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SCUDEM Executive Summary
Problem C: Chemical Espionage

Introduction

The large cabbage white butterfly *Pieris brassicae* (*P.b.*) experiences brood parasitism by the wasp species *Trichogramma brassicae* (*T.b.*) and *Trichogramma evanescens* (*T.e.*). *T.b.* and *T.e.* are attracted to the sexual chemical messengers present on mated female *P.b.*, causing them to significantly prefer attaching to mated females over virgin females or male *P.b.* (1). Female *P.b.* release aphrodisiacs to attract males, and male *P.b.* release the anti-aphrodisiac benzyl chloride (BC) upon mating with a female to dissuade other males from mating with the same female. This ensures monogamy and allows the female, who is no longer being harrassed by males, to invest more time and energy into laying her eggs in a safe area; however, the mix of female and male pheromones attracts *T.b.* and *T.e.* wasps, which attach to the mated female *P.b.* and lay their eggs within the *P.b.* eggs. Thus, male *P.b.* are under two opposing selective pressures; increased BC release reduces the likelihood of competition with other males, but increases the likelihood of the parasitism of their offspring by *T.b.* and *T.e.* (1).

Modeling and Assumptions

We made several assumptions in our models. For our first model, we had an initial population of 1200 butterflies, half of which were female. We assumed that female mated *P.b.* lay 35 eggs at a time (1), and that the female *P.b.* dies upon laying eggs. We also assumed that when a female wasp of either species successfully parasitizes a batch of eggs laid by a female *P.b.*, 29 of the 35 eggs laid by *P.b* are parasitized (2). Although the ratio of male to female *P.b.* is not truly equivalent, we chose to simplify our model by making the assumption that the total butterfly population is equal to twice the total live female population at any given time. In other words, the population of male *P.b.* is always equivalent to the population of female *P.b.*.

It should be noted that *T.b.* are naturally attracted to mated *P.b.*, whereas *T.e.* become more likely to parasitize *P.b.* after “one successful ride”, meaning that they have successfully parasitized a batch of eggs once; to simplify the model, though, we assumed *T.b.* always have a 7.1% chance of successfully parasitizing eggs (2), and that *T.e.* have a slightly lowered 6% chance given they must learn to attach to *P.b.*

For our second model, we kept the same initial conditions and parameters as the first model. We then assumed that every egg laid in a safe location hatches and survives, whereas eggs laid in an unsafe location will only survive 30% of the time. We also assumed that, when pestered by males, females will lay their eggs in an unsafe location ¾ of the time.

Conclusion

From these assumptions we created two models. The first modeled the effect of the interaction between the butterflies and wasps on the butterfly population, and the other modeled the effect of the interaction of unwanted male butterflies with female butterflies on butterfly populations. From our models, we saw that, over time, the butterfly population increased with the anti-aphrodisiac but decreased without the anti-aphrodisiac. This is supported by the empirical observation that enforcement of monogamy provides *P. brassicae* a selective advantage.

Future Directions

In the future, we would like to expand our model to include known sex ratios for butterflies, which is 3:2, female to male. We would consequently account for the interaction between male and female *P.b.* populations to account for changes in breeding rates due to unequal male and female populations. We would also want to account for eggs that fail to hatch by including an ‘egg death rate,’ though this could be accounted for by further reduction in the rate at which eggs transition into adults. In addition to this, we want to account for the lifespan of butterflies and wasps by giving them an age limit (14 days after hatching). We would also want to explicitly include the fact that *T.e* are more likely to parasitize eggs after one successful ride and parasitization of *P.b* eggs. Finally, we would like to include a carrying capacity, to indicate the largest size that the population could exist as without causing damage to the ecosystem or depleting the environment of resources, since populations cannot indefinitely grow exponentially.

Appendix

Our Models:

With Anti-Aphrodisiac:

Pop of female butterflies before/after eggs begin to hatch:

$\frac{dV}{dt} = -V - V \qquad \frac{dV}{dt} = \frac{1}{2}(E_b + E_e + E_n) - V - V$

$\frac{dM}{dt} = V$

Population of *T.b.* before/after eggs begin to hatch:

$\frac{dV\,Tb}{dt} = -Tb - Tb \qquad \frac{dV\,Tb}{dt} = \frac{24}{29}(TE_b) - Tb - Tb$

$\frac{dM}{dt} = V\,Tb$

Population of *T.e.* before/after eggs begin to hatch:

$\frac{dV\,Te}{dt} = -Te - Te \qquad \frac{dV\,Te}{dt} = \frac{24}{29}(TE_e) - Te - Te$

$\frac{dM}{dt} = V\,Te$

Eggs laid each day:

$\frac{dEb}{dt} = (\lambda - \Phi)(??_b M T_b) \qquad \frac{dTEb}{dt} = \Phi(??_b M T_e)$

$\frac{dEe}{dt} = (\lambda - \Phi)(??_e M T_e) \qquad \frac{dTEe}{dt} = \Phi(??_e M T_e)$

$\frac{dEe}{dt} = \lambda(??_n M)$

With Anti-Aphrodisiac:

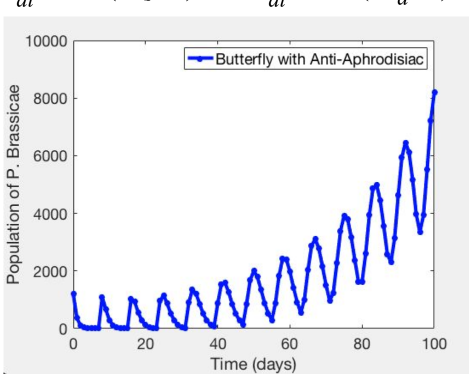
Pop of female butterflies before/after eggs begin to hatch:

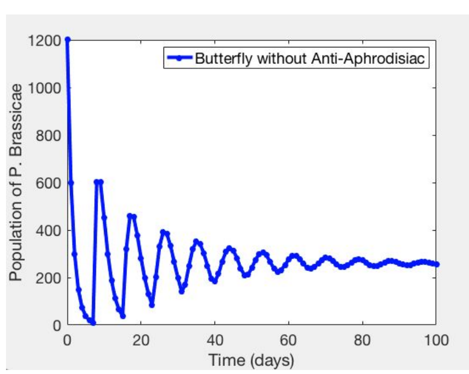
$\frac{dV}{dt} = -V - V \qquad \frac{dV}{dt} = E_s + \gamma E_d - V - V$

$\frac{dM}{dt} = V$

Eggs laid each day:

$\frac{dEs}{dt} = \lambda(??_s M) \qquad \frac{dEd}{dt} = \lambda(??_d M)$





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