NAME:

LAB OVERVIEW

This laboratory consists of 4 exercises. Questions and problem sets are located at the end of each laboratory section and tables are located at the end of the document. Note the numbering of the questions reflecting the laboratory exercise and the question number (e.g., 1.1, 1.2). Use this numbering when answering the questions and turning in laboratory. Responses to questions will be due by 5pm September 11th. Responses are to be entered at https://goo.gl/forms/Xw787V1T7jeoGaZB2. This lab is worth 25 points.

LABORATORY EXERCISE 1: PUBLIC TRUST RESOURCE AND TRAGEDY OF THE COMMONS

This exercise will require 3 class volunteers to "fish' and population. We will fill in the table below as a class. Note the recruitment rate is 1 for gold and 3 for silver.

	Gold ($300)	Silver ($100)	Profit
	Round 1 (30 Seconds)		
1.			
2.			
3.			
	Round 2 (30 Seconds)		
1.			
2.			
3.			

Questions (2 points)

1.1. Did any of the fish species go extinct? If so which ones? (1 Point)

1.2. How could you have managed the catch to prevent the fish from becoming extinct? (1 Point; Note: There is no right or wrong answer, just propose and idea and defend why it may work)

LABORATORY EXERCISE 2: POPULATION DYNAMICS IN LAKE BULLDOG

Lake Bulldog is a 10 acre lentic system located in Mississippi. The population dynamics of Largemouth Bass *Micropterus salmoides* in the system is characterized by the number of births and immigrants, less the number of deaths and emigrants, a model known as the BIDE model. This model formally calculates the change in a population over time as:

$$\frac{dA}{dt} = B + I - (D + E) \tag{1}$$

This equation is not too scary, it simply states:

$$\frac{\textit{The change in abundance}}{\textit{The change in time}} = \textit{Births} + \textit{Immigrants} - (\textit{Deaths} + \textit{Emmigrants}) \tag{2}$$

and conceptually it looks like figure 1 below.

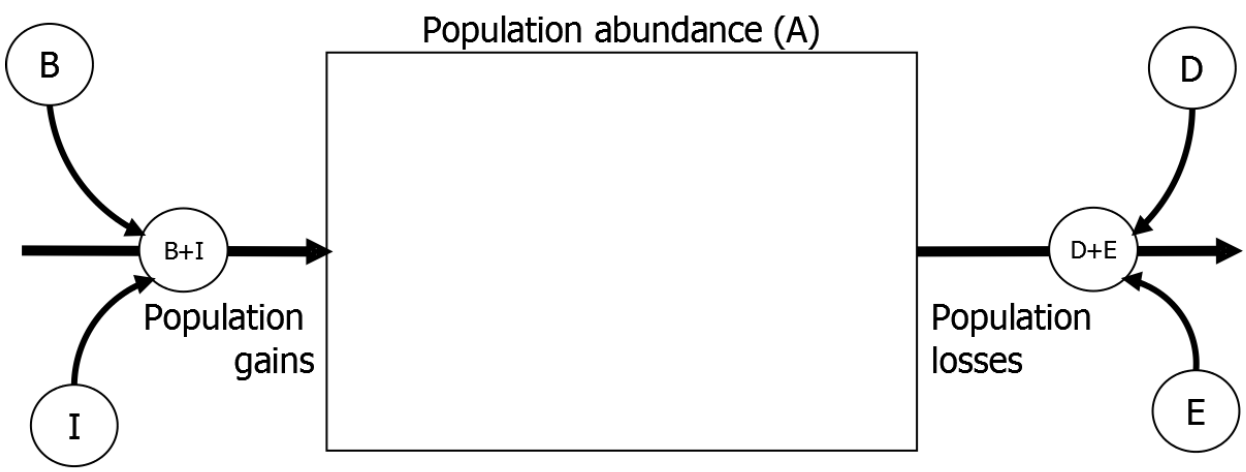


Figure 1.—Conceptual representation of the BIDE model. The population gains represents additions to the population and the population losses are flows out of the population. The arrows pointing into and out of the box are called 'flows'. This is what is commonly referred to as a stock and flow or a box and flow diagram.

