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Cheng Wang, Xiang Zhang

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Relaxation oscillations in a slow-fast modified Leslie-Gower model

Cheng Wang^a, Xiang Zhang^{b,*}

^a*School of Mathematical Sciences, Shanghai Jiao Tong University, Shanghai 200240, P. R. China*

^b*School of Mathematical Sciences, Key Laboratory of Scientific and Engineering Computing (Ministry of Education), Shanghai Jiao Tong University, Shanghai, 200240, P. R. China*

Abstract

In this paper, we prove the existence and uniqueness of relaxation oscillation cycle of a slow-fast modified Leslie-Gower model via the entry-exit function and geometric singular perturbation theory. Numerical simulations are also carried out to illustrate our theoretical result.

Keywords: Slow-fast system, entry-exit function, geometric singular perturbation, relaxation oscillation.

1. Introduction

Alaoui and Okiye [3] in 2003 proposed the next modified Leslie-Gower model:

$$\begin{aligned}\frac{dx}{dT} &= \left(r_1 - b_1 x - \frac{a_1 y}{x + k_1} \right) x, \\ \frac{dy}{dT} &= \left(r_2 - \frac{a_2 y}{x + k_2} \right) y,\end{aligned}\tag{1.1}$$

where x represents the prey density and y the predator density, and the parameters $r_1, b_1, a_1, k_1, r_2, a_2, k_2$ are positive and have biological meaning described as follows. The parameters r_1 and b_1 represent the intrinsic growth rate and the strength of competition among individuals for the prey, respectively. The natural growth rate of the predator is given by r_2 , while a_2 and a_1 are respectively the maximum values of the per capita reduction rates of the predators and prey species. The parameters k_1 and k_2 measure the extent to which environment provides protection to prey x and predator y , respectively.

System (1.1) has been investigated by several researchers in different aspects. Alaoui and Okiye [3] studied the boundedness of solutions and global stability of the positive equilibrium points of the system. By utilizing the coincidence degree theorem and Lyapunov function, Zhu and Wang [20] obtained some sufficient conditions for the existence and global attractivity of positive periodic solutions of the system.

Now consider the rescaling

$$x = \frac{r_1}{b_1} \bar{x}, \quad y = \frac{r_1 r_2}{a_2 b_1} \bar{y}, \quad T = \frac{1}{r_1} t.\tag{1.2}$$

Substitute (1.2) into system (1.1) and still use x and y to denote \bar{x} and \bar{y} , it yields

$$\begin{aligned}\frac{dx}{dt} &= x' = x(1-x) - \frac{axy}{x+e_1} := f(x, y, \lambda), \\ \frac{dy}{dt} &= y' = \varepsilon y \left(1 - \frac{y}{x+e_2} \right) := \varepsilon g(x, y, \lambda),\end{aligned}\tag{1.3}$$

*Corresponding author

Email addresses: mathwc@sjtu.edu.cn (Cheng Wang), xzhang@sjtu.edu.cn (Xiang Zhang)

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