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Host–virus evolutionary dynamics with specialist and generalist infection strategies: Bifurcations, bistability, and chaos

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ABSTRACT

In this work, we have investigated the evolutionary dynamics of a generalist pathogen, e.g., a virus population, that evolves toward specialization in an environment with multiple host types. We have particularly explored under which conditions generalist viral strains may rise in frequency and coexist with specialist strains or even dominate the population. By means of a nonlinear mathematical model and bifurcation analysis, we have determined the theoretical conditions for stability of nine identified equilibria and provided biological interpretation in terms of the infection rates for the viral specialist and generalist strains. By means of a stability diagram, we identified stable fixed points and stable periodic orbits, as well as regions of bistability. For arbitrary biologically feasible initial population sizes, the probability of evolving toward stable solutions is obtained for each point of the analyzed parameter space. This probability map shows combinations of infection rates of the generalist and specialist strains that might lead to equal chances for each type becoming the dominant strategy. Furthermore, we have identified infection rates for which the model predicts the onset of chaotic dynamics. Several degenerate Bogdanov–Takens and zero-Hopf bifurcations are detected along with generalized Hopf and zero-Hopf bifurcations. This manuscript provides additional insights into the dynamical complexity of host–pathogen evolution toward different infection strategies.

The strategies of infection for infectious pathogens have an extremely important role in the expected dynamical behaviors. In this manuscript, we investigate the dynamics of a generalist pathogen (e.g., virus) able to infect and replicate using two different host cell populations being also capable of evolving toward a new specialist strain during within-cell replication. As a difference, the evolved specialist strain only infects a single cell population. By using a seven-dimensional nonlinear differential equations model, we identify several dynamical regimes involving outcompetition and coexistence of strains, focusing on the rates of infection for each strain. Detailed analyses of equilibria and stability are provided, together with thorough bifurcation analyses. The expected behaviors are quantified in the two-parameter space of infection rates. Also, we identify a strange chaotic attractor embedded within a four-dimensional space involving unpredictable dynamics between both host cells populations, infected cells by the specialist strain, and the specialist strain itself. The remaining variables, associated to the generalist strain become