On the consequences of the interdependence of stabilizing and equalizing mechanisms

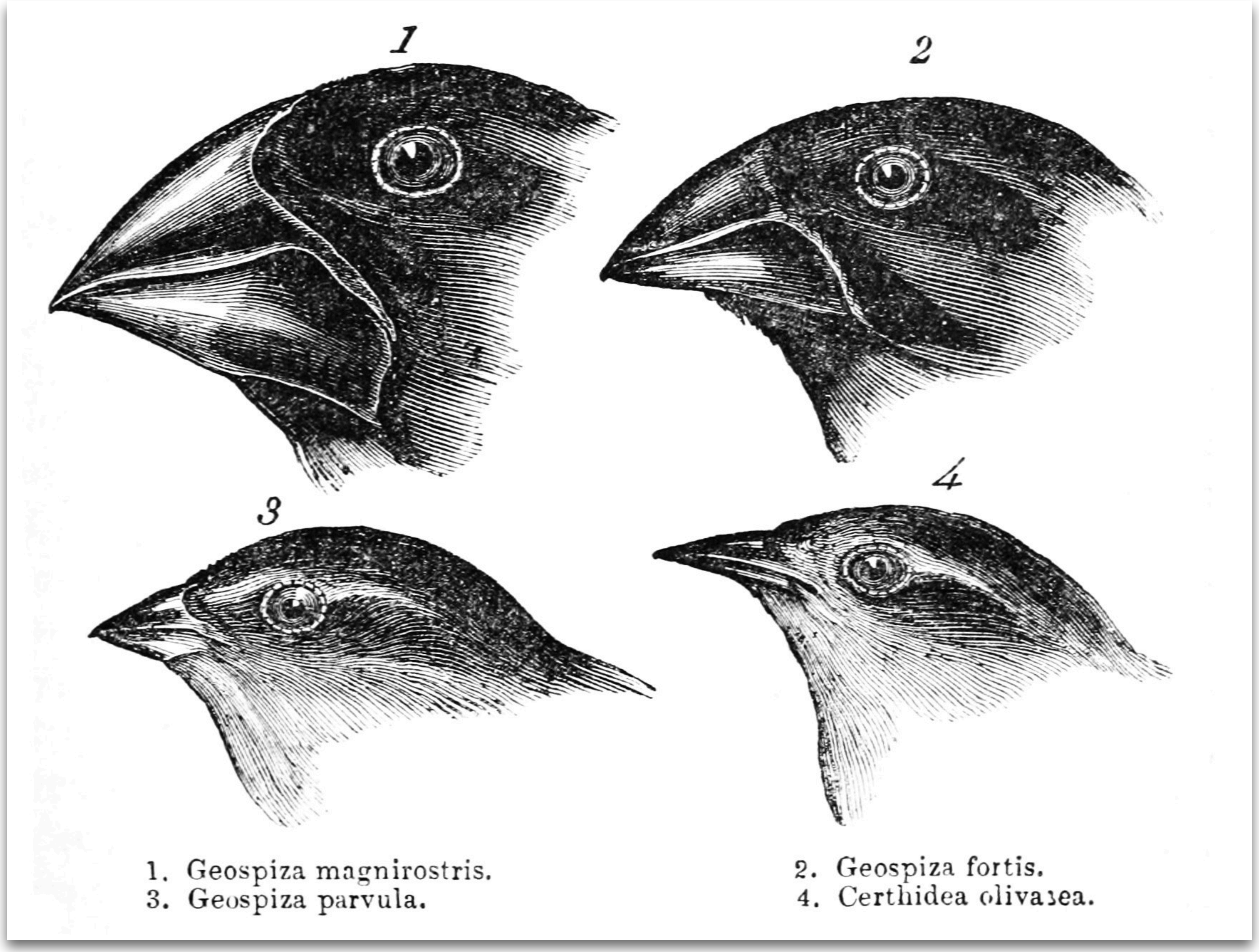
Chuliang Song

Department of Civil and Environmental Engineering, MIT

STRUCTURAL ECOLOGY

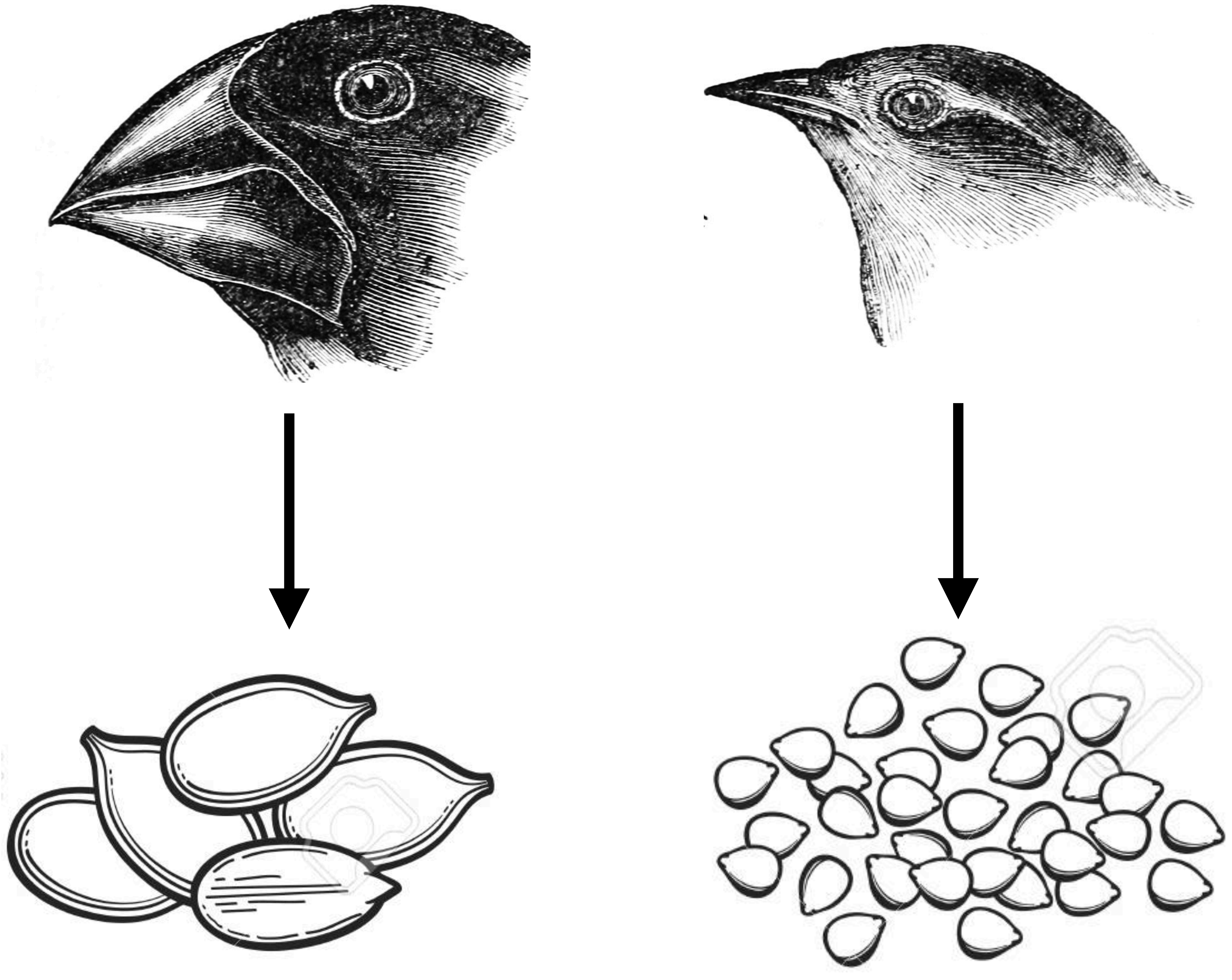
January 7th, 2020

Modern Coexistence Theory in a nutshell



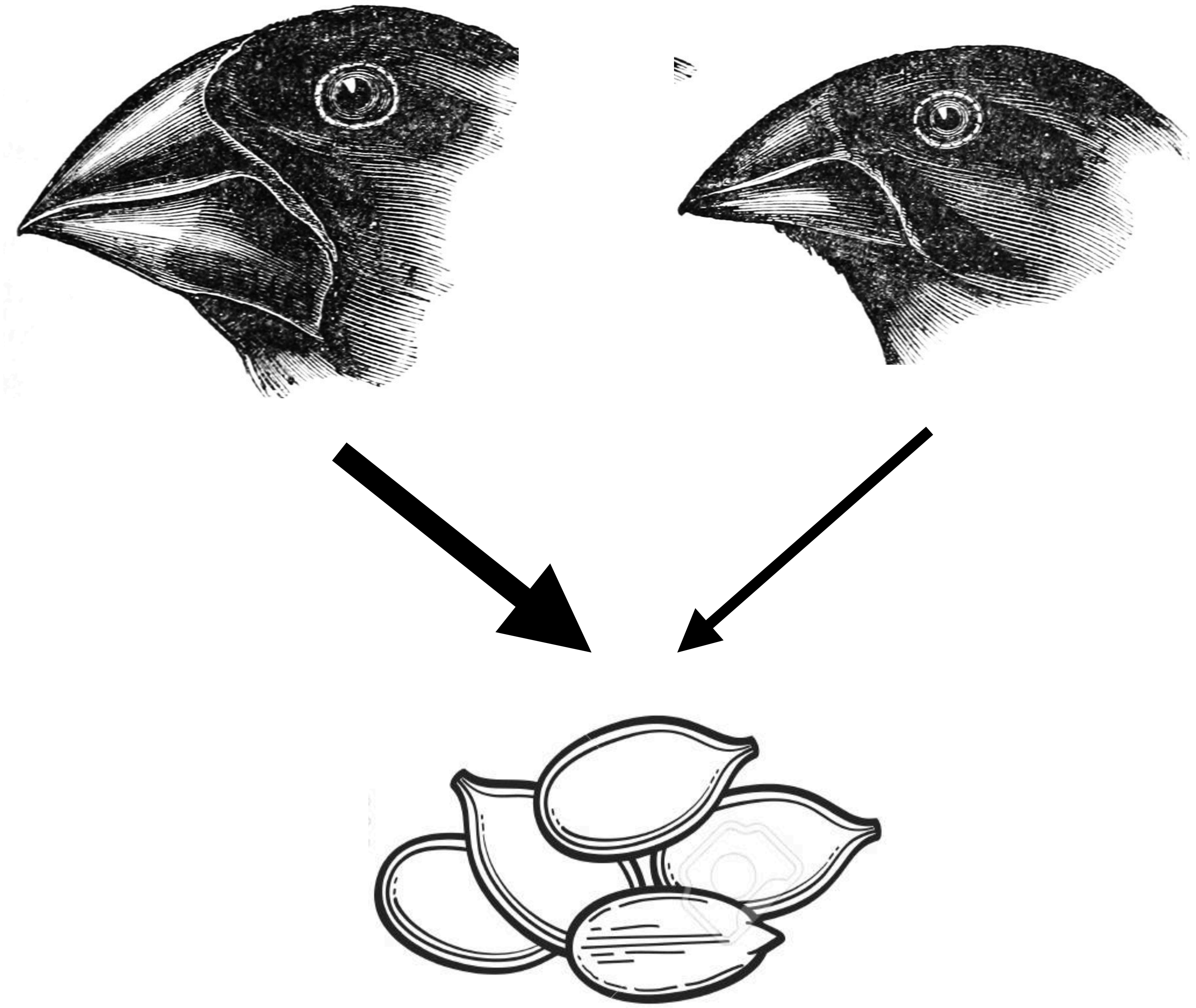
Modern Coexistence Theory in a nutshell: Disentangling ecological differences

