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Steady states of nonlinear reaction-diffusion-advection models: phase plane approach

Steady states of nonlinear reaction-diffusion-advection (RDA) models can be viewed as solutions of a system of two first order ODEs (subject to appropriate boundary conditions). Geometrically, they are represented by orbits in the phase plane, generated by the corresponding flow operator. In the basic case of a logistic RDA model describing population dynamics in a finite river segment, the phase plane approach helped to establish the existence and uniqueness of a positive steady state solution for sufficiently low advection speeds and sufficiently large domains. In this talk, I will discuss applications of the phase plane technique in two extensions of this basic model. In one setting, we increase the complexity of the habitat by considering a binary river network. In the second setting, we increase the complexity of the reaction term. Namely, we study an extension of the classical spatial spruce budworm (SBW) model (where reaction term accounts for predation), with advection term describing biased movement of larvae due to prevailing winds. In the river network case, the phase plane approach helps us to find conditions for existence and uniqueness of positive steady state. In the SBW model, we use phase plane analysis to determine the conditions for existence of the outbreak solutions. In particular, we observe that increasing advection can prevent outbreaks while allowing persistence in form of an endemic state. We obtain upper and lower bounds for the critical advection for outbreaks.