WFA4314 Laboratory 4

Name:

LAB OVERVIEW

The objectives of this lab are to increase your understanding of how we use models to evaluate actions that can achieve management objectives. Responses to questions, at the end of this document, are **due by 5 pm, one week from today's lab**. Enter responses at https://goo.gl/forms/0gjNpIxeuV8aPk152. *This lab is worth 20 points.*

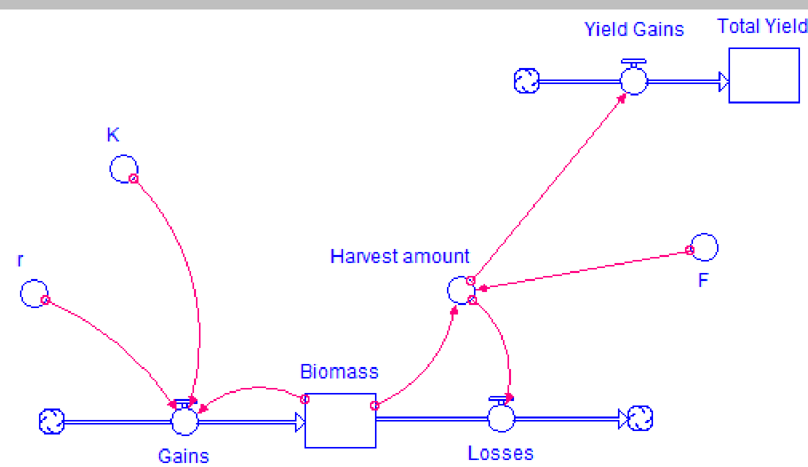
EXERCISE 1. MAXIMIZING YIELD

1.1. EXERCISE OVERVIEW

In general, the **objective(s)** of any fishery is to maximize societal or economic value from fish populations. In commercial fisheries, this is typically biomass yield, but economic pressures can influence yield (i.e., harvesting more fish may saturate the market and decrease economic yield). We will ignore the underlying economics for this example and identify the harvest rate that maximizes yield.

This exercise will evaluate how we can identify what fishing mortality rate (i.e., management action) achieves the management objective to maximize yield.

1.2. THE MANAGEMENT MODEL

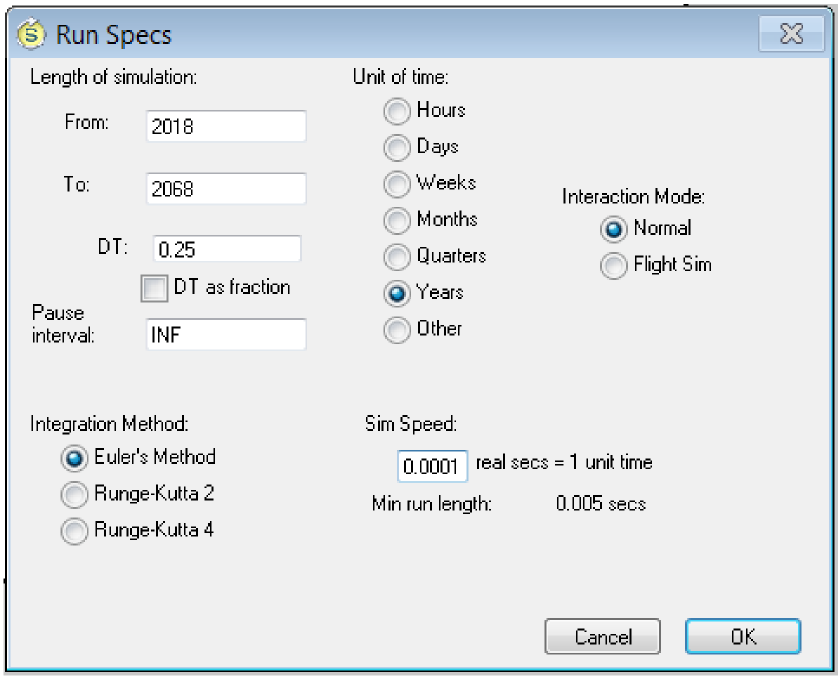


1) Open the STELLA and create the model above.
2) Parameterize the model as follows (this simulates a Graham-Schaefer formulation, logistic form, of biomass dynamics). **Be sure you are working in the model tab!**
3) The model should look familiar because we used it last week! Remember! Do you?
4) Parameterize the model using the specifications below.

