Lab Report on Predator-Prey Dynamics

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1 Abstract

In this report we want to analyse the predator prey dynamics, and find the most successful predator. Here we construct a model experiment using trays, paper cups and various cutlery as appendages. We performed this experiment until 7 rounds of generation, and concluded that for our experimental *niche*, the predator with **spoon**(i.e Raptorial legs) emerged as the most successful predator with formulated **PSI = 0.8850**. Finally we tried to find answers to a few questions related to our experiment.

2 Introduction

2.1 Population Growth Equation

In a population, Birth Rate, $B = b_o - aN$ and Death Rate, $D = d_o + cN$

Population growth equation that includes **birth(B) and death(D)** rates:

$$\frac{dN}{dt} = B - D = (b_o - d_o) - N(a + c)$$

where, N is the population size at time t.

Carrying capacity (K)- maximum sustainable population size for the prevailing environment.`Birth and death rates are equal.` It is a function of the supply of resources (e.g. food, water, space, etc.).
Population growth equation in terms of carrying capacity (K):

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

where, $K = \frac{b_o - d_o}{a+c}$,
the per capita growth rate, $r = \frac{b_o - d_o}{N}$.
The term $(1 - \frac{N}{K})$ regulates the population growth.

- When $N < K$, the term $(1 - \frac{N}{K})$ approaches 1,and the population growth is exponential (rN).
- When $N > K$, the term $(1 - \frac{N}{K})$ approaches negative value, and the population declines.
- When $N \to K$, the term $(1 - \frac{N}{K})$ approaches zero, and the population growth slows down.

2.2 Classification of species

1. Generalist species - A generalist species is able to thrive in a wide variety of environmental conditions and can make use of a variety of different resources (for example, a heterotroph with a varied diet).
2. Specialist species - A specialist species can thrive only in a narrow range of environmental conditions or has a limited diet.

2.3 Species Interactions

In most habitats, we find mainly two types of species interaction exists:

1. Intraspecific competition - Interaction between individuals of same species for resources.
2. Interspecific competition - Interaction between two different species for resources. Eg. Two different species sharing same habitat, predator-prey interactions.

Some populations undergo cyclical oscillations in size. *Cyclical oscillations* are repeating rises and drops in the size of the population over time. In many cases they are due to interspecific interactions.

2.4 Predation

Predation involves four steps: **search, recognition, capture, and handling.**

The possibility of co- evolution of predator and prey operates at each of these steps. Among insects, three predator forms are common:

1. Mandibles - ground beetles, tiger beetles, and ant lion larvae
2. Raptorial legs - praying mantids, giant water bugs, and ambush bugs.
3. Grasping legs - dragonflies, robber flies, and scorpion flies.

3 Methodology

In this exercise, we have used a variety of feeding appendages to search the environment (*tray*), grab prey items and place them into the stomach (*paper cups*). Forks, spoons and knives have been used to represent *Grasping legs, Raptorial legs and Mandibles* respectively.
We set up our model experiment in the following way:

3.1 Set-Up

3.1.1 Foraging Rules:

1. Foraging represents predator searching and capturing prey items. Foraging time was modulated.
2. The predator had to use only its feeding appendage to capture prey.
3. The paper cups given represented the predator's stomach. All prey had to be put here. Prey items that did not reach the stomach or fall on the way to the cup were discarded and not counted.
4. Once the prey was inside the predator's stomach, another predator could not take it. However, while carrying the prey to the stomach, another predator could attack and snatch it away.
5. The predator stopped foraging when the stomach had been filled or when the time expired(whichever happened first).
6. The stomach had to be held upright at all times (no shovelling).

3.1.2 After Foraging/Digestion:

1. After feeding, the predators digested their prey. It was represented by the time taken to determine the number and kind of prey species in their stomachs.
2. The data was recorded after each round in the sheet given.
3. The exercise stopped when either one prey or predator went extinct, or after 7 rounds were completed.

