SCUDEM: Chemical Espionage

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Statement of the Problem

Parasitic wasps employ a wide range of chemical cues to find their host.

The male cabbage white butterfly Pieris brassicae often use sexual chemical signals called anti-aphrodisiacs to mask or dissuade other males during the mating season.

The anti-aphrodisiacs help to fertilize eggs meanwhile attracting egg parasitoids.

Goal:

Find the trade-offs and balance between the two competing interests.

Assumptions

1. Trichogramma Wasp and Pieris brassicae are living in a certain area.
2. The more Pieris brassicae, the more easier for wasp to find them; the more wasp, the easier for the wasp to find Pieris brassicae.
3. Pieris brassicae is not the only host for wasp, i.e. wasp can live on other species as well.
4. We assume there is no any other environmental factors that related to time.

The Approach

- Use the **Logistic Model with Extinction** for the growth rates of two population.

$$\dot{P} = r_1 P(1 - \frac{P}{k_1})(\frac{P}{e_1} - 1) + \alpha h P - s_1 \alpha W P$$

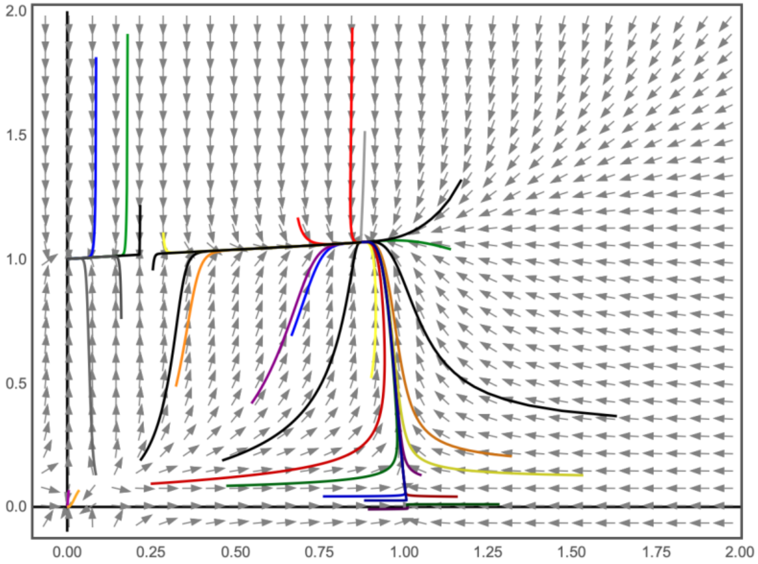
$$\dot{W} = r_2 W(1 - \frac{W}{k_2})(\frac{W}{e_2} - 1) + (\alpha s_2 + \beta) W P$$

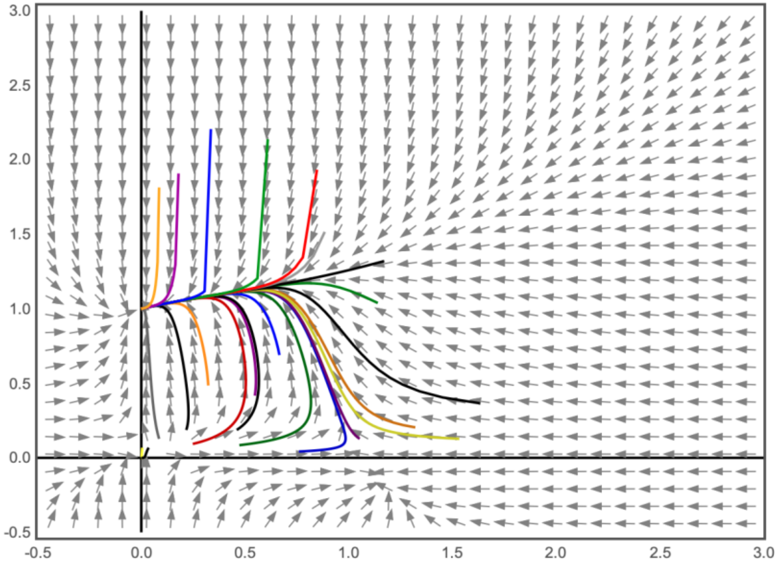
Turn into dimensionless eq.