Differences in niche:
Which seeds to eat



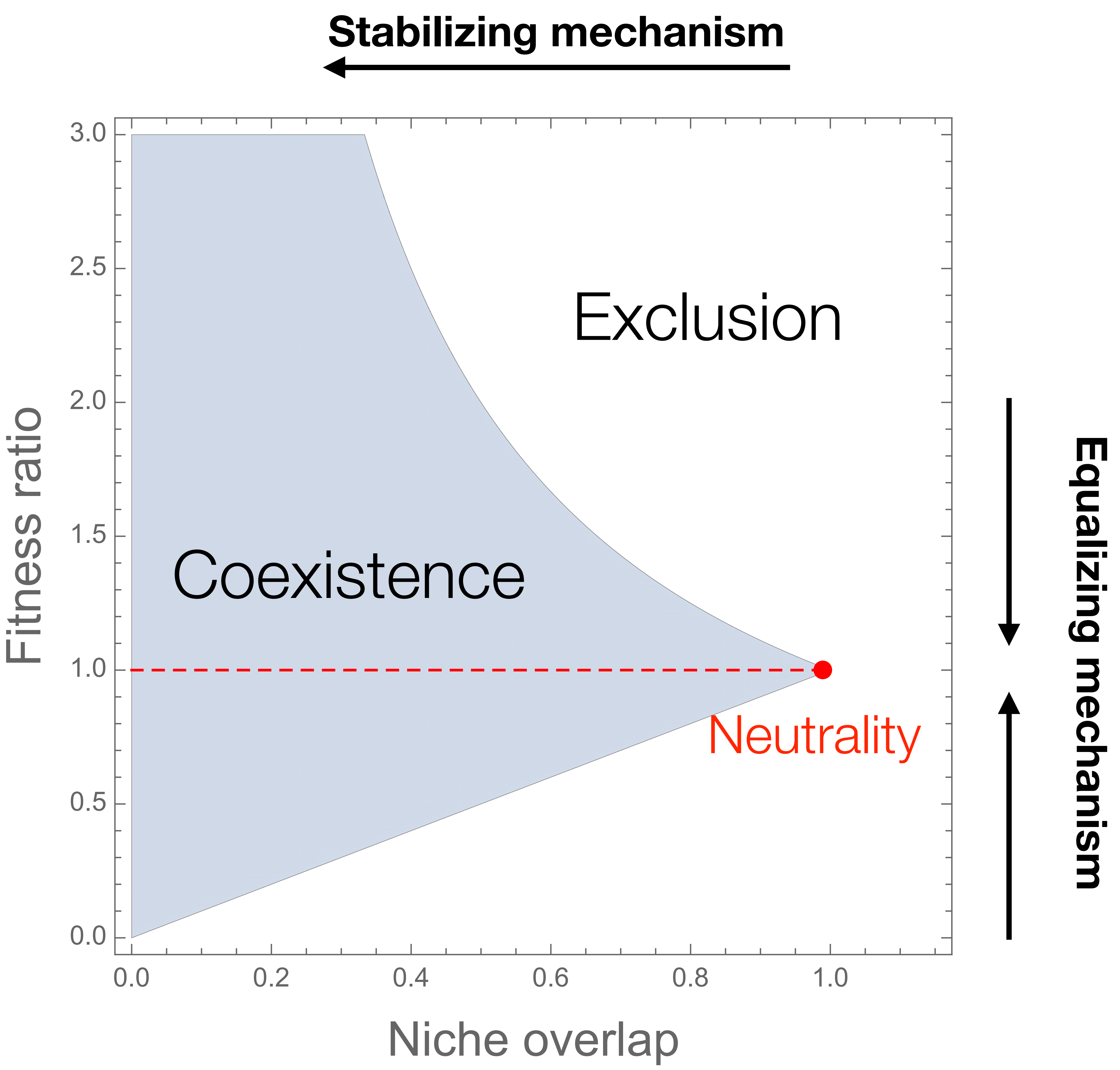
Stabilizing mechanism

Differences in fitness:
How good at eating a seed

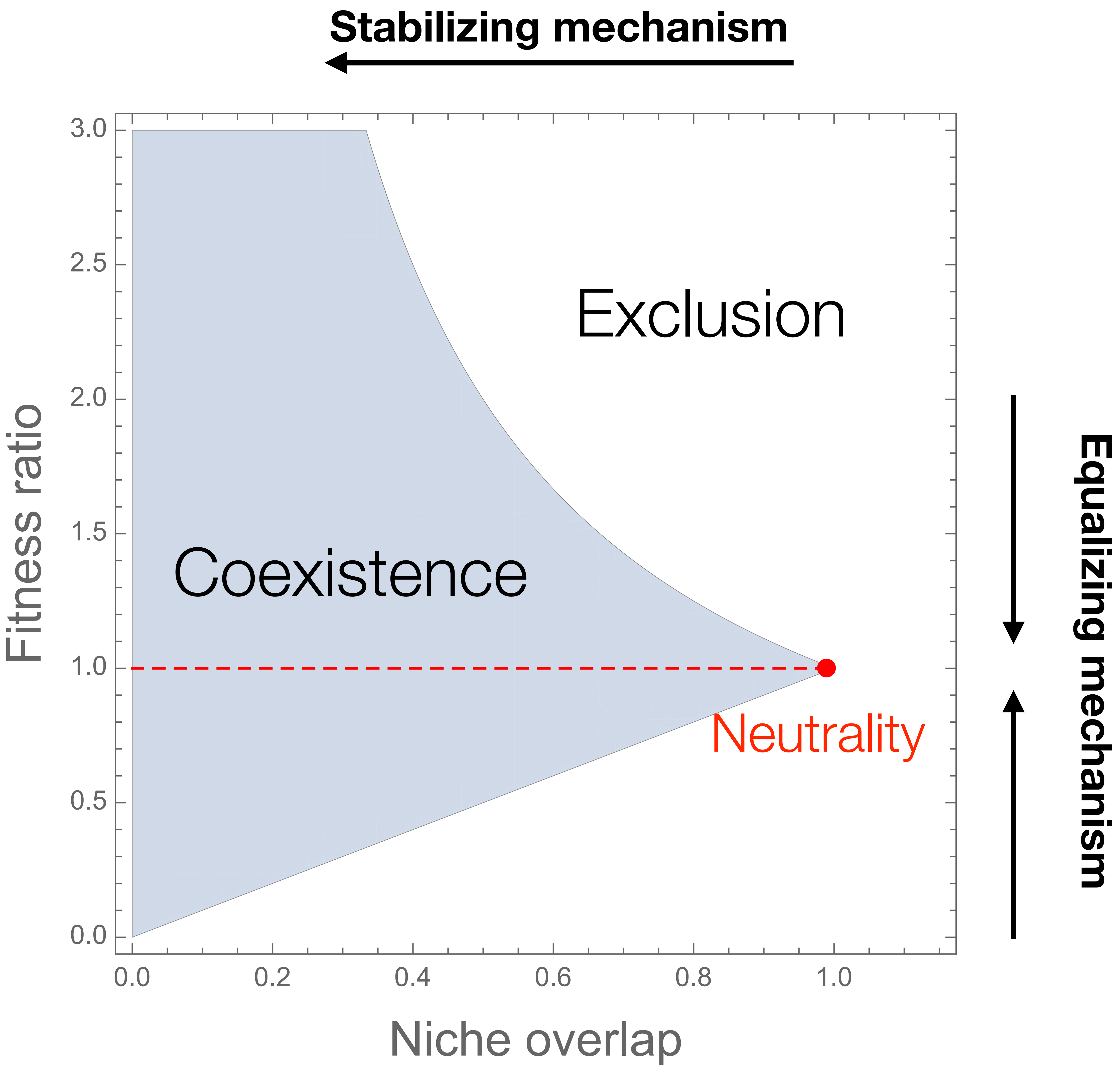


Equalizing mechanism

Modern Coexistence Theory in a nutshell: Coexistence as a balance of niche overlap and fitness ratio



Widely-held premises of Modern Coexistence Theory



Premise 1

Disentangle the relative roles of the stabilizing and equalizing mechanisms in shaping species coexistence

Premise 2

Provide a continuum of niche-neutrality continuum for species coexistence

Q1: What do we mean when we talk about stabilizing and equalizing mechanisms?

Two parallel sub-frameworks within Modern Coexistence Theory

Two-species framework

A niche for neutrality

Peter B. Adler, Janneke HilleRisLambers, Jonathan M. Levine

The importance of niches for the maintenance of species diversity

Jonathan M. Levine & Janneke HilleRisLambers

Concepts & Synthesis | Full Access

Linking modern coexistence theory and contemporary niche theory

Andrew D. Letten, Po-Ju Ke, Tadashi Fukami

Multi-species framework

Reviews | Full Access

Chesson's coexistence theory

György Barabás, Rafael D'Andrea, Simon Maccracken Stump

Letter | Full Access

