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Fungi Decomposition Rates in Relation to Growth Rate and Moisture Tolerance

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Problem

Researchers found that fungi that grow faster tend to be less resistant to changes in temperature and moisture. Exploring the relationship between a fungus's growth rate and moisture tolerance, our team modeled the decomposition rates of woody material by different fungi to analyze how the changing environment will impact decomposition of ground litter.

Models

Lotka - Volterra Competition Model[2]: This system of differential equations uses each fungus's competitiveness rating (a_{12} and a_{21}) to determine populations of each fungi.

$$\frac{dx_1}{dt} = r_1 \cdot x_1(1 - (\frac{x_1 + \alpha_{12}x_2}{k_1}))$$

$$\frac{dx_2}{dt} = r_2 \cdot x_2(1 - (\frac{x_2 + \alpha_{21}x_1}{k_2}))$$

In our first equation, the absence of species x_2 results in a logistic growth for species x_1, which assumes a carrying capacity k_1. Including species x_2, results in growth decay for species x_1 due to competition. Similarly, in our second equation, we examine species x_2 with the presence of species x_1, assuming some carry capacity k_2.

Decomposition Model: The total decomposition is given by D_T which is given by each fungus's decomposition rate multiplied by its population size and the amount of time passed.

$$D_T = D_1 + D_2$$

$$d_1 \cdot x_1 \cdot t + d_2 \cdot x_2 \cdot t$$

References

[1] Lustenhouwer, Nicky, et al. "A trait-based understanding of wood decomposition by fungi." Proceedings of the National Academy of Sciences 117.21 (2020): 11551-11558.

[2] Morris, Steven A., and David Pratt. "Analysis of the Lotka–Volterra competition equations as a technological substitution model." Technological Forecasting and Social Change 70.2 (2003): 103-133.

[3] Maynard, Daniel S., et al. "Consistent trade-offs in fungal trait expression across broad spatial scales." Nature microbiology 4.5 (2019): 846-853.

[4] Maynard, Daniel S., et al. "Diversity begets diversity in competition for space." Nature ecology evolution 1.6 (2017): 1-8.

Acknowledgments

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Parameter Justification

By comparing regional temperatures and moisture rates seen in [3] of each fungal species, we estimate the growth (extension) rate, r, and the decomposition rate, d, per day. Moisture rate is based on humidity. Decomposition rate is found by averaging the temperatures and wood/litter decay within a given area.

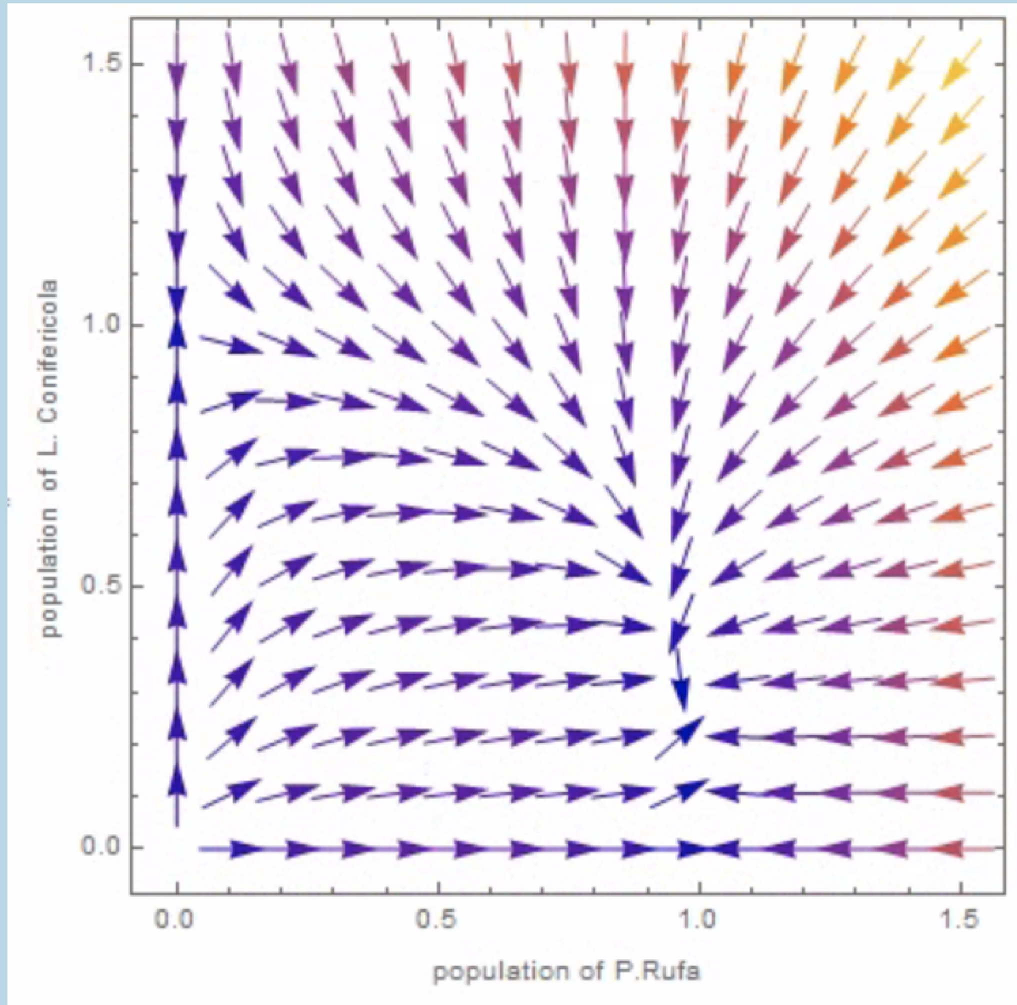
We used parameters for competition as presented by the Elo ranking in [4] to obtain the competitiveness ranking of each fungal species, α_{12} and α_{21}. *Phlebia rufa* and *Phlebiopsis flavidoalba* are both dominant species. *Laetiporus conifericola* was utilized to compare competitive results.