3.2 Rules

3.2.1 Predator Rules General

1. A predator who had less than or equal to 3 prey species for three consecutive rounds went extinct.
2. At the end of the exercise, the most successful predator was identified by formulating the **PSI**[4.2].
3. In the 1^{st} round, consuming more than 2 poisoned prey will cause vomiting (the poisoned prey will only be revealed after completion of 1^{st} round). From the 2^{nd} round, consuming 2 or 3 poisoned prey, will cause vomiting, and consumption of more than 3 poisoned prey will cause death.

3.2.2 Prey Rules General

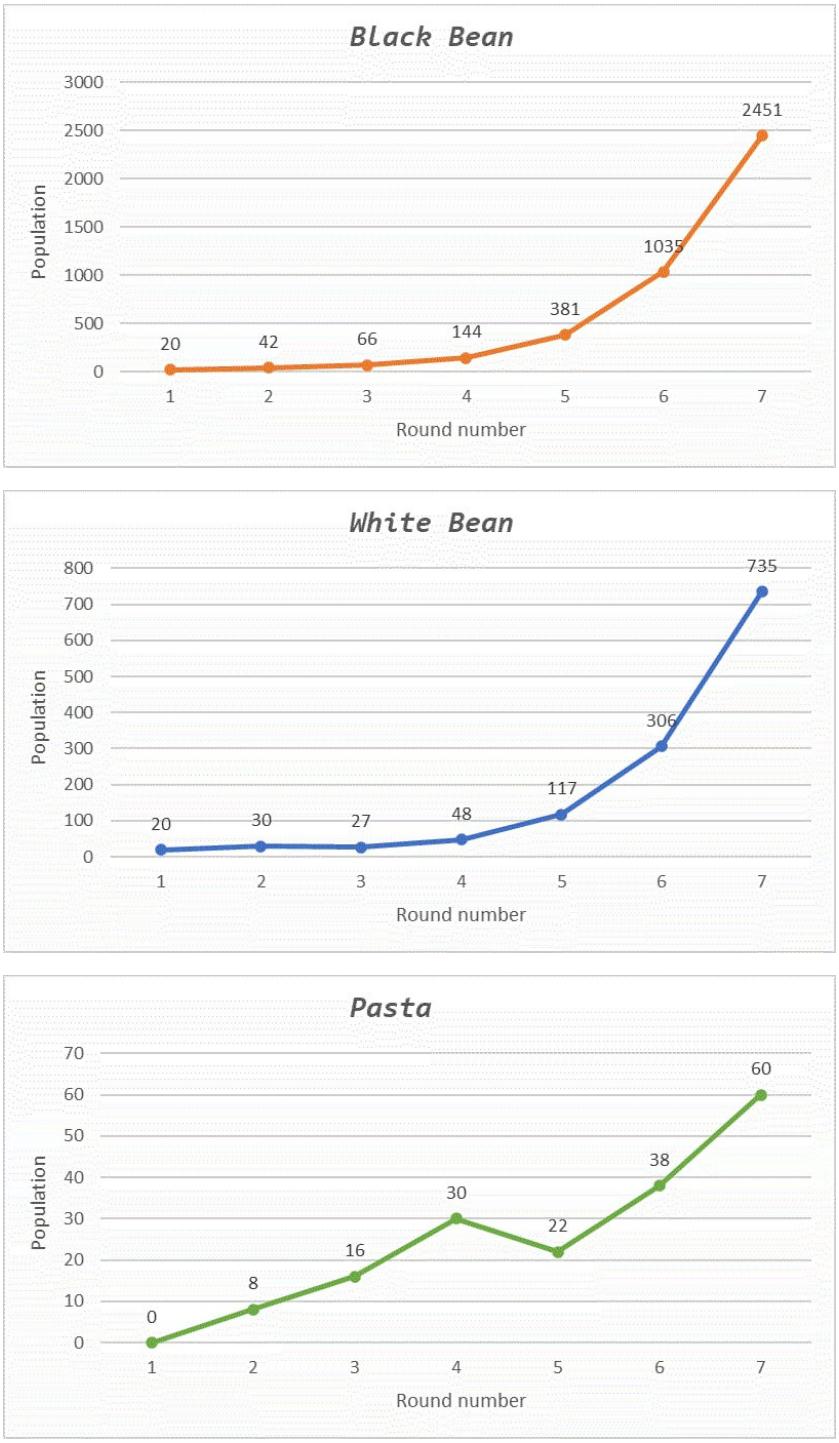
1. Based on the number captured, the number of prey remaining in the environment per species was calculated, `Total number - Number of preys eaten = Number of preys surviving.`
2. The prey reproduced at a rate of three individuals for each that remained in the environment. While, the *poison* prey reproduced at a rate of two individuals.
3. In general, no. of prey species could not exceed the capacity of the tray provided.

