

# SCIENCE·3D

## RAINFOREST BIODIVERSITY

In this packet, sample student answers are provided in **red** and notes to teachers are in **blue**.

In this **STEM Project** students will build a population model in a spreadsheet and explore how populations grow and are limited by factors in the environment.

Tell students that the change in the size of a population is determined by 1) the starting population size, 2) the number of births and 3) the number of deaths. The computer model will let them make predictions about how the population might change if something influences the birth or the death rates.

**Differentiate Instruction:** If the math in this activity is too difficult, provide students with the excel file that is already pre-programmed or the output graphs in this teacher edition. In addition to the logic of programming the computer, the main takeaways of this activity are 1) that populations are stable when births and deaths are balanced and 2) they would grow forever if nothing limited them.



## ACTIVITY I: USING COMPUTERS TO MODEL POPULATION GROWTH AND LIMITING FACTORS

Scientists use computers to build models. In engineering, computer models may be representations of physical objects. For example, a computer model of a jet engine may help engineers make sure all the parts will fit together before they spend a lot of money building the engine. They can also use the computer to model how it will work before they build it!

Scientists also use models to predict how populations may change through time. They can then change parts of the model to observe possible effects on the population. Let's build a simple model!

Pretend there is a small bird that lives in Tirimbina reserve. Each year, adults produce two chicks that survive to adulthood. At one year old, these chicks start having babies of their own. But, life is difficult for these birds. There are many predators. Let's say that over the course of the year, 10% of the adult birds don't survive. At the start of observations, there are 50 birds. What will happen to the population over time? Let's make a computer model to find out!

Our first task is to define all the variables. These are given in Table 1.

**Table 1. Variables used in the bird population model**

Name	Variable symbol	Value in model
Population size at a particular time	$N_t$	Calculated by model (starting value ( $N_1$ ) is 50)
Population size at the next time	$N_{t+1}$	Calculated by model
Number of chicks that each adult produces that survive to adulthood	H	2
Total number of chicks that survive to adulthood in a particular year	$B_t$	Calculated by model
Proportion of adults that die per year	M	0.1
Total number of adults that die in a particular year	$D_t$	Calculated by model
Change in population size per year	$C_t$	Calculated by model

In computer science, an algorithm is a set of instructions that tells the computer what to do. The instructions need to be very specific. Now that we know the variables we are going to use, our next task is to define the equations that the computer will need to use.

*1: Tell the computer how to calculate how many chicks hatch and survive to adulthood in a particular year.*

To calculate  $B_t$  we multiply the number of adults in the population in a year by the number of chicks each adult produces. On the computer, use the \* symbol for multiplication.

$$B_t = N_t * H$$

*2: Tell the computer how to calculate how many adults die in a particular year.*

To calculate  $D_t$  we multiply the number of adults in the population in a year by the proportion of adults that die.

$$D_t = N_t * M$$

*3: Tell the computer how to calculate how many new birds to add to the population each year.*

The change in the population size is the number of new individuals minus the number that die

$$C_t = B_t - D_t$$

*4: Tell the computer to calculate the new size of the population.*

We can then calculate the number of individuals in the population at the start of the next year using the equation:

$$N_{t+1} = N_t + C_t$$

Let's put these equations into a spreadsheet to make our model.

**Step 1: Getting Started**

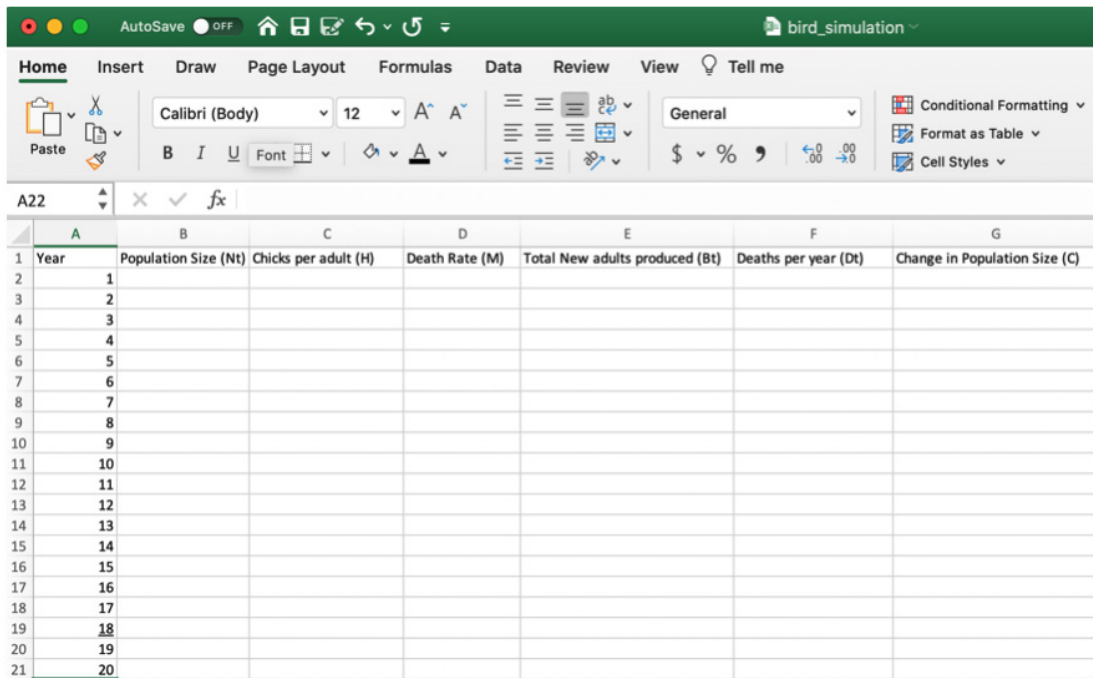
Open your spreadsheet program. In order to not lose your work, save your spreadsheet to your favorite folder. You can click the disk icon at the top of the page or click on File → Save As.

