BIOL 4607/6131: Lab 1

Completed assignments are due at the start of the lab class on January 31 (2 weeks). You should submit your scripts to the course dropbox and any handwritten answers can be scanned and submitted to the dropbox too. Total = 18 pts (UG), 21 pts (G).

Q1. Functions (3 pts)

Understanding the shape of different mathematical functions is a helpful skill for model derivation and model analysis. For example, if you hypothesize that the number of slugs, *S*, found in an area, *A*, is a saturating function, to model this relationship you need to know the mathematical formula for such a function. Consulting Primer 1 of the textbook (beginning on p89) we see that suitable formulas for saturating functions are $S = \frac{a\,A+c}{b\,A+d}$ with $ad - bc > 0$ (i.e., a rational function, p93) or $S = \frac{ce^{aA}}{ce^{A}+(1-c)}$ where A, $c > 0$ (i.e., an S-shaped function, p94). In this way, understanding the shape of functions is helpful for model derivation. When analyzing a model, for example $\frac{dN}{dt} = rN(1 - \frac{N}{K})$ the equation tells us how $\frac{dN}{dt}$ changes as a function of *N, r,* and *K*. The rate of change, $\frac{dN}{dt}$, might be positive or negative, but the parameters and variables, *N, r,* and *K* are only biologically meaningful when they are positive. If you are able to recognize that $\frac{dN}{dt}$ is a quadratic function of *N,* where the coefficient in front of the N^2 term is negative and the coefficient in front of the *N* term is positive, knowing the shape of a such a function will help you to understand the regions of *N* for which $\frac{dN}{dt}$ is positive. In this way, understanding the shape of functions can help with model analysis.

(i) Provide the R code to generate 3 of Figs. P1.3-P1.7 from the textbook. It is up to you which of these 5 figures you choose to reproduce. The choice of parameters is up to you as long as the parameters chosen are appropriate to reproduce the textbook figures.

Q2. Model derivation

A.1 Discrete time (6 pts)

Question: how does the number of juvenile and adult mice in a population change over time?

Assumptions:

- There are two types of mice in the population: juvenile and adults.
- Only adult mice are able to reproduce and they give birth to juvenile mice.
- It takes 1 year for juvenile mice to mature to adults.
- The time step of the discrete time model is 1 year.
- The order of events are: immigration (independent of the number of mice), birth, maturation, and then deaths.
- Only juvenile mice immigrate and all mice (whether they are born locally or elsewhere) are born at the same time.
- The death rates of juvenile and adult mice are different.

You are to:

(i) Define your parameters and variables (with units and constraints)

(ii) draw a pair of life cycle diagrams (one for juveniles and one for adults); and

(iii) derive a discrete time model based on the assumptions above.

A.2 Continuous time (6 pts)

Question: how does the number of showshoe hare found in one of two habitat types change over time?

<u>Assumptions:</u>

- Individuals in a population of snowshoe hare are found in either grassy, G(t), or forested habitat, F(t).
- Food quality differs in either habitat. The per capita number of offspring produced by each hare depends on the type of habitat they occupy at the time of giving birth.
- Newborn hare are born into the habitat that their parent occupied.
- The per capita mortality rate of hare is the same in each habitat.
- Each hare in forested habitat moves to grassy habitat at a rate φ. Each hare in grassy habitat moves to forested habitat at a rate γ.

You are to:
(i) Define your parameters and variables (with units and constraints),
(ii) draw a flow diagram, and
(iii) derive a continuous time mathematical model based on the assumptions above.

Q3. Numerically solving a discrete time model (3 pts)
The model that you wrote down for **Q2 A.1 iii** can be solved using a for loop.

- Start writing your code by assigning numerical values (of your choosing) to all the model parameters.
- Define a vector `time=seq(0,50,1)` which states that you wish to find the size of the mouse population from time 0 to time 50.
- Create a vector `J=rep(0,length(time))`. This vector has the same length as the time vector. At the moment, all the values of the `J` vector are equal to 0. This is called pre-allocation. When we enter the loop we will calculate the values of the number of juveniles, `J`, corresponding to the different time points, and we will replace the 0 values in the `J` vector with the correct calculated values.
- Create a vector `A=rep(0,length(time))`. This vector will be updated in the loop to record the number of adults at the corresponding points in time.
- Assume that at `time` = 0, the number of juveniles is 3 and the number of adults is 3. In the next lines of code we want to make the first value of the `J` vector equal to 3. To do this we write `J[1]=3`. Use the analogous command to set the initial number of adults to 3.
- Now we are ready to start our time loop. Do so, using the following command: `for(t in seq(1,length(time)-1,1)){`
- Next, type `J[t+1]=` 'your equation from question (3) for juveniles'. To reference *J(t)*, use the syntax `J[t]` because you are extracting an element of the `J` vector. If you use round brackets this would supply the value of `t` to the first argument of the function `J`. In our code there is no such thing as a `J` function, so this syntax would generate an error.
- Now add in the equation for adults at the next time step, in the same way.
- Now, end the loop with `}`.
- Finally, you would like to plot the results. Do so by plotting `time` on your x-axis and `J` on your y-axis. Then use the `lines`() command to add in the `A` vector to your plot.

(i) Once you have completed and implemented this code, submit it to the Brightspace dropbox.

Graduate students only (3 pts)

(ii) All else being equal (i.e., all other parameters kept constant), what is the effect of increasing the juvenile immigration rate on the number of juvenile and adult mice?

a. Provide R code demonstrating the effect.

b. Provide a short paragraph (3-5 sentences) discussing the ecological implications of increasing juvenile immigration rate.