Mean growth rate when rare is not a reliable metric for persistence of species

Jayant Pande, Tak Fung, Ryan Chisholm, Nadav M. Shnerb

Idea and Perspective | Free Access

An expanded modern coexistence theory for empirical applications

Stephen P. Ellner, Robin E. Snyder, Peter B. Adler, Giles Hooker

The definitions of stabilizing and equalizing mechanisms in the two sub-frameworks

Two-species framework

Dynamics: $$\frac{1}{N_i}\frac{dN_i}{dt} = r_i\left(1 - \sum_{j=1}^{2} a_{ij}N_j\right) \quad (i = 1,2)$$

Competition strength

Stabilizing: $$1 - \rho := 1 - \sqrt{\frac{a_{12}a_{21}}{a_{11}a_{22}}}$$

Equalizing: $$\frac{\kappa_1}{\kappa_2} := \sqrt{\frac{a_{21}a_{22}}{a_{12}a_{11}}}$$

Multi-species framework

Dynamics: $$\frac{1}{N_i}\frac{dN_i}{dt} = f_i(E_i, C_i) \quad (i = 1,\ldots,S)$$

Scaled invasion rate

Stabilizing: $$A := \frac{1}{S}\sum_{i=1}^{S}\boxed{\frac{R_i}{\phi_i}}$$

Equalizing: $$\frac{\xi_i}{\xi_j} := \frac{\frac{R_i}{\phi_i} - A}{\frac{R_j}{\phi_j} - A}$$

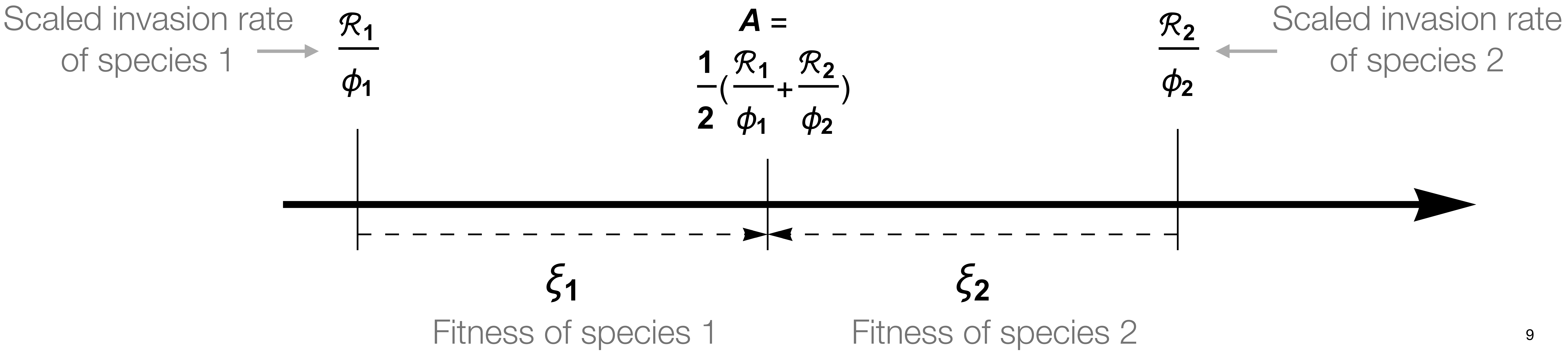
Stabilizing and equalizing mechanisms are incompatible in the two-species and multispecies frameworks

Fitness ratio in two-species framework

$$\frac{\kappa_1}{\kappa_2} := \sqrt{\frac{a_{21}a_{22}}{a_{12}a_{11}}} \boxed{\geq 0}$$