In most applications the change in time is 1 year (i.e., dt = 1), which makes it easy to forecast population dynamics over time. Let's expand the equation above to do this (notice that dt is equal to 1)

$$\frac{dA}{dt} = B + I - (D + E) \tag{3}$$

$$\frac{A_{t+dt} - A_t}{dt} = B + I - (D + E) \tag{4}$$

$$\frac{A_{t+1} - A_t}{1} = B + I - (D + E) \tag{5}$$

$$A_{t+1} - A_t = B + I - (D + E) \tag{6}$$

$$A_{t+1} = A_t + B + I - (D + E) \tag{7}$$

And circling back we can forecast population dynamics as the abundance in year *t* plus the change in abundance as:

$$A_{t+1} = A_t + \frac{dA}{dt} \tag{8}$$

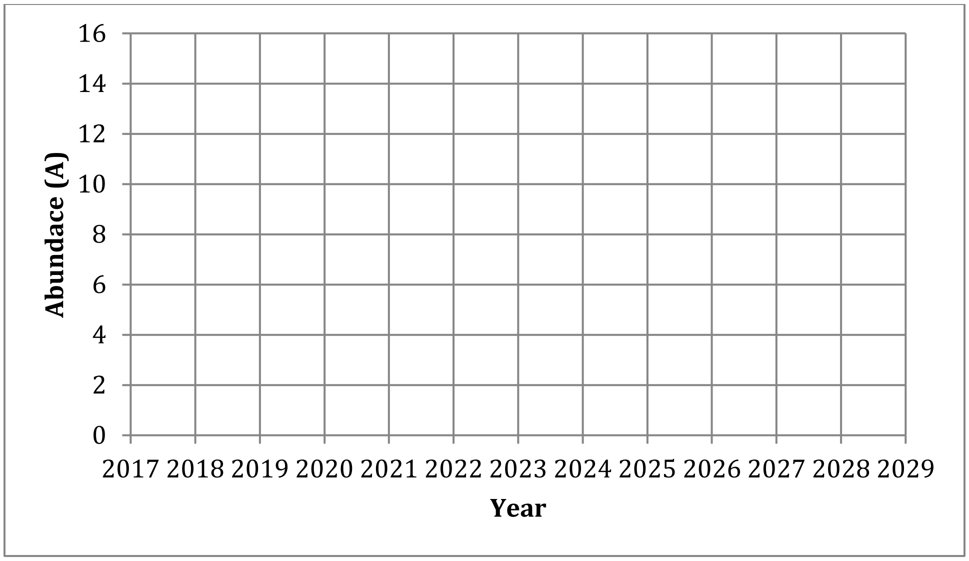
OK I have hopefully proved my point, let's move on to the fun stuff. Suppose, the birth, immigration, death, and emigration rates[1] for Lake Bulldog are:

Birth (fish per year; B) = 4
Immigration (fish per year; I) = 0
Death (fish per year; D) = 3
Emigration (fish per year; E) = 0

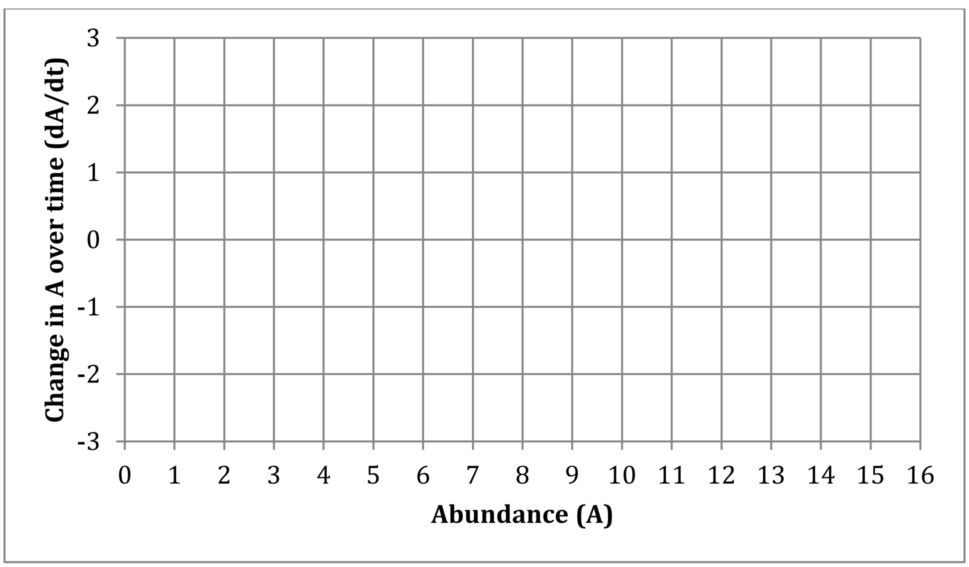
Using the figure for Lake Bulldog (laminated sheet 1):

1) Add 5 goldfish to the outline of Lake Bulldog. This represents the initial population abundance in 2018, see Table 1 (tables are located at the end of this document).
2) Add 4 representing goldfish births and remove 3 goldfish representing deaths from the lake and count how many goldfish remain in the Lake Bulldog. The difference of births and deaths is $\frac{dA}{dt}$ (Equation 3). Record this number for $\frac{dA}{dt}$ in year 2018.
3) Count how many goldfish are in Bulldog Lake and record that number in table 1 as the abundance for year 2019.
4) Repeat steps 2 and 3 until Table 1 is filled.
5) Using the data in Table 1 plot the population abundance (A; y-axis) versus Year (t; x-axis).