3.3 Report Preparation

This experiment was performed in Biology Laboratory(DBS), at AAC building, IISER-K. Graphs and pie charts were plotted using `MS-Excel`. And the report was typeset with the help of LaTeX, using TexStudio.

4 Results

From our model experiment, we find the population growth of the three species(through 7 generations) of prey namely: black bean, white bean and pasta. They are plotted below.



From first two figures, we find an *exponential* increase in the population of black and white beans respectively. While the last figure, indicates an approximately *linear* increase in pasta population.

In the next page we analyse prey consumption of each predator type.

We can infer that, predator 1 preferred white beans, whereas predator 2 and 3 preferred black beans.

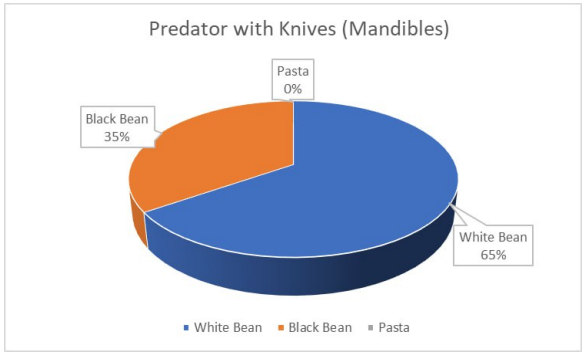


Figure 1: Predator 1: Knives

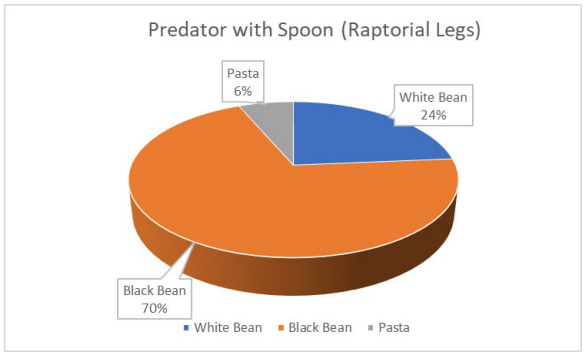


Figure 2: Predator 2: Spoons

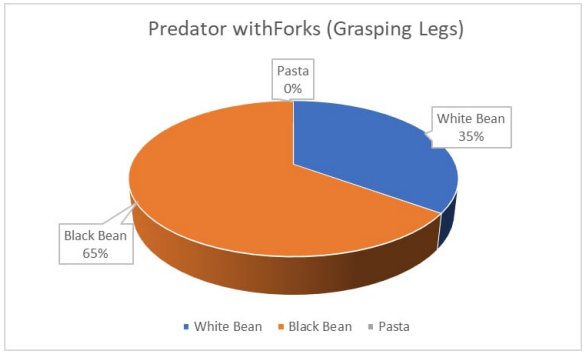


Figure 3: Predator 3: Forks

4.1 Poisoned Prey

After the first round was over, the pasta was declared to be poisoned and a predator having 2 or more of it was considered dead.

After the 3^{rd} round however, the predator with raptorial legs (represented by a pair of spoons), developed resistance against this poison. It could consume any kind of prey thereafter. The other two predators thrived on black beans and white beans only.