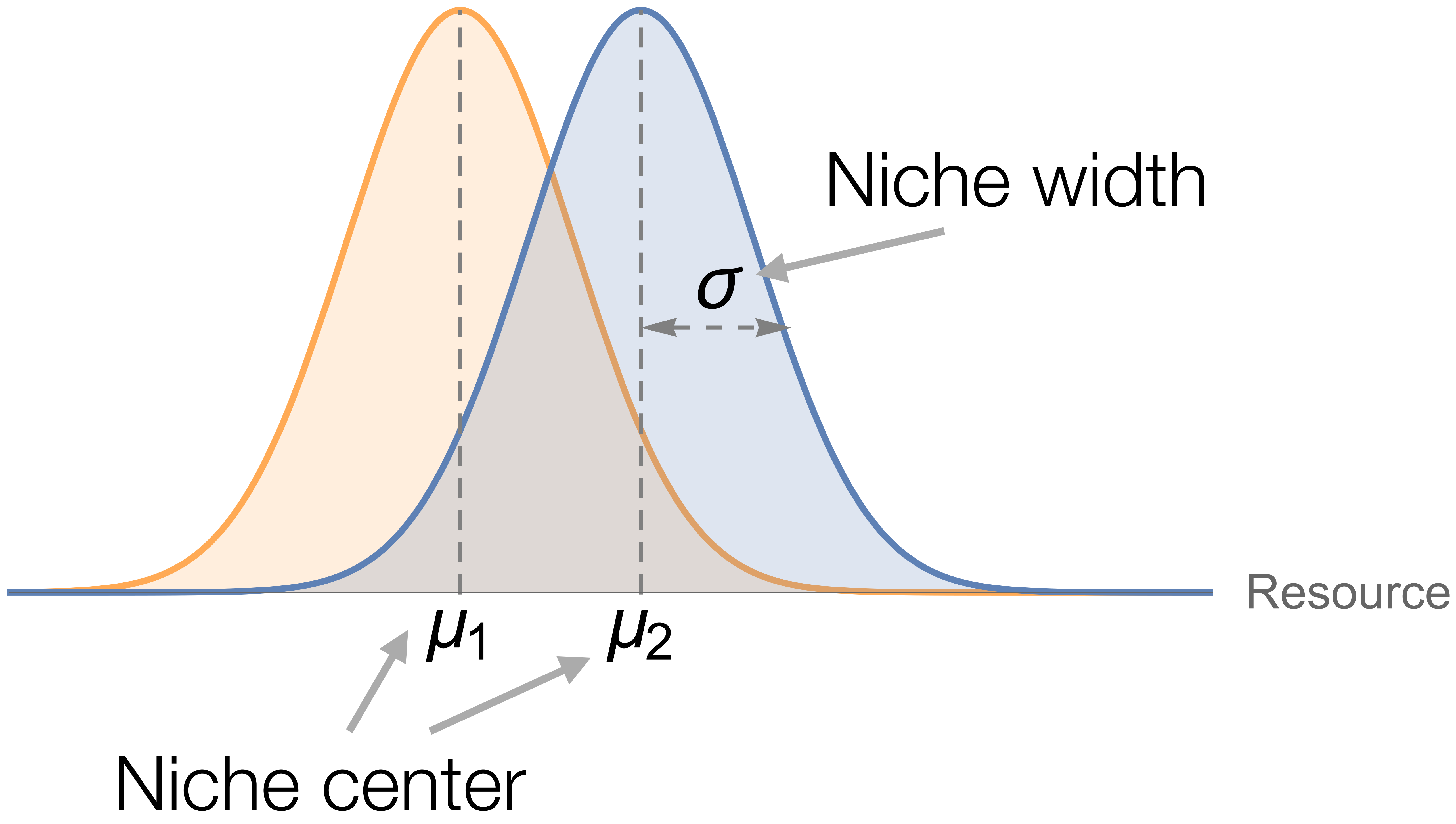
Fitness ratio in multispecies framework

$$\frac{\xi_i}{\xi_j} := \frac{\frac{R_i}{\phi_i} - A}{\frac{R_j}{\phi_j} - A} \boxed{= -1}$$



Q2: Can we disentangle the relative contributions of stabilizing and equalizing mechanisms?

MacArthur's consumer-resource model as an example



Niche overlap

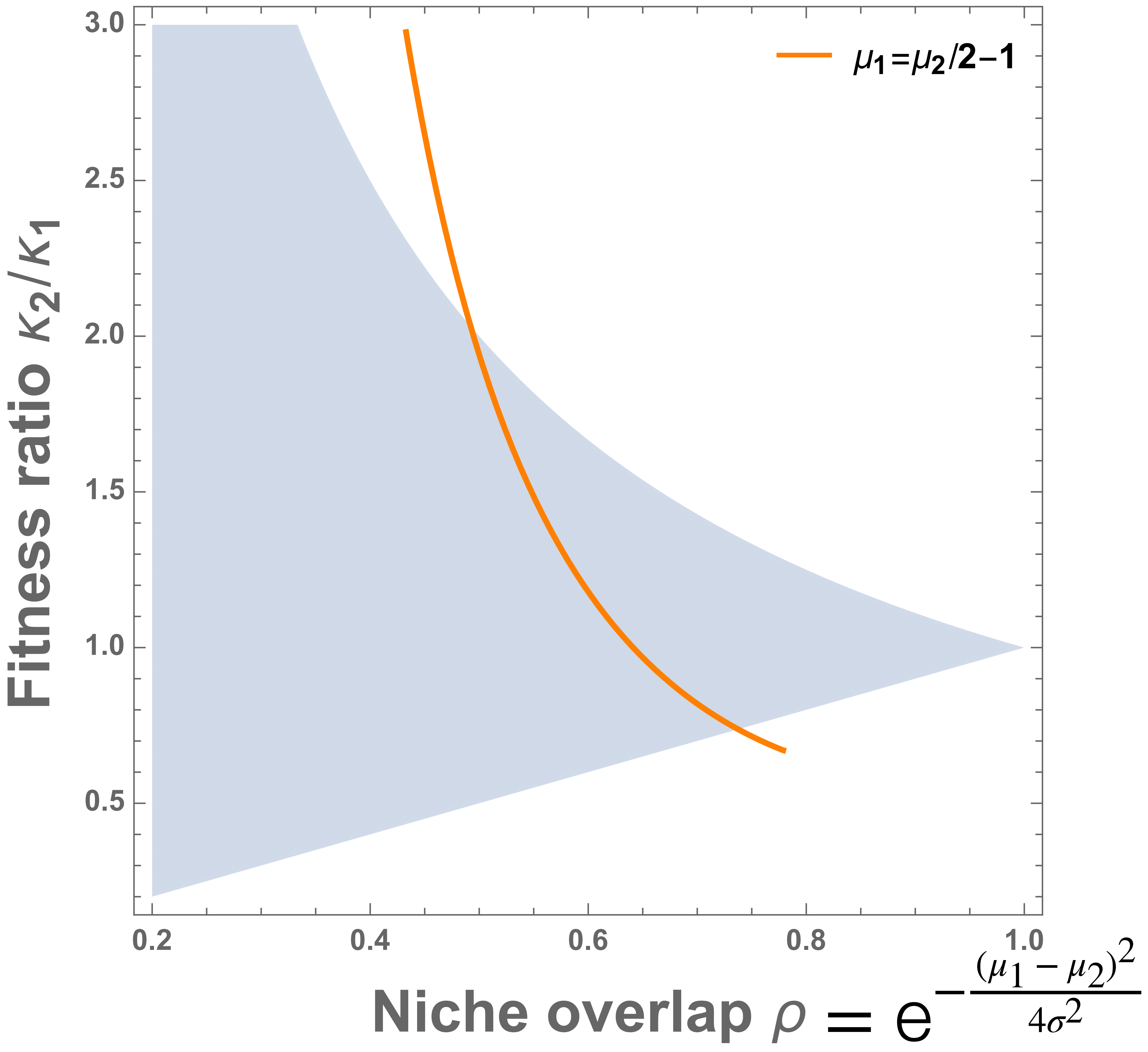
$$\rho = \sqrt{\frac{a_{12}a_{21}}{a_{11}a_{22}}} = e^{-\frac{(\mu_1 - \mu_2)^2}{4\sigma^2}}$$

Fitness ratio

$$\frac{\kappa_1}{\kappa_2} = \sqrt{\frac{a_{21}a_{22}}{a_{12}a_{11}}} = e^{-\frac{\mu_1^2 - \mu_2^2}{2(\sigma^2 + 1)}}$$

