An Agent-Based Model of Recurring Epidemics in a Population with Quarantine Capabilities

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Abstract

Even with today's modern scientific and medical breakthroughs, there exists the threat of a widespread epidemic. Could an epidemic wreck havoc on the human population like the Spanish Influenza of 1918? Widespread epidemics have historically acted as a population control, as seen by the Black Plague. How do recurring epidemics control a population over long periods of time? If a population quarantines the infected, how will it affect long-term carrying capacity?

Background

If an epidemic were to occur, there would be two factors that would affect its duration and severity: behavior and characteristics of the individuals within a population (interactions, movement, mating, immunity, and self-quarantine) and characteristics unique to the disease. By assigning different agents varying values representing characteristics such as susceptibility, and allowing for on-the-fly changing of variables such as agent age and immunity, one can find out how the population as a whole would react to epidemics and any resulting quarantines over the long term.

Procedures & Methodology

The modeled world (Figure 1.) is initially populated with agents, who are infected, susceptible, and immune, with the distribution and number determined by user input (Figure 2.) If a quarantine is in effect, quarantine officers are added to the world on the randomly placed 3x3 quarantine zone. With each tick, healthy agents step in a random direction, attempting to avoid infected persons being impounded by quarantine officers, as well as the quarantine zone. Infected persons move one space at a time, though if they come into the vicinity of a quarantine officer, they are forced to follow the officer to the quarantine zone. Aging is controlled by internal equations which increase an agent's chance of death every tick, and change the susceptibility of a person. The changes in susceptibility related to age are modeled by a polynomial (Figure 3.) which mimics the W-shaped distribution of the 1918 Spanish Influenza[1]. If agents successfully mate, their children's characteristics such as susceptibility

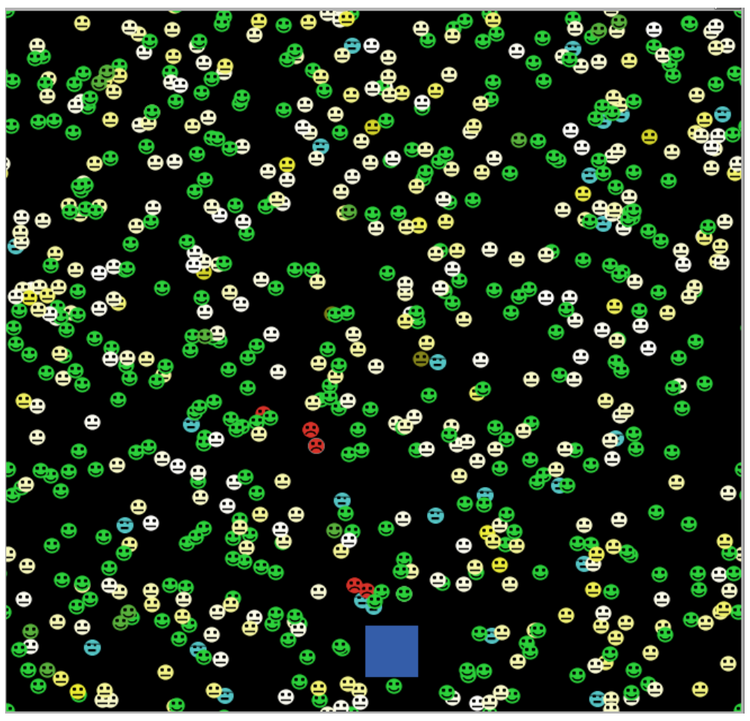

Figure 1. Infected (red) agents are led to the blue quarantine zone by cyan quarantine officers