4.2 Predator Success Index (PSI)

Now we find the most successful predator in our group, by defining an index I_S:

$$I_S = \frac{c_i}{T}$$

where,
c_i= No. of prey consumed by i^{th} predator
T = Total prey consumed by all predators

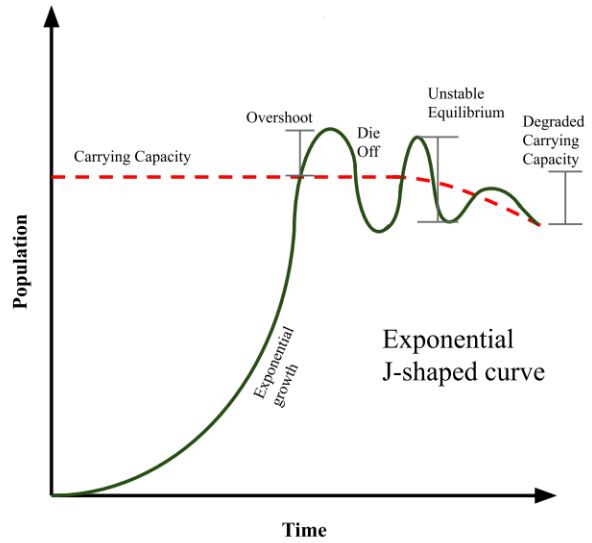
Predator	**Species**	c_i	I_S
1	Knives	26	0.0336
2	Spoons	685	0.8850
3	Forks	63	0.0814
		T= 774	

Hence the most successful predator in our group is Spoon (Raptorial Legs).

5 Discussions

Q1. When a potential prey becomes toxic, what happens to the number of prey individuals of this population initially? Will their numbers increase indefinitely?

Ans) When a potential prey becomes toxic, the predators stop feeding on that prey. So, the immediate effect is seen to be an abrupt increase in their population. As the population of the prey increases, it reaches the carrying capacity of the environment (that depends on different factors like nutrition availability, sunlight, climate,etc) and overshoots. Then the population starts decreasing and after few generations, it becomes *constant*(equal to the carrying capacity). If a predator develops resistance to the poison, then the carrying capacity decreases further.



Q2. What happens when prey reproduce more quickly than that can be controlled by predators? What other factors control populations?

Ans) When a prey reproduces more quickly than that can be controlled by predators, its population will grow and overshoot the carrying capacity of the environment. This results in an increase in the death rates (due to increased competition) of the prey species and the population will come down. It will slowly become constant at the carrying capacity of the environment.

The other factors that can control the population size (which essentially contributes to the carrying capacity of the environment) include: -

1. **Birth Rate -** High birth rate will cause quick rise in the population
2. **Mortality Rate -** Low mortality rate cause a rise in the population
3. **Climate -** If the climate is favourable for the population, then the carrying capacity of the environment will increase.

Q3. What would happen if the environment was affected by chance events like cyclone or drought. Which of the species (Specialist or Generalist) will survive and why?

Ans) In case of chance events like cyclone or drought, both predator and prey population will fall drastically. Now, only the *Generalist* species will thrive as they consume a wide variety of foods that may be available after the calamity.

Due to limited food supply, the *Specialist* species will find it difficult to satisfy their dietary needs and thus their population will experience severe intraspecific competition and they will face a risk of getting endangered (extinct if situation is too harsh).

Q4. Did all predator and prey types remain in the environment in your experiment? Or was your environment reduced to two species? If yes, then give reasons why this could have happened.

Ans) Yes, in our experiment all predator and prey types remained in the environment. This was because, the production rate of prey population exceeded the consumption rate of the predators.

6 Conclusions

- The predator with Raptorial legs *(spoon)* was the most successful one.
- We could observe a *partial resource partition*, as predator 2 and 3 were competing for black bean whereas the main food for predator 1 was white bean.
- After vomiting in the first round, the predators refrained from consuming pasta (the poisoned food), but the predator 2 was able to develop immunity against the poison from round 3 and could feed on pasta as well. This represents *evolution*. If the other food source would have been exhausted, then only predator 2 would have survived (although nothing such happened in our experiment).