MALARIA MODELING PROJECT

The malaria model you will initially implement will assume that there are no gestation periods for the disease to appear. Empirical rates for infection, immunity, deaths, other parameters will be used to forecast the subpopulations of villagers with and without the disease and the mosquito population.

Start by reading the references from the CDC, World Health Organization, NIH, and the review article on modeling malaria. Those articles offer insights on the disease cycle as well as the various ways that the cycle has been modeled by others.

For your model, you will need to implement a number of time variant equations related to the populations of villagers and mosquitoes. Those are shown below.

Malaria Model Equations

Total Humans= Healthy Villagers+Sick Villagers+Immune Villagers
Births= Birth Rate*Humans
Healthy Dies= Healthy Villagers*Death Rate
Infected= Bite Rate*Healthy Villagers*(Infected Mosquitoes/Mosquitoes)
Sick Dies= (Malaria Death Rate+Death Rate)*Sick Villagers
Immune Dies=Death Rate*Immune Villagers
Recover= Sick Villagers*Recovery Rate
Immune=Sick Villagers*Immune Rate
Sick Villagers= Infected-Recover-Immune-Sick Dies
Immune Villagers=Immune-Immune Dies
Healthy Villagers= Births+Recover-Healthy Dies-Infected
Mosquitoes= Healthy Mosquitoes+Infected Mosquitoes
Mosquito Births= Mosquitoes*Mosquito Birth Rate
Mosquito Dies=Healthy Mosquitoes*Mosquito Death Rate
Mosquito Infection= (Sick Villagers/(Humans+1))*Healthy Mosquitoes*Bite Rate
Infected Mosquito Dies= Infected Mosquitoes*Mosquito Death Rate
Infected Mosquitoes= Mosquito Infection-Infected Mosquito Dies
Healthy Mosquitoes= Mosquito Births-Mosquito Dies-Mosquito Infection

Each of the equations can be represented as digital equations and translated into difference equations that can be used in the model much as was done in our unconstrained growth exercise. For example, for the healthy village population:

$H(t+1) = H(t) + H(t) * BirthRate - H(t) * DeathRate + S(t) * RecoveryRate - H(t) * InfectionRate$

Where

$H(t)$= Healthy population at time t

$S(t)$ = Sick population at time t

Similarly, you can construct an equation for each part of the human population using the relationships given above. For the mosquito population, a simpler equation taking into account births, deaths, and infected can be added. Your final model should include a plot the populations of each sector of the human population and a plot of the mosquito population over time.

For your model, here are some starting parameter values:

Starting number of healthy mosquitoes = 1000
Starting number of infected mosquitoes = 0
Starting number of healthy humans = 499
Starting number of sick humans = 1
Starting number of immune humans = 0
Human birth rate = 0.000092/day based on an annual rate of 0.03358
Human death rate = 0.00001945/day based on an annual rate of 0.0071
Human malaria induced death rate = 0.00016123/day based on an annual rate of 0.0588486
Human recovery rate = 1- malaria induced death rate
Human immunity rate = 0.01
The parameters for mosquitos:
Mosquito birth rate = 0.01/day
Mosquito death rate = 0.011/day
Bite rate from mosquitos = 0.24

Create the basic model and run it for 200 days. Examine the resulting breakdown of the human populations and the infected and uninfected mosquito population. Then, run the model for 2000 days and compare what happens to the trends in the disease. Analyze the sensitivity of the model results to changes in the immunity rate and in the bite rate for mosquitos. Prepare a written and oral report on your findings including any of the optional additional model components outlined in the detailed assignment.

Once you have the basic model working and verified, you may choose to implement one or more of the optional additions to your modeling effort:

1. The progression of the disease is not nearly as simple as depicted in this basic model. Consider a different form of malaria in which sick villagers can go into remission stage and have relapses. The probability of a relapse for some forms of malaria is 17%. Refine the model to calculate the
2. Suppose there is a seasonal increase in the number of mosquitoes, such as a rainy season in tropical areas. The mosquito birth rate mbr and death rate mdr are then defined by:

   mbr=(cos((time_in_days*(2*PI))⁄(365)+1))*max_mosquito_birth_rate/2,
   mdr=(cos((time_in_days*(2*PI))⁄(365)+1))max_mosquito_death_rate/2.

   Where the max_mosquito_birth_rate = 0.02
   max_mosquito_death_rate = 0.022

   Refine the malaria model to reflect these seasonal variations and analyze the results as compared with the original model.
3. According to a study about the effectiveness of mosquito nets in reducing the infection rate, insecticide treated nets (ITN) reduced the incidence of uncomplicated malarial episodes by 50% compared to no nets, and 39% compared to untreated nets. If the cost of treated nets is $3.50 and untreated nets is $2.50, how much will it cost to provide nets to your population and how will this impact the incidence of the disease? Assume that each net can cover two people. Assume your village is in Ghana so that you can look insert the average family size into your calculations. Adjust the model to test this policy and describe both the cost of treatment and the benefit in terms of reduced cases of malaria. (See http://en.wikipedia.org/wiki/Mosquito_net).

References

National Institutes of Health. https://www.niaid.nih.gov/diseases-conditions/malaria

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