Parameter	*Phlebia rufa*	*Phlebiopsis flavidoalba*	*Laetiporus conifericola*
r (mm/day)	0.053	0.057	0.028
d (mm/day)	0.17	0.14	0.058

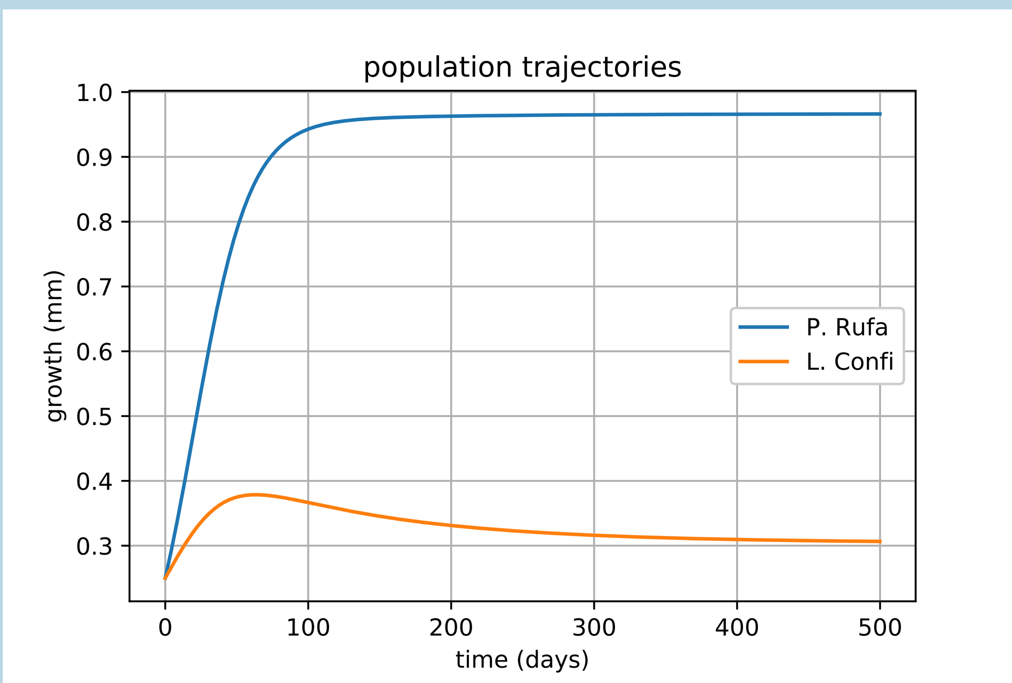
Estimated parameters for fungi species where r is the growth rate and d is the decomposition rate. All estimated parameters are per day.

