Differential dependence on a shared mutualist partner leads to coexistence between competing species

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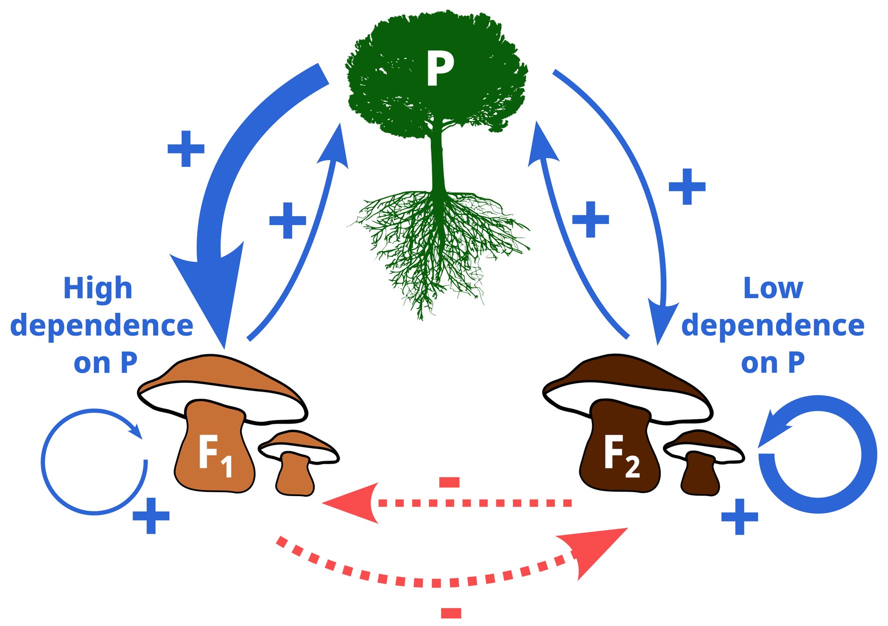
Background

- How species can coexist despite antagonistic biotic interactions within an environment is fundamental to understanding biodiversity.[1]
- Mutualistic interactions can act as a mechanism driving coexistence between competing species.[2]
- Dependence is the factor of population growth attributed to a mutualist partner.[3]
- Few ecological models of competition both include mutualistic interactions and are spatially-explicit.[4]
- We constructed a model of three interacting species and simulated generations of growth and dispersal to answer the question: ***How does differential dependence on a shared mutualist partner influence the ranges and coexistence of two competing species in a spatial landscape?***

Species Interactions



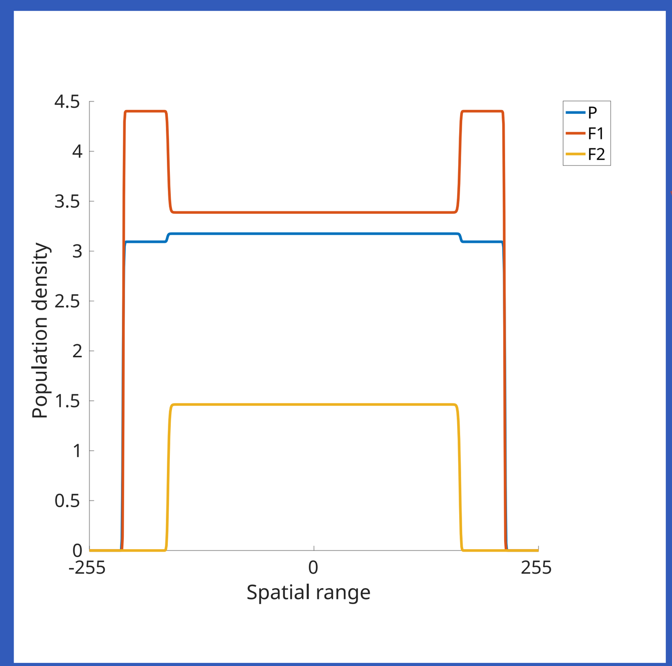
The growth of F_1 depends mainly on benefits provided by P, whereas F_2 has a higher intrinsic growth rate. We varied the competitive abilities of F_1 and F_2 in each simulation.