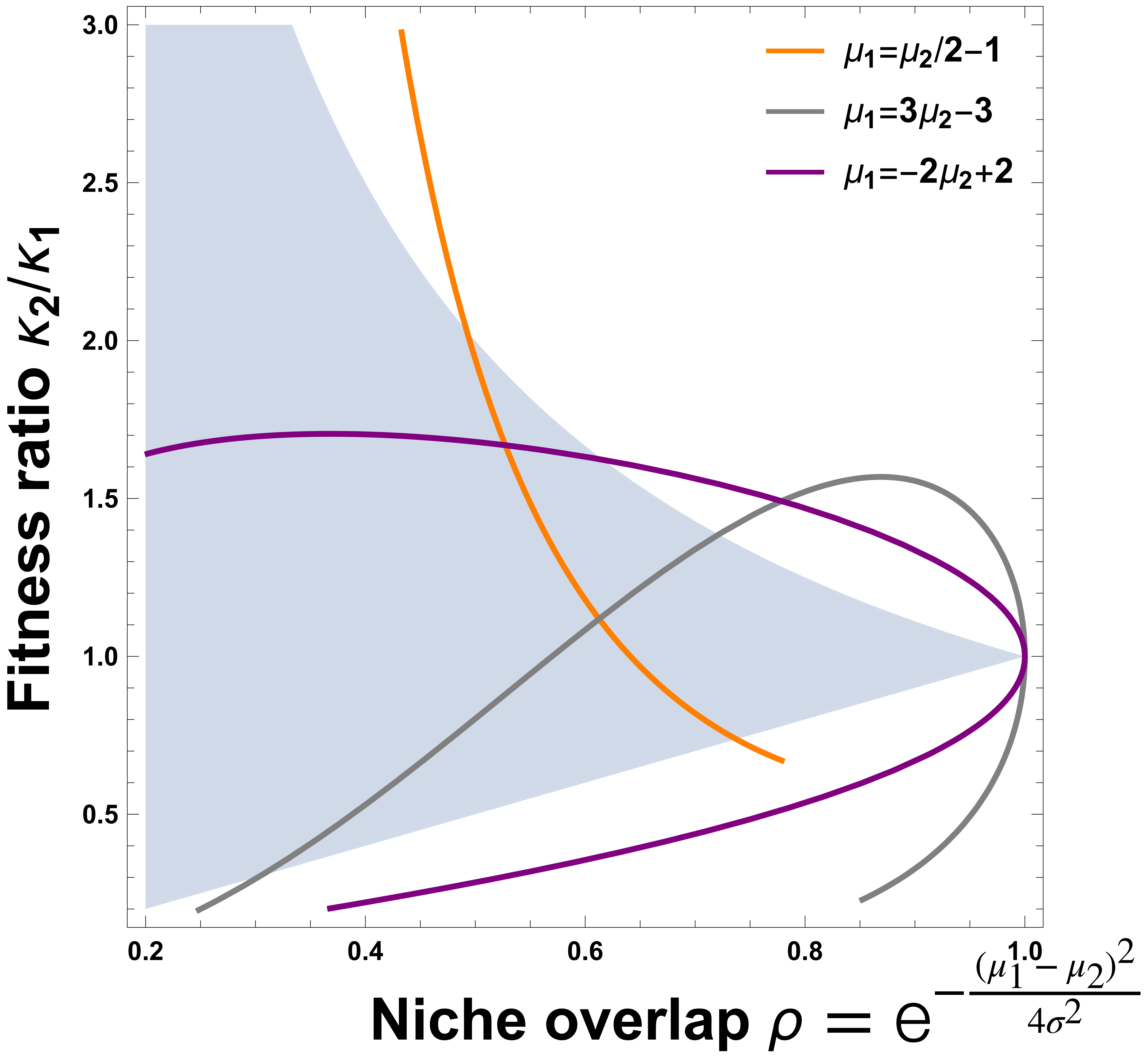
The effect of stabilizing/equalizing mechanism changes sensitively

