Problem C -Chemical Espionage

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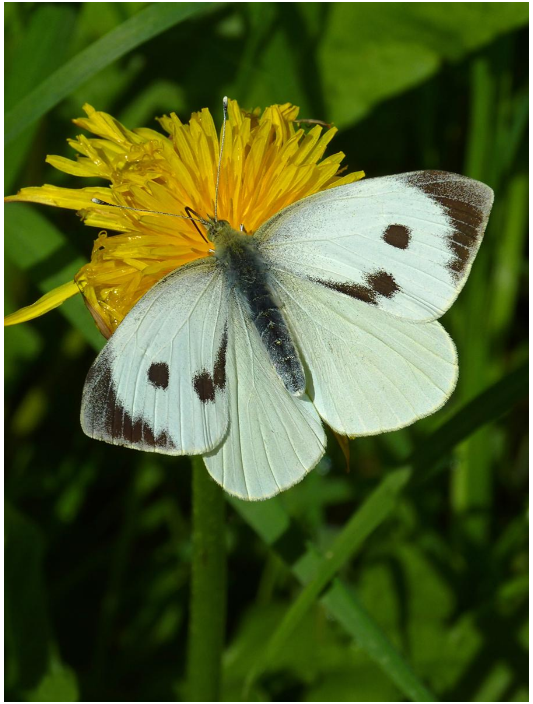
Introduction

- Male excretes anti-aphrodisiac pheromone onto female during mating

- Wasps exploit the anti-aphrodisiac pheromone
  - Pheromone detection innate, and learned
  - Wasps lay eggs in butterfly eggs
  - Wasp larvae eats butterfly larvae



Large Cabbage White Butterfly

https://www.ukbutterflies.co.uk/species.php?species=brassicae

Our Assumptions

- If there is no anti-aphrodisiac, butterflies are not mating, and the species will die
- Wasps can only reproduce by laying their eggs in butterfly eggs
- Assume food source for both species is limitless
- Half of the butterfly population is male and half is female at all time
- For simplicity, paraticizing behavior of the species of wasps in our model is innate.

Predator Prey Model

$$\frac{dB}{dt} = \alpha B(t) - \beta B(t)W(t)$$

$$\frac{dW}{dt} = \delta B(t)W(t) - \gamma W(t)$$

$\alpha B(t)$ - natural growth rate of butterfly

$\beta B(t)W(t)$ - predation rate

$\delta B(t)W(t)$ - growth rate of wasps (by predating butterfly eggs)

