Modeling of Predator-Prey Interaction between Fur Craft Predators and Muroidea Rodents

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Abstract

Muroidea rodents have a lot of natural enemies, because they are link in food system of most mammals and especially for fur craft predators. A good model must be simple enough to be mathematically tractable, but complex enough to represent a system realistically. Realism is often sacrificed for simplicity, and one of the shortcomings of the Lotka-Volterra model is its reliance on unrealistic assumptions. Predators and prey can influence one another's evolution. Traits that enhance a predator's ability to find and capture prey will be selected for in the predator, while traits that enhance the prey's ability to avoid being eaten will be selected for in the prey. The «goals» of these traits are not compatible, and it is the interaction of these selective pressures that influences the dynamics of the predator and prey populations. Predicting the outcome of species interactions is also of interest to us trying to understand how communities are structured and sustained. The predictions of the created Lotka-Volterra model are supported by empirical evidence.

Keywords: muroidea rodents, fur craft predators, predator-prey model

I. Introduction

A narrative account of how estuaries around the world are being altered by human forces and human-induced global climate changes, Climate Change and Geological Ecosystems: Long-Term Effects of Climate and Nutrient Loading on Trophic Organization chronicles a more than 30-year-old research effort conducted by Dr. I. Sharipov and his team at Hossa Ahmet Yesevi's International Turkish-Kazakh Institute.

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Designed to evaluate system-level responses to natural and anthropogenic nutrient loading and long-term climate changes, the study focused on the hot climate of South-Kazakhstan region, and concentrated on muroidea rodent's productivity and associated food web organization. It addressed the changes of food web structure relative to long-term trends of climatologically conditions, and was carried out using a combination of field-descriptive and experimental approaches.

This research   includes comparative analyses of how the trophic organization of different ecosystems responded to variations of both anthropogenic impacts and natural driving factors in space and time. It incorporates a climate database and evaluates the effects of climate change in the South-Kazahkstan region. It also provides insights into the effects of nutrient loading and climate on the trophic organization of   hot climate systems in other the South-Kazahkstan   geological regions. Based on a longitudinal study of anthropogenic and natural driving factors on sand and mountain systems in the South-Kazahkstan region, Climate Change and Coastal Ecosystems: Long-Term Effects of Climate and Nutrient Loading on Trophic Organization is useful as a reference for researchers working on hot climate systems of Kazakhstan.

With over 2000 living species placed in about 30 families, rodents are by far the largest order of mammals, at least in terms of number of taxa (well over 40% of mammalian species belong to the order Rodentia!) [3]. Ecologically, they are incredibly diverse. Some species spend their entire lives above the ground in the canopy of rainforests; others seldom emerge from beneath the ground. Many are to some degree omnivorous; others are highly specialized, eating, for example, only a few species of invertebrates or fungi.

Despite their morphological and ecological diversity, all rodents share one characteristic: their dentition is highly specialized for gnawing. All rodents have a single pair of upper and a single pair of lower incisors, followed by a gap (diastema), and followed by one or more molars or premolars. No rodent has more than one incisor in each quadrant, and no rodent has canines. Rodent incisors are rootless, growing continuously. Their anterior and lateral surfaces are covered with enamel, but their posterior surface is not. During gnawing, as the incisors grind against each other, they wear away the softer dentine, leaving the enamel edge as the blade of a chisel.

This «self sharpening» system is very effective and is one of the keys to the enormous success of rodents.

In terms of number of species—although not necessarily in terms of number of organisms (population) or biomass—rodents make up the largest order of mammals. Their success is probably due to their small size, short breeding cycle, and ability to gnaw and eat a wide variety of foods [4].So the object of our research muroidea rodents have a lot of natural enemies, because they are link in food system of most mammals and especially for fur craft predators in the South-Kazahkstan region. That is why reproduction is quick and about 10 cubs could be borned in one time.

The Lotka-Volterra model is composed of a pair of differential equations that describe predator-prey dynamics in their simplest case (one predator population, one prey population). It was developed independently by Alfred Lotka and Vito Volterra in the 1920's, and is characterized by oscillations in the population size of both predator (fur craft predators) and prey (muroidea rodents), with the peak of the predator's oscillation lagging slightly behind the peak of the prey's oscillation. The model makes several simplifying assumptions: 1) the prey population will grow exponentially when the predator is absent; 2) the predator population will starve in the absence of the prey population (as opposed to switching to another type of prey); 3) predators can consume infinite quantities of prey; and 4) there is no environmental complexity (in other words, both populations are moving randomly through a homogeneous environment).