$$\frac{\kappa_1}{\kappa_2} = e^{-\frac{\mu_1^2 - \mu_2^2}{2(\sigma^2+1)}}$$

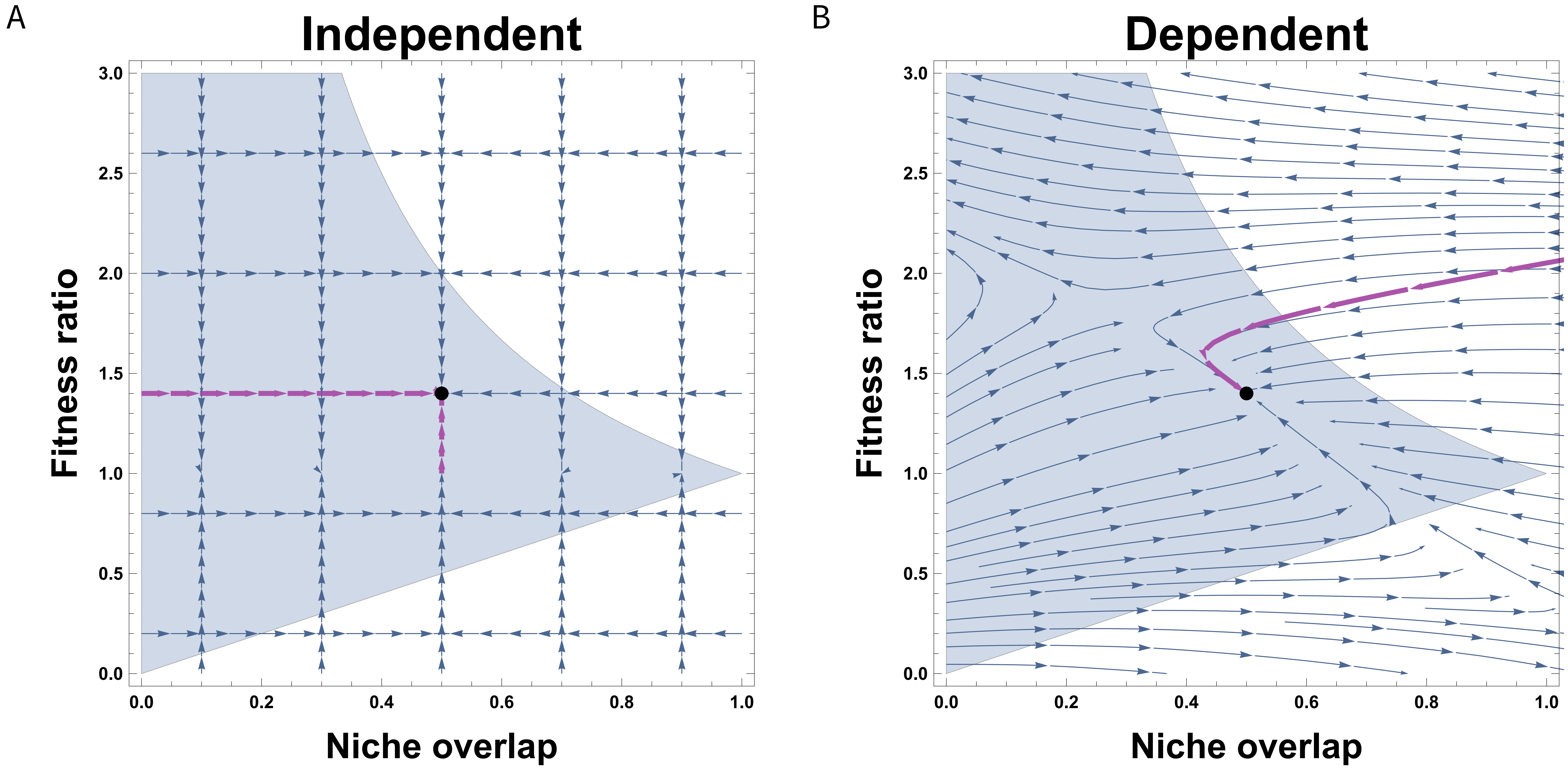


No simple or single pattern of the interdependence

$$\frac{\kappa_1}{\kappa_2} = e^{-\frac{\mu_1^2 - \mu_2^2}{2(\sigma^2+1)}}$$

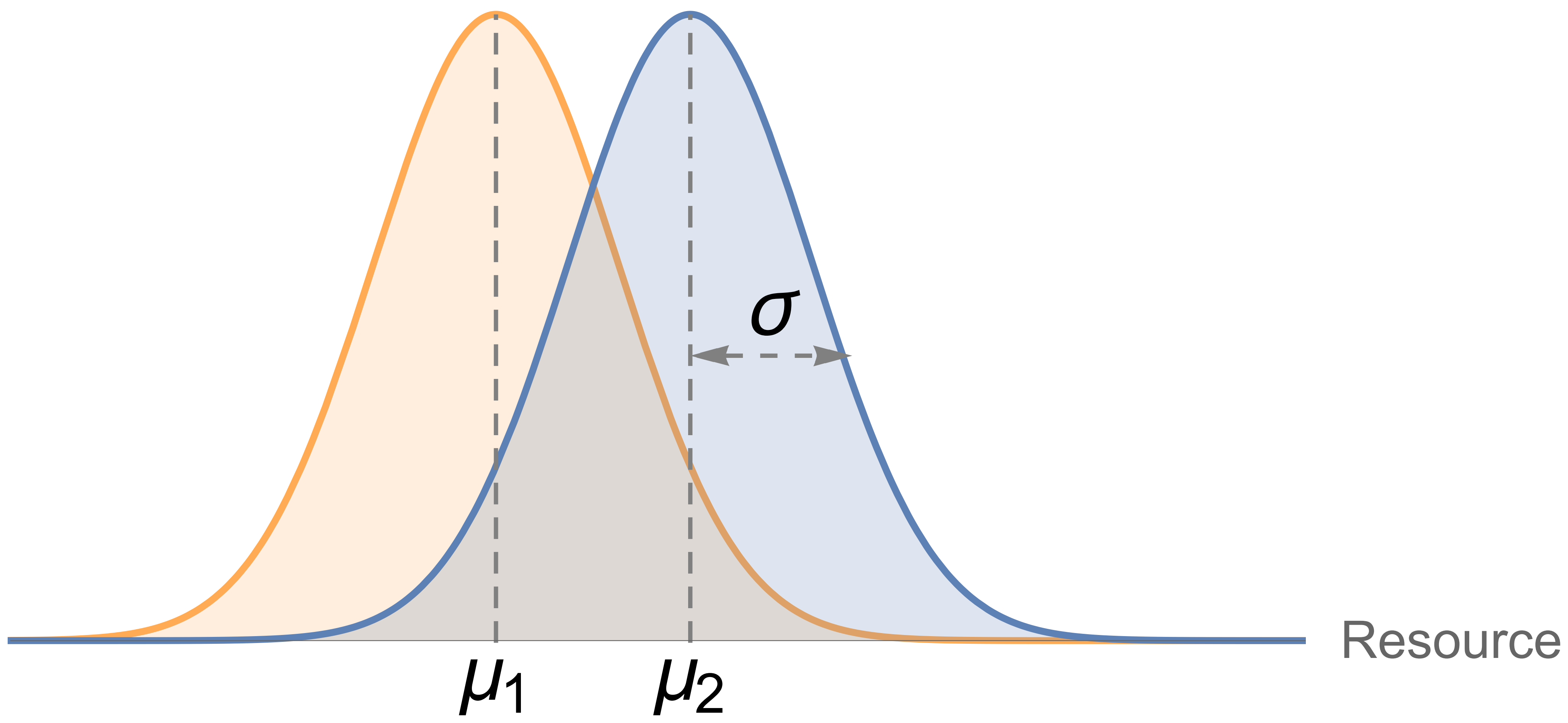


Relative contribution of each mechanism is not necessarily indicative of how the two species coexist, unless we know the governing mechanistic model

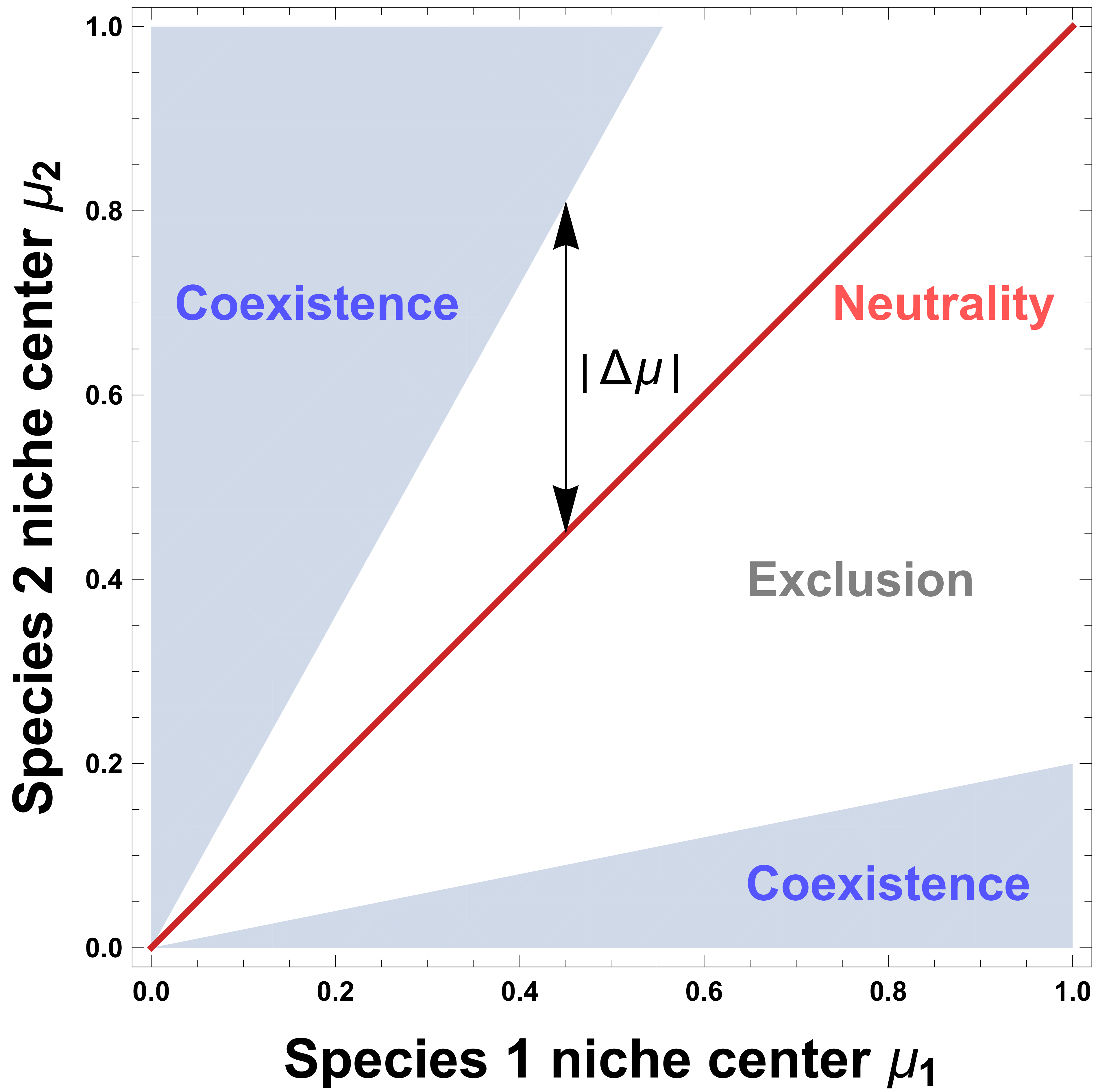


Q3: Do stabilizing and equalizing mechanisms provide a niche-neutrality continuum?

