Article

A review on research of the predator-prey interactions

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Abstract

In this review article, we aim to study predator-prey interactions and their historical development from time to time. A general overview of the predator-prey model, its evolution, and the physical meanings of this model has been discussed here. A brief discussion on the classification of predators and process of predation it its effect on the environment is presented in this review article. One important characteristic of the predation process is that predators co-operate with each other against preys which becomes more visible when the prey are strong enough to be over-powered easily.

Keywords predator-prey interactions; classification of predators; predators' co-operation; research developments.

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1 Introduction to Predator Prey Interactions

The predator-prey models are the basis which helps to see the life and ecosystems in which the predator and prey have certain role. This model explains how the predators interact with its prey. It explains the sustenance, evaluation and alternative dispersion of some species in the case of failure to complete in the life in which the stronger has advantage of dominate role. The predator-prey model is like the survival of the fittest-theory (Zhang and Liu, 2015). The fittest are the stronger species targeting the weaker species and win life for themselves and this evaluation of life for one species results in the numerical and sometime general extinction of other weaker species. The weaker species remain in constraint struggle to achieve their security in the diaspora where general fear of life remains ever present. The weaker species which become prey adopt many measures to trick the predator to avoid being hunted.

Briefly predator prey interaction is like a win-loss interaction (Zhang, 2012), it is the victory for one and loss for the other; and life for one and elimination of the other.

2 A General Predator-Prey Model

Let us consider two kinds of populations, that have sizes at a reference time t and shown by $X(t),$ and $Y(t),$ respectively. Where X and Y might show population number or the size of the respective population. Any change in the size of population with reference to time or based is described by the time derivatives; $\dot{X} \equiv dX / dt$ and $\dot{Y} \equiv dY / dt$ respectively. The general model of interacting populations is usually put in terms of independent differential equations presented by

$$\dot{X} = Xg(x, y), \quad (1)$$

$$\dot{Y} = Yh(x, y). \quad (2)$$

For instance, the time $'t'$ does not seem clearly in the functions of $Xg(x, y),$ and $Yh(x, y)$ and the functions of g and h show the respective per capita growth rate of the two species. One assumption that comes to us about this is as follows:

$$\frac{dg(x, y)}{dy} < 0, \quad \text{and} \quad \frac{dh(x, y)}{dx} > 0.$$

The general name for this model is the predator-prey model of Kolmogorov (Freedman, 1980).

3 The Historical Model of Lotke-Volterra

This model was presented by Vito-Volterra and Alfred J. Lotka. Vito, who studied the population of different species of fish in the Adriatic sea (Voltera, 1926). He saw increasing number of predators and decreasing number of prey in the Adriatic fauna. Thus, he observed on the three fishing markets. He gave his assessment that reducing number of fish (prey) was due to the hostile interaction between predators and prey. Alfred J. Lotka and Volterra presented many mathematical formulae in order to explain the Vito's observation in the form of mathematics (Kingsland, 1985). Lotka in his book provided predator-prey systems which consisted of a plane population and herbivorous animals which dependent on the plants for food (Lotka, 1958).

4 Lotka-Volterra Model

This model is also called the predator prey equations, which is the non-linear, pair of first order differential equations, given as

$$\dot{X} = Xa_1 - a_2 XY \quad (3)$$

$$\dot{Y} = b_1 XY - Yb_2 \quad (4)$$

where a_1, a_2, b_1, b_2 are parameters representing the interaction of the two species.

This model was the first ever mathematical model on the population which achieved a balanced in a

population in a very cyclical way. This model shows the eco-logical systems in which the predator and prey interact resulting in the competition between the two (Hoppensteadt, 1977). This model has following important variables;

- $\dot{X}$: The prey-population
- $\dot{Y}$: The predators-population
- a_1 : The natural growth rate of prey in the predation absence
- a_2 : The predator's effect on the prey-population
- b_1 : The prey's effect on the predator-population
- b_2 : The natural predator's death rate in the absence of prey to eat.

The following are the important Assumptions:

1) If a predator is absent, the population of the prey will increase at the rate proportional to the current population.

Therefore, $\frac{dX}{dt} = a_1 X$, when $Y = 0$.

2) If the prey is absent, then there are no chances for predator to live.

Thus $\frac{dY}{dt} = -b_2 Y$, where $b_2 > 0$ when $X = 0$.

3) The number of encounters between a predator and the prey is proportional to the product of their populations. Every encounter will increase the population of the predator and reduce the population of the prey.

Thus the growth rate of predator increases in the form of XY, if the growth rate of prey decreases in the form of $-a_2 XY$, where a_2 is positive constant, and a_1, b_1, b_2 all are positive constants. a_1 and b_2 show the growth rate of prey and the death rate of predator, respectively. a_2 and b_1 measure the level of effect of interaction between the prey and predator.