Model component	Value or equation
r	0.6
K	10000
F	0
Biomass	10000
Harvest amount	F*Biomass

Model component	**Value or equation**
Gains	r * Biomass * ((K-Biomass)/K)
Losses	Harvest amount
Total yield	0
Yield gains	Harvest amount

5) Set your Run Specifications (RUN → Run Specs) as follows:



6) Set up a Graph Pad and Table Pad on your model canvas and **<u>pin them down</u>**. Once they are pinned down, add **Biomass** and **Total Yield** to the data pad and graph pad (Be sure to double click on them to bring them over).

7) Run the model and record the amount of biomass and harvest in the final year of the simulation.

Biomass:_________ should be 10,000

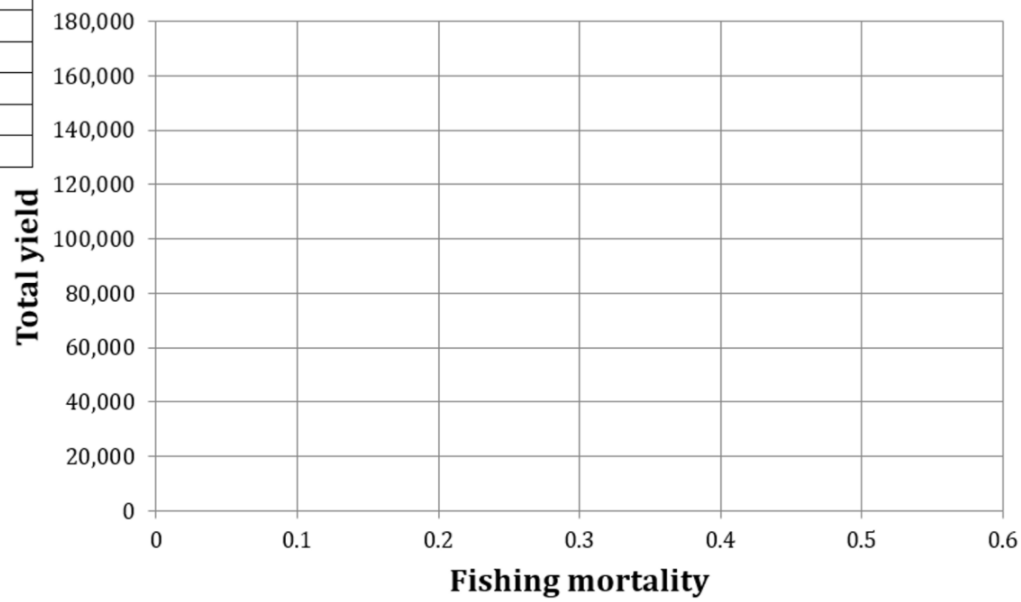
Harvest:_________ should be 0

If your numbers do not match, then ask your instructor for assistance. If they do match, then proceed to 1.3.

1.3. FORECASTING AND EVALUATING MANAGEMENT ACTIONS

1) Run the model for the fishing mortality rates listed in the table below and record the biomass and total yield for the final time step of the simulation. Then plot the values of total yield (*y*-axis) for each fishing mortality (*x*-axis) on the graph below.

Fishing mortality	Total yield
0	
0.1	
0.2	
0.3	
0.4	
0.5	



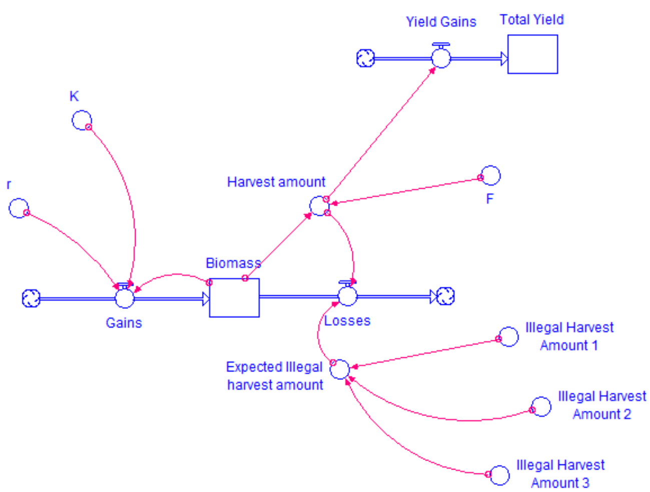
EXERCISE 2. ACCOUNTING FOR ILLEGAL HARVEST

