Lab/Homework #3

HUMBIO 154D/HRP 204

Due Date: May 18, 2020

**Instructions:** This homework assignment is designed to accompany the in-class lab on 5/14/20 and to be partially completed during lab. You should be able to complete all of exercises using equations defined in lecture and from assigned reading in Keeling & Rohani, and model and plotting functions available on Canvas (see Lab3\_functions.R) and demoed in Lab 3. While we will grade this homework assignment based on completion, you should use this as an opportunity to concretize what you have learned in class and labs so far. Future homework assignments and labs will build on what you learn while completing this assignment. You are welcome to work with your classmates but we ask everyone to submit their own responses (as a Word doc) and their own accompanying R code to Canvas.

**Section 0:**

The first step in the lab is to install any packages you do not have. For example, you may need to install the package plsgenomics using Tools->Install Packages…

We also include a helper function to graph runs of our SIR models. Take a look at the comments which clarify which colored line corresponds to which compartment in the model

***Select and run the code in Section 0***

**Section 1:**

Next examine the code for Open SIR Model With Imperfect/Waning Vaccination

*Question 1: What happens to individuals whose immunity wanes?*

*Question 2: Can natural immunity wane? What change(s) would you make if you wanted natural immunity to wane as well <DON’T MAKE ANY CHANGES THOUGH>?*

***Select and run the code in Section 1***

**Section 2:**

Next examine the code in in Section 2. We are ensuring that the population size is stable by making the birth and death rates the same.

***Select and run the code in Section 2***

*Question 3: What is the peak prevalence of Infectious individuals? At what time t does it occur approximately? What is the equilibrium prevalence?*

*Question 4: Does the equilibrium prevalence match with theory?*

**Section 3:**

Next examine the code in this section which encompasses a helper function and running the helper function on our output from the no vaccination run.

*Question 5: The helper function is called “compute\_cumulative\_infection\_time”. Describe what it is does? Why is the quantity it computes interesting <REMEMBER LAST LECTURE BUTDON’T WORRY IF YOU CAN’T ANSWER THIS AS IT WILL BECOME CLEAR LATER ON>?*

***Select and run the code in Section 3***

**Section 4:**

Examine the parameter set in section 4. Notice that p\_vax is 0.1 (10% of babies get vaccinated). Notice that p\_imm\_vax is 1.0 (100% of vaccinated babies are immunized).

***Select and run the code in Section 4***

*Question 6: With vaccination, what is the peak prevalence of Infectious individuals? At what time t does it occur approximately? What is the equilibrium prevalence? How do these differ from your answers to Question 3? How does the cumulative infection time with vaccination differ from what you computed in Section 3?*

**Section 5:**

In this section we consider a simple threshold analysis.

First look at the function call\_ode. It is a wrapper function that will be useful when we want to run our model many times while only changing parameters. *Notice what quantity it returns.*

The rest of the code in this section makes a set of 90 parameter sets. The first is no vaccination, and the second is perfect vaccination with increasing levels of coverage from 0.01 to 0.90 (1% to 90%). You can see this with the head and tail commands that show params\_to\_try.

Next our model is applied to each of the parameter sets using the apply command and using as the function to be applied the call\_ode wrapper function mentioned earlier. This generates output that is stored in cum\_infections, which we plot.

***Select and run the code in Section 5***

*Question 7: Interpret the plot. Explain what our simple threshold analysis shows.*

**Section 6:**

We now examine imperfect vaccination (where the probability that a vaccinated child is immunized is less than 100%). Notice that we assume that in our new parameter set the probability is 40%

***Select and run the code in Section 6***

*Question 8: For imperfect vaccination, what is the peak prevalence of Infectious individuals? At what time t does it occur approximately? What is the equilibrium prevalence? How does this compare to perfect vaccination?*

**Section 7:**

To prepare for running a 2-way sensitivity analyses of vaccine coverage (p\_vax) against vaccine efficacy (p\_imm\_vax), ***run the first three lines of code (the calls to call\_ode) in this section***. Notice the pattern in the number of infection-years from perfect vaccination to no vaccination.

Next, examine the nested for loops. The loop over all combinations of 2 numbers i and j. The index i goes from 0 to 19 and is divided by 40. This means that the parameter it sets is in the range of 0.0 to just under 0.5. It is related to p\_vax. Your answer to the simple threshold analysis explains why we use this range. The other parameter j is related to p\_imm\_vax and is 1 – values from 0.0 to just under 0.5 – p\_imm\_vax ranges from 100% (perfect vaccination) to 50% efficacy. ***Select and run the rest of the code in the section including the heatmap plot of the results.***

The heat map plots things a little strangely. The upper right is i=0 and j=0. The upper left is i=0 and j=19. The lower right is i=19 and j=0. So this means the upper right is 0% coverage, 100% efficacy. The lower right is 100% coverage and 50% efficacy. The lower left is 100% coverage and 100% efficacy. The upper left is 0% coverage 50% efficacy.

*Question 9: Notice how the colors in the graph form curves. What does this tell us about combinations of coverage and efficacy? If increasing coverage and increasing efficacy cost the same amount and you had a limited budget, what combination of increases would you choose and why?*

**Section 8:**

This section deals with waning vaccine-induced immunity. ***Run the code and examine the plot and the 4 numbers produced in the console output.***

Question 10: *For imperfect waning-immunity vaccination, what is the peak prevalence of Infectious individuals? At what time t does it occur approximately? What is the equilibrium prevalence? How does this compare to perfect vaccination?*

*OPTIONAL: Try to code and run a two-way sensitivity analysis as suggested by the comment after section 8. Use a range of 0 to 0.5 for the waning rate. Paste the heatmap you produce into the answers you submit.*