Biomathematics Innovation Group
Modeling Biological Phenomena

Life or Death: Decision Making in Sexual Disease Treatment Matters

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Abstract

Syphilis is an STI that has recently made a resurgence in homosexual populations. When infected, a patient has two options: seek treatment immediately or do not seek treatment. I used a system of differential equations that includes susceptible, exposed, treatment receptive, treatment unreceptive, cured, and dead state variables in order to determine the relationships among transmission rate, treatment options, and death rate. My model suggests that an individual's treatment option has a larger effect on death rate than the transmission rate inherent to the disease. The model also contains two sets of equilibria: an unstable trivial disease free condition and stable non-trivial equilibria in which the susceptible state converges on 0.063, exposed converges on 0.024, treatment receptive converges on 0.012, treatment nonreceptive converges on 0.63, cured converges on 0.26, and dead converges on 0.012. My results indicate that education about treatment options may reduce the burden of syphilis in the population.

Introduction

The number of reported syphilis cases has been on rise, particularly in homosexual populations on the American West Coast, and Africa. Left untreated, a syphilis infection can lead to death. The purpose of this study is to model the spread of syphilis in a 100% susceptible population using a model of differential equations and examine how treatment option affects prognosis. Specifically, there are two options: treatment friendly and treatment hostile. Treatment friendly individuals seek treatment immediately after symptoms appear, whereas treatment hostile individuals never seek treatment. The results of the model can be used to demonstrate the importance of public knowledge in order to reduce the burden of syphilis in a population.

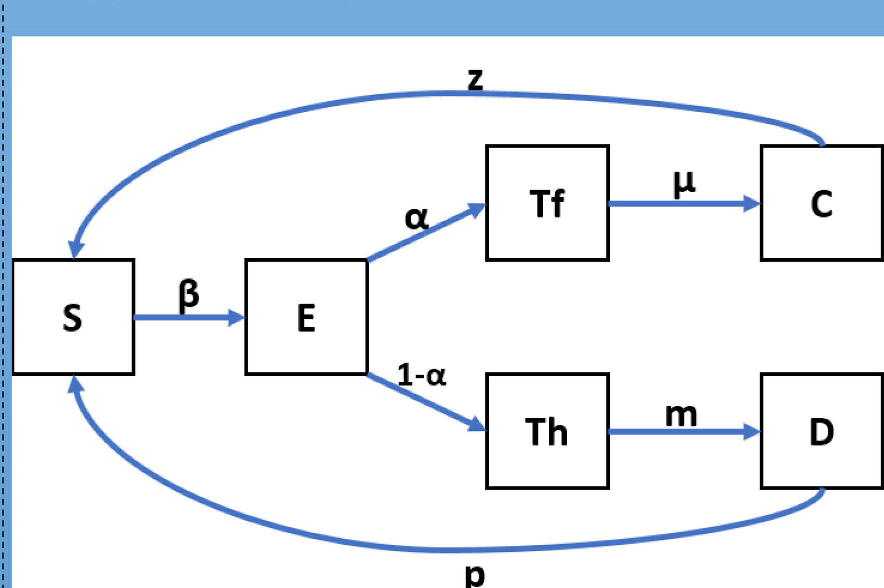

Figure 1. Compartment model visualizing state variables and parameters of the SEIR model. Arrows indicate members of the population moving from one state to another.