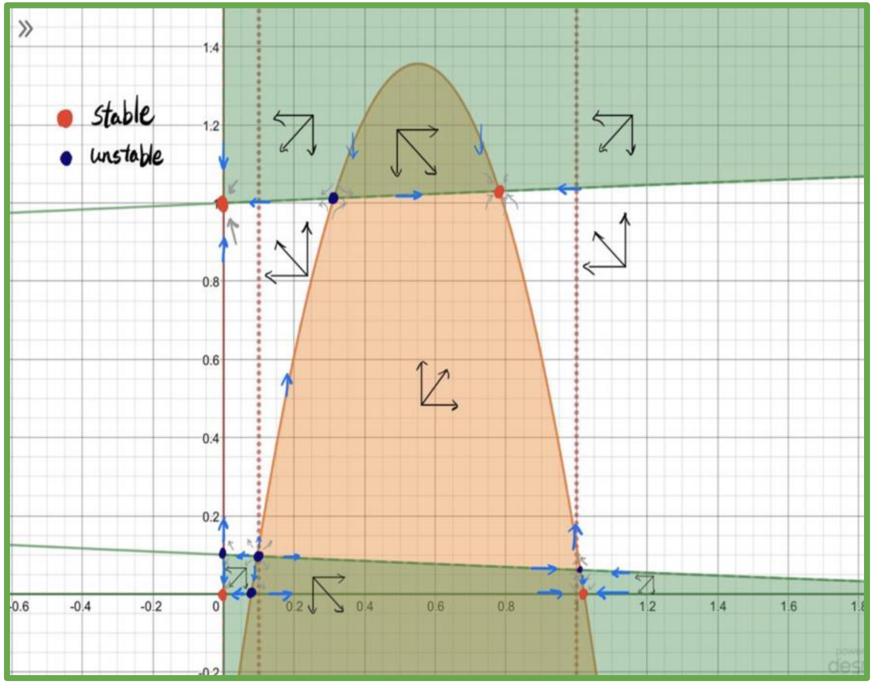
$$X' = X(1 - X)(R_1 X - 1) + AX - M_1 AXY$$
$$Y' = \rho Y(1 - Y)(R_2 Y - 1) + M_2 AXY + NXY$$

Result

- In the long run, you can see two populations will reach an equilibrium pt.
- The solution trend plots are shown below






