Problem C: Chemical Espionage
SCUDEM IV 2019

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Contents:

The Problem:

- Anti-aphrodisiacs help female *Pieris brassicae* to be able to focus on finding the best location to place their eggs; however, these chemical signs increase the egg's risk of being eaten by the wasp larvae.

- Determine the best balance between both interests and what is most likely to happen in the future.

Assumptions:

- The two identified wasp larvae are the species aiming to eat the *Pieris brassica's* eggs.
- "Most likely" the wasp larvae's eggs will eat the butterflies' eggs.
- The wasp larvae detect the anti-aphrodisiacs (chemical signals) when a male produces them to seduce other males.
- Wasps eggs will "arise" before butterfly eggs or they hatch at the same time, but wasp larvae are more dominant than butterfly larvae.
- Larvae will eat butterfly eggs and impinge on their population growth.
- When wasps are "more likely" to consume butterfly eggs, we assume it means between 50% to 99.9%.

Variables:

- The variables that we came up with are relating population with time

Two Groups:

1. Dependent Variables:

- Population of eggs.
- How many parasitic wasps (larvae) are formed
- How many females want to reproduce
- How many males are ready to reproduce
- How many wasps want to be parasitic and lay their eggs.

2. Independent Variables:

- Time
- Amount of chemical signals (anti-aphrodisiacs)
- How many eggs are eaten
- Amount of female and male butterflies as well as wasps

Variables Continued:

- $\frac{dP}{dt}$ = The rate of butterfly population growth with respect to time
- P = Population
- P_o = Initial Population
- F = Number of females that can reproduce
- X = Number of eggs per clutch (butterfly)
- Y = Number of eggs per clutch (wasp)
- L = Number of parasitic wasps

Derivation:

Relating population with time, this differential equation generates:

$$\frac{dP}{dt} = P_O + F_x - L_y$$

Simplifying the equation gives us,

$$\frac{dP}{dt} = \text{M} + \text{F} + F_x - L_y$$

To further elude, M + F = P_o

Derivation Continued:

Simplifying more:

$$dP = \left[(M + F) + F_x - L_y \right] dt$$

$$P = (M + F) + F_x \mathrm{t} - L_y \mathrm{t}$$

$$(M + 2F)t + F_x - L_y t$$

The Solution:

- The tradeoffs of this system are that both male competition and parasitic larvae dwindle the population growth of the butterfly species. While the clutch size of the butterfly is larger than the clutch size of the parasites, the number of butterflies that are females are half the population of the eggs that survive (if we assume a 1:1 ratio of male to female gender). While not only the population grows slower due to parasites, the number of wasps increase as well which will further endanger the population. At the same time, the strength of the chemicals and their success rate must be taken into consideration as well. We have not solved the differential equation, but we did take into account all possible variables. Our theory is that as time progresses, the population of wasps will overcome the butterfly population, therefore making the butterfly species extinct.

What is likely to happen in the long run?

- As long as there is a strong enough chemical strength, then the population of the butterflies should grow, given that the clutch size of butterflies is larger than the clutch size of the wasps. However, if the chemical strength is not strong enough, then the number of successful eggs will decrease due to other males interfering with the females with the combination of parasitic wasps.

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 .

Thank You

Questions ?