$\gamma W(t)$ - natural death rate of wasps

Variables

$\alpha =$ Birth rate * survival rate * (½) - death rate

$$\alpha = \frac{35}{8}\frac{1}{2}k_1 p - \frac{1}{45}$$

$\beta = \delta =$ Rate wasp and butterfly meet

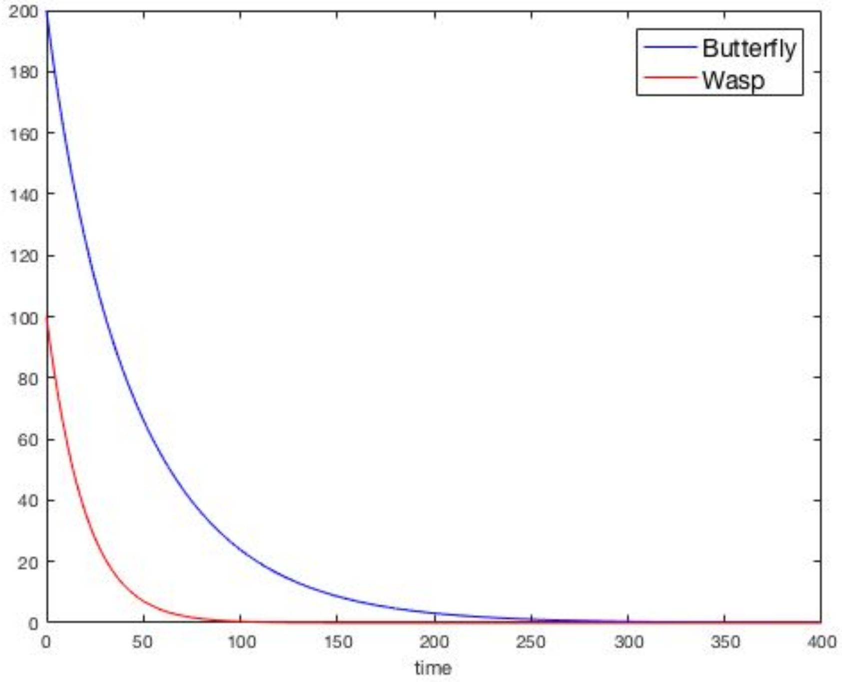
$$\beta = \delta = \frac{1}{2}k_2 p$$

$\gamma =$ Wasp death rate

$$\gamma = \frac{1}{17}$$

Results – Low p

$P = 0.1 \times 10^{-6}$

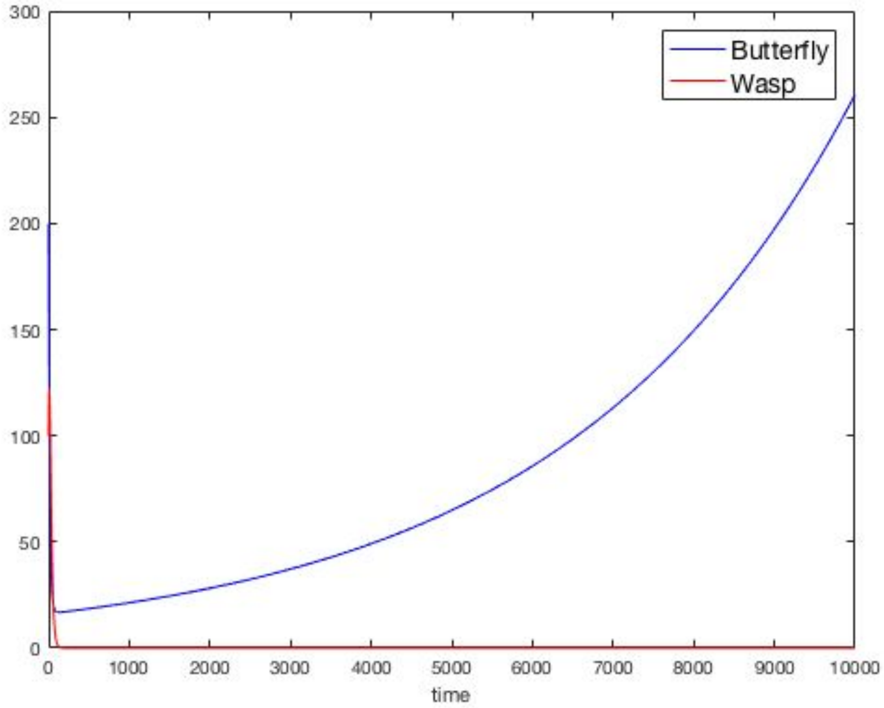


We fix the k1, k2 and also initial conditions in all the following cases:

$$k_1 = 10^4 \quad B(0) = 200$$
$$k_2 = 5 * 10^2 \quad W(0) = 100$$

Results

P = 1.04 x 10^{-6}

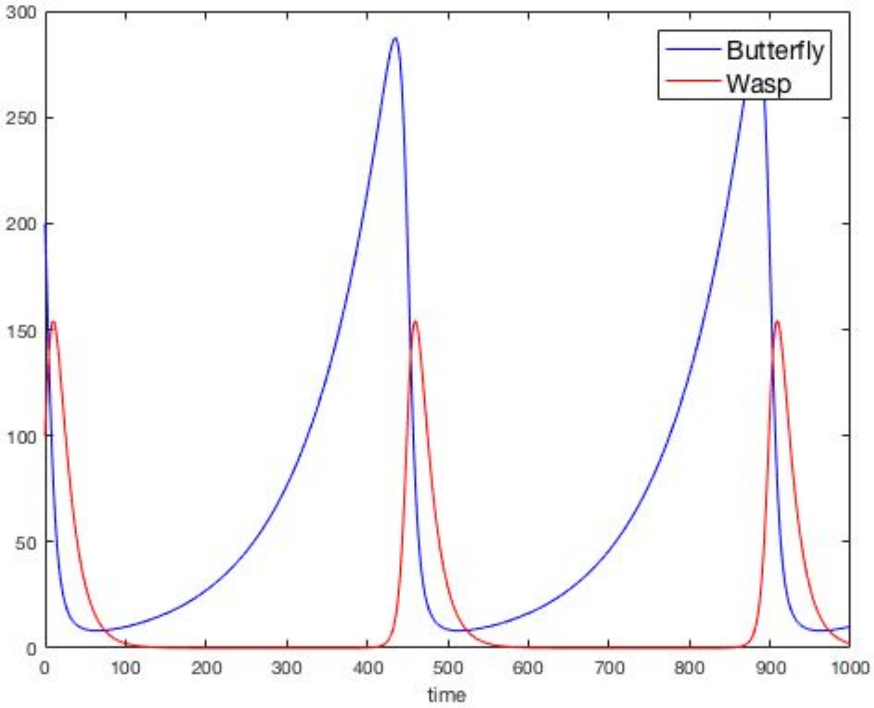


We fix the k1, k2 and also initial conditions in all the following cases:

$$k_1 = 10^4 \qquad B(0) = 200$$
$$k_2 = 5 * 10^2 \quad W(0) = 100$$

Results – Medium p

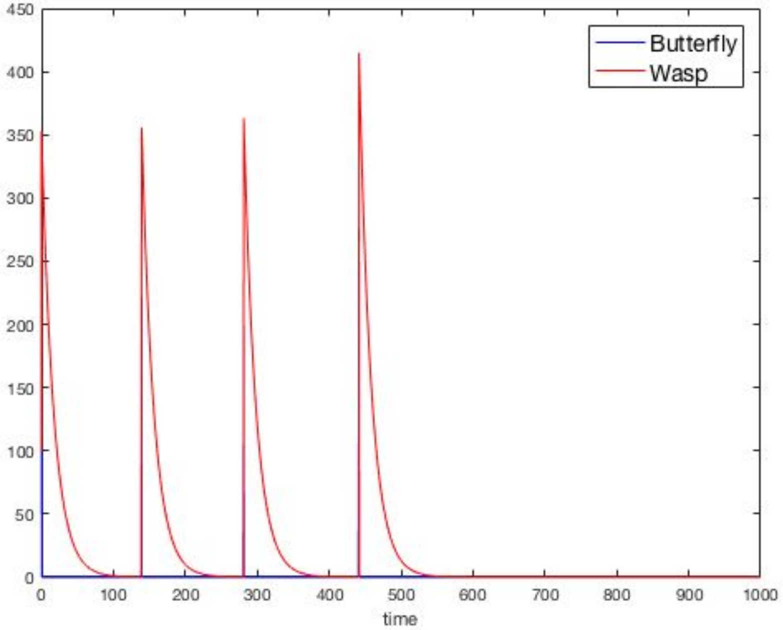
P = 1.5 x 10^{-6}



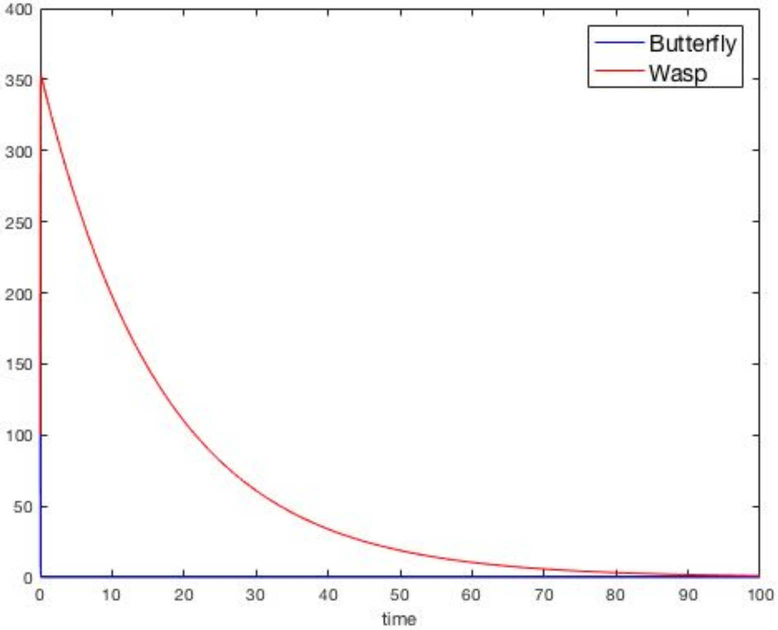
We fix the k1, k2 and also initial conditions in all the following cases:

$$k_1 = 10^4 \qquad B(0) = 200$$
$$k_2 = 5 * 10^2 \quad W(0) = 100$$

Results – High p



$P = 400 \times 10^{-6}$



$P = 500 \times 10^{-6}$

Conclusion

Findings:

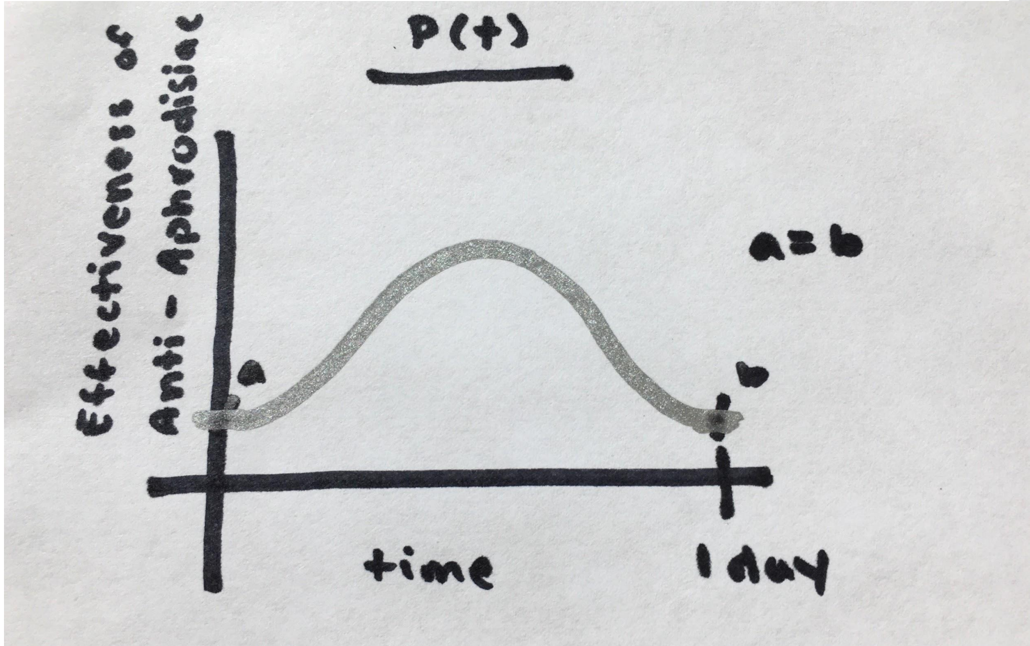
- Changes in the anti-aphrodisiac pheromone can have a drastic effect on both populations

- Choices of the weights (k1, k2) are crucial to model the trend of growth/decay in both populations