Give the file the name “bird\_simulation.xlsx.” Make sure you save your sheet frequently while you work!

**Step 2: Inserting the Constants**

Next, we want to set up the sheet for the simulations.

1. In row 1, insert the headings shown in the picture below.
2. In column A, insert the numbers 1 to 20 in under the “Year” label as shown in the picture below.



Next, we need to enter the values that the algorithm will use to make calculations.

3. Type the word “Variable” in cell I1 and the word “Value” in cell J1.
4. Type the names of the variables in rows I2 to I4 as shown in the picture below.
5. Type the values from the intro paragraph about our bird species in cells J2 to J4. The values are shown in the picture below.

	I	J	K
1	<b>Variable</b>	<b>Value</b>	
2	Nt in Year 1	50	
3	H	2	
4	M	0.1	
5			

### Step 3: Coding the Algorithm

Depending on how comfortable students are using Microsoft Excel, you might consider having students experiment and practice with using simple commands like copy and paste and writing simple commands. You may also have them experiment with copying and pasting different codes (like the one suggested in point 2 below). Have them compare what happens when you copy and paste the code as it is written with \$ in front of just the row, just the column, and in front of both. In addition to having them look at the visible code, have them check what the code looks like when they click on the cell. This will help reinforce using the \$ and programming logic.

Before we start coding, you need to know a couple tricks in Microsoft Excel.

- If you want the computer to calculate a formula in a cell, start by typing an equal sign (=).
- If you want the computer to use the value for a cell instead of a specific number, type the column letter and row number of the cell. For example, if you want the computer to put the value written in cell J2 in cell A2, enter =J2 in cell A2. This is called a "formula." With this code, if you change the value of cell J2, the value of A2 will automatically update to match.
- Copying and pasting formulas can be tricky. If you copy the formula mentioned above in cell A2, and then paste it into cell B3, the formula will change to =K3. The row and columns in the formula change by the number of rows and columns you moved from the original cell. If you want to always use the value in cell A2, use a \$. The \$ tells the computer to always use that specific row or column no matter where the formula is pasted. So, if you always want to use cell J2 for a formula no matter where you paste it, enter it as =\$J\$2.

Now we are ready to write some formulas.

1. Type =\$J\$2 in cell B2.
2. Type =\$J\$3 in cell C2.
3. Type =\$J\$4 in cell D2.

Now, your sheet should look like this:

Year	Population Size (Nt)	Chicks per adult (H)	Death Rate (M)	Total New adults produced (Bt)	Deaths per year (Dt)	Change in Population Size (C)	Variable	Value
1	50	2	0.1				Nt in Year 1	50
2							H	2
3							M	0.1
4								
5								

Our next step is to create formulas to calculate the values of  $B_t$ ,  $D_t$ , and  $C_t$ . We just have to take the equations from our basic algorithm and turn them into Excel formulas.