[1] These are rates because there is a component of time (e.g., 3 fish per year)



6) Using the data in Table 1 plot the change in abundance over time (dA/dt ; *y*-axis) versus abundance (*A*; *x*-axis).



Questions (9 points)

2.1. Given the parameters used to calculate dA/dt and *A* report the following values (*3 points*):

A) What will dA/dt be in year 2029?

B) What will *A* be in year 2030?

C) Suppose the birth rate was 3 and the death rate was 4 (immigration and emigration are 0) and the initial population was 8 in 2018. How many fish will there be in 2020?

2.2. The model of population dynamics in Lake Bulldog assumes 3 fish/year are added per year. Does this seem biologically realistic to you? Why or why not? (*3 points*)

2.3. What does setting Immigration and Emigration to 0 assume? (*3 points*)

LABORATORY EXERCISE 3: POPULATION DYNAMICS IN BULLDOG CREEK

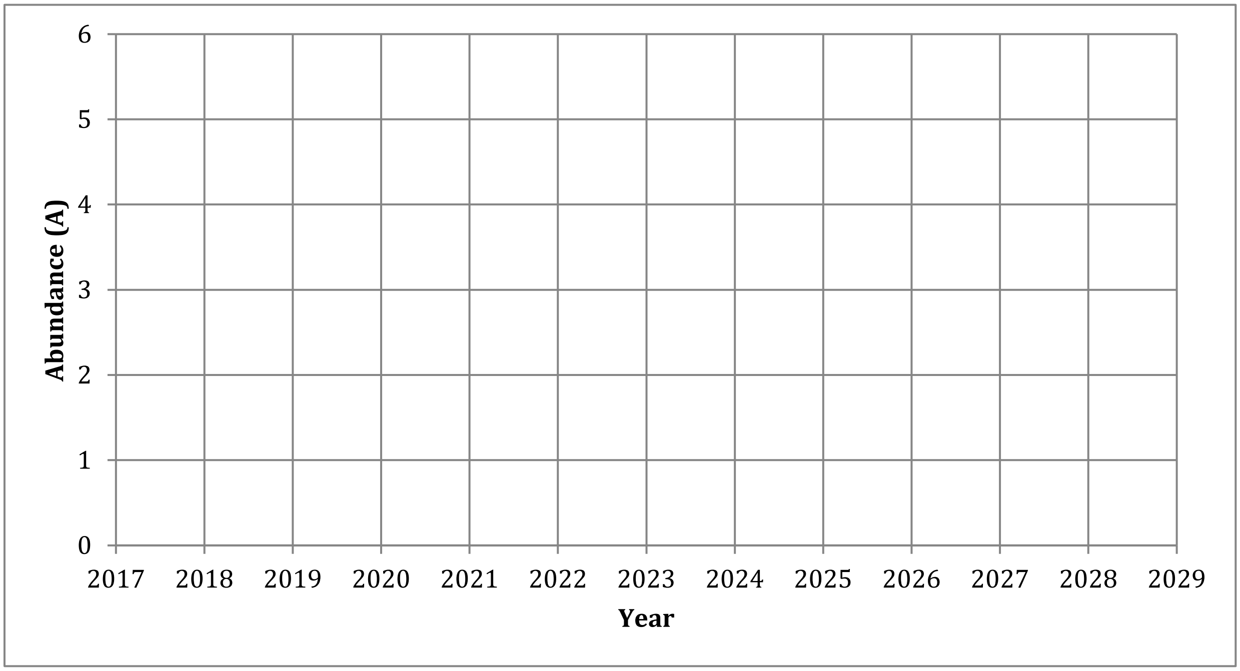
Bulldog Creek is a first order tributary (i.e., headwater stream)[2] to Lake Bulldog and is occupied by Largemouth Bass. There is a 5 m scenic waterfall located at river kilometer (RKM) 0.5. The birth rate is similar to Lake Bulldog **but the death and emigration rates differ**.

