Using Infectious Disease Models to Study Gang Activity Through Computational Mathematics

Allison Lenhardt and Hana Tinch
Advisor: Muhammad Usman, PhD.
University of Dayton

Abstract:

Gang activity shows a similar pattern to infectious diseases which can be modelled using nonlinear differential equations. Using the model of infectious diseases, predictions can be made to relate gang interactions with the population and the recruitment of new gang members. By manipulating personal interaction, conviction, recidivism, and jail time, awareness of which combination of factors results in the least amount of gang activity can lead to preventative measures to see how to best minimize gang activity. We study this model using numerical solutions of systems of differential equations and MATLAB's built-in ODE solver "ode45" for this simulation.

Variables and Equations Used

n - Non- susceptibles, those who are not susceptible to a life in the gang

g - committed core gang members (the gang leaders, hard core members and associates)

β_1- contact rate with susceptibles (N)

r - gang members who are removed from the gang by placing them in jail.

s - susceptibles (denotes potential gang members these correspond to those who have not yet committed to the gang lifestyle and may drift in and out of the gang.)

β_2- contact rate with gang members

f – rehabilitation rate

α – the intervention/interference parameter

ρ – the average length of the jail sentence

Φ – imprisonment rate

Equations:

(1) $dn/dt = -\beta_1 n(s+g) + \alpha s + f\rho r$

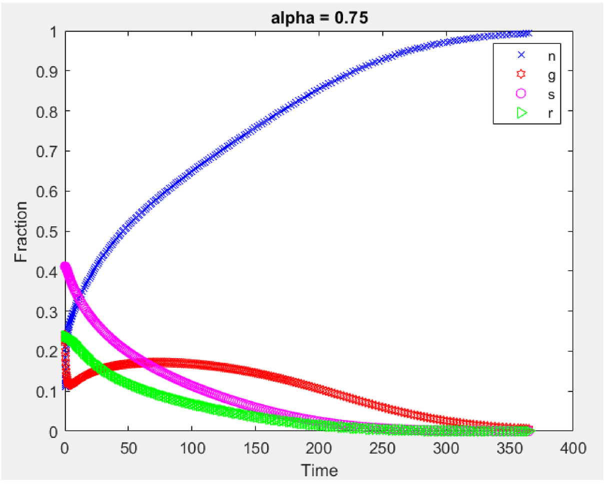
(2) $ds/dt = \beta_1 n(s+g) - \beta_2 s g - \alpha s$

(3) $dg/dt = \beta_2 s g + (1-f)\rho r - \Phi g$

(4) $dr/dt = \Phi g - \rho r$

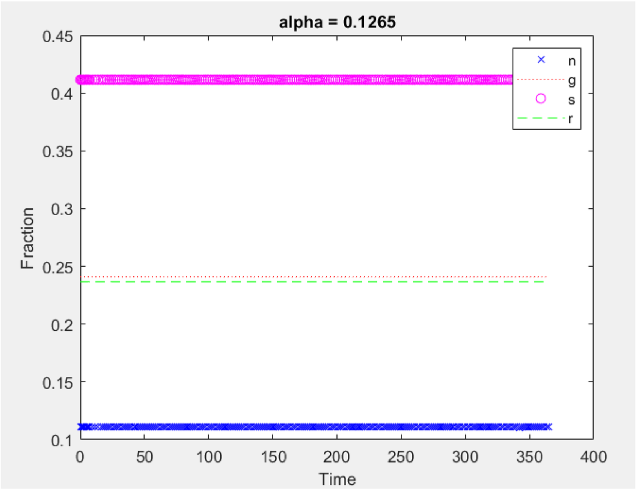
Findings:

α = 0.75



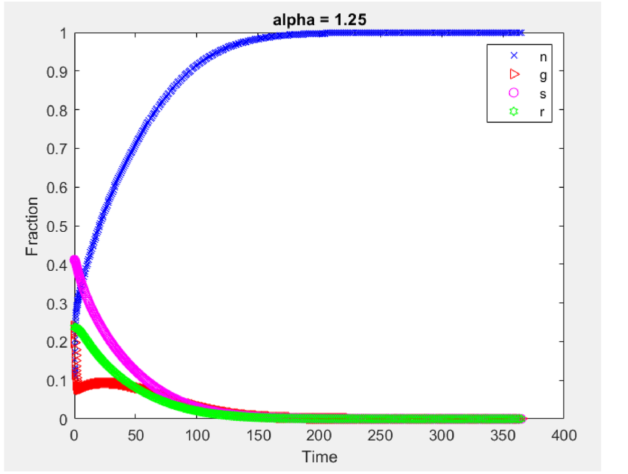
The rate of hardcore gang members increases at first before decreasing to almost none.

