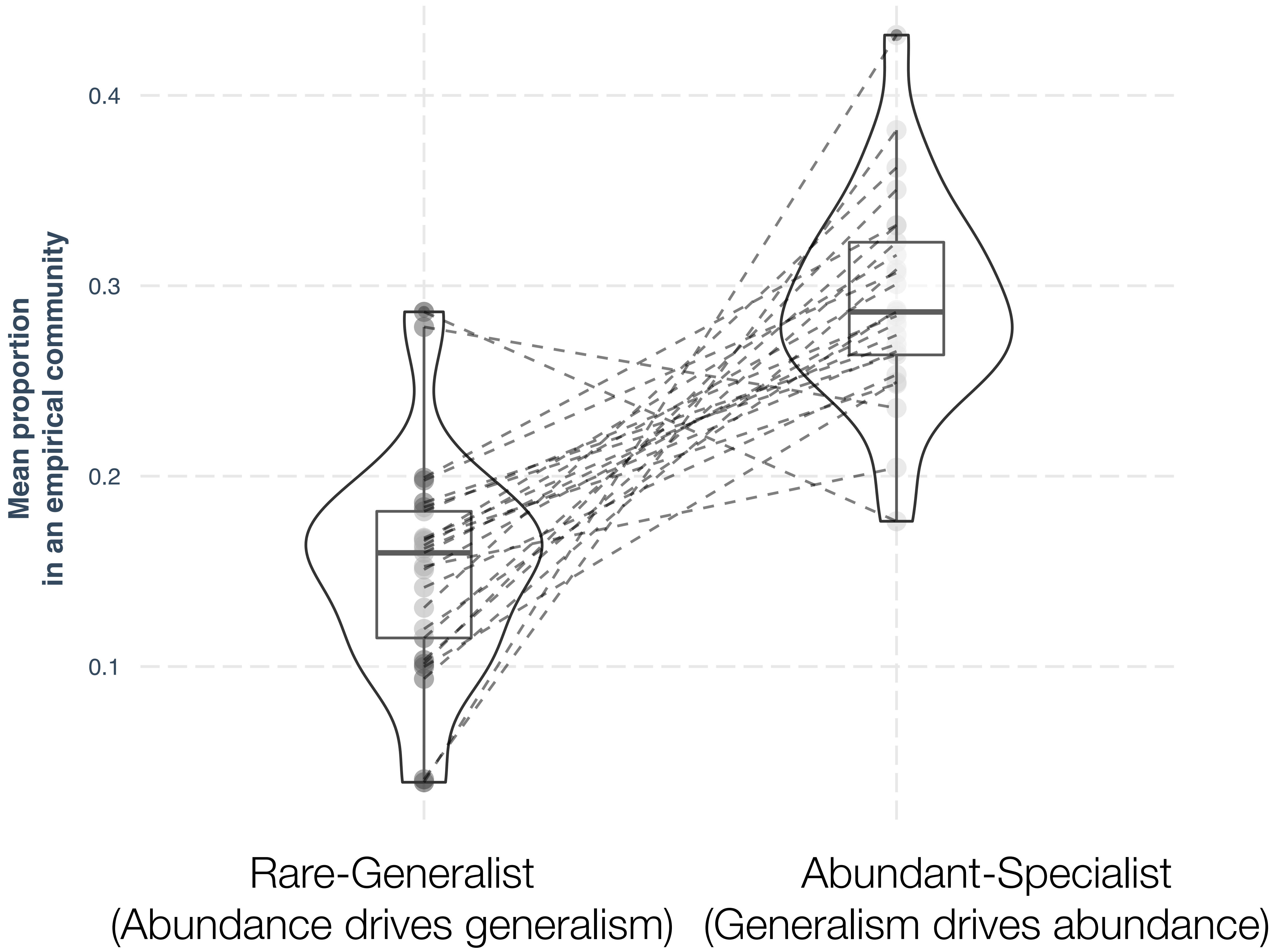
Formal logic on binary variables does not automatically apply to continuous variables



