Article

Dynamic complexity in a discrete-time predator-prey system with Holling type I functional response: Gompertz growth of prey population

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Abstract
We consider a discrete-time predator-prey system with Holling type I functional response and Gompertz growth of prey population to study its dynamic behaviors. We algebraically show that the predator-prey system undergoes a flip bifurcation (FB) and Neimark-Sacker bifurcation (NSB) in the interior of $\mathbb{R}_+^2$ when one of the model parameter crosses its threshold value. We determine the existence conditions and direction of bifurcations by using the center manifold theorem and bifurcation theorems. We present numerical simulations to illustrate theoretical results which include the bifurcation diagrams, phase portraits, appearing or disappearing closed curves, periodic orbits, and attracting chaotic sets. In order to justify the existence of chaos in the system, maximum Lyapunov exponents (MLEs) and fractal dimension (FD) are computed numerically. Finally, chaotic trajectories have been controlled by applying feedback control method.

Keywords predator-prey system; Gompertz growth; bifurcations; Lyapunov exponents; feedback control.

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1 Introduction

In ecological systems, the most significant studied theme is the interaction between predator and prey species. Many mathematical models have been developed to interpret and analyze qualitative behaviors of such systems. One can describe the dynamics of population growth if the functional behavior of growth rate is known. Different predator-prey models can be found in the literature (May, 1974; Freedman, 1980; Berryman, 1992). The simplest mathematical model describing a predator-prey interaction is the following well-known Kolmogorov type predator-prey model with Holling type I functional response:

$$\begin{aligned} \dot{x} &= g(x,K) - \alpha xy \\ \dot{y} &= \beta xy - dy \end{aligned} \tag{1}$$

where $g(x,K) = rx\left(1 - \frac{x}{K}\right)$; x and y stand densities of prey and predator, respectively;

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