$$\text{Birth:}\,B = 3$$
$$\text{Immigration:}\,I = 0$$
$$\text{Death:}\,D = 2$$
$$\text{Emigration:}\,E = 1$$

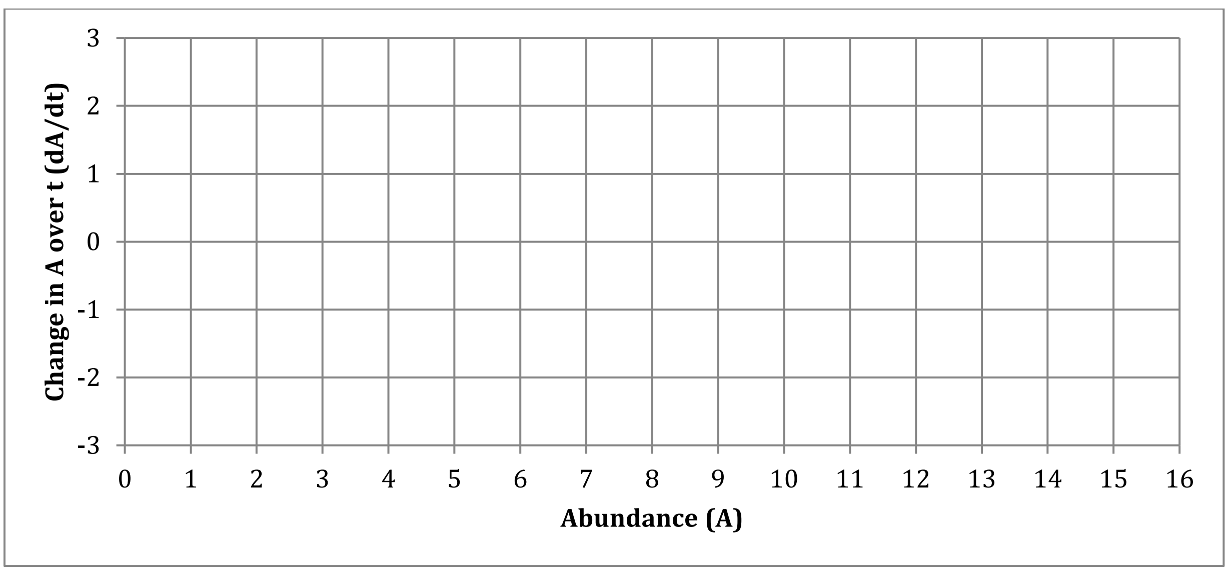
Using the figure for Bulldog Creek (laminated sheet 2):

1) Add 5 goldfish to the outline of Bulldog Creek. This represents the initial population abundance in 2018, see Table 2.
2) Add 3 Goldfish representing births and remove 2 goldfish representing deaths and 1 goldfish representing emigration from the system. Births less deaths and emigration is $\frac{dA}{dt}$ (Equation 3). Record this number for $\frac{dA}{dt}$ in year 2018 in Table 2.
3) Count how many gold fish remain in the Bulldog Creek and record this number as the abundance (A) in year 2019 in Table 2. This should equal equation 8 if you simply add them up in Table 2.
4) Repeat steps 2 and 3 for the remaining years until Table 2 is filled.
5) Using the data in Table 2 plot the population abundance (A; y-axis) versus Year (t; x-axis).

[2] https://en.wikipedia.org/wiki/Strahler_number



6) Using the data in Table 2 plot the change in abundance over time (dA/dt ; *y*-axis) versus abundance (*A*; *x*-axis)



Questions (9 points)

3.1. The BIDE model allows for emigration from the system, but the immigration rate is 0. Is this biologically reasonable to you given <u>this</u> system? Why or why not? (*3 points*)

3.2. In the Bulldog Creek example, what was the difference between births and deaths? Was the number positive, negative, or 0? Based on whether the number is positive, negative or 0, what should the population do if the initial abundance was 20 (hint: look at the figure of abundance versus year). (*3 points*)