α = 0.1265



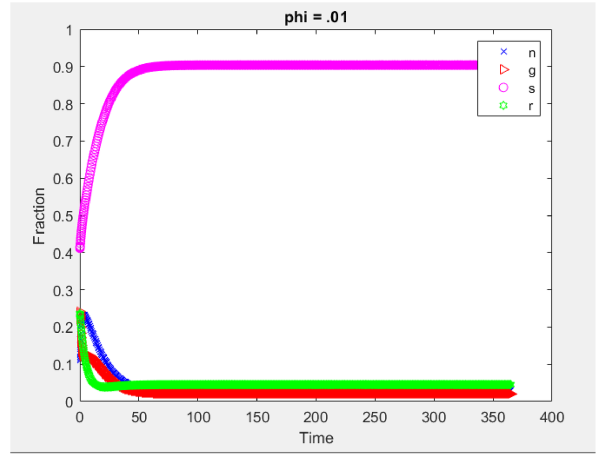
The susceptibles and non-susceptibles are in a steady state as not enough action is taken to put this graph in an unsteady state.

α = 1.25



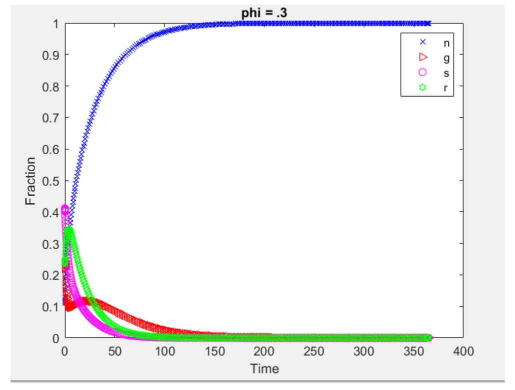
As the intervention parameter increases, the rate of hardcore gang members decreased faster.

Φ = 0.01



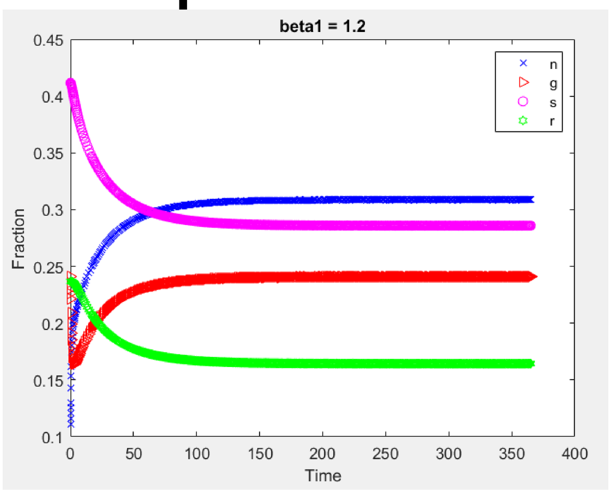
The susceptibles increase as the hardcore gang members decrease.

Φ = 0.3



The non-susceptible population increases as the susceptible and hardcore gang members decrease showing how increasing the imprisonment rate impacts these populations.

β1= 1.2



Increasing the contact rate with susceptibles causes the non-susceptible population to drop and hardcore gang membership to rise.

Conclusion:

It is found that as α, the intervention parameter, increases it takes less time for hardcore gang member numbers to decrease. Changing α also decreases the susceptible population, making it harder to recruit more hardcore gang members. Increasing Φ, the imprisonment rate, increases the number of people who are not susceptible and decreases hardcore and potential gang members. Increasing β1, contact rate with potential gang members, increases number of hardcore members. However, this is a simplified model of reality and fails to take into account other variables such as population change, a longer period of time, and the specifics of each location that it is applied to. Therefore, the model will become more accurate as these variables are taken into consideration.

References:

Sooknanan, J., Bhatt, B., & Comissiong, D. (2013). Catching A Gang -- A Mathematical Model Of The Spread Of Gangs In A Population Treated As An Infectious Disease. International Journal of Pure and Applied Mathematics, 83(1). doi: 10.12732/ijpam.v83i1.4

Nagle, R. K., Saff, E. B., & Snider, A. D. (n.d.). Fundamentals of Differential Equations (9th ed.). Pearson Education.