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Existence of the solutions of a reaction cross-diffusion model for two species[☆]

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Abstract

In this paper, we investigate a two-cooperation species model with reaction cross-diffusion under the Dirichlet boundary value condition. By applying Lyapunov-Schmidt reduction method and some important formulas, we obtain the existence of coexistence solutions under some given conditions.

Keywords: Cooperative species; cross-diffusion; semi-trivial steady state; coexistence solution; Lyapunov-Schmidt reduction.

1. Introduction

Recently, the dynamics models in the form of reaction cross-diffusion systems have received considerable researchers' attentions, one can refer to [1, 2, 8, 9]. Ecologically, positive solutions correspond to the existence of steady states of species. So the set of positive solutions may contain crucial clues for the stationary patterns. Kuto and Yamada[1] studied the following prey-predator model with cross-diffusion:

$$\begin{cases} -\Delta[(D_1 + \rho_{12}v)u] = u(\lambda_1 - a_1u - b_1v), & \text{in } \Omega, \\ -\Delta[(D_2 + \rho_{21}u)v] = v(\mu_1 - d_1u + c_1v), & \text{in } \Omega, \end{cases} \quad (1)$$

where $\Omega \subset \mathbb{R}^N$, $N \geq 1$, is a bounded domain with a smooth boundary, $u(x)$ and $v(x)$ denote the population density of two species at location x , which are interacting and migrating in the same habitat Ω , $a_1, b_1, c_1, d_1 > 0, D_j > 0 (j = 1, 2)$ and $\lambda, \mu \in \mathbb{R}$. Here, D_j represents the diffusive coefficient and ρ_{12}, ρ_{21} are considered as cross-diffusion pressures. Here, λ_1 and μ_1 denote the growth rates of the species, respectively, a_1 and d_1 are the mortal rates of u and v , respectively, b_1 and d_1 are the interaction rates between the two species. By some rescaling the forms as follows:

$$\begin{aligned} (\bar{u}, \bar{v}) &= \left(\frac{a_1}{D_1}u, \frac{c_1}{D_2}v \right), \\ (\alpha, \beta, \lambda, \mu, b, d) &= \left(\frac{\rho_{12}D_2}{c_1D_1}, \frac{\rho_{21}D_1}{a_1D_2}, \frac{\lambda_1\mu_1}{D_1D_1}, \frac{b_1D_2}{d_1D_1}, \frac{c_1D_1}{a_1D_2} \right), \end{aligned}$$

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