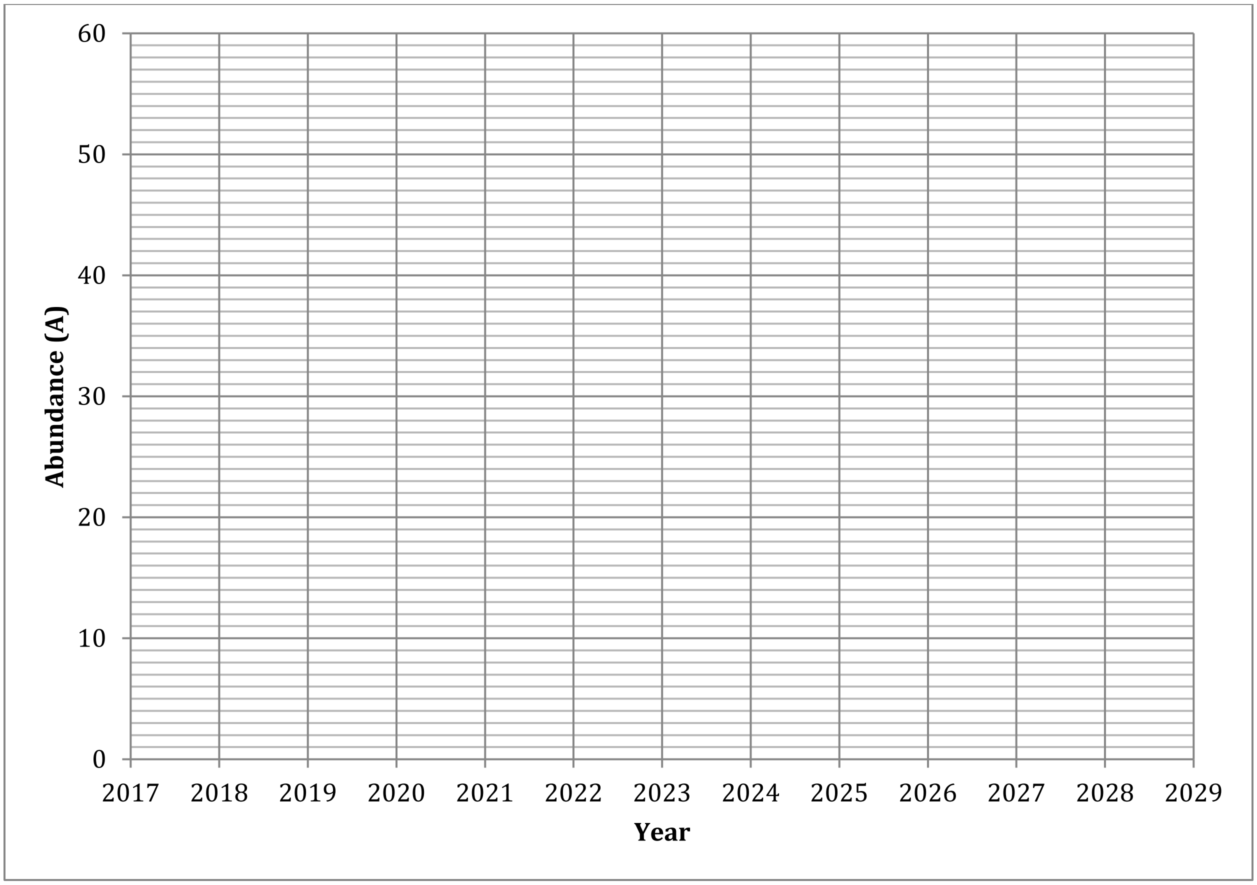
3.3. How does the plot of abundance for Bulldog Creek compare to the same plot for Lake Bulldog? How does the difference between births and deaths for Lake Bulldog compare to Bulldog Creek? (*3 points*)

