Modeling and simulation of the caste ratios in ant genus Pheidole

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Overview

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Introduction

Ant colonies are composed of a single queen,soldiers and workers. The ratio between soldiers to minor workers is always in the range of 5 to 25 percent. Colonies self regulate and produce the aforementioned range.
An ant colony can be used as a model to gain insight to other systems since they can be divided into individual parts and studied.

Influences

A couple of factors influence the caste ratios, they include [1]

- Internal influences
- External influences
- Colony Development and life cycle
- Evolution

Approach

There are many avenues to explore when trying to predict the subcaste ratios. And they include

- Mapping the Genomics to the phenotype.
  - Gene regulation modeling
  - influence of the ecological and social behaviour on the phenotype and in turn the genomics.
- Evolutionary strategies (e.g. Darwinian Dynamics, Evolutionary Game theory)
- Biological and Mathematical modeling for this project difference equations were used.

Difference Equations

For the number of eggs we have

$$N_{egg_{t+1}} = N_{egg_t}(1 - \mu_{eggs_{f_1}} + ... + \mu_{eggs_{f_n}}) + k_{egg} \quad (1)$$

For the number of soldiers we have

$$N_{s_{t+1}} = N_{s_t}(1 - \mu_{s_{f_1}} + ... + \mu_{s_{f_n}}) + k_s N_{egg_t} \quad (2)$$

For the number of workers we have

$$N_{w_{t+1}} = N_{w_t}(1 - \mu_{w_{f_1}} + ... + \mu_{w_{f_n}}) + k_w N_{egg_t} \quad (3)$$

Caste Ratio

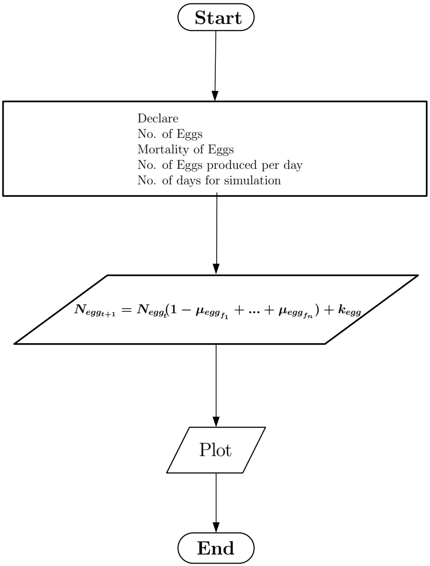
Ratio between soldiers to eggs is

$$\frac{N_{s_{t+1}}}{N_{w_{t+1}}} \tag{4}$$

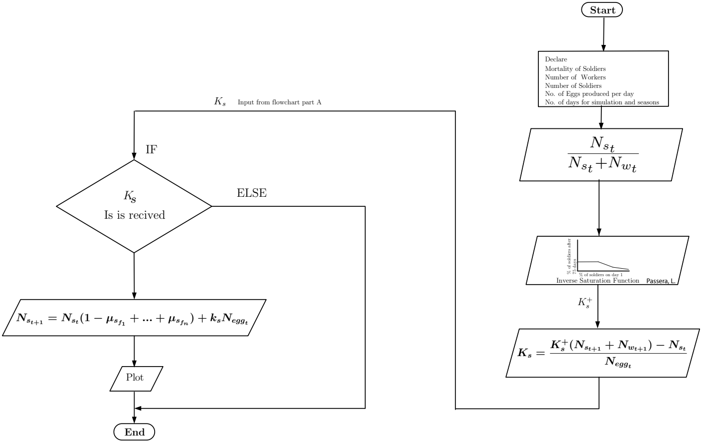
which is in the range between 5 to 25 %
or in vector form is