Predators and prey can influence one another's evolution [1]. Traits that enhance a predator's ability to find and capture prey will be selected for in the predator, while traits that enhance the prey's ability to avoid being eaten will be selected for in the prey. The «goals» of these traits are not compatible, and it is the interaction of these selective pressures that influences the dynamics of the predator and prey populations. Predicting the outcome of species interactions is also of interest to us trying to understand how communities are structured and sustained.

What are the predictions of the Lotka-Volterra model? Are they supported by empirical evidence?

Variables

P	number of predators or consumers
N	number of prey or biomass of plants
t	time
r	growth rate of prey
a′	searching efficiency/attack rate
q	predator or consumer mortality rate
c	predatorís or consumerís efficiency at turning food into offspring (conversion efficiency)

II.   Methods

We begin by looking at what happens to the predator population in the absence of prey; without food resources, their numbers are expected to decline exponentially, as described by the following equation:

$$\frac{dP}{dt} = qP \qquad\qquad [1]$$

This equation uses the product of the number of predators (P) and the predator mortality rate (q) to describe the rate of decrease (because of the minus sign on the right-hand side of the equation) of the predator population (P) with respect to time (t). In the presence of prey, however, this decline is opposed by the predator birth rate, $ca_i'PN$, which is determined by the consumption rate ($a_i'PN$, which is the attack rate [a'] multiplied by the product of the number of predators [P] times the number of prey [*N*]) and by the predatorís ability to turn food into off spring (c). As predator and prey numbers (P and N, respectively) increase, their encounters become more frequent, but the actual rate of consumption will depend on the attack rate (a_i'). The equation describing the predator population dynamics becomes

$$\frac{dP}{dt} = ca'PN\text{-}qP \qquad\qquad [2]$$

The product ca'P is the predator's numerical response, or the per capita increase as a function of prey abundance.

The entire term, ca'PN, tells us that increases in the predator population are proportional to the product of predator and prey abundance. Turning to the prey population, we would expect that without predation, the numbers of prey would increase exponentially. The following equation describes the rate of increase of the prey population with respect to time, where r is the growth rate of the prey population, and N is the abundance of the prey population:

$$\frac{dN}{dt} = rN \; - a'PN \qquad\qquad [3]$$

In the presence of predators, however, the prey population is prevented from increasing exponentially. The term for consumption rate from above (a_i' PN) describes prey mortality, and the population dynamics of the prey can be described by the equation

$$\frac{dN}{dt} = rN \qquad\qquad [4]$$

The product of a' and P is the predator's functional response, or rate of prey capture as a function of prey abundance. Here the term a'PN reflects the fact that losses from the prey population due to predation are proportional to the product of predator and prey abundances.

Equations (2) and (4) describe predator and prey population dynamics in the presence of one another, and together make up the Lotka-Volterra predator-prey model. The model predicts a cyclical relationship between predator and prey numbers: as the number of predators (P) increases so does the consumption rate (a'PN), tending to reinforce the increase in P. Increase in consumption rate, however, has an obvious consequence- a decrease in the number of prey (N), which in turn causes P (and therefore a'PN) to decrease. As a'PN decreases the prey population is able to recover, and N increases. Now P can increase, and the cycle begins again. This graph shows the cyclical relationship predicted by the model for hypothetical predator and prey populations (fig.1).
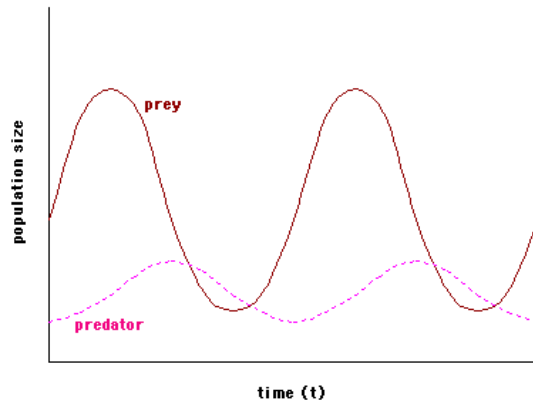
Figure 1: The cyclical relationship predicted by the model for hypothetical predator and prey populations.

