Exploring Ecological Interactions:
Coexistence and Resilience of Populations

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Are the patterns linking stability and structure in ecological communities ubiquituos? What about the coexistence of randomly assembled communities: How many species can coexist?

We performed simulations based on the generalized Lotka-Volterra model (gLV) across a wide parameter space range in order to test the interplay of structure, stability and coexistence in a broad region of the parameter space.

generalized Lotka-Volterra Model:

$$\frac{\mathrm{d}\vec{X}}{\mathrm{d}t} = \mathrm{diag}(\vec{X})\left(\underbrace{\vec{r}}_{\text{Basal Growth Rates}} + \underbrace{\mathbf{A}}_{\text{Matrix of Interaction}}\vec{X}\right)$$

$r_i = 1$

$a_{ii} = -1$

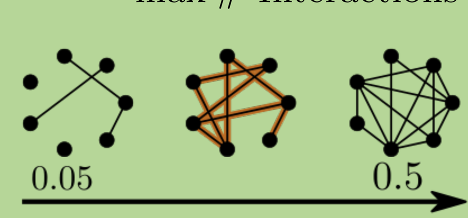
$X_i(t=0) = 1$

How many Populations?

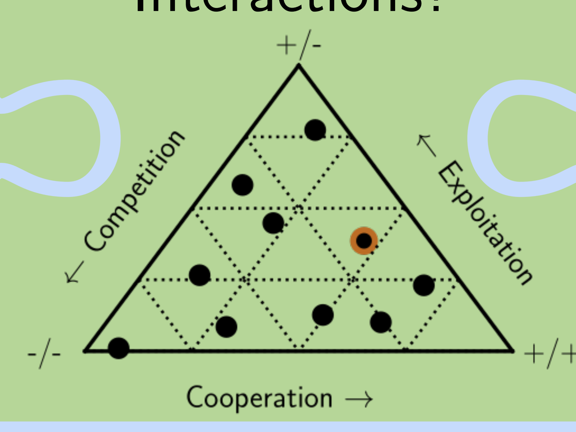
$N = 400$

How many Interactions?

$D = \frac{\#\ \text{Interactions}}{\max \#\ \text{Interactions}}$

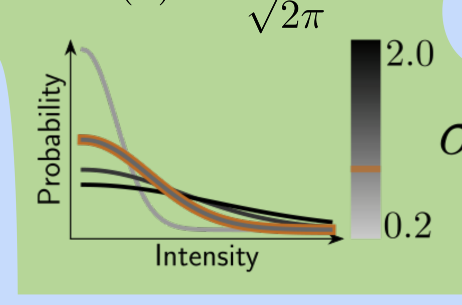


Which Interactions?



How intense?

$P(x) = \frac{e^{-\frac{x^2}{2\sigma^2}}}{\sqrt{2\pi}}$



... we randomize...