2.1. EXERCISE OVERVIEW

Exceeding the optimal fishing mortality can result in a decrease in total yield and result in unsustainable fisheries. Illegal harvest can increase *F* and exceed allowable harvest. As good fisheries managers, we are cognizant of the potential for illegal harvest, but it is difficult to estimate with absolute certainty. However, the local conservation officers have a good feel for what the levels of illegal harvest might be, and we can use information elicited from their "on the ground knowledge." This is a process we call expert elicitation. During the process, we can use information like how much illegal harvest was detected and how much might be going on that officers were not able to detect.

A range of illegal harvest levels was elicited from the conservation officers. Specifically, the officers believed there could be 250, 500, or 1000 kg of illegal harvest and the probability of those 3 outcomes is 0.8, 0.15, and 0.05 respectively. We can account for illegal harvest when identifying the optimal fishing mortality level for the fishery in our management model. In this exercise, we will see how you can handle uncertainties like illegal harvest and still make management decisions.

2.2. THE MANAGEMENT MODEL



1) Update your model from exercise 1 with the components illustrated above.
2) Parameterize those new components as specified below. **Be sure you are working in the model tab!**

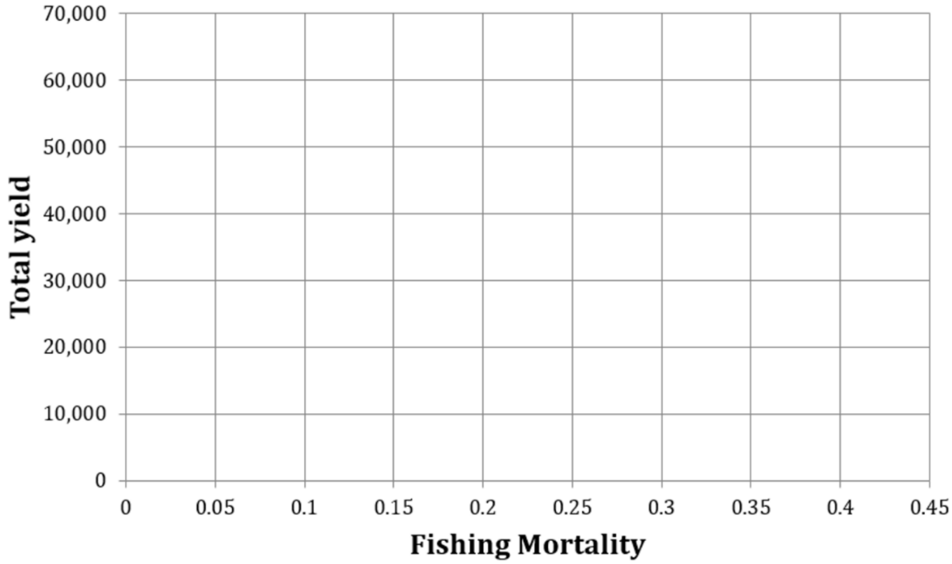
Model component	Value or equation
Biomass losses	Harvest amount + Expected illegal harvest amount
Expected illegal harvest amount	0.8*Illegal harvest amount 1 + 0.15*Illegal harvest amount 2 + 0.05*Illegal harvest amount 3
Illegal harvest amount 1	250
Illegal harvest amount 2	500
Illegal harvest amount 3	1000

3) Use the same Run Specifications (RUN → Run Specs) as Exercise 1.
4) Set up a Graph Pad and Table Pad on your model canvas and **pin them down**. Once they are pinned down, add **<u>Biomass</u>** and **<u>Total Yield</u>** to the data pad and graph pad and run the model.
5) Run the model and record the amount of biomass and harvest in the **<u>final year</u>** of the simulation.
Biomass:_________ should be ~ 9,425
Total yield:_________ should be 0
If your numbers do not match then ask your instructor for assistance. If they do match, then proceed to 2.3.

