Chemical Espionage in Butterflies(Problem c)

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Problem (I)

Pieris brassicae (large white)

Male butterflies transfer an anti-aphrodisiac to the female butterflies during mating to make sure that other male butterflies do not interrupt the female butterflies while they are laying the eggs.

Trichogramma brassicae wasp

Wasps use the anti-aphrodisiac of the butterflies to detect the mated-female butterflies, in order to get find and lay their own eggs in the fertilized butterfly eggs.

Our model determines how factors like amount of anti-aphrodisiac and the population of wasps affect the population of butterflies over time.

Assumptions made

Although there are 2 kinds of wasps, we combined both groups in to one parasitic wasp group and represented the rate of fertilized eggs be taken as one combined rate.

We used an average value for anti-aphrodisiac levels. Since we are covering larger populations, this should be close to what is seen in nature.

We assume an equal ratio of male to female butterflies.

We assume the rate of death of each insect.

Building the Model (I)

We start using a standard predator-prey model. We then added maximums, dictated by other environmental features (food, space, etc.), to both populations.

F(A) is the percentage of fertilized eggs, which is multiplied to the number of female wasp in the population.

P(A) is the percentage of fertilized eggs that were parasitized by the wasps.

D_w is the the wasp population’s die-off rate, and D_M is the die-off rate for butterflies.

$$P(A) = 0.01 + 0.04A$$

$$F(A) = \frac{1}{1 + e^{-10A + \ln(5)}}$$

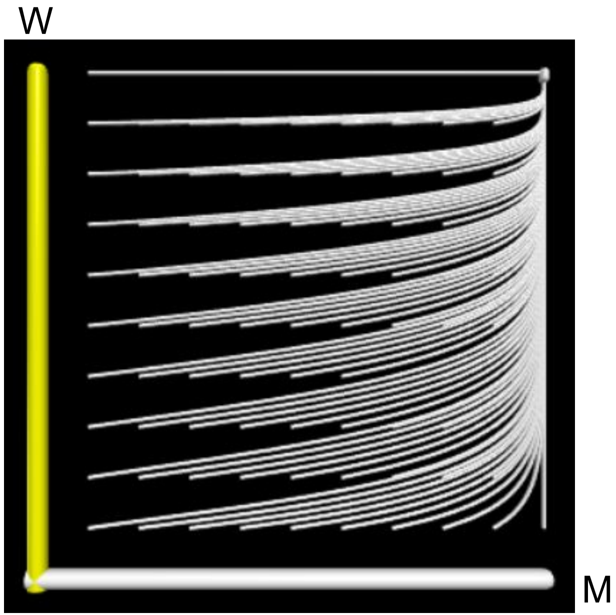
Building the Model (II)

To make our model adjustable for any population size, we made the range of both populations [0,1]. Which represent the percentage relative to the maximum possible population in the given environment.

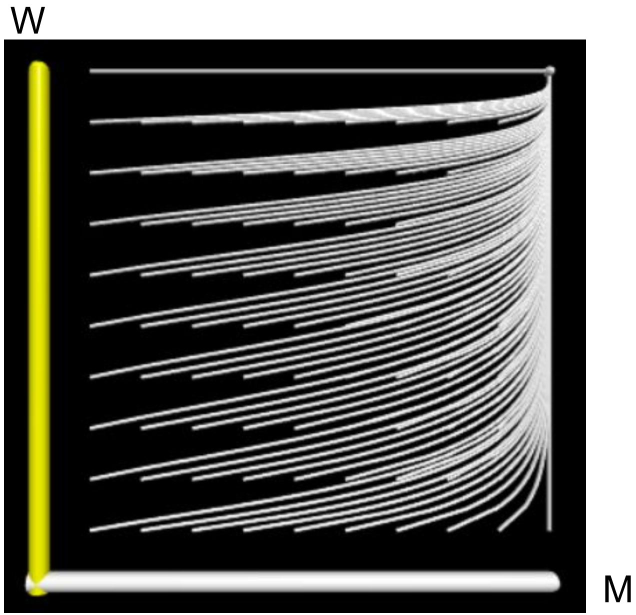
$$\frac{\partial W}{\partial t} = (1 - W)(-W D_W + W f M F P)$$

