

Computational Modeling & Simulation I (Interdisciplinary Science)  
CS 346  
Spring 2020

Ungraded, optional exercise on Mutualism (Please see the notes below!)

- This is an **ungraded, optional** exercise for students interested in following up on Prof. Chris Moore's guest lecture and learning more about mutualism! If you choose to submit work for this exercise, it will not be graded and will not count toward your CS346 grade; if you're interested in doing the work and getting feedback, however, your Prof.'s will give you feedback on your work.
- Because this is ungraded and optional, you are welcome to work on it individually, or in any size team you'd like. (You are also welcome to not work on it at all, if that's what's best for you!)
- Please use the string `Mutualism` as part of the folder name (along with names / userids / etc., as required) for submitting this assignment. See documents on the course website for general HW guidelines and submission instructions. (Not following guidelines may result in small deductions on this HW—please see your Prof. with any questions!)
- Relevant instructions and guidelines for HW2 (e.g., what to include in a write-up) apply to this exercise, too.

## Mutualism and Moore!

As discussed in Chris Moore's guest lecture (see course website for video links), extending the logistic equation (e.g.,  $\frac{dX}{dt} = rX - r\frac{X^2}{M}$ ) by adding an interaction term (e.g.,  $\beta XY$ ) into the numerator can model various kinds of interactions between species, depending on the sign of the interaction term and whether or not the interaction coefficient is 0. When the interaction term is positive, the focal species benefits from interacting with the other species; when the interaction term is negative, the interactive is to the detriment of the focal species; and when the interaction coefficient is 0, interacting with the other species has no effect on the focal species.

Considering the two interaction terms—i.e., one term for each of the two interacting species—there are six possible pairwise combinations of the positive / negative / 0 values of the interaction terms:  $(++, +0, +-, 00, 0-, --)$ . These six pairwise combinations describe six different types of ecological interactions: *mutualism*, *commensalism*, *enemy-victim*, *neutrality*, *amensalism*, and *competition*.

You learned about mutualism and competition from Chris' guest lecture. Mutualism had two qualitatively different possible behaviors as outcomes: coexistence with increased equilibrium; or unbounded (unconstrained) growth. Competition had three qualitatively different behaviors: coexistence with decreased equilibrium; competitive exclusion; or priority effects. We determined these behaviors by setting each differential equation to 0, mapping the *zero-growth isoclines* in phase space (i.e., species  $X$  and  $Y$  on the axes—as opposed to a time series), and visually / graphically determining the behaviors of each interaction type

by increasing or decreasing the strength of the interaction coefficient (i.e., the slopes of the zero-growth isoclines).

For this exercise, determine the scope of behaviors of the remaining four interaction types (amensalism, neutralism, commensalism, enemy-victim), following the same kind of procedure as was used for mutualism and competition: For each type of interaction, draw a phase plane; then, consider changing the strength of the interaction.

1. What are the qualitatively different behaviors for each interaction type? In your write-up, give a figure and brief description for each behavior of each interaction type. (Also, submit the code you wrote for this exercise—please see below.)
2. Additionally, please comment on how the behavior(s) of the enemy-victim interaction is different than the Lotka-Volterra predator-prey model you learned the previous week.

For Exercise 1, please be sure to submit all code used to support your conclusions (including creating the figures) in a single `.m` file that, when run, will produce all needed figures—and be sure to label output for easy readability!

For Exercise 2, no additional code is needed—please answer this question in writing as part of your write-up document, but if your answer includes some data visualizations / figures that serve as foundational for your conclusions, please include complete instructions on how to generate those figures from your code, for replicability (as usual).