Appendix D

Computational Projects

These projects are designed around the computational implementation of one or more mathematical models and the use of that implementation to explore the properties of the model, and are intended to be done individually, rather than in groups. The projects should be treated as a computational experiments, with results written in the style of a lab report that is aimed at a third party with little background in the subject. The results thus need to be fully explained with such an audience in mind. A recommended structure would include:

Title: Project title, author and date.

Abstract: A *brief* summary of the key questions, results and conclusions. In general this should not be longer than a half page, double spaced.

Introduction: A description of the problem(s) under consideration, and any relevant background information. This section should include both a summary of the biological problem(s) being considered, as well as the mathematical modeling frameworks that will be used.

Results and Discussion: An integrated presentation of the results of each "experiment" and any relevant discussion. This should be written in narrative prose (that is, complete sentences that walk the reader through everything that was done), with any generated graphics and code inserted at the appropriate location.

Conclusion: A brief summary of the key insights obtained, and perhaps any unanswered questions that remain.

References: A list of all resources used in completion of the project. If a resource is used in generating a specific result or in support of specific point made in the introduction or discussion, this should be noted with a citation at the appropriate place in the report text. A specific format for citations/references is not required, but the format used should be consistent.

Note that the projects were created with the use of MATLAB in mind, and in my classes this is expected. However, the projects are not dependent on this choice, and could be handled equally well with other programming languages.

D.5 A model of malaria transmission

The following differential equations can be used as a model for malaria, treating the illness as SIS in the human population and SI in the mosquito, and ignoring demographic processes among people but explicitly including "births" and deaths of mosquitoes (but with constant population size).

$$Human: \quad \frac{dS_H}{dt} = -\epsilon_1 \beta \frac{S_H}{N_H} I_M + \gamma I_H \qquad \frac{dI_H}{dt} = +\epsilon_1 \beta \frac{S_H}{N_H} I_M - \gamma I_H$$

$$Mosquito: \quad \frac{dS_M}{dt} = \alpha N_M - \epsilon_2 \beta \frac{I_H}{N_H} S_M - \alpha S_M \qquad \frac{dI_M}{dt} = +\epsilon_2 \beta \frac{I_H}{N_H} S_M - \alpha I_M$$

Here, β is a mosquito feeding rate, while ϵ_1 and ϵ_2 describe the fraction of bites involving a susceptible/infective pair that lead to transfer of the infectious agent; γ is the human recovery rate; α is the mosquito birth/death rate.

1. Implement a simulation of this model of infectious disease in Matlab using the Forward Euler algorithm (as in HW #1 and #3), using a total simulation length of 200 days and a time step of 0.01. A starting set of parameters is: $\beta = 5$, $\epsilon_1 = 0.01$, $\epsilon_1 = 0.1$, $\gamma = 0.05$ and $\alpha = 0.02$, with total population sizes of 10^6 for both mosquitoes and humans.

2. Run three simulations using this model all with an initial population of infective humans of 0 and initial populations of infective mosquitoes equal to 10%, 50% and 90% of the total mosquito population. Plot the populations over time and discuss your observations.

3. Run another three simulations using this model all with an initial population of infective mosquitoes of 0 and initial populations of infective humans equal to 10%, 50% and 90% of the total human population. Again, plot the populations over time and discuss your observations.

4. Run another four simulations using this model, but with $\beta = 5$, $\beta = 2$, $\beta = 1$, and $\beta = 0.5$; use initial populations of both infective humans and mosquitoes equal to 10% of the total populations in all cases. Plot the populations over time and discuss your observations.

5. Run another set of simulations using the original parameters ($\beta = 5$), but with the total mosquito population size equal to to 10^6, 10^5 and 10^4.Plot the populations over time and discuss your observations.

6. Use your results to discuss how reducing mosquito feeding rates (*e.g.* through the use of mosquito nets over beds) and reducing mosquito populations (*e.g. by eliminating water sources for breeding sites* can be used in malaria control. Your discussion should include a distinction between interventions that simply reduce the incidence of disease and those that lead to disease eradication.