Takeaways

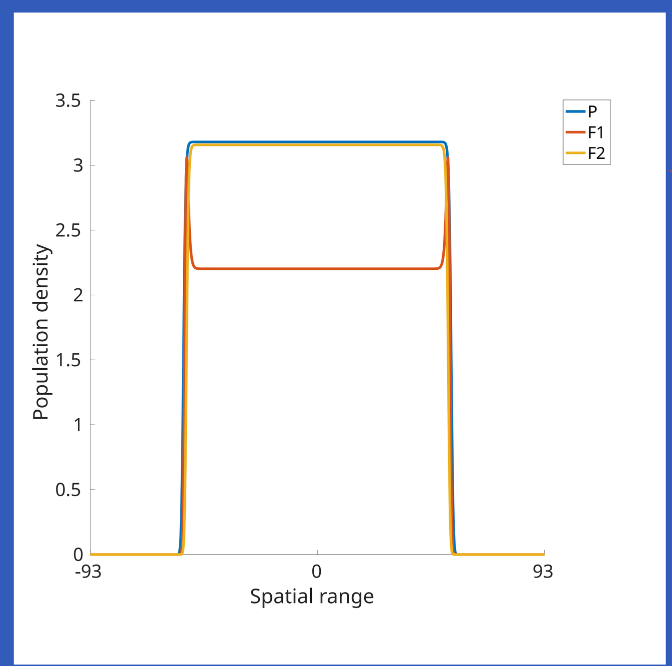
- Mutualism dependence is a mechanism by which a weaker competitor can coexist with a stronger one.
- The advantages of mutualism dependence diminish as competition increases.
- In co-invasions of a new habitat, this three-species dynamic can facilitate both local and regional coexistence.
- A more mutualist-dependent species dominates the range edges when competition is weak, but is excluded from the range edges when competition is strong.