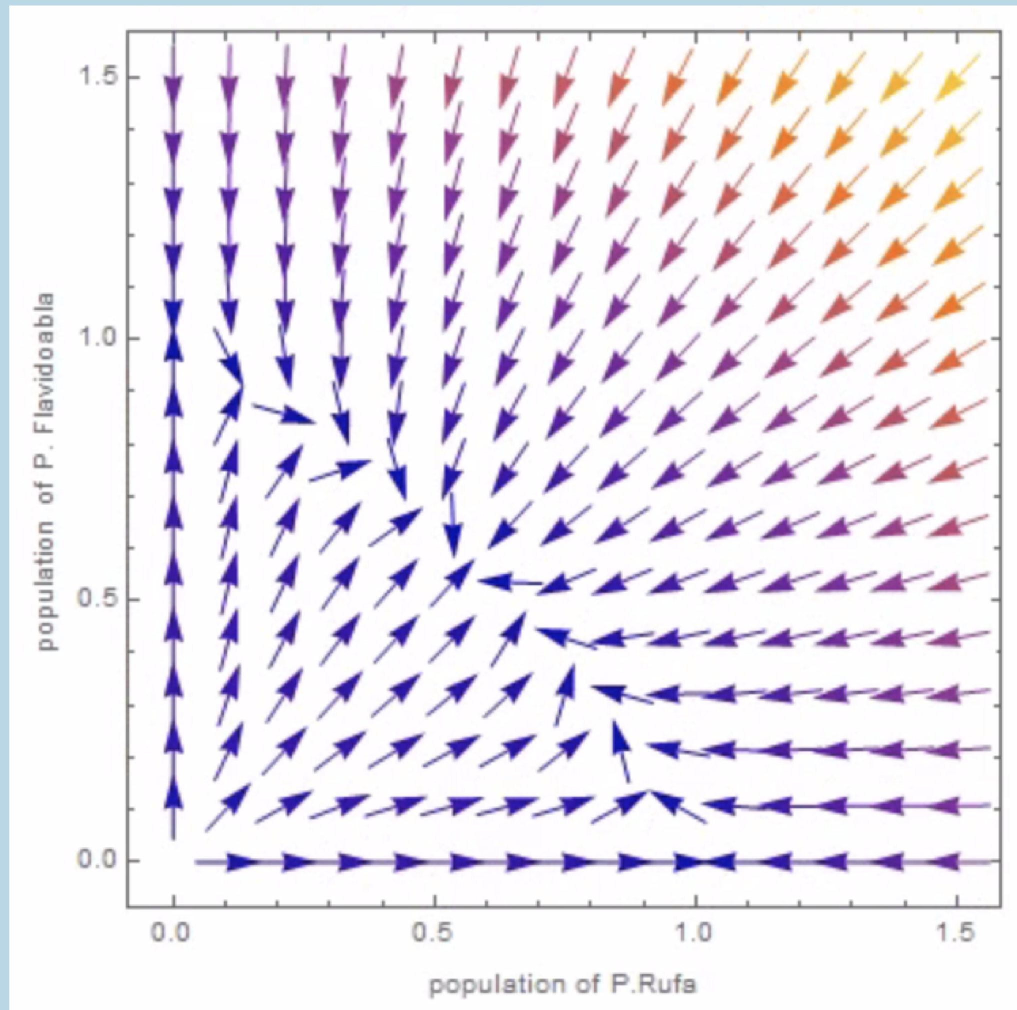
Competition Model Analysis

In order to estimate ground litter decomposition, we used the projected decomposition rates of each species and the final population of each species after analyzing the competition model. Figures 1 and 2 show that *P. rufa* competitiveness cause it to have a higher final population than *L. conifericola* after 500 days. Additionally, *P. rufa* has a much higher decomposition rate of 0.17 mm/day compared to 0.058 mm/day meaning that *P. rufa* would be the primary decomposer in this pairing. In figures 3 and 4 we see that *P. rufa* and *P. flavidoalba* have equal populations after 500 days where *P. flavidoalba* has a decomposition rate of 0.14 mm/day, only slightly lower than *P. rufa*. This, along with their equal populations, tells us that *P. rufa* will decompose lightly more ground litter in this pairing. When comparing both pairings with population size and individual decomposition rates considered, both pairings have similar overall decomposition rates.



Figures 1 and 2: *Phlebia rufa* VS *Laetiporus conifericola*: Figure 1 (above) shows the phase portrait for *P. rufa* and *L. conifericola* where the population of each species is depicted on each axis respectively. The arrows indicate how the populations change with time according to the system of equations. Figure 2 (below) shows a possible population growth trajectory for both species. Here, both species begin with a a population that covers 0.25 square meters but *P. rufa*'s much higher growth rate allows its population to grow much faster.





Figures 3 and 4: *Phlebiopsis flavidoalba* VS *Phlebia rufa* Figure 3 (above) shows the phase portrait for *P. flavidoalba* and *P. rufa*. Notice the trajectory arrows point to the system settling with both species having equal populations. Figure 2 (below) shows a possible population growth trajectory for both species. Again, both species begin with a a population that covers 0.25 square meters and end with similar populations. *P. flavidoalba* ends with a slightly larger population due to its larger growth rate.