LABORATORY EXERCISE 4: EXONENTIAL POPULATION DYNAMICS

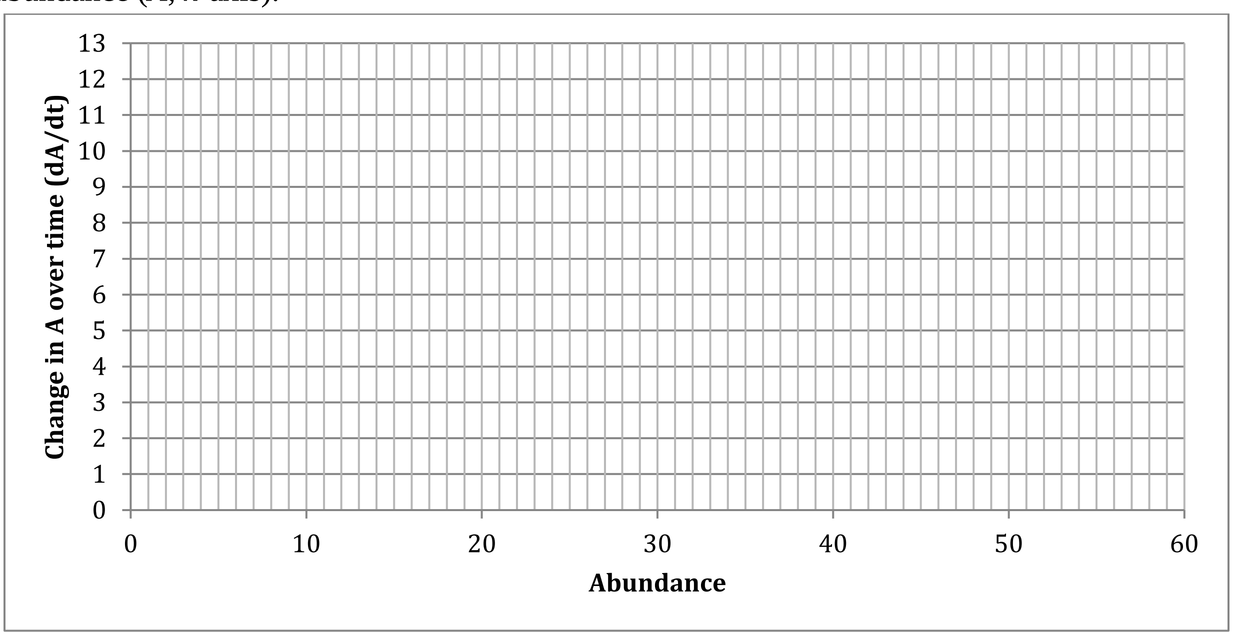
Exponential model

The exponential model adds biological realism to the generic BIDE model. This is done by making population growth dependent on population abundance. Follow the exercise below for a better understanding of exponential population dynamics.

1) Put 5 goldfish on the rectangle representing the stock (Exponential dynamics, laminated sheet 3).
2) Multiply the number of goldfish in the box by the intrinsic growth rate (*r*) which is 0.25 for this demonstration (i.e., $\frac{dA}{dt} = r \cdot A$) to calculate the population gains for 2018. Record this number for $\frac{dA}{dt}$ in year 2018 in Table 3.
3) Round that number to the nearest whole number and add that many goldfish to the stock box (i.e., $A_{t+dt} = A_t + r \cdot A_t$). Count how many goldfish there are in the box and Record this number for *A* in 2019 in Table 3.
4) Repeat steps 2 and 3 until Table 3 is completed.
5) Using the data in Table 3 plot the population abundance (*A*; *y*-axis) versus Year (*t*; *x*-axis).



6) Using the data in Table 3 plot the change in abundance over time (dA/dt ; y-axis) versus abundance (A; x-axis).