$$\frac{\partial M}{\partial t} = (1 - M)(f M F - W f M F P - M D_M)$$

Solutions for various initial conditions and AA-levels



AA = 0.1

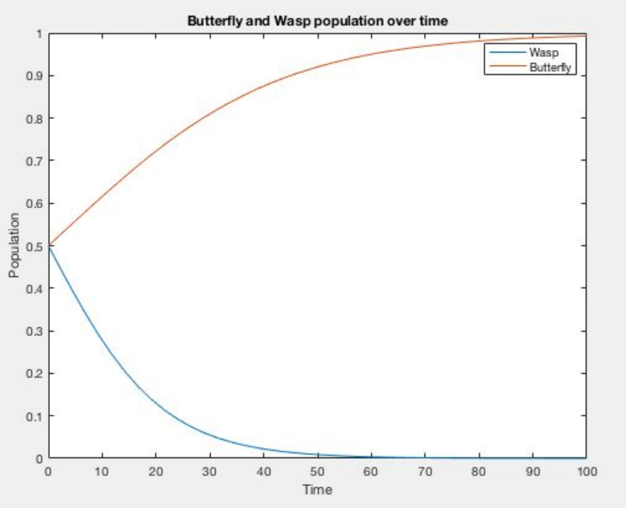


AA = 0.8

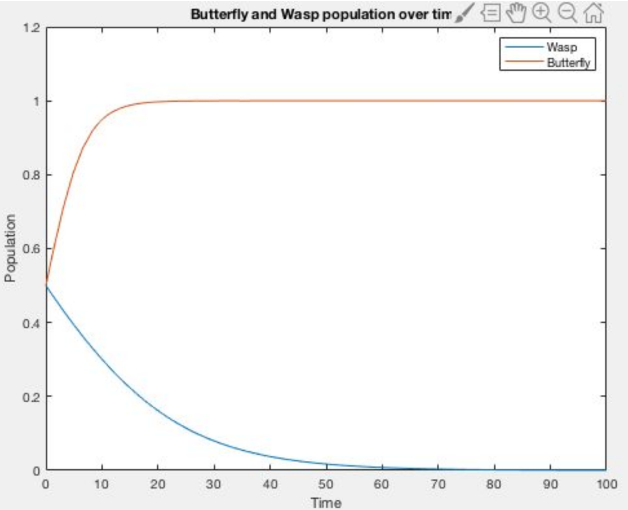
Constants: Dw = 2%, Dm = 1%

Graphs with different F values

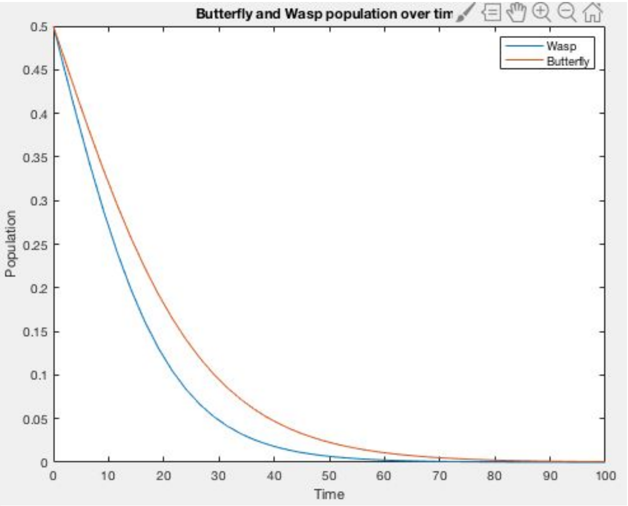
Constants:
P = .05
D_M = .1
D_W = .1
M = 50% of Max = .5
W = 50% of Max = .5