stable
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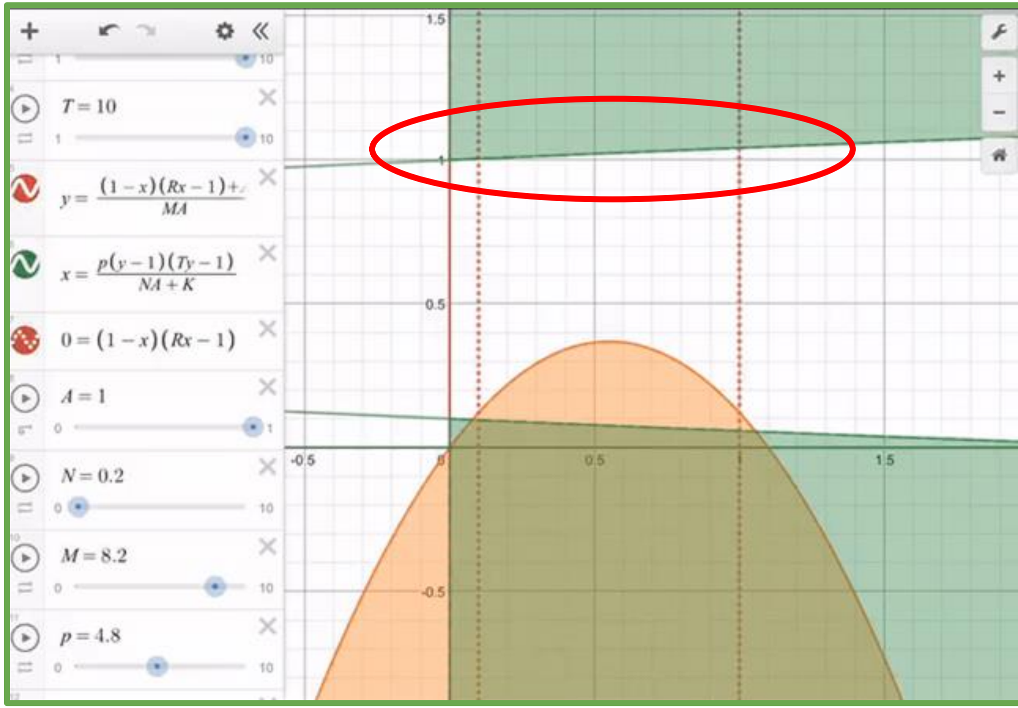