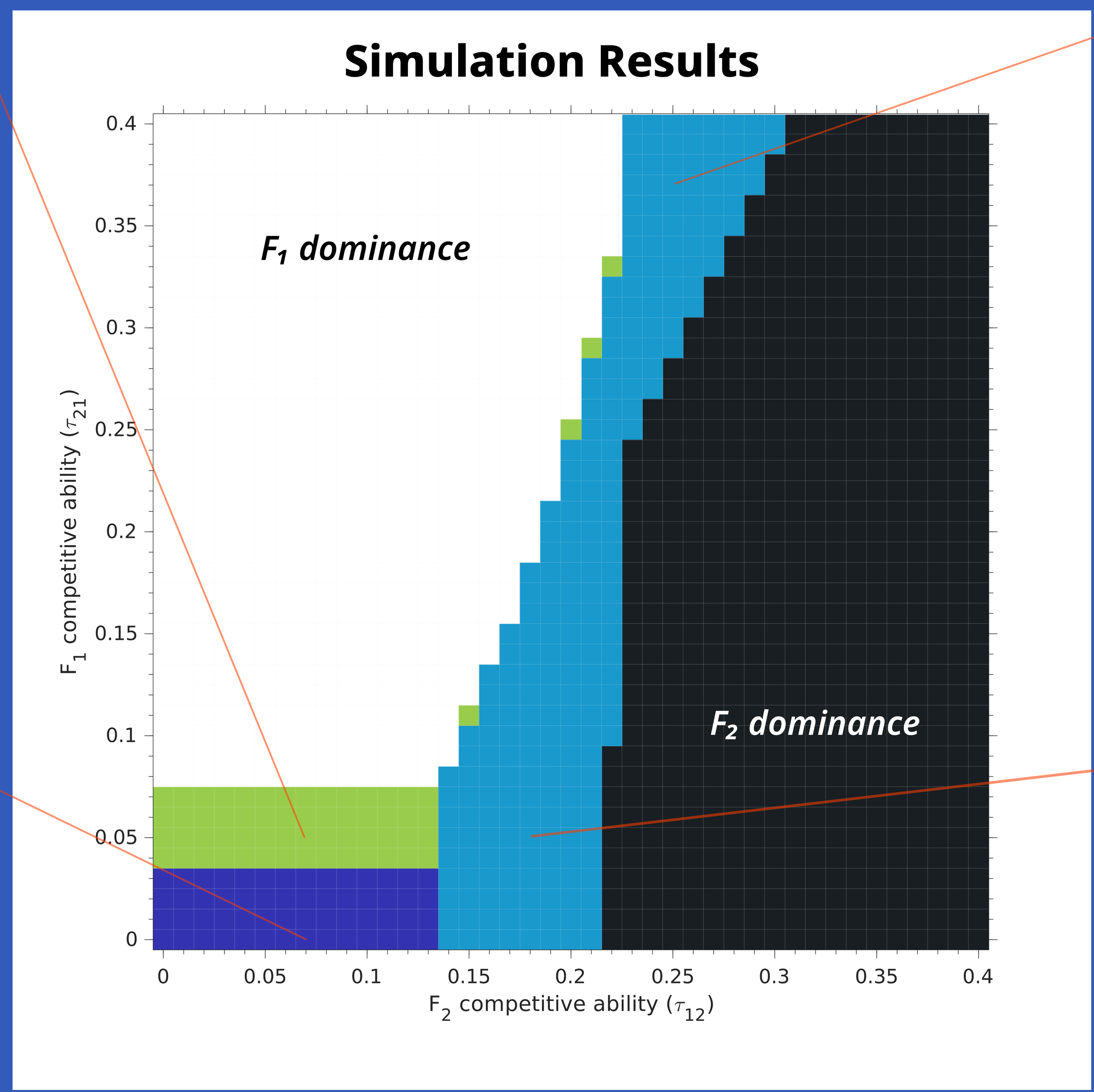
Mutualism dependence can shape how dispersing competitors **coexist** across a newly invaded landscape.

Local coexistence + F_1 dominance
($\tau_{12} = 0.07$, $\tau_{21} = 0.05$)

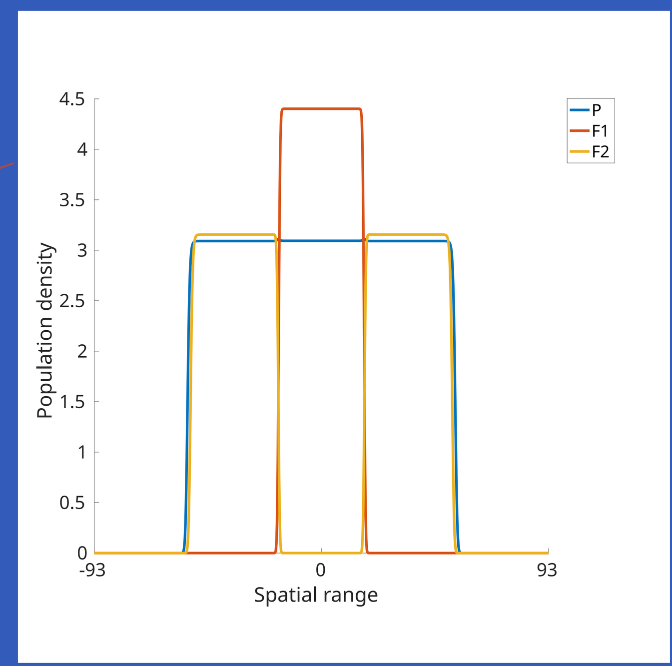


Local coexistence
($\tau_{12} = 0.07$, $\tau_{21} = 0$)

