Chemical Espionage

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Scenario:

The large cabbage white butterfly *Pieris brassicae* uses chemical signals to find mates. The female uses an aphrodisiac to attract males, and the males will use an anti-aphrodisiac to mask or dissuade other males. These chemical signals can be exploited by parasitic wasps, which detect the anti-aphrodisiacs, follow the female butterfly, and lay their own eggs in the butterflies' eggs.

The use of these chemicals presents two competing pressures on the butterfly population. Using the chemicals increases the chances of fertilizing eggs and promotes population growth, but it also increases the chance of the eggs being eaten by wasp larvae.

The relationship between the two competing interests can be modeled by the interactions between the male and female *P. brassicae* as well as the parasitic wasps.

Simplified Assumptions:

1. Climate does not play a factor
2. Plant type does not matter for the butterflies
3. All butterflies take a mate
4. Death rate of butterflies accounts for all death types
5. No distinction between the two types of wasps
6. Wasps only reproduce through taken *Pieris brassicae* eggs

Model:

To model the relationship between P. brassicae and the wasps, we need to look at how each of the species are affected. To start, we look at how the wasp population changes with respect to time. Since the wasps only reproduce through P. brassicae eggs, their birth rate depends on the number of butterflies (B), the ratio that are female butterflies (K_2), the average amount of eggs laid by female butterflies (K_3), and the chance a female wasp mounts a mated female butterfly (K_4). We also need to account for the fact that male butterflies will sometimes not place the anti-aphrodisiac on the female if it is not threatened by other males, or if the wasp population is very large. This is accounted for by the ratio of the two populations multiplied by the ratio of males that use the anti-aphrodisiac (K_5).

$$\frac{dW}{dt} = (K_1 W)(BK_2K_3K_4) - K_5\frac{W}{B} - K_7W$$

$$\frac{dB}{dt} = BK_2K_3 - K_6B - WK_1K_4(K_5\frac{W}{B})$$

Variables:

W: wasp population

B: butterfly population

K_1: ratio of female wasps to total population

K_2: ratio of female butterflies to the total population

K_3: average amount of eggs laid by female butterflies

K_4: chance female wasp mounts a mated female butterfly

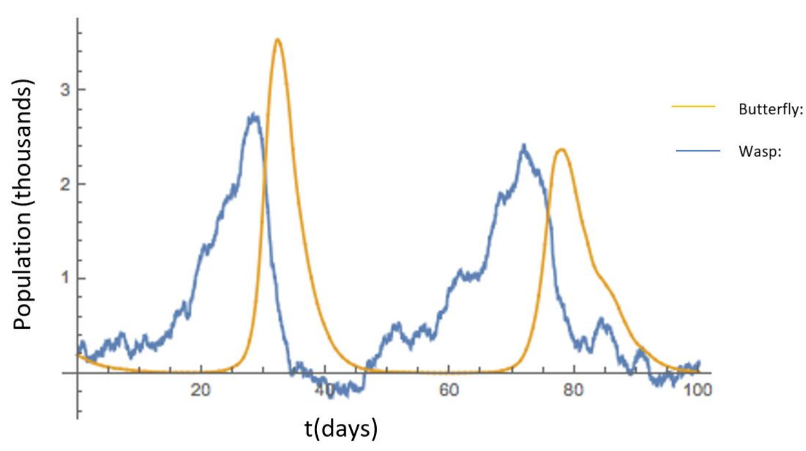
K_5: ratio of male butterflies using the anti-aphrodisiac

K_6: natural death rate of the of butterfly population per day

K_7: natural death rate of wasp population per day

Analysis:

Using data from Huigens' paper "Chemical espionage on species-specific butterfly anti-aphrodisiacs by hitchhiking Trichogramma wasps," we found reasonable values for our constants. Female P. brassicae produce on average 35 eggs, and their ratio of females is about 0.2. We assumed that the wasps also had similar female ratios. We also assumed that the average lifetime of a butterfly is about 10 days, and that a wasp lives for about 15 days. While the male butterflies want to use anti-aphrodisiacs, when the population of butterflies is lower, they will not need to mask the females, thus keeping their population from being overrun by the wasps. As the butterfly population increases, more males will begin masking their mates, creating more room for wasps to thrive. In our graph below, as time goes on, both populations go to zero, but in nature this will not happen due to other outside factors.



References:

[1] “Chemical espionage on species-specific butterfly anti-aphrodisiacs by hitchhiking Trichogramma wasps, “ Martinus E. Huigens, Jozef B. Woelke, Foteini G. Pashalidou, T. Bukovinszky, Hans M. Smid, and Nina E. Fatouros. Behavioral Ecology. Volume 21, Issue 3, MayJune 2010, Pages 470–478, 11 February 2010. https://doi.org/10.1093/beheco/arq007 .