NAME:

LAB OVERVIEW

The objectives of this lab are to increase your understanding of:

1. Making management models
2. Instantaneous versus finite rates
3. Harvest of fishery systems
4. Evaluating a fish stocking decision
5. Parameter importance in fishery management systems

Responses to questions, at the end of this document, will be **due by 5pm, Tuesday, September 12th**. Responses can be entered here https://goo.gl/forms/UkZv57eOzQ8V4CMU2.

This lab is worth 25 points.

IN CLASS DEMONSTRATION: MAKING A MODEL

In class demo of silver and gold fish to illustrate making a management model in STELLA.

EXERCISE 1: MAKING A MODEL

The basic exponential model we worked with last week is the basis for most models in fisheries. It is parameterized below as:

$$\frac{dAbundance}{dt} = Gains$$

$$Gains = intrinsic\ growth\ rate \cdot Abundance_t$$

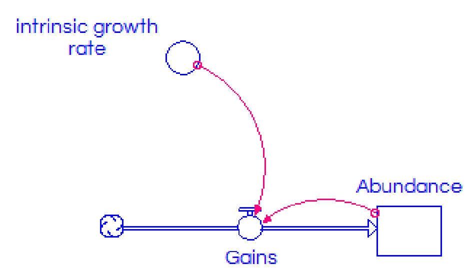
$$\frac{dAbundance}{dt} = intrinsic\ growth\ rate \cdot Abundance_t$$

$$\frac{Abundance_{t+dt} - Abundance_t}{dt = 1} = intrinsic\ growth\ rate \cdot Abundance_t$$

$$Abundance_{t+dt} - Abundance_t = intrinsic\ growth\ rate \cdot Abundance_t$$

$$Abundance_{t+dt} = intrinsic\ growth\ rate \cdot Abundance_t + Abundance_t$$

The key parts are on the right hand side of the equation, *intrinsic growth rate* and *Abundance*$_t$. Using STELLA we will make the model illustrated below which is a conceptual representation of the model above.



There is a video tutorial that provides you all the information you need to build, parameterize, and run the model defined in the equations above. The video (mp4 format) can be found in the lab folder. Follow the steps in the video tutorial and put the model together. You will be using the model during the lab to run simulations and modify to represent common fisheries situations.

EXERCISE 2: INSTANTANEOUS VERSUS FINITE RATES

One of the major differences you will run into when comparing fisheries to any terrestrial counterpart is the use of instantaneous rates. Instantaneous rates are applied over very small time increments (i.e., dt →0). The differences between instantaneous and finite rates is further complicated by the fact that as both types of rates approach 0 they become more and more similar in value. **Finite rates are what you are most likely used to, like the population decreased 30% from one year to the next.** The rates can be converted from instantaneous to finite and back again using the equations below. In the example above the intrinsic instantaneous growth rate was 0.3.

Instantaneous rates can be converted to finites rates using the equation and example below.

$$finite\,rate = \mathrm{e}^{instantaneous\ rate} - 1$$
$$finite\,rate = \mathrm{e}^{0.3} - 1$$
$$finite\,rate = 0.349859$$

To convert the finite rate back to an instantaneous rate simply use the equation:

$$instantaneous\,rate = \ln(1 + finite\,rate)$$
$$instantaneous\,rate = \ln(1 + 0.349859)$$
$$instantaneous\,rate = 0.3$$

Let's explore this property and consequences to get a better feel for the <u>subtle</u> difference between instantaneous and finite rates and why using the right one is important with the following exercise. Using the model you built in <u>exercise 1</u> perform the following steps (Note. Feel free to reference the video tutorial to do any of the steps):

1) Open the run specs for the model (Run→ Run Specs or ALT+CTL+R) and make sure that the *dt* is set to 0.01 and the years to run is set to 10, and press OK.

2) Be sure to set *intrinsic growth rate* = 0.3 and press CTL+R to run the model and record the biomass at the end of the simulation. <u>This will be the last row in the data pad in STELLA</u>.

Abundance (t = 1): ___________

Abundance (t = 5): ___________

Abundance (t = Final): ___________

3) Repeat steps 1 and 2 <u>but set *dt* to 1</u> and record the following from the data pad.

Abundance (t = 1): ___________

Abundance (t = 5): ___________

Abundance (t = Final): ___________

4) Now let's see what happens when instantaneous and finite rates are treated appropriately by correctly applying rate and dt. **Be sure to set *intrinsic finite growth rate* = 0. 349859 and press CTL+R** (*Recall you set dt to 1 in the previous exercise, do that here too!*) to run the model and record the following from the data pad.