5000 different choice of parameters

10 replicates for each choice

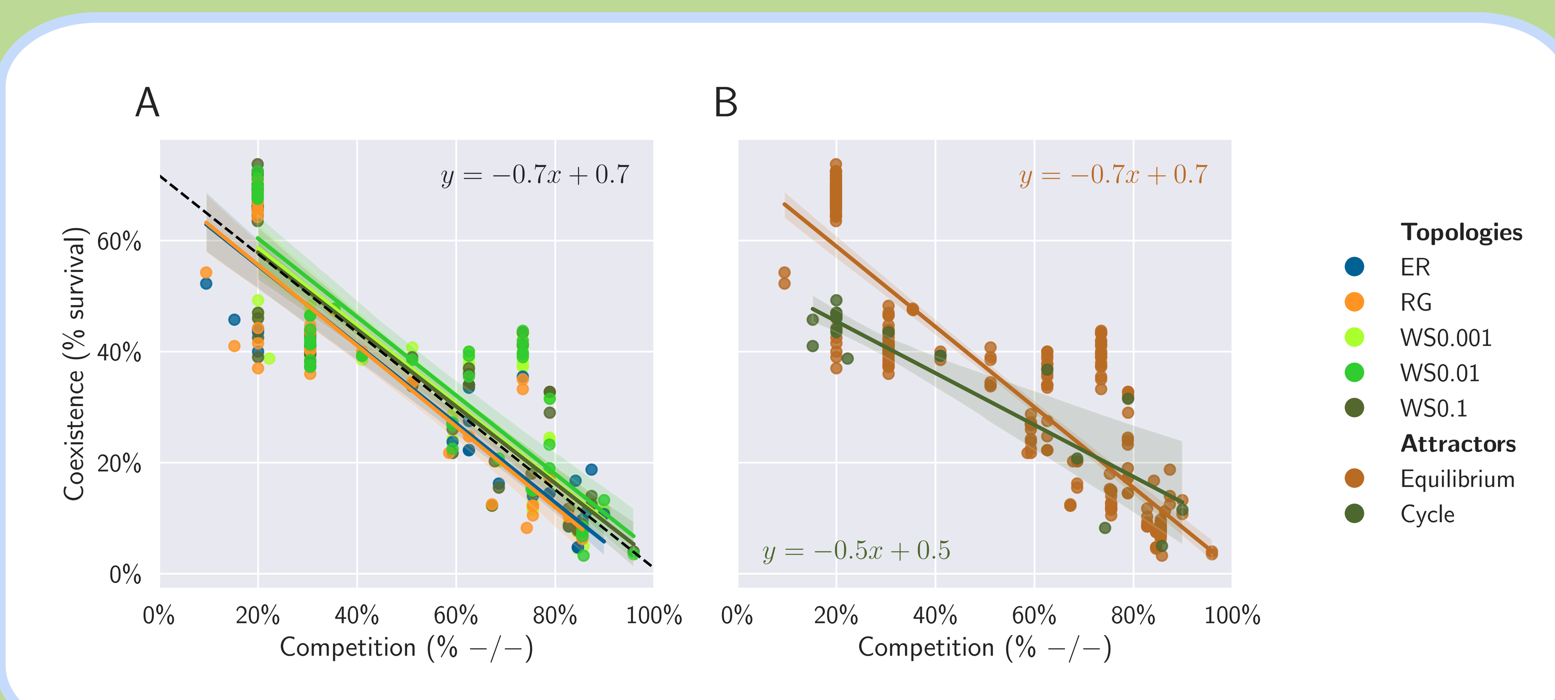
.... 50 000 simulations

... Simulated Matrix of Interaction.

$$\begin{bmatrix} -1. & -0.3 & 0. & \cdots \\ -1.6 & -1. & 0.8 & \cdots \\ 0. & 0.03 & -1. & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

We then perform a numerical integration and identify the long-term behavior (attractor), the proportion of populations that survive and the resilience of the interaction Matrix

Communities with More Competition have Lower Coexistence



The **proportion of survival** was measured as ratio between the number of populations having non-neglible abundances at the end of the simulation over the number of initial populations (400).

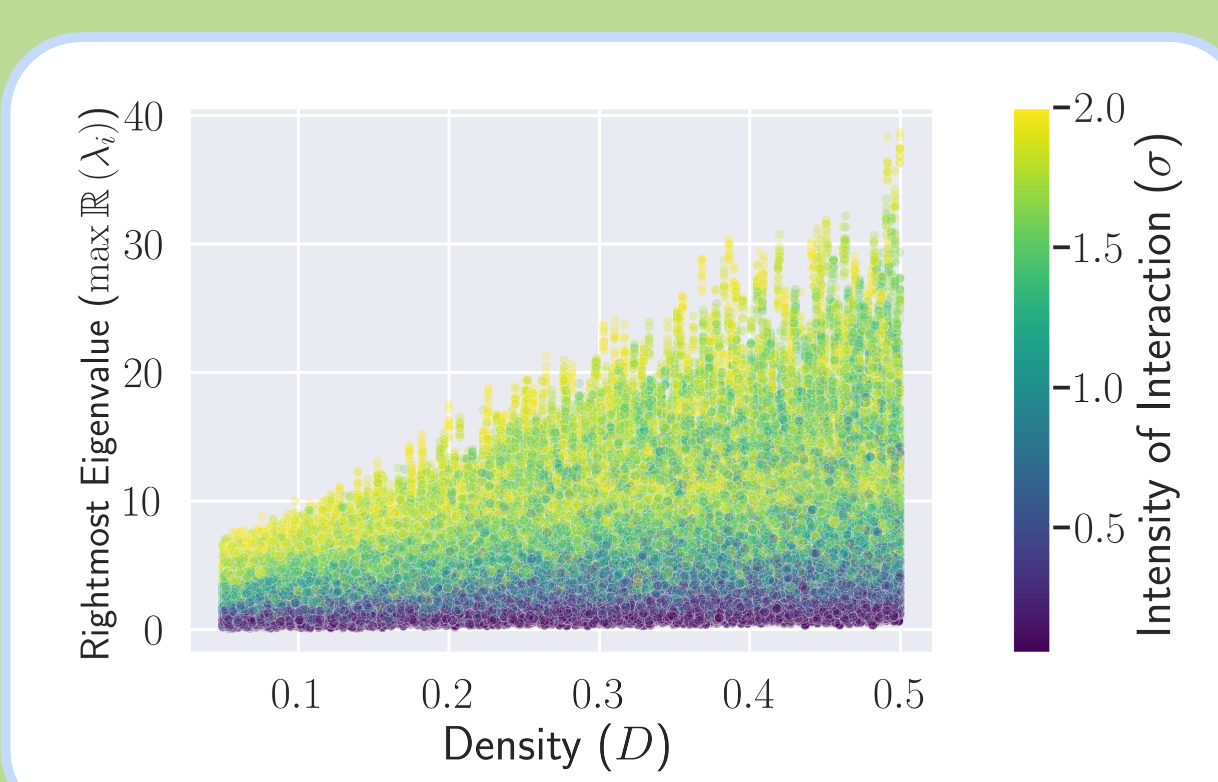
Our results support the idea that the exclusive competition principle is at play for larger communities, even though its traditional formulation is based on reasoning ecological interactions between populations pairs.

