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Propagation dynamics for a spatially periodic integrodifference competition model ☆

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Abstract

In this paper, we study the propagation dynamics for a class of integrodifference competition models in a periodic habitat. An interesting feature of such a system is that multiple spreading speeds can be observed, which biologically means different species may have different spreading speeds. We show that the model system admits a single spreading speed, and it coincides with the minimal wave speed of the spatially periodic traveling waves. A set of sufficient conditions for linear determinacy of the spreading speed is also given.

MSC: 35K57; 35B40; 37N25; 92D25

Keywords: Integrodifference equation; Spatially periodic traveling waves; Spreading speeds; Linear determinacy

1. Introduction

Competition exists widely in the multispecies interaction. One of the crucial concepts on describing the competitive dynamics is called the competition exclusion principle, also referred to as Gause's Law [14], which states that if two species attempting to occupy the limited resources cannot coexist, then one species will drive out the other. Competition exclusion provides useful

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insights on ecological balance, for instance, beneficial invasion can be introduced in pest control. Among those theoretical models, a spatially-independent difference system is the following Leslie/Gower competition model:

$$p_{n+1} = \frac{r_1 p_n}{1 + \frac{r_1 - 1}{C_1}(p_n + a_1 q_n)}, \qquad (1.1)$$
$$q_{n+1} = \frac{r_2 q_n}{1 + \frac{r_2 - 1}{C_2}(q_n + a_2 p_n)},$$

where p_n and q_n are the population densities of two competing species at time n. The competition between two species is governed by Beverton–Holt dynamics. r_i $(r_i > 1)$, C_i and a_i are growth rates, carrying capacity of i-th species $(i = 1, 2)$, and interspecific competition coefficients, respectively. The global dynamics of system (1.1) was discussed by Cushing et al. (see [1, Lemma 2]), and the competition exclusion occurs if interspecific competition is too large [1].

In nature, real species are usually spatially extended, and hence, the effects of dispersal processes are of high interest in spatial ecology. In well-known diffusion models, growth is usually assumed to occur at the same time with dispersal. However, in many situations such as annual and perennial species plants, migrating bird species, growth and dispersal are in distinct stages. Thus, integrodifference equations, which are continuous in space and discrete in time, become more realistic and popular. Kot and Schaffer [16] first applied integrodifference equations to population modeling. Since then, the study of integrodifference equations in ecology gained a lot of attention, see, e.g., [3,4,7,18,23,26,27,31]. Mathematical investigations includes the study of traveling waves [11,13,15,35] and analytical approximation schemes [6]. Recently, Zhou and Kot [40] considered an integrodifference equation with shifting species ranges subject to climate changes, and Zhou and Fagan [39] investigated a single-species integrodifference model with time-varying size.

Apart from population dispersal, how species interact with space is another important topic in spatial ecology, since most landscapes are heterogeneous (see, e.g., [2,24]). Travelling waves and spreading speeds are commonly used to explore the propagation dynamics (see, e.g., [14,29]). Shigesada et al. [30] first studied the spreading speeds for single-species continuous-time model in a periodic patchy habitat. Later, Kawasaki and Shigesada [12] extended the work to discrete-time models. A general theory of travelling waves and spreading speeds in a periodic habitat was developed by Weinberger [33], Liang and Zhao [22], and Fang and Zhao [5]. Recently, Yu and Zhao [36] studied the propagation phenomena of a two species reaction–advection–diffusion competition model in a periodic habitat by appealing to the abstract results in [5,22].

Naturally, system (1.1) can be extended to the following spatial model:

$$p_{n+1}(x) = \int_{\mathbb{R}} \frac{r_1(y) p_n(y)}{1 + b_1(y)(p_n(y) + a_1(y) q_n(y))} k_1(x, y) \mathrm{d}y, \qquad (1.2)$$
$$q_{n+1}(x) = \int_{\mathbb{R}} \frac{r_2(y) q_n(y)}{1 + b_2(y)(q_n(y) + a_2(y) p_n(y))} k_2(x, y) \mathrm{d}y, \quad x \in \mathbb{R},$$

where

$$b_i(x) = \frac{r_i(x) - 1}{C_i(x)}, \quad (i = 1, 2),$$

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