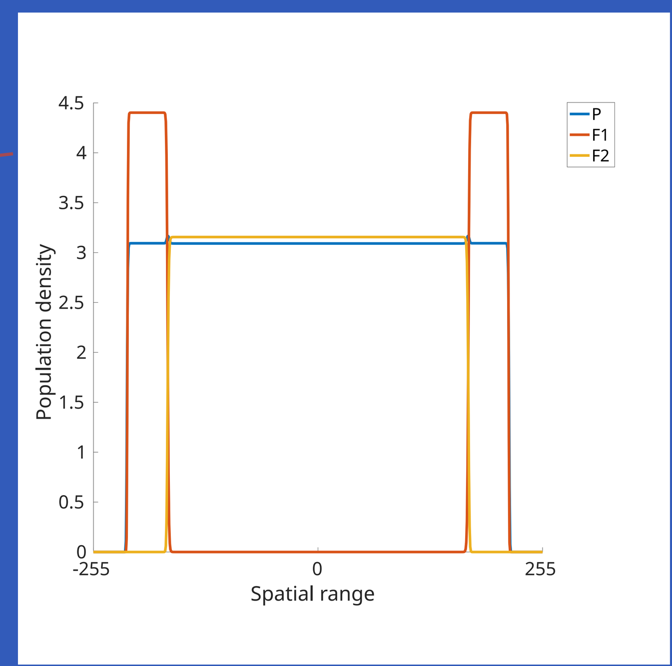




Regional coexistence
($\tau_{12} = 0.25$, $\tau_{21} = 0.37$)



Regional coexistence
($\tau_{12} = 0.18$, $\tau_{21} = 0.05$)



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Modeling Growth and Dispersal

The 3 species interact and repeat a cycle of growth and dispersal across one-dimensional space.

We model growth and dispersal with a set of integro-difference equations of the form

$$P_{t+1}(x) = \int_{-\infty}^{\infty} k_P(x-y) M_P(P_t(y), F_{1,t}(y), F_{2,t}(y))\,dy$$

$$F_{i,t+1}(x) = \int_{-\infty}^{\infty} k_{F_i}(x-y) M_i(P_t(y), F_{i,t}(y), F_{j,t}(y))\,dy$$

where
- $i, j = 1, 2$
- x and y are points in space after and before dispersal, respectively
- k is a dispersal kernel
- M is a nonlinear growth function

We model species interactions and population growth with a set of ordinary differential equations:

$$\frac{dP}{dt} = P\left[r_P + \left(\frac{\alpha_{PF_1}F_1}{h_{PF_1}+F_1} + \frac{\alpha_{PF_2}F_2}{h_{PF_2}+F_2}\right) - d_P P\right]$$

$$\frac{dF_i}{dt} = F_i\left[(1-\boldsymbol{\delta}_{F_i})r_{F_i} + \boldsymbol{\delta}_{F_i}\left(\frac{\alpha_{F_iP}P}{h_{F_i}+P}\right) - d_{F_i}F_i - \boldsymbol{\tau}_{ij}F_j\right]$$

where
- $i, j = 1, 2$
- $\boldsymbol{\delta}$ is mutualist partner dependence
- r is the species' intrinsic growth rate
- α is benefits received from the mutualism
- h is the half-saturation constant
- d is the species' death rate
- $\boldsymbol{\tau}$ is the effect of competition

Future Directions

- Some species highly dependent on a mutualism have adapted to disperse further[5]; modifying each species' dispersal kernel in our model would allow us to better understand this dynamic.
- Variation in environment would likely affect each species' carrying capacity[6]; we could simulate spatial heterogeneity in the model to study how it would alter coexistence.

References

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4. Wilson, W. G., W. F. Morris, and J. L. Bronstein. 2003. Coexistence of Mutualists and Exploiters on Spatial Landscapes. Ecological monographs 73:397–413.
5. Correia, M., R. Heleno, P. Vargas, and S. Rodríguez-Echeverría. 2018. Should I stay or should I go? Mycorrhizal plants are more likely to invest in long-distance seed dispersal than non-mycorrhizal plants. Ecology letters 21:683–691.
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