Abundance (t = 1): ___________

Abundance (t = 5): ___________

Abundance (t = Final): ___________

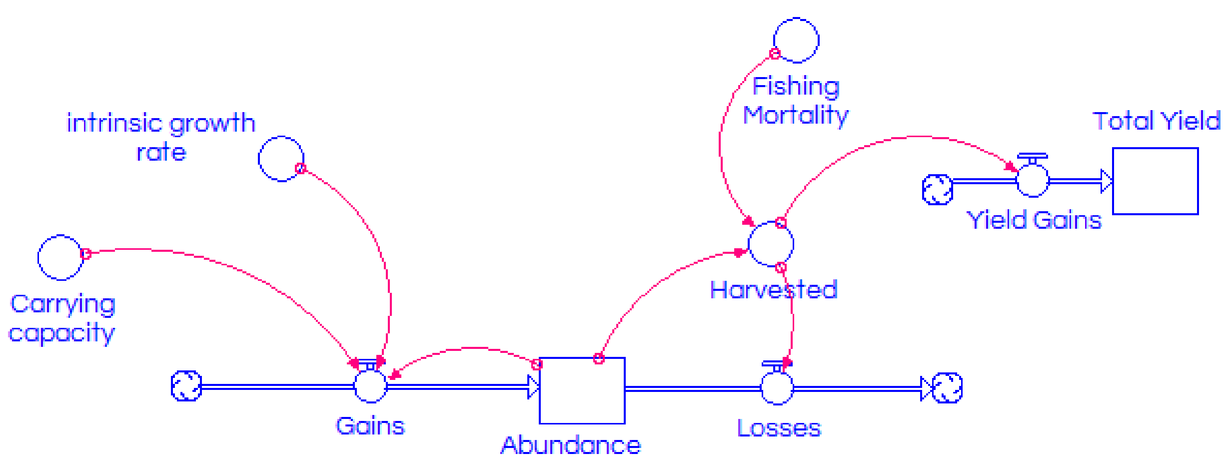
5) Save the model. File→ Save.

Exercise questions

2.1. How do the values for each time point differ from the values reported in 2 and 3 where the only difference there was the *dt*? What about 3 and 4 where the *intrinsic growth rate* was converted from instantaneous to finite but *dt* was the same? Lastly, what about 2 and 4 where rates were instantaneous and finite and *dt* was different? (4 points)

EXERCISE 3: OPTIMAL FISHING MORTALITY

We can use the model developed in exercise 2 to add biological realism. In this case we will add carrying capacity and fishing to the population illustrated below conceptually.



The figure on the previous page looks similar to the exponential model, just with the addition of carrying capacity and a flow out of the abundance box for losses to fishing mortality. New in this model is the addition of a box (state variable) to keep track of yield. This exercise will work through adding biological realism to your exponential model. Work through the steps below.

1) Open the model you created for exercise 2 and save it as a new model. You will be adding to it for this exercise.

2) Add *Carrying capacity*, *Fishing mortality*, and *Losses* to your model and connect them as shown above and label them accordingly.

3) Now add a stock for *Total yield* with a flow going into it for *Yield gains* and label them accordingly.

4) Parameterize model as follows

- *Intrinsic growth rate* = 0.3
- *Carrying capacity* = 1000
- *Gains = intrinsic growth rate *Abundance * ((Carrying capacity-Abundance)/(Carrying capacity))* {this is what is known as the Graham Schaefer model}
- *Fishing mortality* = 0
- *Harvested* = *Fishing mortality * Abundance*
- *Losses* = *Harvested*
- *Yield gains* = *Harvested*
- *Abundance* = 500
- *Total yield* = 0

5) Add a graph and data pad to keep track of the state variables *Abundance* and *Total Yield.*

6) Open the run specifications (Run→ Run Specs) and make sure that $dt = 0.1$ and the number of years to simulate is 100.

7) Run the model and record the final value for *Total yield* for the following values of fishing mortality:

a) 0 ___________

b) 0.05 ___________

c) 0.1 ___________

d) 0.15 ___________

e) 0.2 ___________

f) 0.25 ___________

d) 0.3 ___________

g) 0.35 ___________

8) Now change the Gains flow to be the following equation:

*Gains = intrinsic growth rate *Abundance * (1-ln(Abundance/Carrying capacity))*

This is known as the "Fox model"