5 The Model Equations and Their Physical Meanings

This model presents some assumptions as to how predator and prey populations operate/interact, and evolve or disappear.

1) The prey population has always more than required food.

2) Food supply for predator depends on how much size the prey population has.

3) The rate of change of population remains proportional to its size, in this process environment becomes unhelpful for any species.

4) The predators have un-limited appetite and this process is cyclical. The generation of both species continues to interact this way (Cooke et al., 1981).

6 The Predator and Prey Interaction

The earth inhabits millions of such species that assume the role of predators. They kill other herbivores or even the carnivore predators in order to achieve the survival for them. The predator prey interaction results in the continuation of life for some and elimination for the others (Begon et al., 1996). Charles Darwin's theory of survival of the fittest appears to be very relevant in the life and elimination of different species. The predators may have herbivores as their target, or may be, have even small predators as targets, thus giving us the glimpses of an ever insecure world for smaller species. This piece of work will focus on following important points:

7 Defining a Predator

A predator is one which kills and eats other living beings in order to live. It happens through the physical outburst of predators that aggressively attack the prey and win life for themselves. In fact, the predators are said to be killing which is an effort to guarantee life for them (Begon et al., 1996).

8 Classification

Predators have a variety of types, and some of them are;

i. Some predators may target large-size preys and may not directly eat them but they dismember or chew them before eating them.

ii. Some predators may eat their prey directly as a whole not in parts. Some examples of this include dolphin which swallows a fish or a snake that devours a frog.

iii. Some predator animals may swallow prey in a whole or in parts depending on the situation.

iv. Some predators kill some other animals or insects but may not eat them. This way, classification goes a long way in which different predators may choose to target or kill the preys differently.

9 The Process of Predation

The process of killing preys may take great deal of caution and careful step-wise planning by predator in order to ensure that prey does not escape. The predators may hunt preys actively in which preys may be chased. The chasing of prey by predator is a race for life for both in which the prey fears life and predators does not want to let the target escape in order to win security against hunger.

Some predators may sit inactive, waiting for the prey to come close to them. They may act in such a way that preys are led to believe that the predator is uninterested in them. This caution plan by predator may be a great success; however, some preys may hesitate to come near to the predator as they are more cautions and have less trust in the apparently good intentions of predators. This hack of trust by prey may save its life and may shatter the confidence of predator in its tricky plans forcing active chasing (Alcock, 1998).

10 Why Predation?

Why animals so for predation? It is a very important question. The answer to that is present in the heart of the argument; is the survival of these animals. The carnivorous animals, faced by ever-increasing hunger, have found a natural principle for their survival in the middle of rich wildlife that serves as the tasty food for them. The other besides life is the increasing competition between different species. Some species, although with

greatest influence in the wildlife, may confront a threat to them should their population shrink. To this effect, they embark on ruthless killings to make sure that other species have got small number around them. This small number of other species may be considered synonymous with security of these predator species.

11 What Happens When Predator Does Not Take Place

If the predation does not take place, there may be two serious consequences;

1) Absence of predation would mean massive increase in the population of these species.

2) The second important consequence is that if predation does not take place, the herbivores increase in population and finally, it affects the grass and green plants which will have more pressure on it.

12 Different Predators in Co-operation

One important characteristic of the predation process is that predators co-operate with each other against preys. The co-operation becomes more visible when the prey species are strong enough to be over-powered easily (Lloyd, 1965).

Moreover, the predators may confront two problems. The first problem may about the large size of prey. The large size may undermine predator's ability to successfully target the prey (Molles, 2002). The second issue facing predators is about the tough terrain. The tough terrain may be the movement of predators and preys affect understanding of location may benefit it. The speed of predator may be affected. They may also get injured while chasing the prey (Ripple and Robert, 2004).

13 Recent Developments

We have introduced the quasi chemical approach to represent the different types of mechanisms between the predator and its prey by taking a case study of foxes and rabbits and determined the modeled equations for these mechanisms including the mechanism of circulation, mechanisms of attraction and repulsion and mechanism of sharing place (Shakil et al., 2014)

In our second serried of papers, we developed the modeled equations for different types of mechanism of the predator-prey interactions with the help of a quasi chemical approach while taking a special study case of foxes and rabbits, these mechanisms include autocatalysis mechanism, pair wise interactions and the mechanism of their movements to some free places (Shakil et al., 2015). The chemical reactions representing the interactions obey the mass action law. The territorial animal like fox is assigned a simple cell as its territory. Under the proper relations between coefficients, this system may demonstrate globally stable dynamics.

14 Future Plan

We aim to build up a concise study of complex biological systems and to tackle some key research questions concerning our study case by proposing some new techniques and algorithms that are inspired by those complex biological systems. After the developments of the models with the help of our quasi-chemical approach, we aim to check the stability of all the mechanisms discussed in our study case (Shakil et al., 2015). We will then find the solution of the mechanism in relation to the existence and uniqueness of those solutions.

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