Song et. al., *submitted*

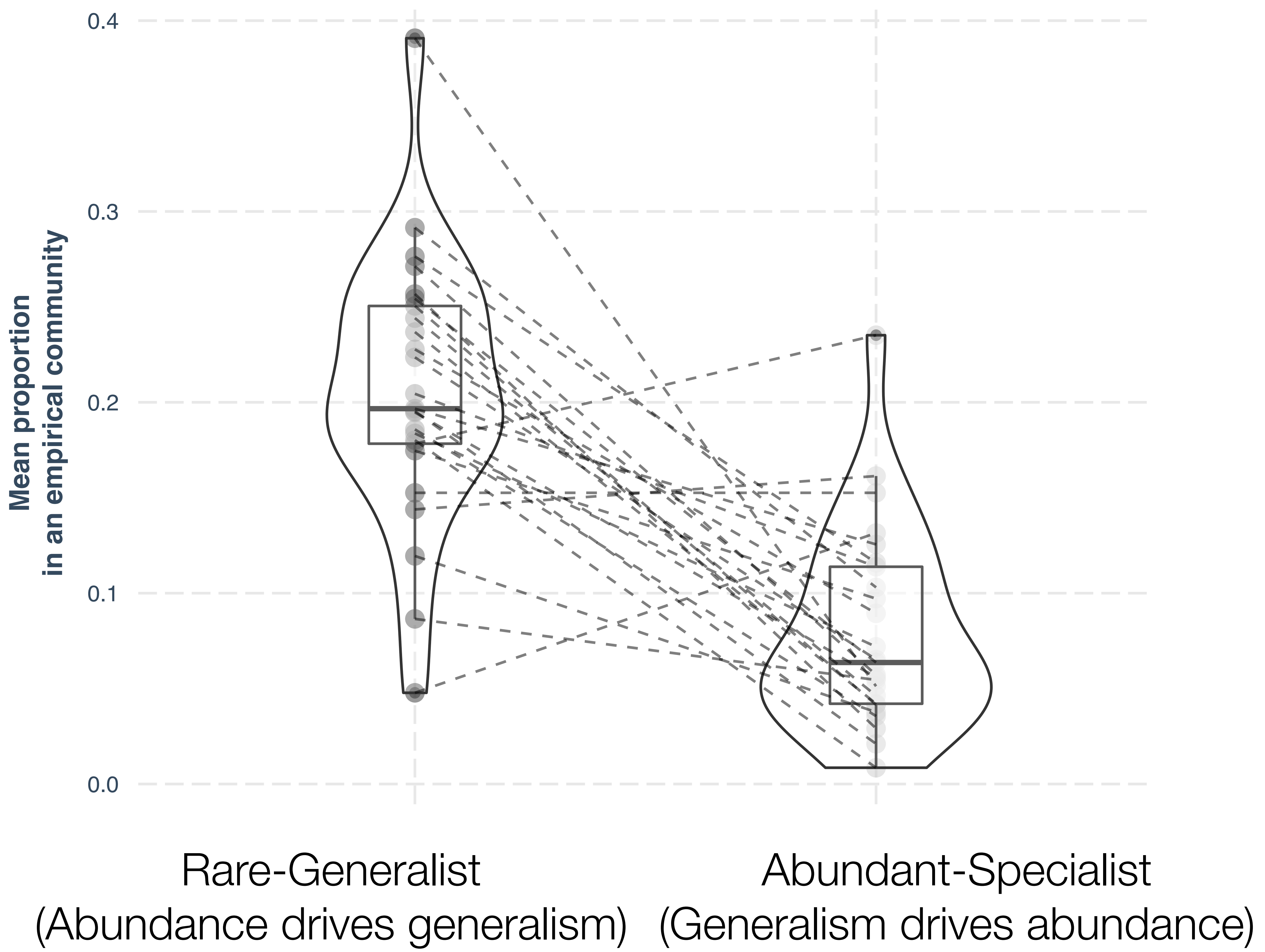
Generalism drives abundance
(selection process is generally stronger than drift process)

Data bias was **corrected**



Song et. al., *submitted*

Data bias was **uncorrected**



Fort et al., *Ecol. Lett.* (2015)

Two other causal discovery methods confirm that generalism drives abundance

$$X \rightarrow Y$$

Nonlinear additive noise model based on nonparametric regression

$$Y = f(X) + \epsilon(Y)$$

Nonlinear function of cause

Noise is independent of X

Hummingbird		Plant	
Abundance	Generalism	Abundance	Generalism
0.001	0.740	0.001	0.608
Dependent with noise	Independent with noise	Dependent with noise	Independent with noise