$$\begin{pmatrix} N_{s_{t+1}} \\ N_{w_{t+1}} \end{pmatrix} \tag{5}$$

Number of Eggs Flowchart



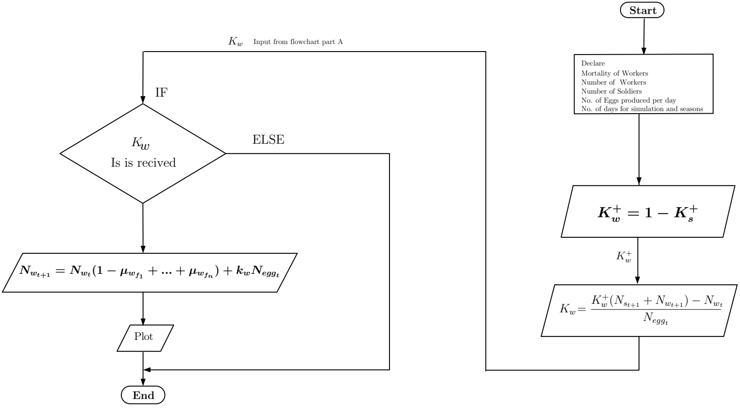
Soldier Flowchart



Flowchart part B

Flowchart part A

Workers Flowchart



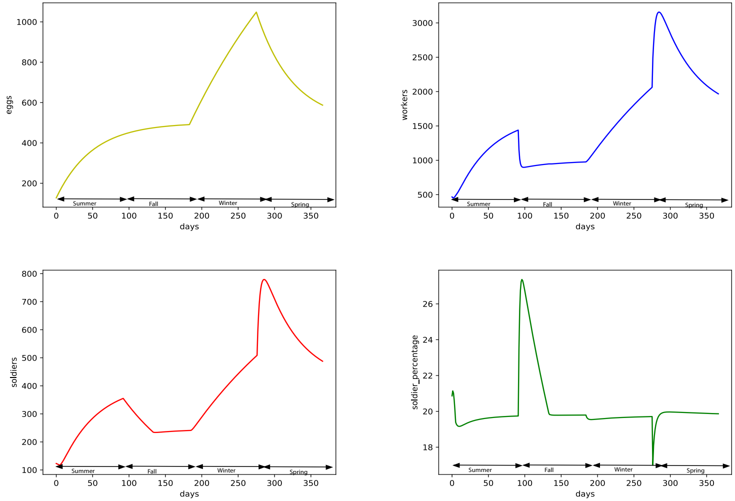
Flowchart part B

Flowchart part A

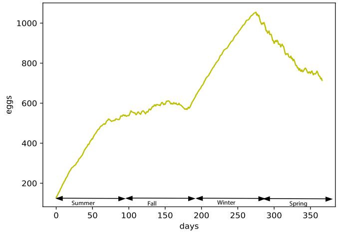
Simulation

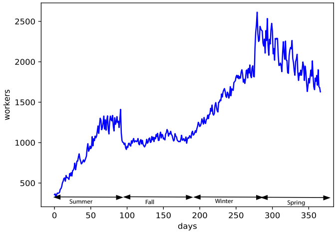
The simulation can be run for either varying seasons or months or years. The simulation starts of with summer at day 0.
Initial values for the simulations were as follows:
No. of Seasons is 4 and days is 365
Eggs produced is per day is 10 and the initial number is $N_{eggs} = 120$
mortality of eggs $U_{eggs} = 0.02$ for all the year except winter when it is $U_{eggs} = 0.005$ when it's lower.
initial number of soldiers $N_s = 50$
mortality of soldiers $\mu_s = 0.010$
initial number of workers $N_w = 600$
mortality of workers is $\mu_w = 0.5$

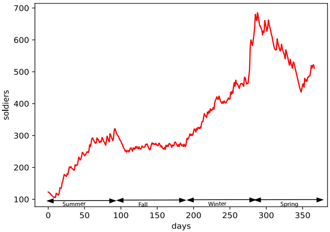
Figures

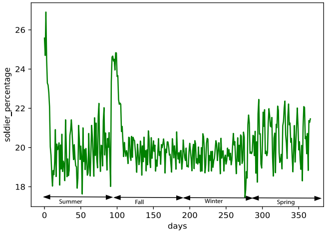

eggs
workers
soldiers
soldier_percentage
days
Summer
Fall
Winter
Spring
0 50 100 150 200 250 300 350
200 400 600 800 1000
500 1000 1500 2000 2500 3000
100 200 300 400 500 600 700 800
18 20 22 24 26

Simulation following a Random uniform distribution









Challenges

Resource modelling
finding if the soldiers or workers are regulating, the caste ratios
In addition to that, including the resource in the model.
It can be an additive term from

$$\frac{dN}{dt} = rN\frac{(K-N)}{K} \tag{6}$$

where r is the rate of change per individual and N is the population number. And K is the carrying capacity. (6) Is known as the VerhulstPearl equation.

Challenges

Another proposed additive or multiplicative term to model resources is

$$x(N_w K + N_w^2) \tag{7}$$

where x is the contribution of each individual in the colony e.g. in mg, and K is the carry capacity i.e. maximum population in the colony. (7) can similarly be written for soldiers.
The effects of nutrition on the production of soldiers. A high protein diet does influence soldier production in an incremental order.

References I

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