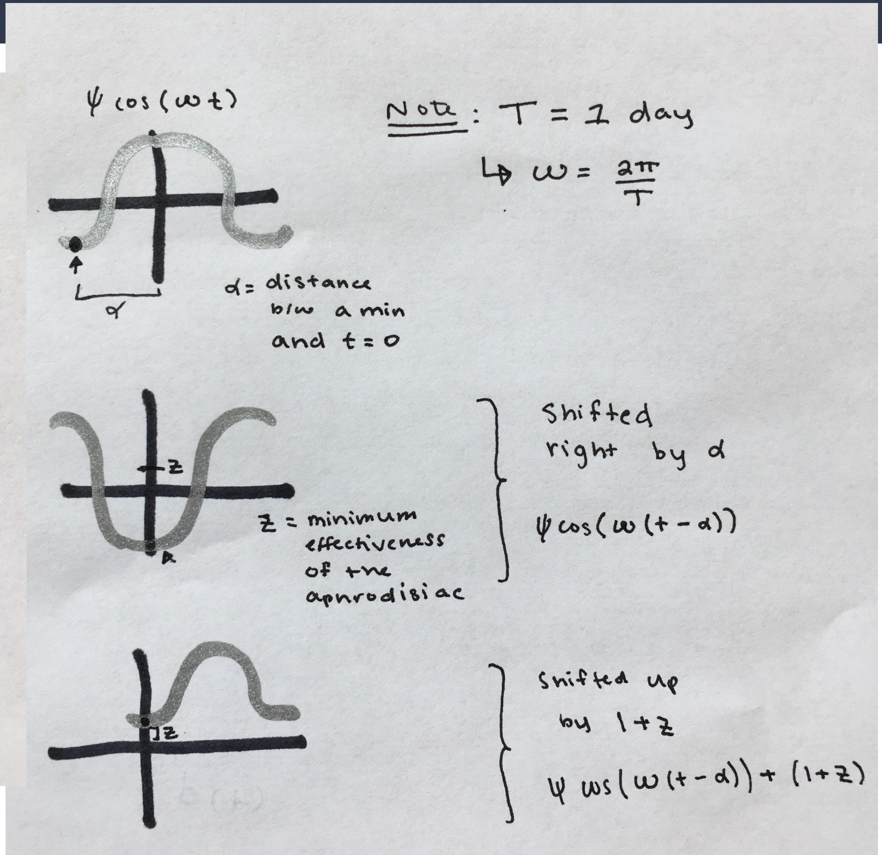
Future Work:

- Adding second wasp species that learns to exploit anti-aphrodisiac
- Improving coefficients estimates
- Better capturing the complexities of a butterflies life cycle
- Pheromone higher order
- Changing the model to go to 0 when population is beneath a certain value.