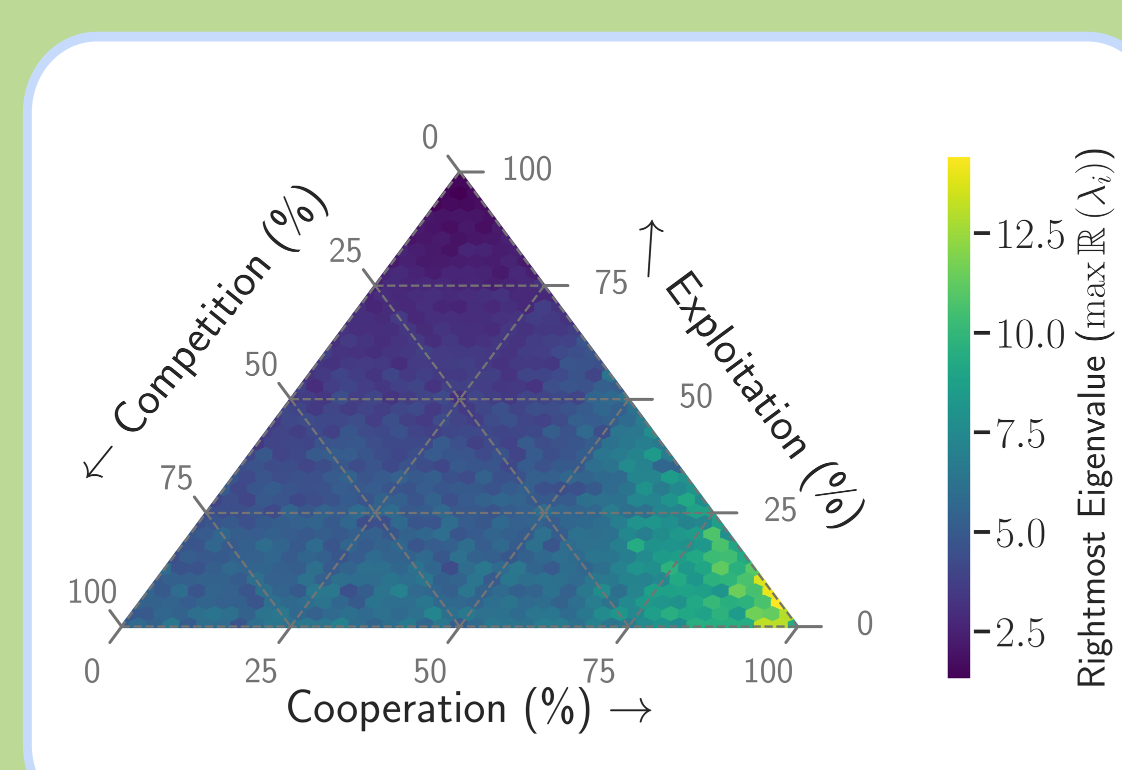
Resilience: The resilience of an ecological community is how fast the community returns to an equilibrium point after being minimally displaced from it (Hofbauer and Sigmund 1998).