2.3. FORECASTING MANAGEMENT ACTIONS

1) Run the model for the quotas listed in the table on the next page and record the biomass and total yield for the <u>final time</u> step of the simulation.
2) Plot the values of total yield (*y*-axis) for each fishing mortality (*x*-axis) on the graph on the next page.

Fishing mortality	Total yield
0.2	
0.225	
0.25	
0.275	
0.3	
0.325	
0.35	
0.375	
0.4	

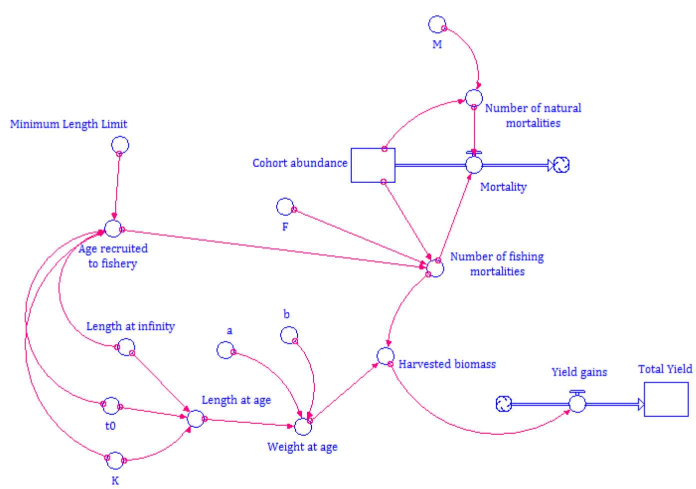


EXERCISE 3. AGE STRUCTURED POPULATION DYNAMICS MODELS

3.1. EXERCISE OVERVIEW

The biomass dynamics models used in exercise 1 and 2 do not account for fish growing and dying as they age. Growth and survival are captured in the intrinsic growth rate (*r*). Fish increase in size until they reach sexual maturity while age-specific abundance decreases. Preventing overfishing in recreational and some commercial fisheries is typically done by setting a minimum length limit (MLL) that protects young fish so they can grow. The typical fishery **objective** is to **maximize** yield by setting an MLL, which is evaluated using a yield per recruit model. However in many cases, it is uncertain what **fishing mortality** is, and therefore we evaluate a range of mortalities, a sensitivity analysis of sorts, to see how they perform in meeting the management objective of maximizing yield.

3.2. THE MANAGEMENT MODEL

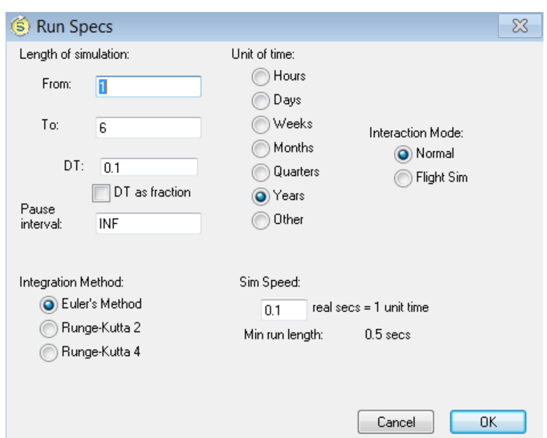


1) Open the STELLA and create the model above. Yes, the model is more complicated, but it is more biologically realistic because of the addition of age structure.

2) Parameterize the model using the specifications below.

