Stochastic Models of Zoonotic Avian Influenza with Multiple Hosts, Environmental Transmission, and Migration in the Natural Reservoir

Kaia M. Smith[1,*], Iona McCabe[2], Rowan Hassman[3], Linda J.S. Allen [4]

[1]*Department of Mathematics, Scripps College, Claremont, CA 91711*
[2]*Department of Mathematics, University of California Santa Barbara, Santa Barbara, CA 93106*
[3]*Department of Mathematics, Bates College, Lewiston, ME 04240*
[4]*Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409*

ksmith3987@scrippscollege.edu

Avian influenza (AI) circulates among wild bird populations and regularly spills over into domestic animals, such as poultry and swine. This raises the risk of a human-to-human-transmissible strain, which would pose a serious threat to public health. Mathematical modeling can be a powerful tool to mitigate such risk. Prior models have included factors such as multiple host populations, spillover into humans, environmental transmission, seasonality, and migration. We develop an ordinary differential equation (ODE) model that combines all of these factors, and translate this into a stochastic continuous time markov chain (CTMC) model. We examine and compare numerical trajectories of the ODE and CTMC models. We calculate the basic reproductive number $\mathcal{R}_0$, and solve the backward Kolmogorov differential equation to calculate the probability of extinction. A parameter sensitivity analysis of $\mathcal{R}_0$ indicates that our model is sensitive to the wild bird recovery rate and environmental transmission-related parameters, which may inform future research. Additionally, we examine sensitivity of the frequency of spillover events into human populations. We find that wild birds can drive infections in other classes even when transmission parameters for those upstream classes are low, and that environmental transmission can be a significant driver of infections.