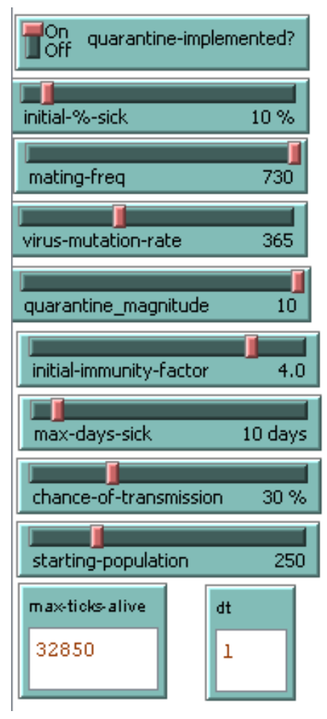

Figure 2. Modifiable settings allow for a plethora of run possibilities

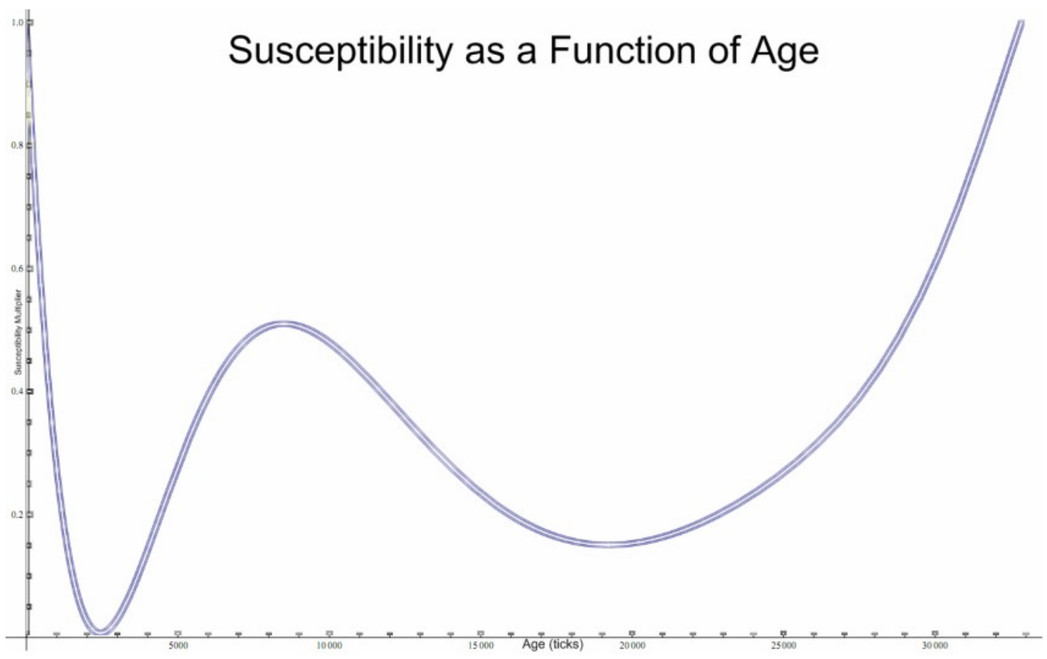

Figure 3. The youngest, oldest, and those in early adulthood are the most susceptible (as was the case in 1918 Spanish Influenza.)

are numerically represented as the average of the two parents characteristics. These interaction, combined with the effect of recurring virus mutations and outbreaks should create long-term oscillations about a carrying capacity.

Conclusions

In a population where population restraints such as food, shelter, and personal safety are met, epidemics can act as a population constraint, preventing populations from experiencing exponential growth for sustained periods of time. Additionally, the implementation of a quarantine can increase the long-term carrying capacity of such a population. Increasing the magnitude of the quarantine results in further increase in carrying capacity. This quarantine magnitude vs. population relationship could not be definitely assigned a mathematical relationship, because determining on the initial starting variables, it could result in either a linear or logarithmic trend line.

In a sample run shown below in Figure 4., the long-term average population increased by 13% when a quarantine was implemented. Quarantines thus have a significant impact on population over a long-term period of time.

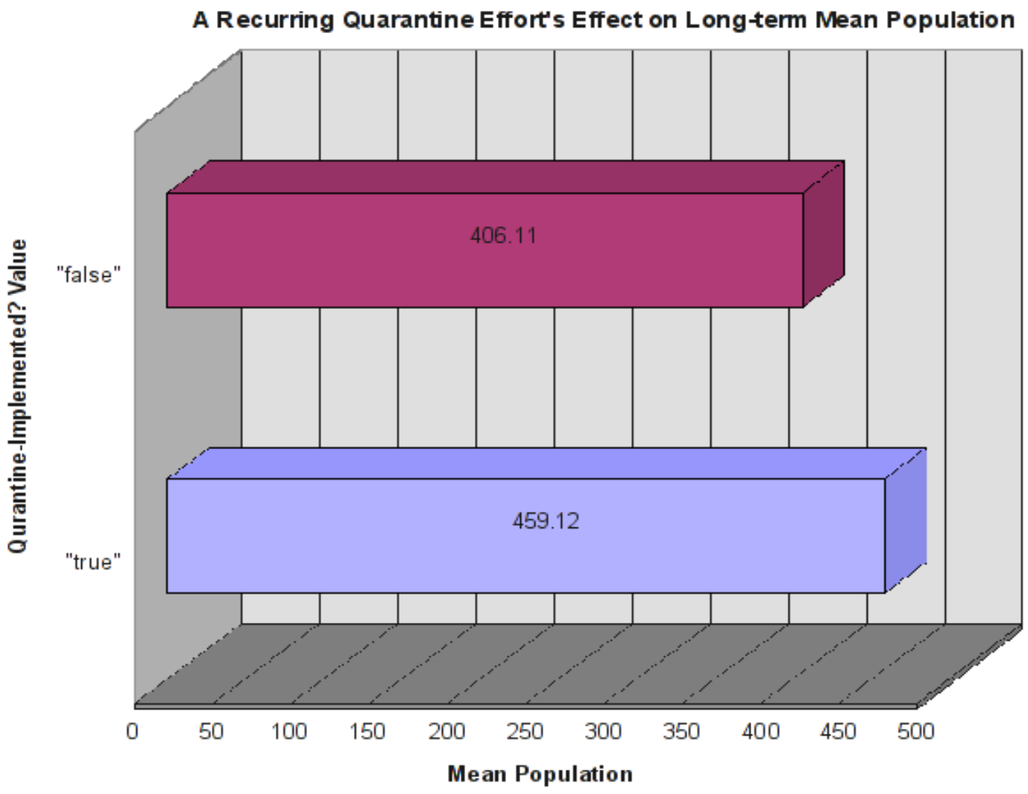

Figure 4. A comparison of two runs with the same base variables except the boolean "quarantine-implemented?"

1. Taubenberger JK, Morens DM. 1918 influenza: the mother of all pandemics. Emerg Infect Dis. 2006 Jan. Available from http://www.cdc.gov/ncidod/EID/vol12no01/05-0979.htm