Exponential model with harvest

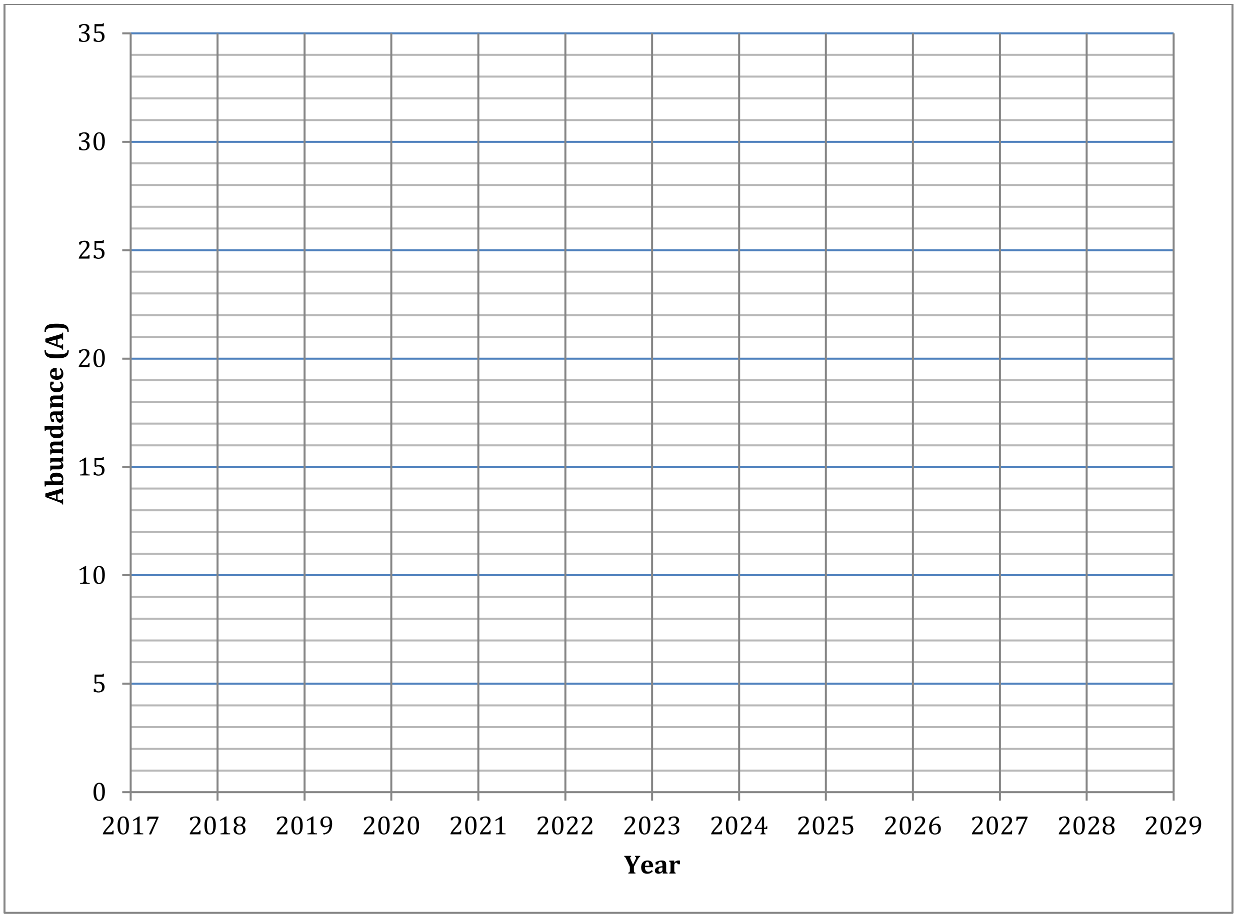
Now that we have an increased understanding in population dynamics, we can add harvest to the population, this will be key for harvesting fish, or any other critter for that matter. Let's build on the previous exponential population by adding harvest to the equation. This can be formally expressed as:

$$\frac{dA}{dt} = r \cdot A - F \cdot A,$$

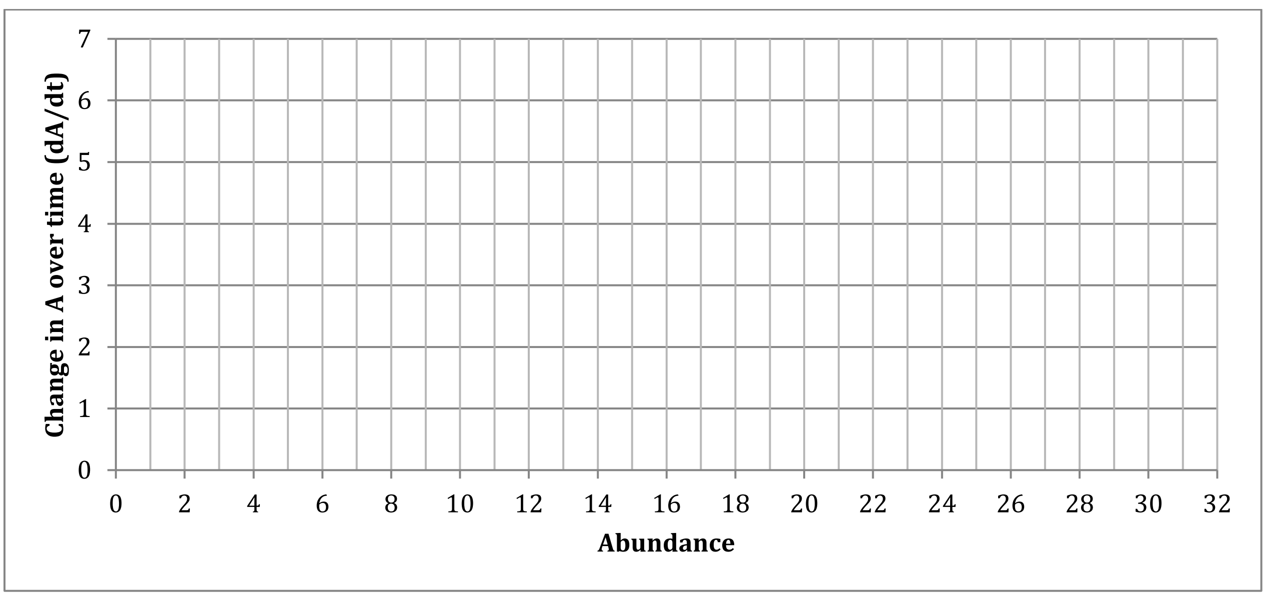
where there is a new parameter *F* which is the fishing mortality rate in fish per year and it is multiplied by fish abundance to calculate how many fish are harvested.