Methods

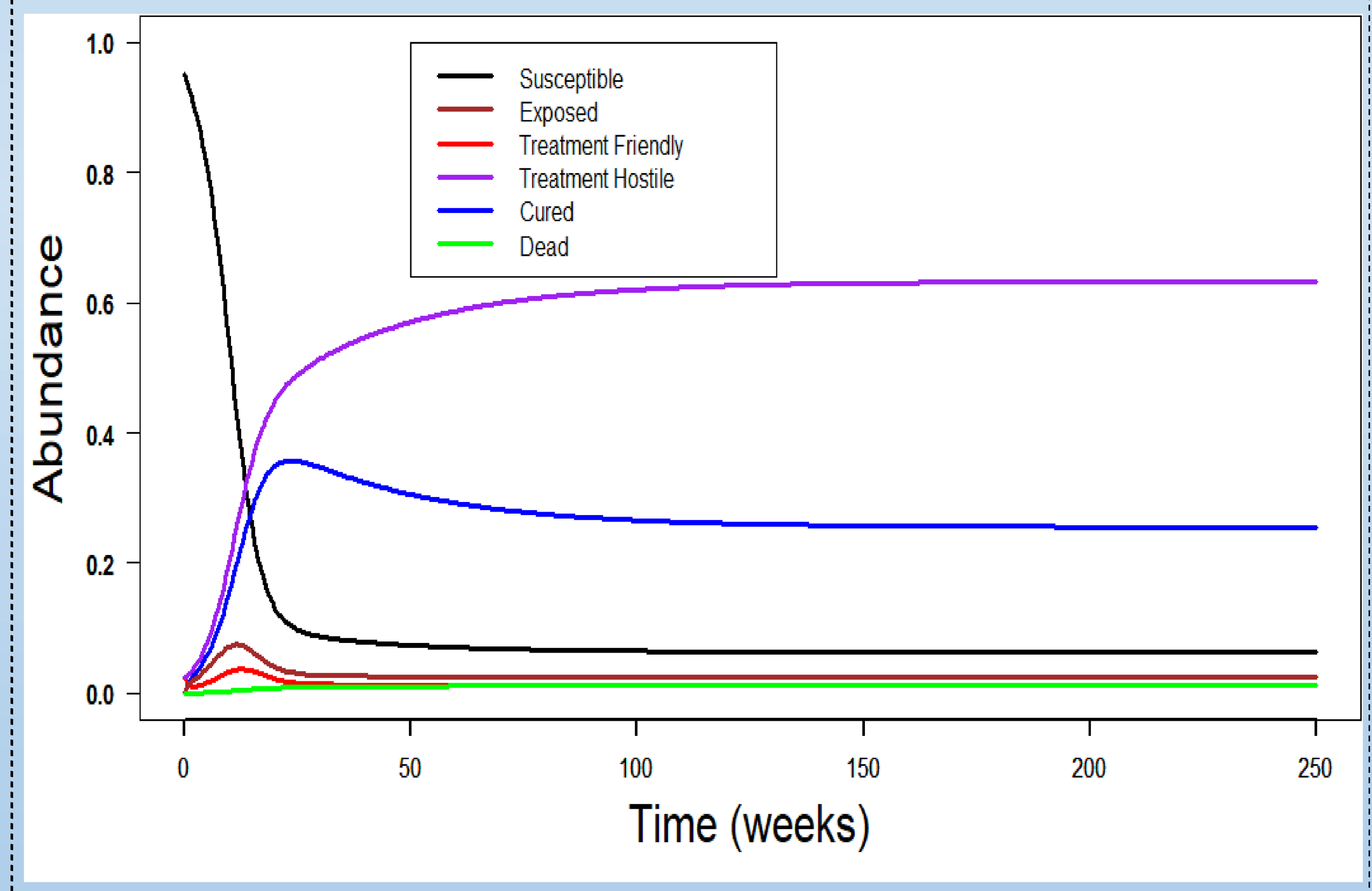

Figure 2. The model uses six differential equations to model the spread of syphilis. Susceptible individuals who contacted an infected individual are moved to exposed. The exposed population then splits into treatment friendly or treatment hostile. Treatment friendly individuals are cured before looping back into the susceptible population. Treatment hostile individuals die before looping back into the susceptible population. By looping back into the susceptible population the model can run multiple times.

Table 1. Guide to symbols used in the model described above.