Breakdown of the niche-neutrality continuum

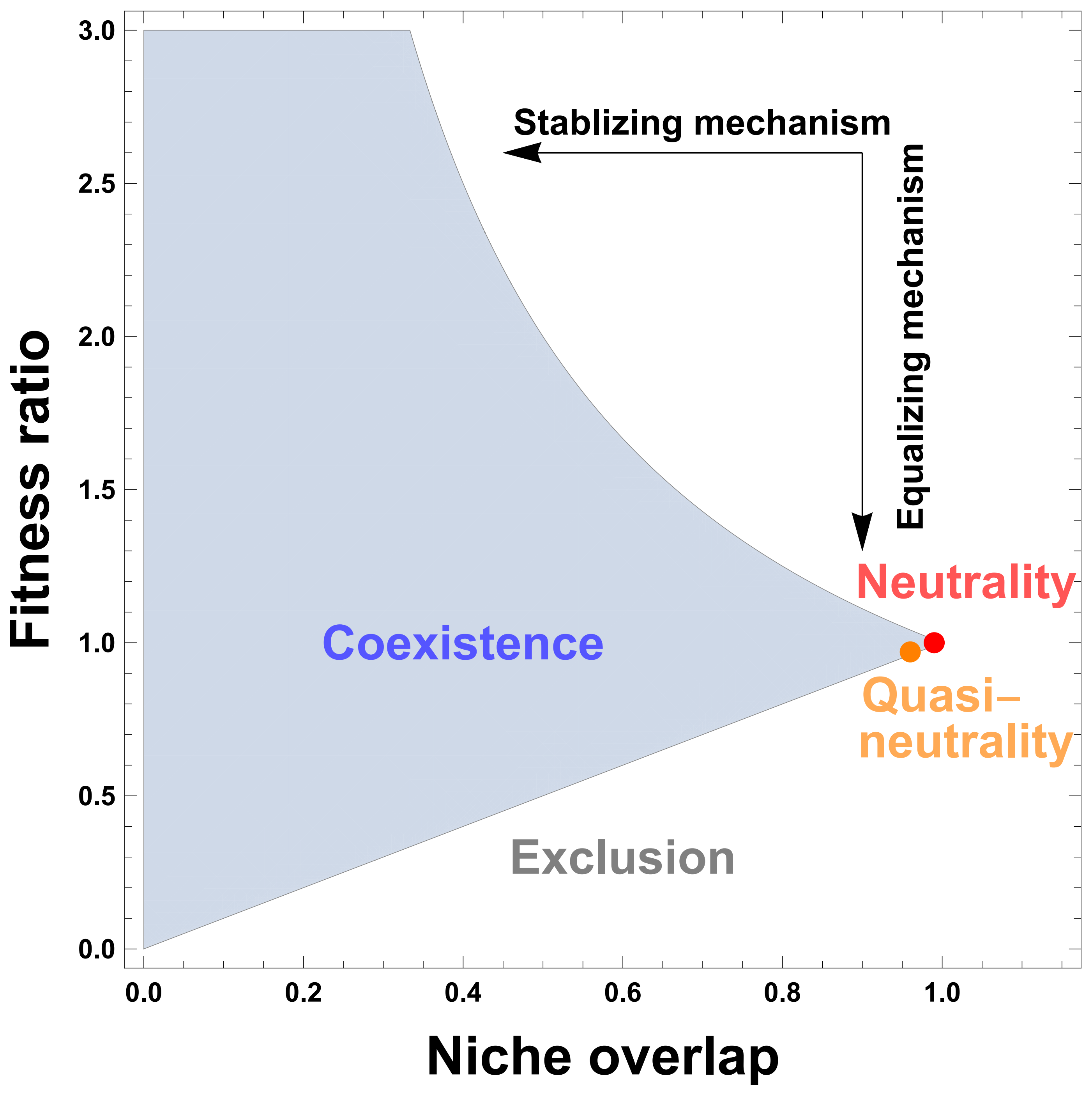


$$\Delta\mu = |\mu_1 - \mu_2| > \frac{4|\mu_1|\sigma^2}{\sigma^2 + 1}$$

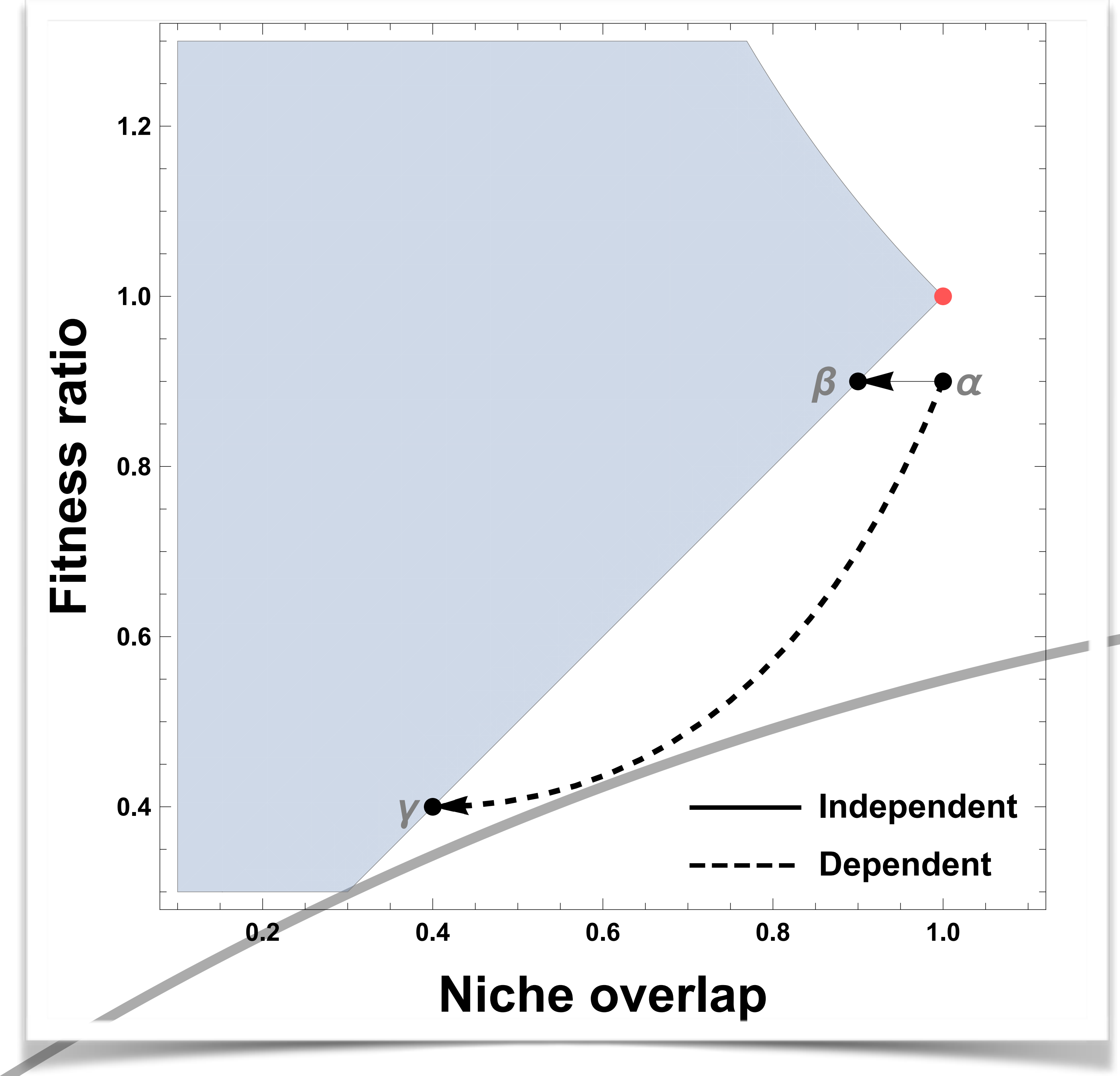


Interdependency leads to the breakdown of niche-neutrality continuum

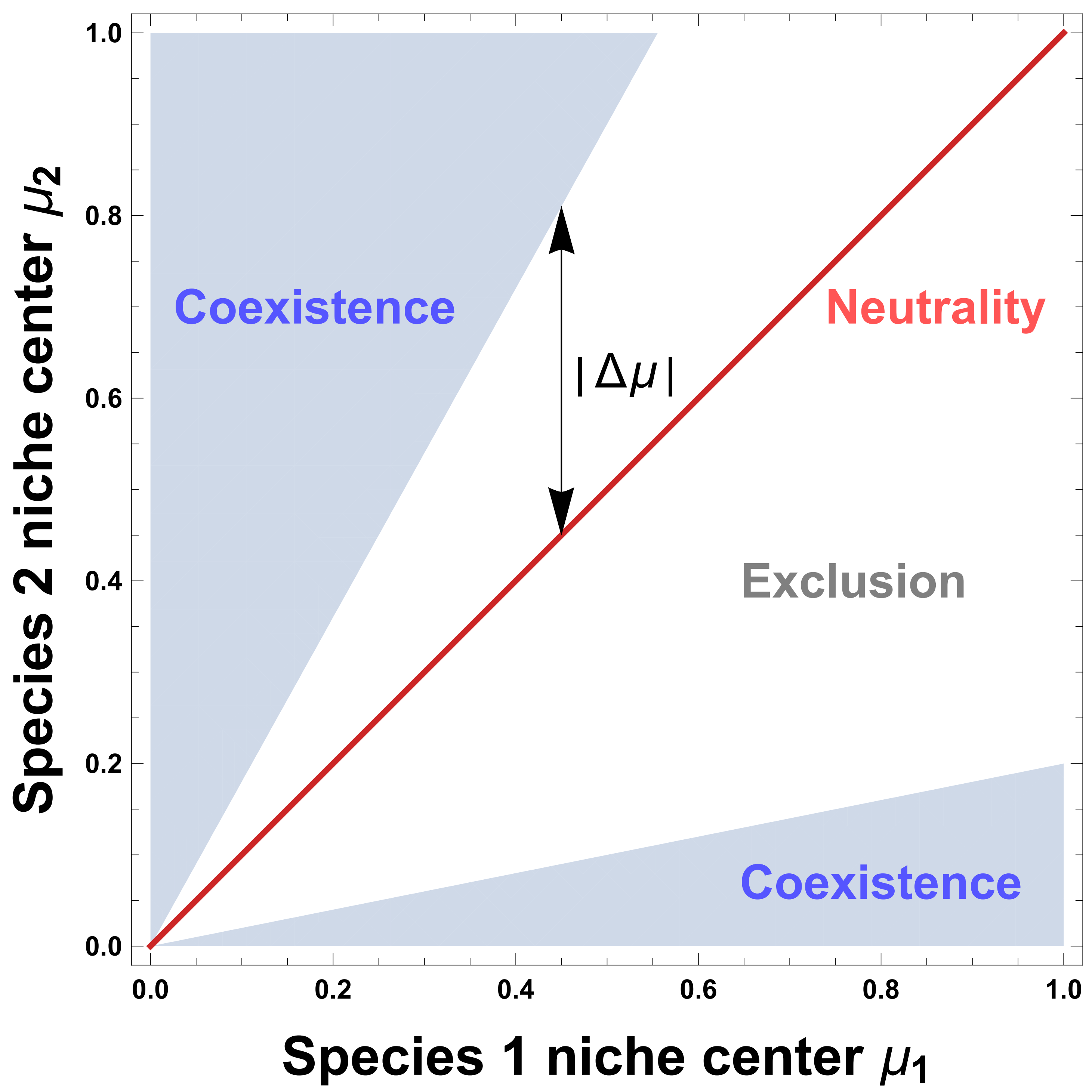
phenomenologically ***connected*** coexistence region



Cause: Interdependence



mechanistically ***disconnected*** coexistence region



Proof of the generality of the breakdown

When trait change occurs in two originally identical species

$$\kappa_1/\kappa_2 \approx 1 + p\Delta\mu$$

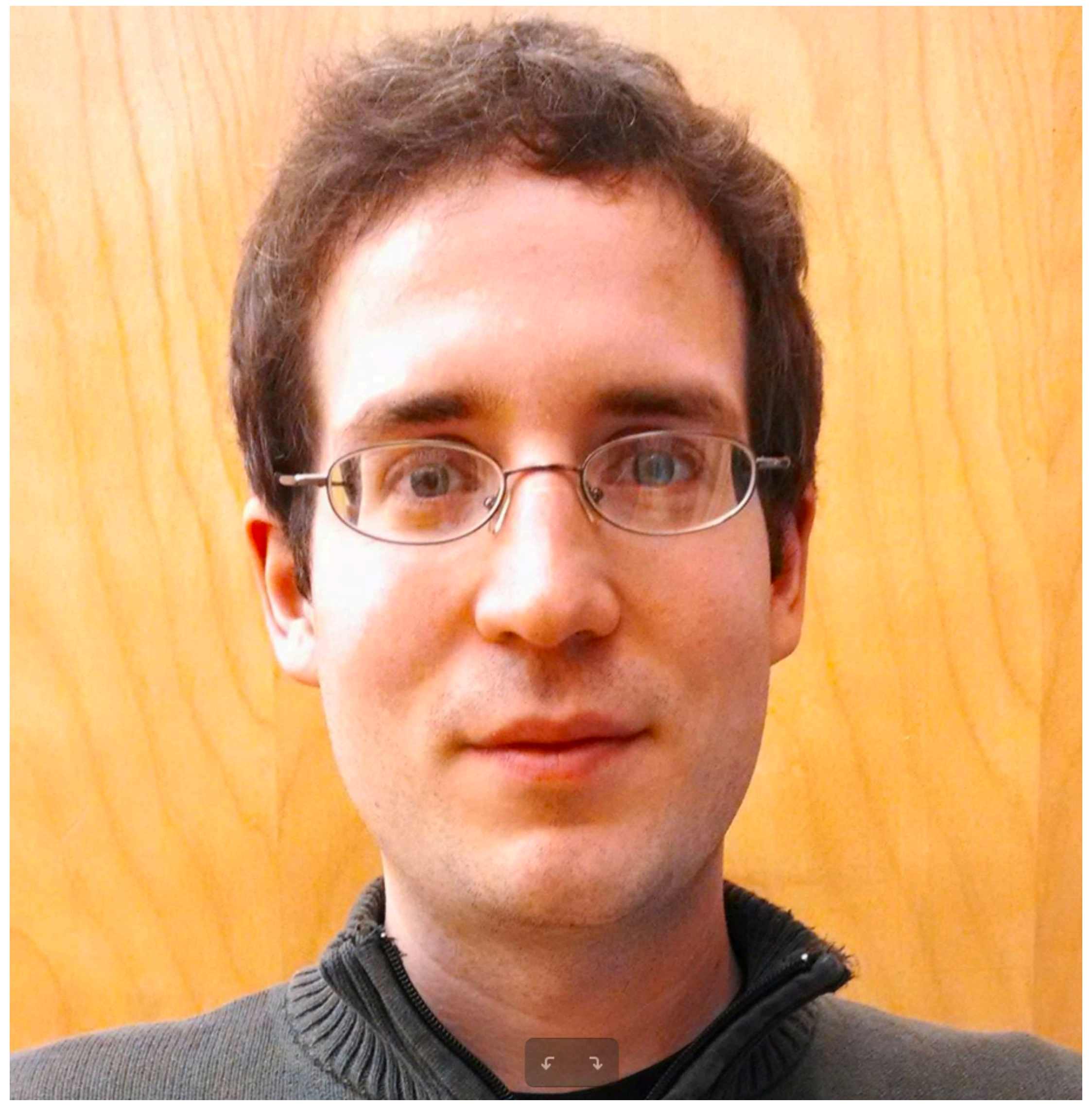
$$\rho \approx 1 - q\Delta\mu^2 \quad \Rightarrow \quad \Delta\mu \gtrapprox p/q$$

$$\rho < \kappa_1/\kappa_2 < 1/\rho$$

Take-home message

- Q1: What do we mean when we talk about stabilizing and equalizing mechanisms?
- A1: Stabilizing mechanisms and equalizing mechanisms have two distinct sets of meanings within Modern Coexistence Theory
- Q2: Can we disentangle the relative contributions of stabilizing and equalizing mechanisms?
- A2: Complex interdependency makes it difficult unless we know the governing mechanistic model with parameters.
- Q3: Do stabilizing and equalizing mechanisms provide a niche-neutrality continuum?
- A3: Interdependency break this continuum under almost any biologically relevant circumstance.

Acknowledgement



György Barabás
Linköping University

Serguei Saavedra
MIT

Song, Chuliang, György Barabás, and Serguei Saavedra. "On the consequences of the interdependence of stabilizing and equalizing mechanisms." The American Naturalist 194.5 (2019): 627-639.

Chuliang_Song **clsong.mit.edu**