We reared two species of mites to demonstrate these coupled oscillations of predator and prey densities in the our researchs. Using fur craft as the predator and the muroidea rodents as the prey, we constructed environments composed of varying numbers of forage (fed on by the prey). The results of one of the many permutations of his experiments are graphed below. Note that the prey (Mus turkestanicus) population size is on the left vertical axis and the predator population (Marmota menzbieri) is on the right vertical axis, and that the scales of the two are different (fig.2).
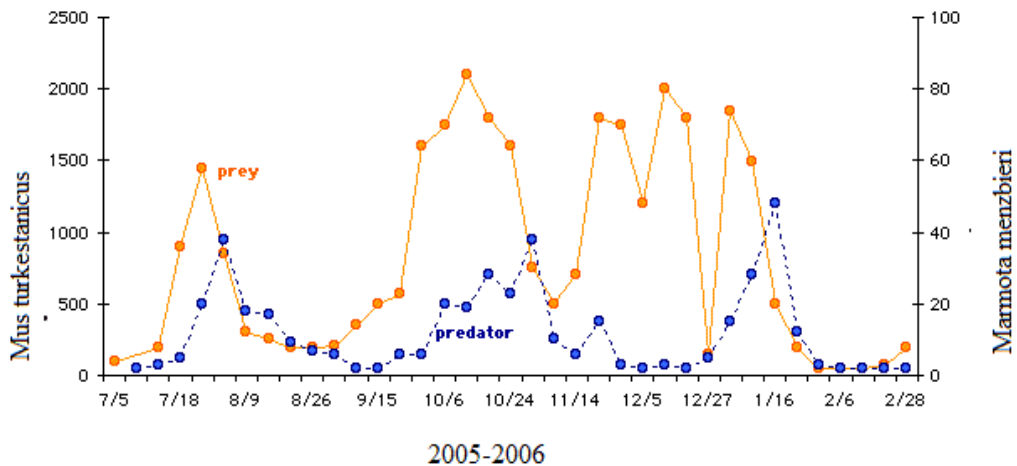
Figure2. The prey and the predator population

III. Interpretation

It is apparent from the graph that both populations showed cyclical behavior, and that the predator population generally tracked the peaks in the prey population. However, there is some information about this experiment that we need to consider before concluding that the experimental results truly support the predictions made by the Lotka-Volterra model. To achieve the results graphed here, Huffaker added considerable complexity to the environment [2]. Food resources for muroidea rodents were spread further apart than in previous experiments, which meant that food resources for fur craft were also spread further apart. In other words, predator and prey were not encountering one another randomly in the environment.

IV. Conclusions

A good model must be simple enough to be mathematically tractable, but complex enough to represent a system realistically. Realism is often sacrificed for simplicity, and one of the shortcomings of the Lotka-Volterra model is its reliance on unrealistic assumptions. For example, prey populations are limited by food resources and not just by predation, and no predator can consume infinite quantities of prey. Many other examples of cyclical relationships between predator and prey populations have been demonstrated in the laboratory or observed in nature, but in general these are better fit by models incorporating terms that represent carrying capacity (the maximum population size that a given environment can support) for the prey population, realistic functional responses (how a predator's consumption rate changes as prey densities change) for the predator population, and complexity in the environment.

References

Dale B. McDonald Sensitivity Characteristics of Response Surface Models for Estimation of Ecological Parameters in Ratio-Dependent Predator-Prey Systems (2014). American International Journal of Contemporary Research Vol. 4, No. 6; June 2014,1-7

Huffaker, C. B. (1958). Experimental studies on predation: dispersion factors and predator-prey oscillations. Hilgardia 27(14) ,343-383

Lambert, T.D & G.H. Adler. (2000). Microhabitat use by a tropical forest rodent, Proechimys semispinosus, in central Panamá. Journal of Mammalogy, 81, 70-76

Wilson, D. E., and D. M. Reeder (2005). Mammal Species of the World. A Taxonomic and Geographic Reference. 3rd edition. Smithsonian Institution Press, Washington. xxxv+2142 pp.

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