Geometric-information inference based on information theory

$$H(X) \geq H(Y)$$

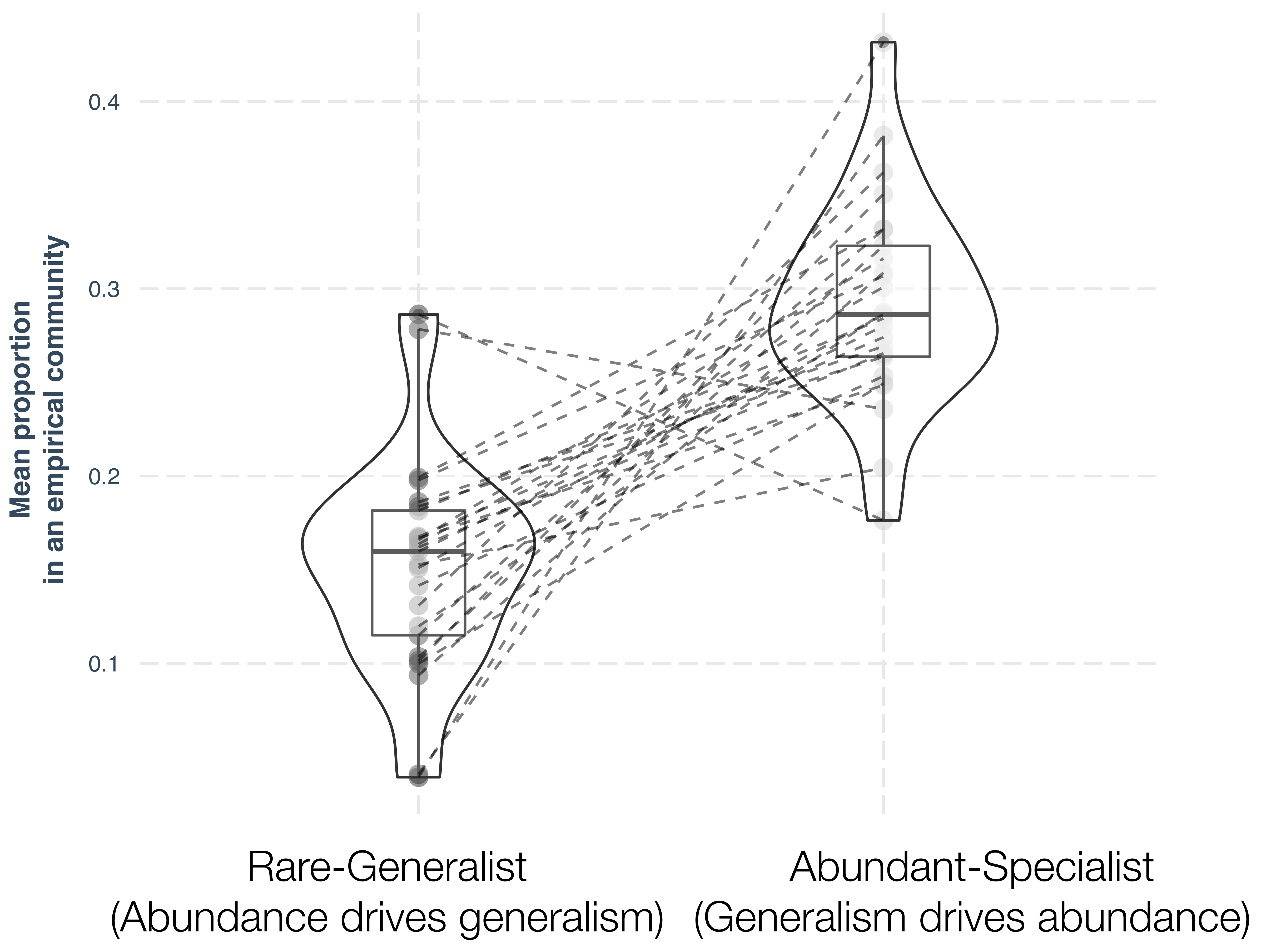
Entropy of ***X***

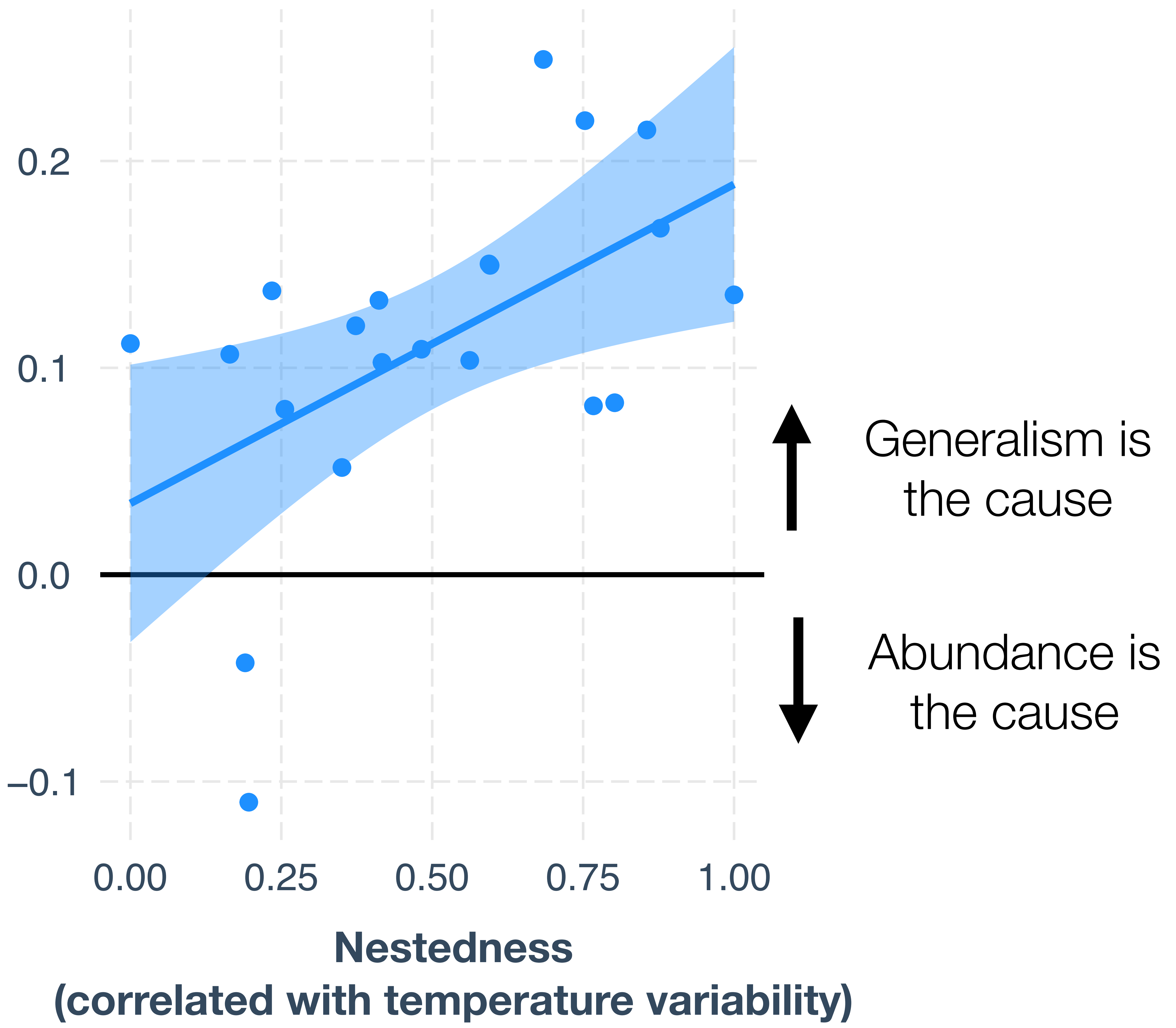
Entropy of ***Y***

Hummingbird		Plant	
Abundance	Generalism	Abundance	Generalism
0.77	2.36	0.41	4.58

Song et. al., *submitted*

The strength of selection processes increases when local temperatures are more variable





Song et al., *J. Anim. Ecol.* (2017); Song et. al., *submitted*

Take-home message

- Our computational approach allows us to use the relative strength of the causal directions as a proxy of the relative roles of either selection or drift process.
- In contrast to previous findings, all three causal discovery methods consistently found strong evidence that generalism drives abundance in pollinator-hummingbird communities and reef fish datasets.
- Selection processes act more strongly than drift processes when local temperatures are more variable. This generalizes previous known results in two-species communities to multispecies communities.

Thanks!

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