9) Run the model again with the Fox formulation for gains and record the final value for *Total yield* from the data pad for the following values of fishing mortality:

a) 0 ___________

b) 0.05 ___________

c) 0.1 ___________

d) 0.15 ___________

e) 0.2 ___________

f) 0.25 ___________

d) 0.3 ___________

g) 0.35 ___________

Exercise questions

3.1. What was the fishing mortality that maximizes cumulative harvest given the possible fishing mortalities evaluated? (2 points)

a) Graham-Schaefer Model: __________

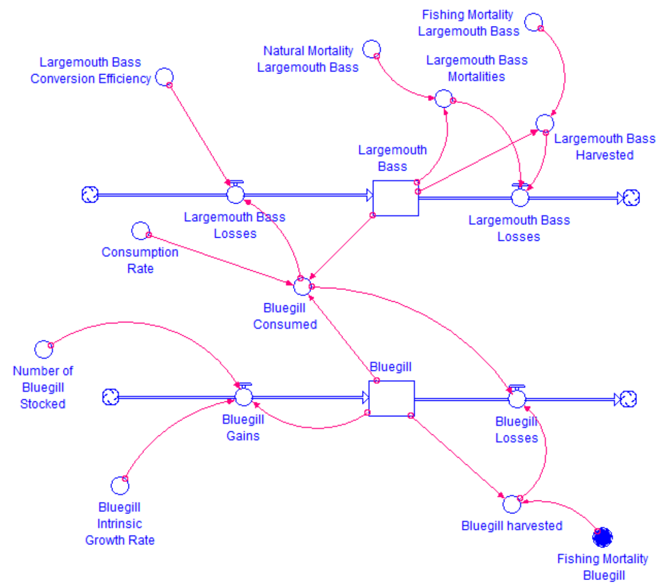
b) Fox Model: ___________

3.2. If you look at the parameters of the two models you will notice they are all the similar and the model is almost exactly the same, but the optimal fishing mortality is different. Why was this case? (3 points)

3.3. Looking at the graph for total harvest for the optimal fishing mortality, do you think fisherman will be happy with catches in the second half of the simulation (years 50 to 100) based on the Graham Schaefer model relative to the first couple of years? Why or why not? (4 points)

EXERCISE 4: FISH STOCKING IN A SMALL IMPOUNDMENT

Management becomes more complicated when there is more than a single stock being exploited. This is a common situation in small impoundments within Mississippi that have been stocked with Bluegill and Largemouth Bass. Both of these fish are considered game species; however Bluegill are prey for Largemouth Bass, creating a predator-prey dynamic. Harvest and predation of a prey species can limit production and predator-prey fish can oscillate over time. Suppose you have been solicited by a local fishing club to manage a small impoundment that has been stocked with Largemouth Bass and Bluegill and has been experiencing oscillating populations over time. The fishing club harvests both Bluegill and Largemouth Bass and the fishing mortality rate is known, instantaneous, and constant. They want to improve the overall fishing experience by reducing population fluctuations, using annual supplemental stocking of Bluegill, but are unsure what level of stocking is required. They have established an annual budget of $2000 and the cost of bluegills from a local supplier is $0.5 per fish. The conceptual model of the system is illustrated on the previous page.



The model for this system has been set up for you in Bluegill stocking.STMX. Use the model work through the exercise steps below to complete the exercise.

1) Open the run specifications (Run→ Run Specs) and make sure that $dt = 0.1$ and the number of years to simulate is 100.

2) Set *Number of Bluegill stocked* to 0

3) Press CTL+R to run the model and look at the population oscillations. Visually inspect the graph to see if the oscillations are dampened (i.e., stabilizing the fishery) and record the approximate year that oscillations dampen (**if they do not report the year as 100**) in the Table below.

4) Repeat steps 2 and 3 for each value of *Number of Bluegill stocked* in the table below and record the approximate year oscillations dampen (if they do not report the year as 100).

Annual bluegill stocking amount	Year populations stabilized*****

(individuals)	
0	
10	
100	
500	
1000	
2000	
3000	
5000	
*** Note this this subjective on your part. You will see that the cycling of Bluegill and Largemouth Bass dampens and stabilizes with increasing bluegill stocking, record this approximate time.**	

Exercise questions

4.1. What stocking amount would you recommend to the fishing club and why? (4 points)

4.2. Given the fishing club's objective to minimize population fluctuations, how could you measure or quantify some part of the fishery to evaluate whether the objective is being achieved? Think creatively here, be sure to describe the metric and how to measure or calculate it. (4 points)

4.3. Given your understanding of natural resources, harvest management, and the fishing club's impoundment, develop describe an alternative management strategy that could potentially meet the fishing club's objectives (This is where you can get creative, within biological constraints). (4 points)

4.4. Given your understanding of natural resources dynamics, harvest management, and the fishing club’s impoundment, what would you add to improve the biological realism of the model and why? (4 points)