Like before let's reinforce this with our goldfish on a stock and flow diagram.

1) Put 5 goldfish on the rectangle representing the stock's initial abundance (Exponential dynamics, laminated sheet 4).
2) Multiply the number of goldfish in the box by the intrinsic growth rate (r = 0.75) to get the population gains and record this number for 2018 in Table 4, including up to 2 decimal places.
3) Multiply the number of goldfish in the box by the fishing mortality rate (F= 0.55) to get the population losses and record this number for 2018 in Table 4, including up to 2 decimal places.
4) Calculate the population change over the year for 2018 as population gains-population losses (i.e., $\frac{dA}{dt} = r \cdot A - F \cdot A$). Round that number to the nearest whole number and record this number for year 2018 in Table 4.
5) Add that many goldfish to the stock box. Count how many goldfish there are in the box and Record this number for A in 2019 in Table 4.
6) Repeat steps 2 and 5 until Table 4 is completed.
7) Using the data in Table 4 plot abundance over time (A; y-axis) versus Year (t; x-axis).



8) Using the data in Table 4 plot the change in abundance over time (dA/dt ; y-axis) versus abundance (A; x-axis).



Questions (5 points)

4.1. How does the plot of dA/dt versus A for both exponential models differ for the BIDE models? (2 points)

4.2. Given the population dynamics and rates for the exponential model with harvest, what would you set harvest to? Why? (2 points; there is really no right or wrong answer here I am curious about your process)

4.3. Can you think of any way to improve this model? (1 point)

Table 1.—Forecasted population dynamics of Largemouth Bass in Lake Bulldog.

Year (t)	A	$dA/dt = B + I - (D + E)$
2018	5	*dA/dt* =_____
2019	_____	*dA/dt* =_____
2020	7	*dA/dt* =_____
2021	_____	*dA/dt* =_____
2022	_____	*dA/dt* =_____
2023	_____	*dA/dt* =_____
2024	11	*dA/dt* =_____
2025	_____	*dA/dt* =_____
2026	_____	*dA/dt* =_____
2027	_____	*dA/dt* =_____
2028	_____	*dA/dt* =_____

Table 2.— Forecasted population dynamics of Largemouth Bass in Bulldog Creek.

Year (t)	A	$dA/dt = B + I - (D + E)$
2018	10	*dA/dt* =_____
2019	_____	*dA/dt* =_____
2020	_____	*dA/dt* =_____
2021	_____	*dA/dt* =_____
2022	_____	*dA/dt* =_____
2023	_____	*dA/dt* =_____
2024	_____	*dA/dt* =_____
2025	_____	*dA/dt* =_____
2026	_____	*dA/dt* =_____
2027	_____	*dA/dt* =_____
2028	_____	*dA/dt* =_____

Table 3.— Forecasted population dynamics of Largemouth Bass in Lake Bulldog. Round dA/dt values to the nearest whole number and add to A to forecast abundance.

Year (t)	A	Population gains $(r \cdot A)$	$dA/dt = r \cdot A$
2018	5	0.25 x _____=_____	_____
2019	_____	0.25 x _____=_____	_____
2020	_____	0.25 x _____=_____	_____
2021	_____	0.25 x _____=_____	_____
2022	_____	0.25 x _____=_____	_____
2023	_____	0.25 x _____=_____	_____
2024	_____	0.25 x _____=_____	_____
2025	_____	0.25 x _____=_____	_____
2026	_____	0.25 x _____=_____	_____
2027	_____	0.25 x _____=_____	_____
2028	_____	0.25 x _____=_____	_____

Table 4.—Forecasted population dynamics of Largemouth Bass in Lake Bulldog. Round dA/dt values to the nearest whole number and add to A to forecast abundance.

Year (t)	A	Population gains $(r \cdot A)$	Population losses $(F \cdot A)$	dA/dt $(r \cdot A - F \cdot A)$
2018	5	0.75 x _____=_____	0.55 x _____=_____	_____
2019	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2020	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2021	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2022	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2023	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2024	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2025	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2026	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2027	_____	0.75 x _____=_____	0.55 x _____=_____	_____
2028	_____	0.75 x _____=_____	0.55 x _____=_____	_____