F = 0.3



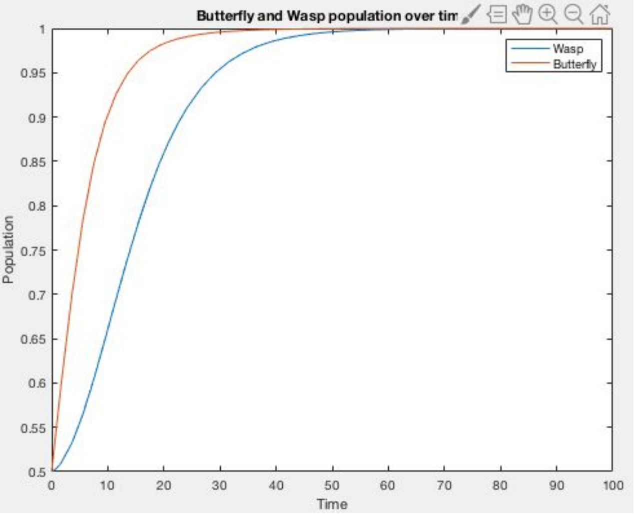
F = 0.8



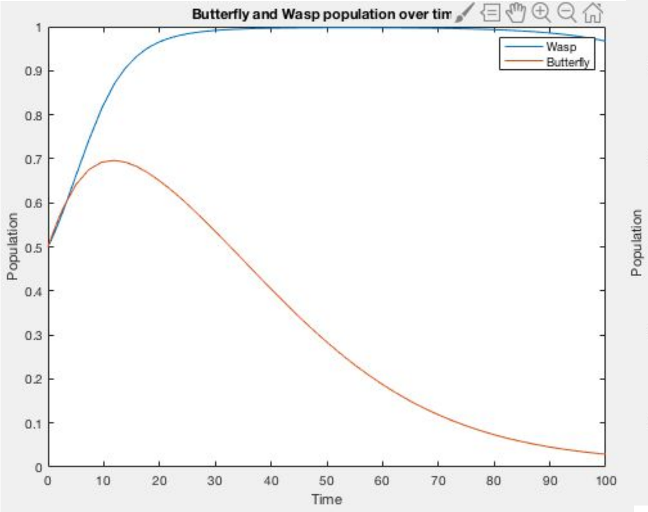
F = 0.05

Graphs with different P values

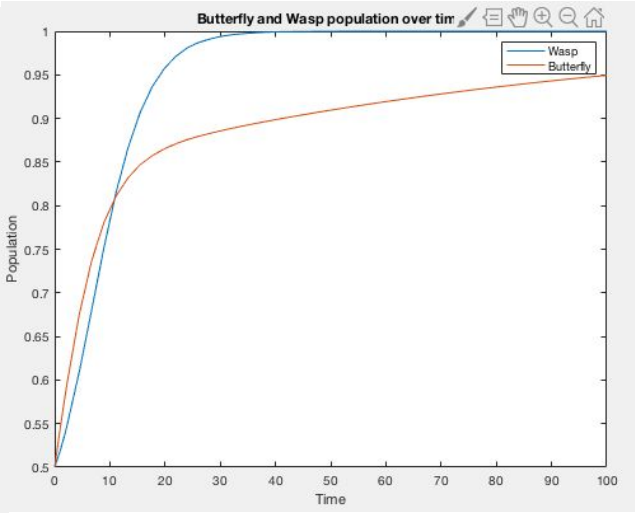
Constants:
F = 0.6
D_M = 0.1
D_W = 0.1
M = 50% of Max = .5
W = 50% of Max = .5



P = 0.9



P = 0.5

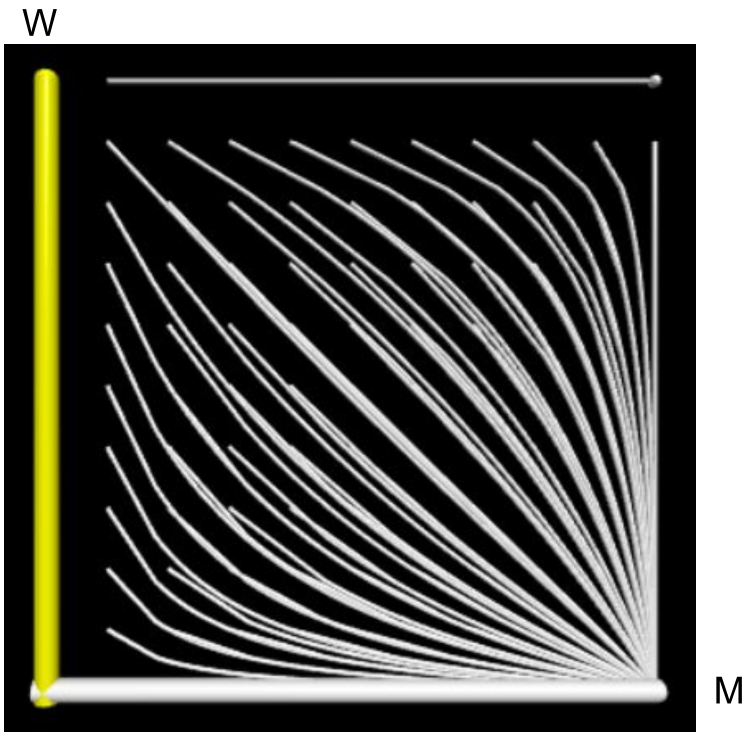


P = 0.75

Additional Problem C1:

To account for a predator that hunted both wasps and butterflies, we would increase the death rates for both species, possibly adjusting for the predator's preferred species.

Depending on the predation rate of, for example, birds, the wasps will go extinct. This is because their population is in a delicate balance between the wasp's Predation rate and their natural death rate. For the wasps to prosper, they will have to become more sensitive to the anti-aphrodisiac.



$A = 0.8$, $D_W = 0.6$, $D_M = 0.4$

Conclusions

In the Population vs Time graphs, the only times the wasp population and butterfly population did not decrease to 0 is when there was a high P value (0.75 and 0.9). Changing the initial values can lower the threshold for the P value. This means that the chance of the wasps actually laying their eggs into a butterflies egg is is very high given the circumstances we set.

Throughout our model building process we made assumptions to make our model simpler or easier to manipulate. When revising our model, we should consider these factors that we took out, such as the different types of wasps and how they behaved. This will hopefully help our model increase in accuracy at predicting real situations.

References

Martinus E. Huigens, et al. “Chemical espionage on species-specific butterfly anti-aphrodisiacs by hitchhiking Trichogramma wasps”. *Behavioral Ecology*, Volume 21, Issue 3, May-June 2010, Pages 470–478, https://doi.org/10.1093/beheco/arq007

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