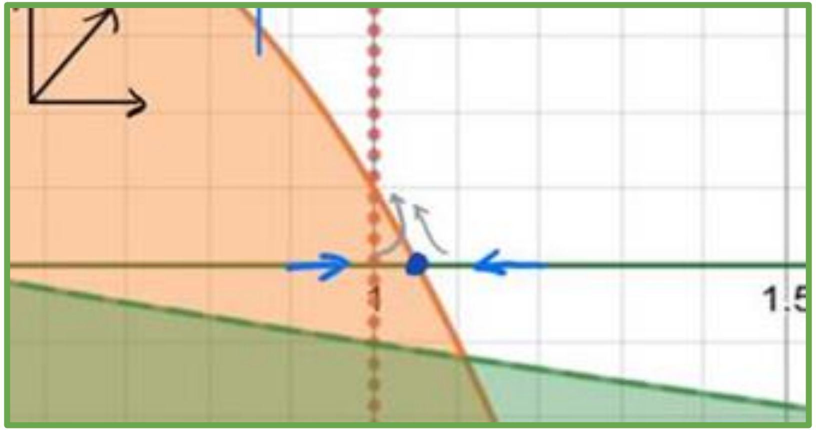
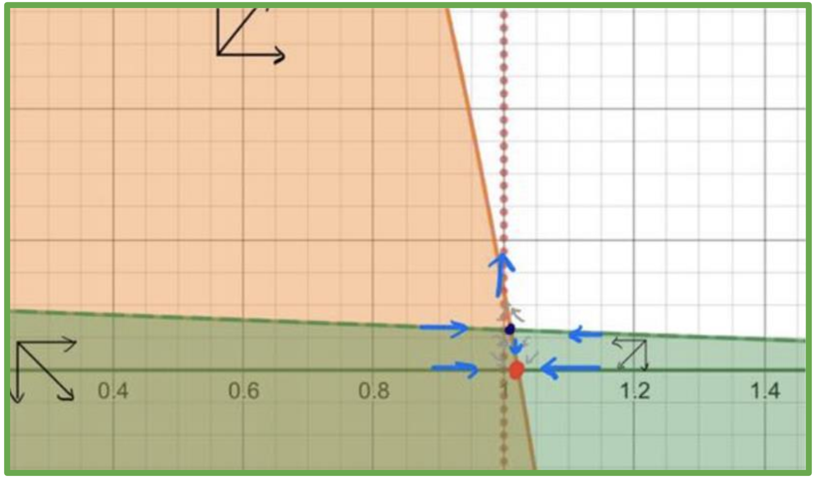
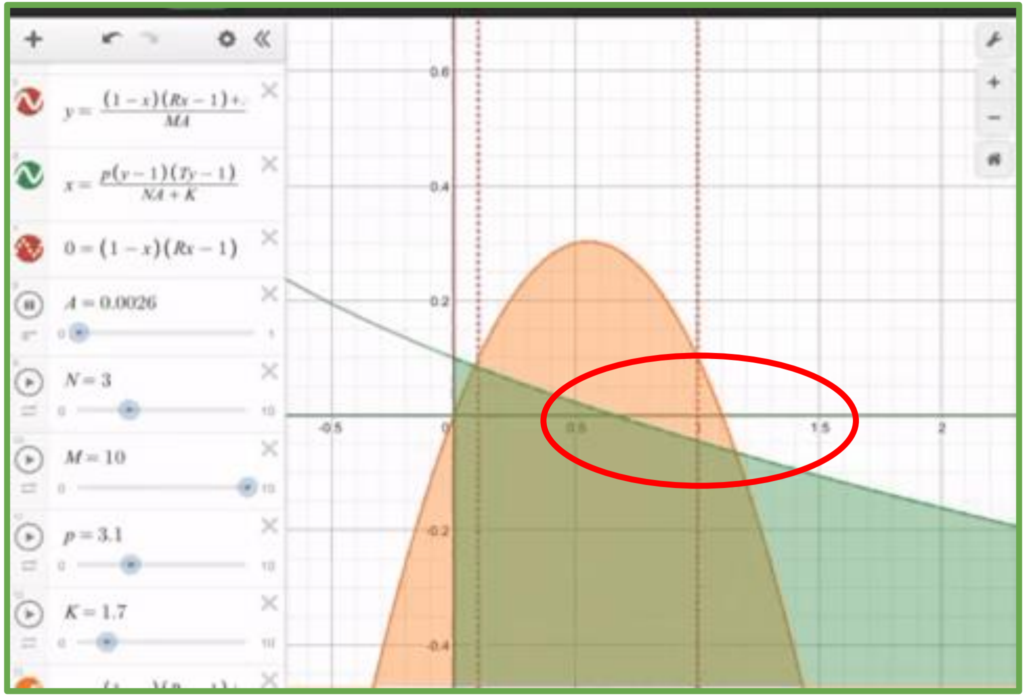