Symbol	Value	Meaning
β	6/10	Parameter-transmission rate
α	0.5	Parameter- assigns individuals to Tf
1-α	0.5	Parameter- assigns individuals to Th
u	1	Parameter- moves Tf to Cured
z	1/21	Parameter- moves Cured to Susceptible
m	1/52	Parameter-moves Th to Dead
p	1	Parameter- moves Dead to Susceptible
S	0.95	State Variable- Susceptible
E	0	State Variable- Exposed
Tf	0.25	State Variable- Treatment Friendly
Th	0.25	State Variable- Treatment Hostile
C	0	State Variable- Cured
De	0	State Variable- Dead

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References

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Results

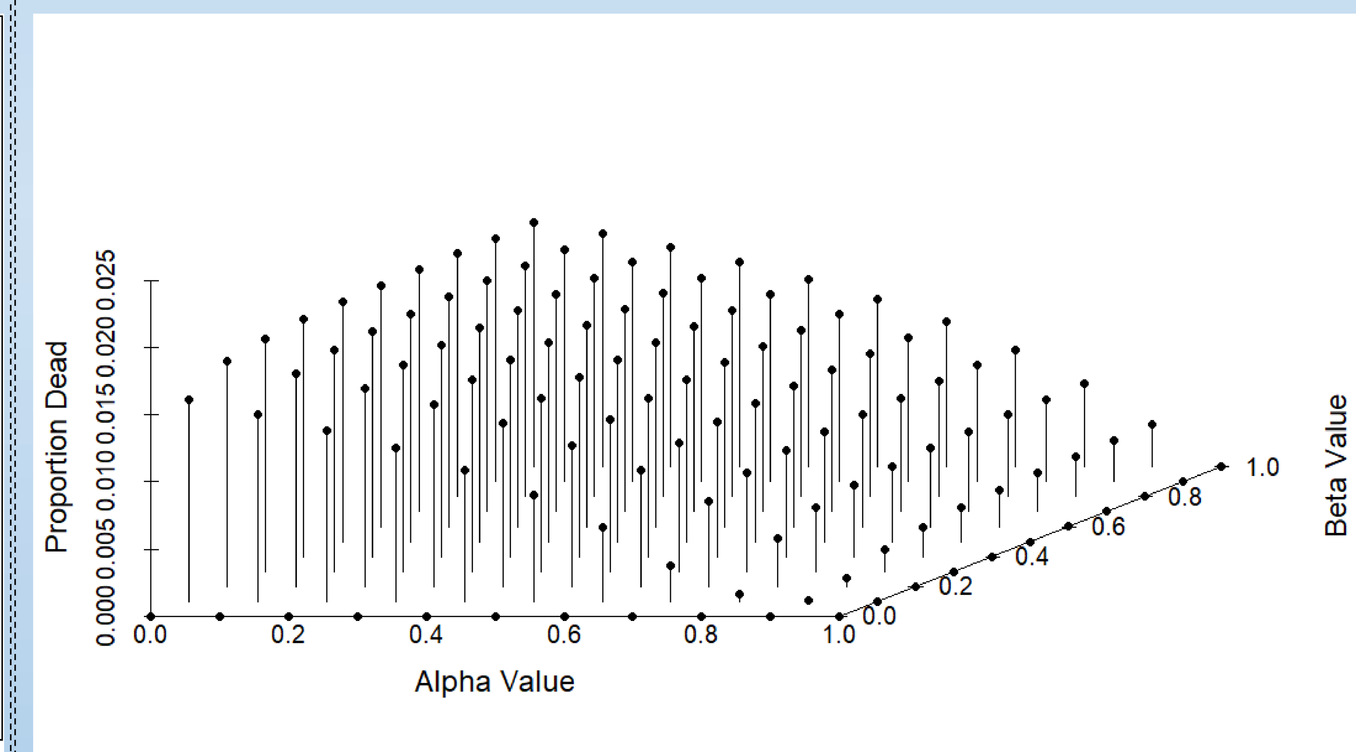

Figure 3. A loop is used to determine the relationship between α and β on the proportion of the population that is dying. 11 values are sampled for both parameters and plotted in three dimensions: α on the x-axis, β on the z-axis, and proportion of population dead on y-axis. The results indicate that the value of α has a larger impact on death compared to β.