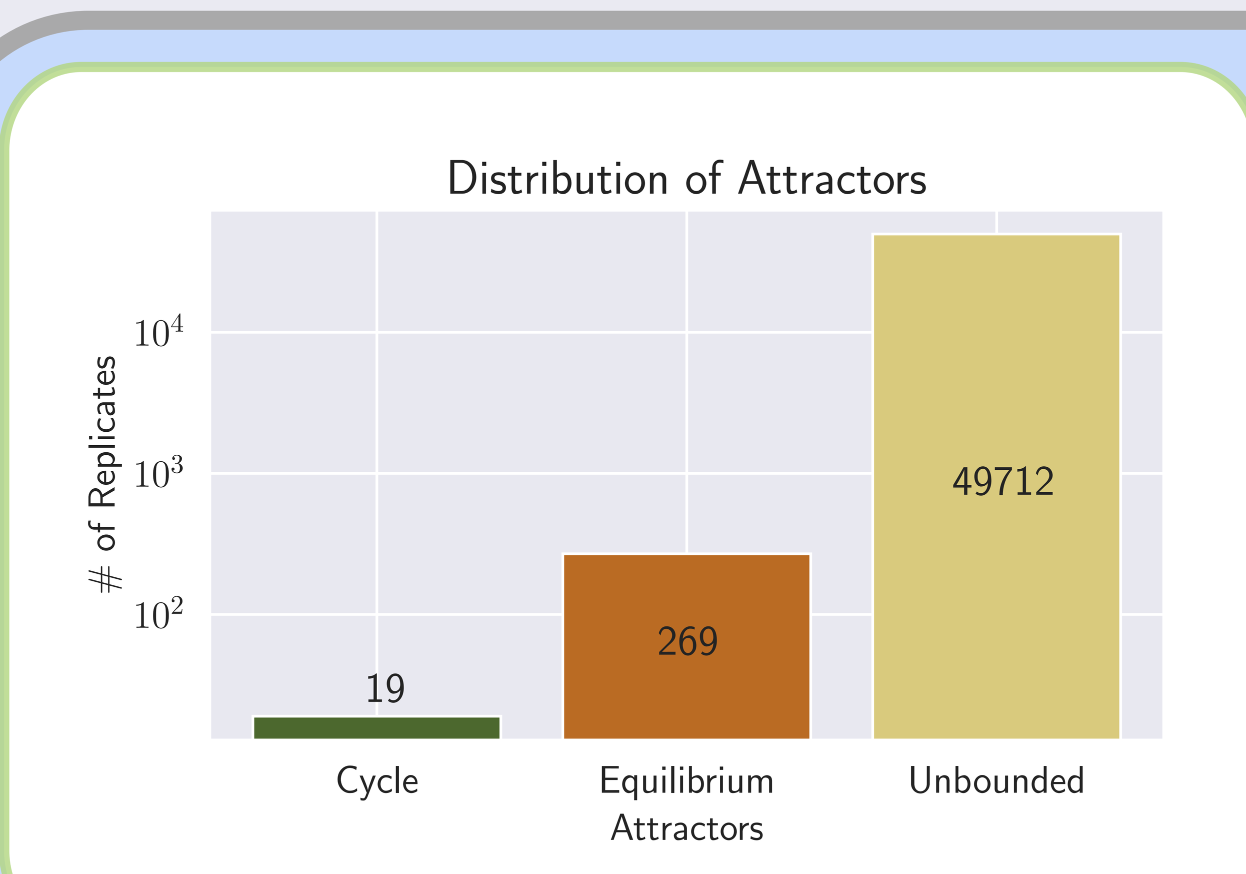
We measure resilience as the real part of the eigenvalue with the largest real part among the eigenvalues of the community matrix **M.**

The community matrix depends both on the interaction matrix and the abundance of all the populations in the equilibrium, but the resilience is primarily determined by the interaction matrix (Gibbs et al. 2018).

Communities with Lower Densities, Weaker Interactions, and More Competition/Exploitation are More Resilient







Most Communities Have Unbounded Dynamics

Unbounded attractors are charaterized by a temporal dynamics in which at least one population present infinite growth.

The unbounded attractors occur whenever a set of populations have mutually beneficial interactions strong enough to overcome the intraspecific competition they are subjected to.

References

Gibbs, Theo, Jacopo Grilli, Tim Rogers, and Stefano Allesina. 2018. "Effect of Population Abundances on the Stability of Large Random Ecosystems." Physical Review E 98 (2): 022410. https://doi.org/10.1103/PhysRevE.98.022410.

Hofbauer, Josef, and Karl Sigmund. 1998. Evolutionary Games and Population Dynamics. http://dx.doi.org/10.1017/CBO9781139173179.

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