Anti-Aphrodisiac as function of Time



$$p(t) = p[cos(\omega(t - \alpha)) + (1 + z)]$$

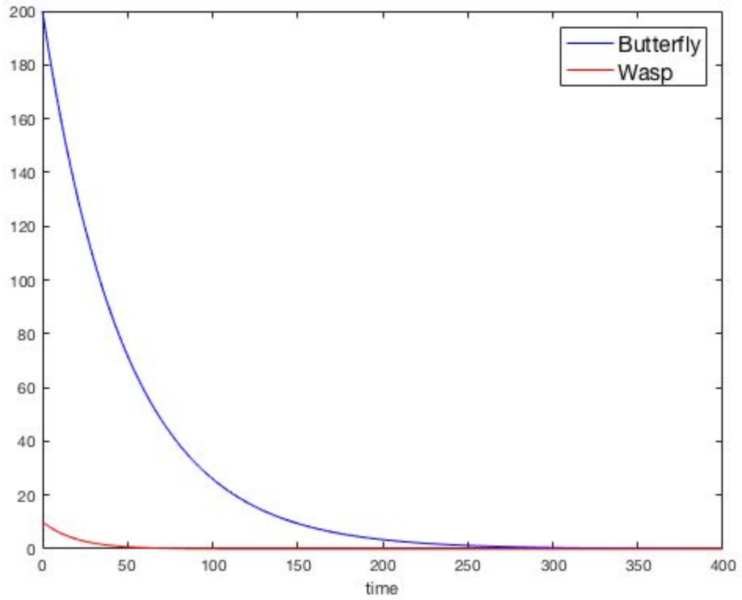


references

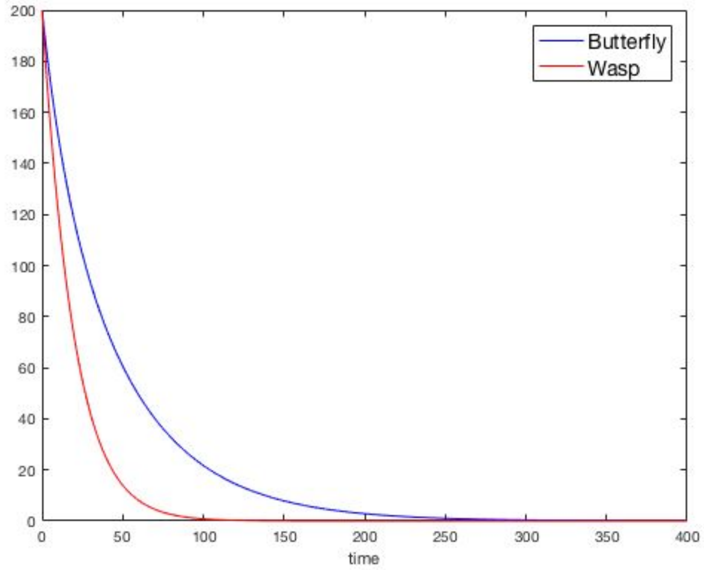
References:
Number of eggs per butterfly brood: https://academic.oup.com/beheco/article/21/3/470/219121
Incidence of butterfly: https://doi.org/10.20546/ijcmas.2017.611.227
Lifespan of butterfly: https://doi.org/10.20546/ijcmas.2017.612.420
Lifespan of Trichogramma wasp: https://greenmethods.com/trichogramma/
Lokta-Volterra Equation: http://www.tiem.utk.edu/~gross/bioed/bealsmodules/predator-prey.html

