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Delay-induced Hopf-zero bifurcation in a Host-parasite model

Host–parasite interactions play a central role in ecological and evolutionary dynamics, shaping population persistence and ecosystem stability. When these interactions are coupled with interspecific competition, they can generate highly nonlinear and often counterintuitive behaviors. In this study, we develop a delayed differential equation model describing host–competitor–parasite dynamics, incorporating a latency period in parasite reproduction. This delay represents the developmental time of infection and introduces memory effects that can significantly alter system stability. Using bifurcation analysis, we investigate codimension-two phenomena, with particular focus on the Hopf–zero bifurcation as an organizing center for complex oscillatory and mixed-mode dynamics. Our results demonstrate how the interplay between temporal delays and multi-species interactions drives the emergence of rich and intricate dynamical patterns in ecological systems.