Model component	**Value or equation**
Length at infinity	400
t0	0.1
K	0.3
Length at age	Length at infinity* (1 - exp(-K * (TIME-t0)))
a	0.0001
b	3
Weight at length	(a*Length at age^b)/1000
Harvested biomass	Number of fish fishing mortalities*Weight at age
Yield gains	Harvested biomass
Total Yield	0
Minimum length limit	203.2
Age recruited to the fishery	LN(1-((Minimum Length Limit/Length at infinity)))/-K + t0
F	0.1
Number of fishing mortalities	IF TIME>=Age recruited to fishery THEN F*Cohort abundance ELSE 0
Cohort abundance	1000
Mortality	Number of natural mortalities + Number of fishing mortalities
M	0.6
Number of natural mortalities	M*Cohort abundance

3) Set your Run Specifications (RUN → Run Specs) as specified below. The from and to are a bit different here because we are following a cohort and if we assume the population is in equilibrium the cohort and population dynamics are the same. The "To" in the figure below represents the maximum age of the fish.



4) Set up a Graph Pad and Table Pad on your model canvas and **pin them down**. Once they are pinned down, add **__Total Yield__** to the data pad and graph pad and run the model.

5) Run the model and record the amount of and total yield in the final year of the simulation.

Total Yield:_________ should be ~88.4

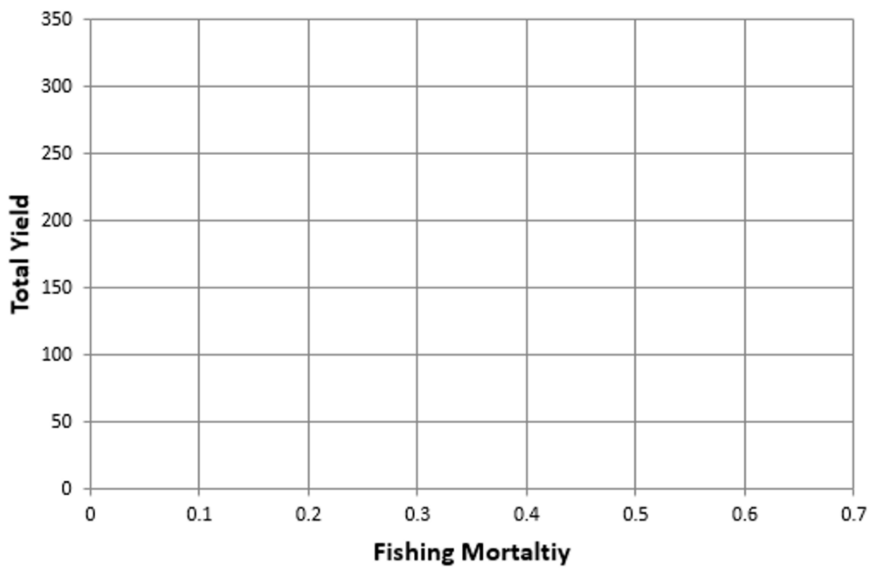
If your number does not match then ask your instructor for assistance. If your total yield does match, then proceed to 3.3.

3.3. FORECASTING MANAGEMENT ACTIONS

1) Run the model for the MLL in cm and the fishing mortalities listed in the table below and record the biomass and total yield for the final time step of the simulation.

2) Plot the values of total yield (y-axis) for each fishing mortality (x-axis) on the graph below. Do a separate curve for the 8 and 12 inch MLL.

MLL (in)	MLL (cm)	Fishing mortality	Total yield
8	203.2	0	
		0.1	
		0.2	
		0.3	
		0.4	
		0.5	
		0.6	
12	304.8	0	
		0.1	
		0.2	
		0.3	
		0.4	
		0.5	
		0.6	



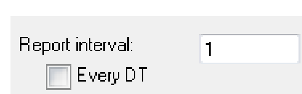
EXERCISE 4. LINKING OBJECTIVES AND DECISIONS

4.1. EXERCISE OVERVIEW

Fishing mortality is difficult to estimate, but tagging studies can be done, and the estimate used to calculate yield, rather than evaluating all ranges of *F*. The tagging study found that *F* was 0.13 for the fishery in exercise 3. This exercise will evaluate varying MLL for a known *F* value and explore how decisions can be made for competing management objective, **yield and size structure**.

