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Invasion speeds in microbial systems with toxin production and quorum sensing

Sharon Bewick[1*], Phillip P.A. Staniczenko[1,2*], Bingtuan Li[3], David Karig[4] & William F. Fagan[1]

[1] *Department of Biology, University of Maryland, College Park, MD 20742, USA*

[2] *National Socio-Environmental Synthesis Center (SESYNC), Annapolis, MD 21401, USA*

[3] *Department of Mathematics, University of Louisville, Louisville, KY 40059, USA*

[4] *Johns Hopkins Applied Physics Laboratory, Fulton, MD 20723, USA*

*Joint first-authors, correspondence should be addressed to mailto:sharon_bewick@hotmail.comsharon_bewick@hotmail.com

The theory of invasions and invasion speeds has traditionally been studied in macroscopic systems. Surprisingly, microbial invasions have received less attention. Although microbes share many of the features associated with competition between larger-bodied organisms, they also exhibit distinctive behaviors that require new mathematical treatments to fully understand invasions in microbial systems. Most notable is the possibility for long-distance interactions, including competition between taxa mediated by diffusible toxins and cooperation among individuals of a single taxon using quorum sensing. In this paper, we model bacterial invasion using a system of coupled partial differential equations based on Fisher's equation. Our model considers a competitive system with diffusible toxins that, in some cases, are expressed in response to quorum sensing. First, we derive analytical approximations for invasion speeds in the limits of fast and slow toxin diffusion. We then test the validity of our analytical approximations and explore intermediate rates of toxin diffusion using numerical simulations. Interestingly, we find that toxins should diffuse quickly when used offensively, but that there are two optimal strategies when toxin is used as a defense mechanism. Specifically, toxins should diffuse