Biology and Medicine Through Mathematics Conference

2018

Jun 1st, 11:00 AM - 11:30 AM

Deriving ODE approximations for spatial networks: modeling environmentally transmitted infections

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Abstract

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Primarily, mathematical modeling of epidemiology has focused on directly transmitted infections. While much progress has been made, there are many infections that are spread via environmental pathogens, without requiring host-to-host contact. While models for environmental transmission exist, they have generally been constructed intuitively, with their structure being analogous to standard models for direct transmission. As model insights are generally sensitive to the underlying assumptions, it is important that we are able understand the details and consequences of these assumptions. Starting from a network model, we rigorously derive systems of ordinary differential equations (ODEs). These ODEs approximate the dynamics of the network model and are derived via three key assumptions: continuity, homogeneity and independence. By varying these assumptions, we can develop more sophisticated systems of ODEs, decreasing the errors due to the assumptions at the expense of increasing the number of equations in the system. We compare these ODE models to a stochastic implementation of the network model, demonstrating that the accuracy of the approximations are somewhat predictable based on the chosen parameters and assumptions of the model.