4.2. THE MANAGEMENT MODEL

You will use the model you developed for exercise 3. The only change will be that you will set *F* to be 0.13 and add another data pad to keep track of **Number of fishing mortalities and length at age. When you create the data pad specify that it should report the report interval is 1 instead of every DT. **



4.3. FORECASTING MANAGEMENT ACTIONS

1) Run the model for an 8 inch MLL and record the number of fishing mortalities (i.e., catch) and the length at age for the catch and record those values in the table below.
2) Multiply the number of fishing mortalities by the length at age for each age class.
3) Calculate the sum of the number of fishing mortalities (Sum 1) and the product of the number of fishing mortalities and length at age (Sum 2).
4) Divide Sum 2 by Sum 1 to get the mean length of the total catch.
5) Repeat for a 9, 10, and 11 inch MLL.

203.2 mm = 8 inch				254 mm = 10 inch			
Age	Num. of fishing morts.	Length at age	Num. of fishing morts. x Length at age	Age	Num. of fishing morts.	Length at age	Num. of fishing morts. x Length at age
1		94.65		1		94.65	
2		173.79		2		173.79	
3		232.42		3		232.42	
4		275.85		4		275.85	
5		308.03		5		308.03	
6		331.87		6		331.87	
Sum	Sum 1		Sum 2	Sum	Sum 1		Sum 2
		Mean	Sum 2/ Sum 1			Mean	Sum 2/ Sum 1

228.6 mm = 9 inch				279.4 mm = 11 inch			
Age	Num. of fishing morts.	Length at age	Num. of fishing morts. x Length at age	Age	Num. of fishing morts.	Length at age	Num. of fishing morts. x Length at age
1		94.65		1		94.65	
2		173.79		2		173.79	
3		232.42		3		232.42	
4		275.85		4		275.85	
5		308.03		5		308.03	
6		331.87		6		331.87	
Sum	Sum 1		Sum 2	Sum	Sum 1		Sum 2
		Mean	Sum 2/ Sum 1			Mean	Sum 2/ Sum 1

6) Run the model and calculate the total yield (total yield in the final year) values for MLLs of 8, 9, 10, and 11 inches and record those numbers in the table below.

7) Using the age structured model we can scale yield and size structure outcomes to evaluate how the minimum length limit may achieve the management objective of maximizing yield and size structure. Record the MLL specific Mean length values in the table below from the above table.

8) Using the equation below calculate the scaled yield and mean length for each MLL evaluated (X will be Yield or Mean length) and record the values in the table below. This is done so we can combine those 2 values. The equation scales values such that low values approach 0 and high values to approach 1.

$$U = \frac{X - \min(X)}{max(X) - min(X)}$$

MLL (in)	MLL (cm)	Total Yield	Scaled yield (SY)	Mean length	Scaled mean length (SM)
8	203.2				
9	228.6				
10	254				
11	279.4				
	Min(x)				
	Max(x)				
	Max(x)-Min(x)				

9) Enter the MLL specific <u>scaled</u> yield and mean length values to the table below and then calculate the value. Circle the entry with the highest value for the equal weight and prioritize size column the MLL that corresponds with the highest value, this is the optimal management decision given the management objective.

MLL (in)	MLL (cm)	Prioritize yield	Prioritize size
8	203.2	0.75* SY + 0.25* SM =	0.25* SY + 0.75* SM =
9	228.6	0.75* SY + 0.25* SM =	0.25* SY + 0.75* SM =
10	254	0.75* SY + 0.25* SM =	0.25* SY + 0.75* SM =
11	279.4	0.75* SY + 0.25* SM =	0.25* SY + 0.75* SM =

LAB QUESTIONS

1.1. Overfishing is defined as a reduction in yield with increased harvest. In the plot you created in exercise 1, what fishing mortality would you select to implement for this fishery? Why did you select it? (5 points)

2.1. What was the optimal fishing mortality rate that maximized yield and how does it compare to the optimal rate identified in question 1.1? Why might they be different? (5 points)

3.1. Which MLL, 8 or 12 inches would be optimal if the agency objective was to prevent overfishing at any fishing mortality? Recall that growth overfishing occurs when yield decreases with increasing fishing rate. (5 points)

4.1. Was the optimal MLL for the equal weight and prioritize size objectives the same? If not, why do you think they differ? (5 points)