T = 10
y = (1 − x)(Rx − 1)+… / MA
x = p(y − 1)(Ty − 1) / NA + K
0 = (1 − x)(Rx − 1)
A = 1
N = 0.2
M = 8.2
p = 4.8


1
1.5


0.4
0.6
0.8
1.2
1.4


0 = (1 − x)(Rx − 1)
A = 0.0026
N = 3
M = 10
p = 3.1
K = 1.7

Drawbacks of the Model

- ➢ The parameters of the constant variables in the differential equation is given by rough guesses.
- ➢ k_1 and e_1 are not realistic carrying capacity and extinction threshold, but some values approach to them.
- ➢ The explicit solution for population in regarding of time is not given.

Addition Issue (1)

- Add an animal that is a predator for both butterflies and the wasps, e.g. a bird.
- Adapt Ludwig's (1978) model.
- **Additional Assumption:**
  - Predators have limitless appetite.

$$\dot{P} = r_1 P(1 - \frac{P}{k_1})(\frac{P}{e_1} - 1) + \alpha h P - s_1 \alpha W P - \frac{B_1 P^2}{L_1^2 + P^2}$$

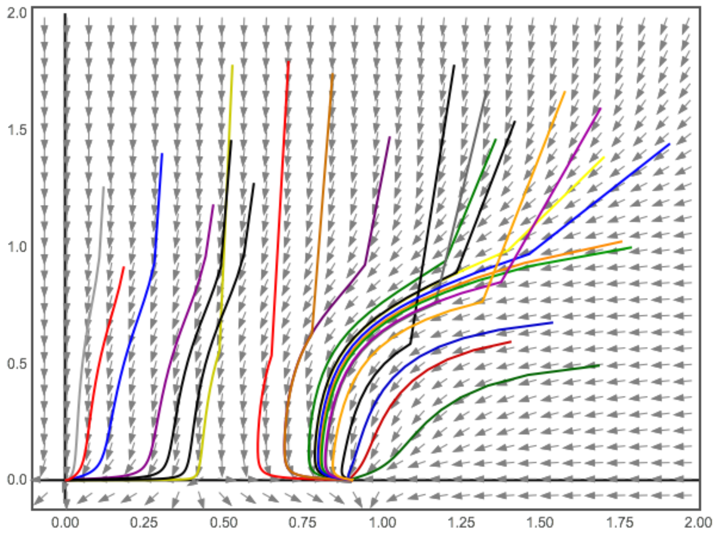
$$\dot{W} = r_2 W(1 - \frac{W}{k_2})(\frac{W}{e_2} - 1) + (\alpha s_2 + \beta) W P - \frac{B_2 W^2}{L_2^2 + W^2}$$

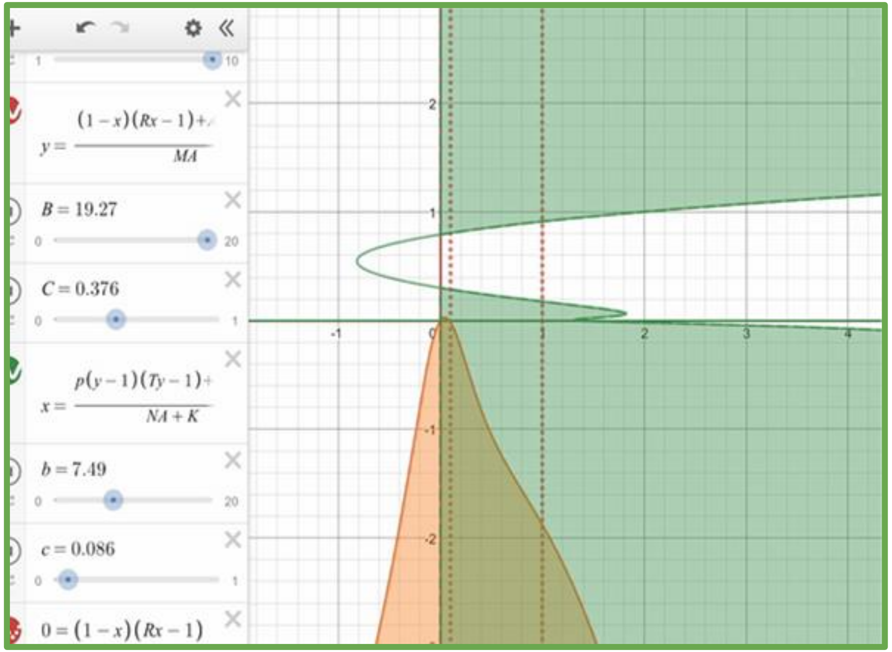
B: Maximum decrease of population per time

Dimensionless Form

$$X' = X(1-X)(R_1X-1) + AX - M_1AXY - \frac{C_1X^2}{D_1^2+X^2}$$

$$Y' = \rho Y(1-Y)(R_2Y-1) + M_2AXY + NXY - \frac{C_2Y^2}{D_2^2+Y^2}$$





References

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Mcleish, M. J., et al. "Parasitoid Fig-Wasp Evolutionary Diversification and Variation in Ecological Opportunity." *Molecular Ecology*, vol. 19, no. 7, 2010, pp. 1483–1496., doi:10.1111/j.1365-294x.2010.04583.x.

Ludwig, D., et al. "Qualitative Analysis of Insect Outbreak Systems: The Spruce Budworm and Forest." *The Journal of Animal Ecology*, vol. 47, no. 1, 1978, p. 315., doi:10.2307/3939.