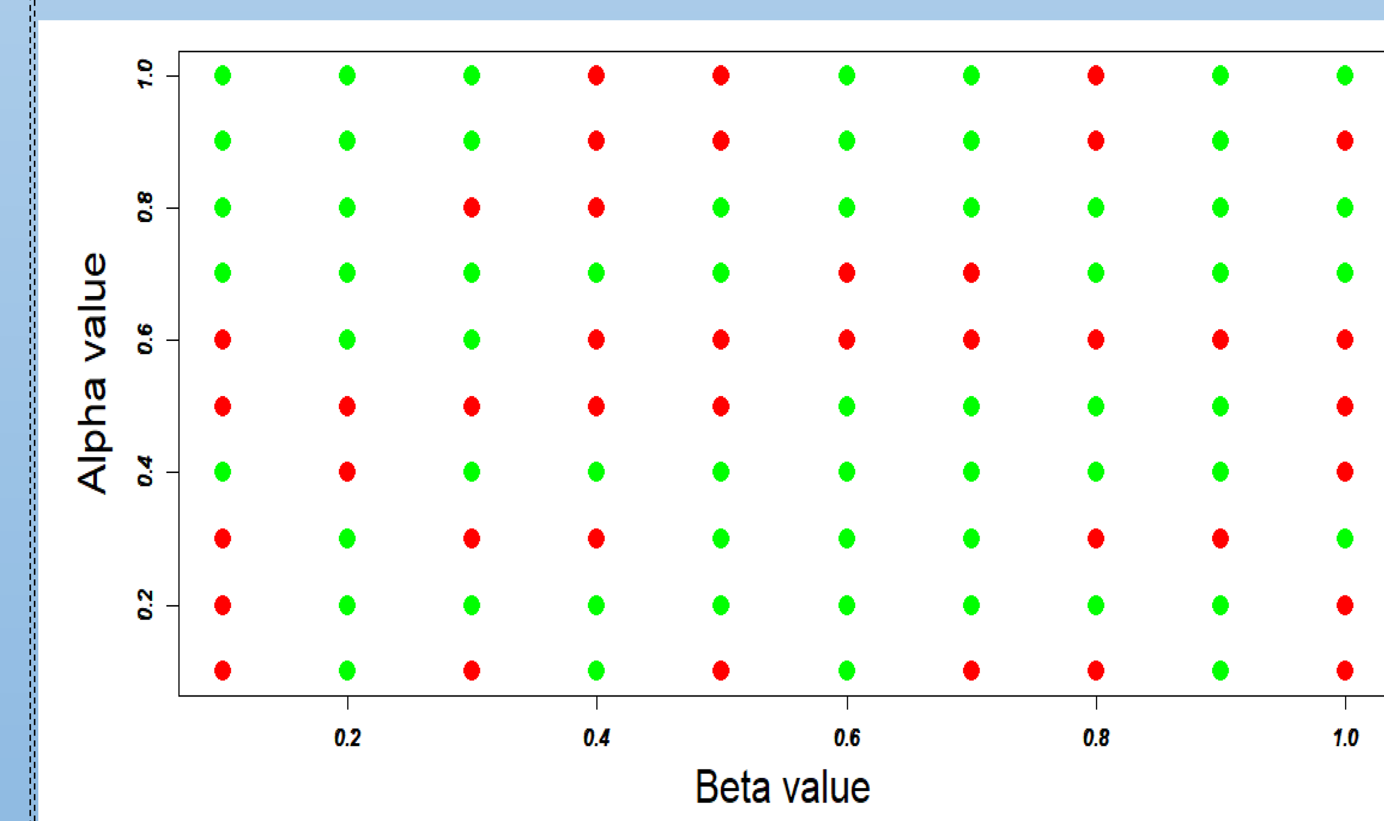

Figure 4. A final loop allows the model to consider multiple values of α and β, while analyzing the equilibrium of each run. This aids in understanding how α and β affects the equilibrium points of the model. After running 100 times, no consistent effect on equilibrium was found between α and β. Green designates a stable equilibrium while red designates an unstable equilibrium.

Conclusion/Discussion

The results of the model suggest the following:

- An individual's treatment decision has a larger impact than the diseases transmission rate on the proportion of individuals dead.
- No clear relationship was determined between α and β and the equilibria of the system.
- Public knowledge regarding a disease and its treatment options, along with fewer or no barriers to treatment can reduce the burden of syphilis in a population.