https://www.cabi.org/isc/datasheet/41157

Extra: p =0.1

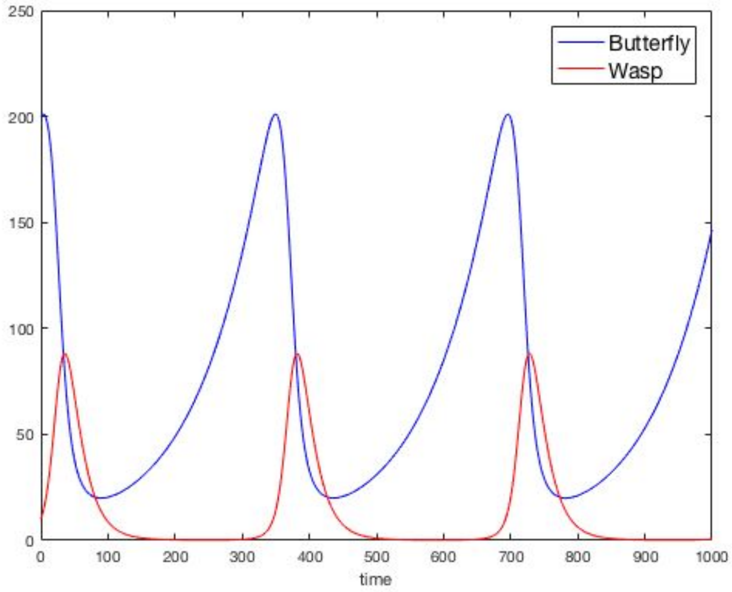


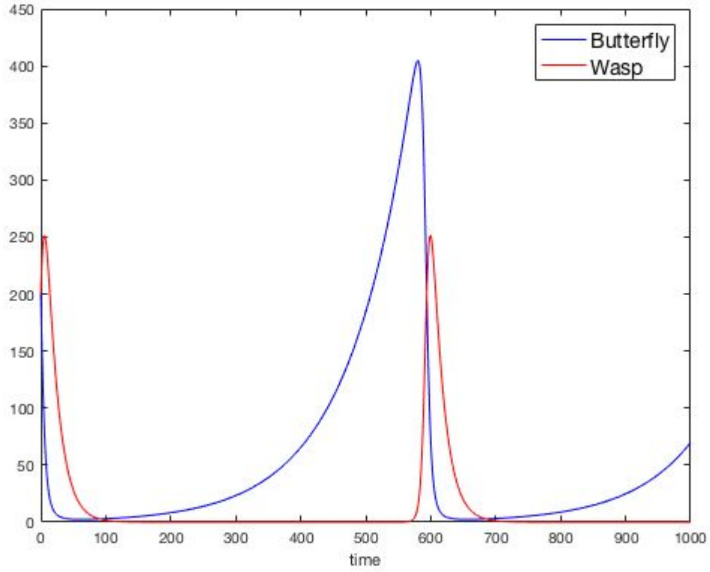
B=200
W=10



B=200
W=200

Extra: p =1.5

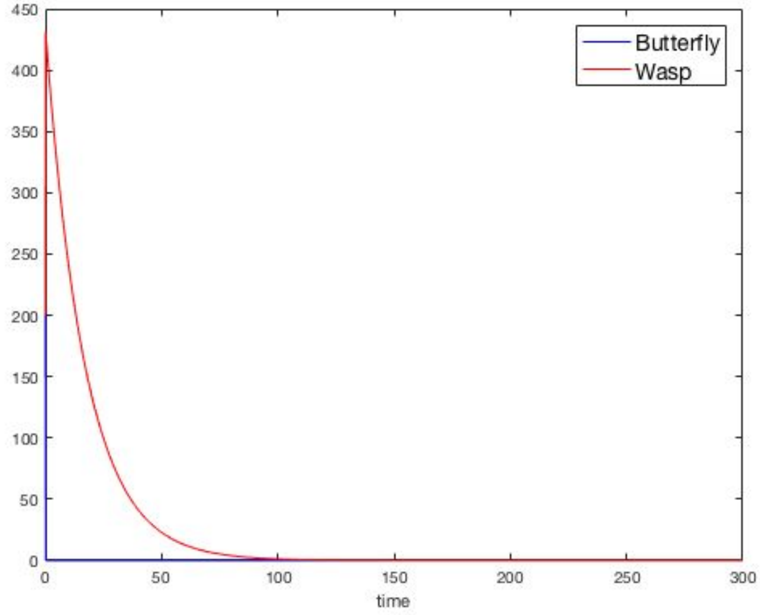




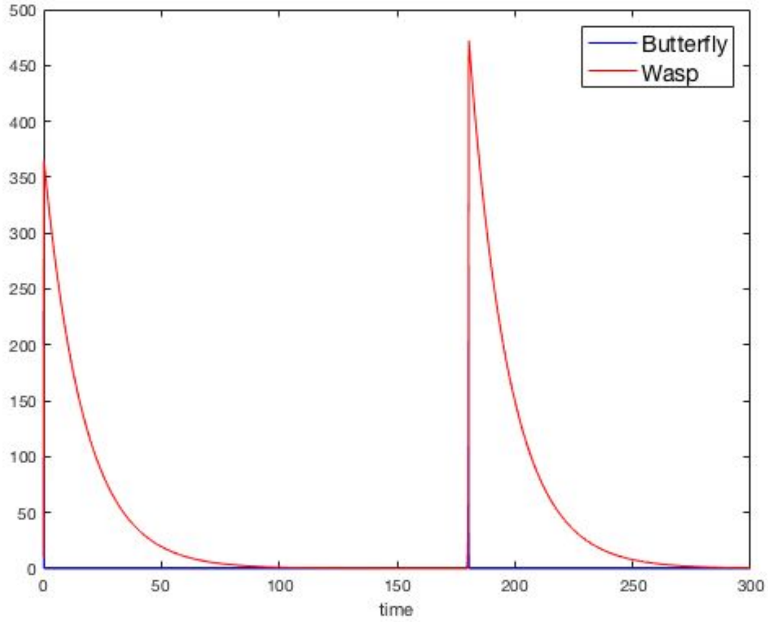
B=200
W=10

B=200
W=200

Extra: p=400 x 10^-6



B=200
W=10



B=200
W=200