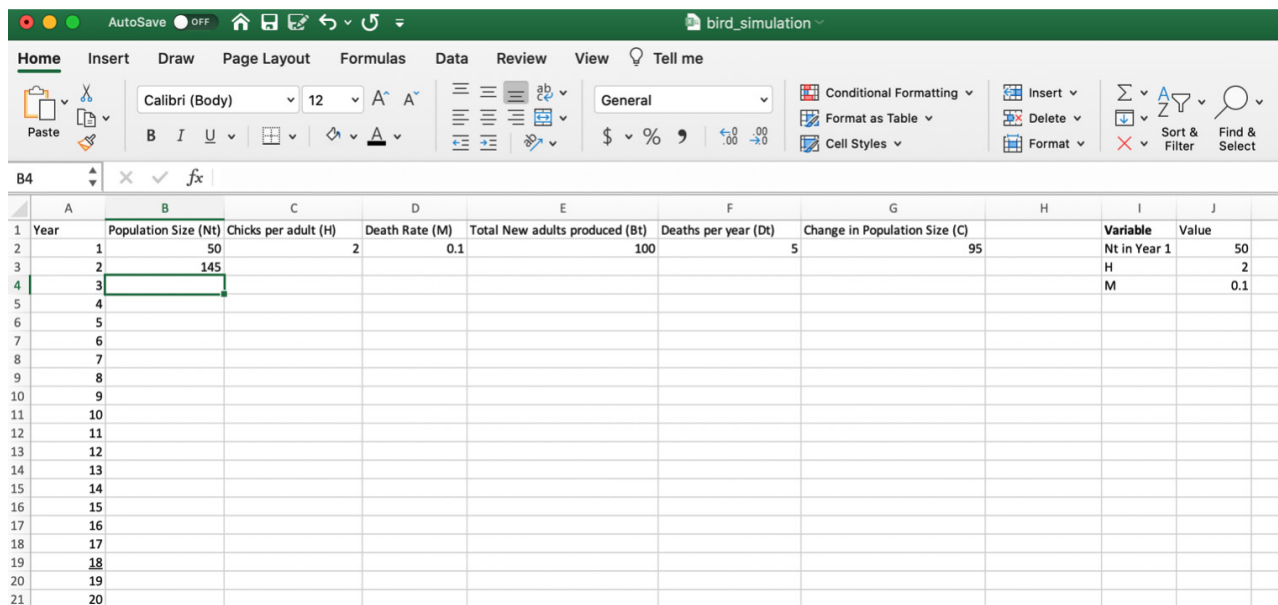
4. To calculate  $B_t$  type  $=B2*C2$  in cell E2.
5. To calculate  $D_t$  type  $=B2*D2$  in cell F2.
6. To calculate  $C_t$  type  $=E2-F2$  in cell G2.

Now, we need to set the model up to see what happens in Year 2.

First, we determine how many birds are in the population. To do this we add the number of new birds ( $C$ ) to the number of birds from the start of the year ( $N_t$ ).

7. To calculate  $N_{t+1}$  (which is  $N$  in year 2 in this case) type  $=B2+G2$  in cell B3.

Your sheet should now look like this:



### Step 4: Automating the Calculations

Now, we want to calculate what happens for 20 generations, but we don't want to have to write a formula in every cell. Luckily, we are set up to automatically make the calculations.

1. Select cells C2 through G2.
2. Copy the cells by pressing the Control key (or Command key on Macs) and the C key at the same time. Or, click on the "Edit" menu along the top and select "Copy" from the dropdown menu.
3. Select cell C3. Paste the information you copied by pressing the Control/Command key and the V key at the same time. Or, click on the "Edit" menu along the top and select "Paste" from the dropdown menu. All the numbers for Year 2 should appear!

Wait! Did you notice that when you did this, the number 275.5 appeared for the change in the number of birds? You can't have half a bird! Let's fix this.

4. In cell H1, type "Final Ct." We will use this column to round the number we calculated for  $C_t$  to the nearest whole number.

5. In cell H2, type =ROUND(G3,0) This tells the computer to round the number in cell G3 to the nearest number with 0 digits after the decimal point.

Time to fix our calculation for the number of birds at the start of the year.

6. Change the formula in cell B3. Type =B2+H2 in cell B3.

Next, we can calculate the rest of the years in the model.

7. Select cells B3 through G3.

8. Copy the cells by pressing the Control/Command key and the C key at the same time. Or, click on the "Edit" menu along the top and select "Copy" from the dropdown menu.

9. Select cells B4 through B21. Paste the information you copied by pressing the Control/Command key and the V key at the same time. Or, click on the "Edit" menu along the top and select "Paste" from the dropdown menu. All the numbers for Years 3 to 20 should appear!

Your model should now look like the picture below.

Year	Population Size (Nt)	Chicks per adult (H)	Death Rate (M)	Total New adults produced (Bt)	Deaths per year (Dt)	Change in Population Size (C)	Final C	Variable	Value
1	50	2	0.1	100	5	95	95	Nt in Year 1	50
2	145	2	0.1	290	14.5	275.5	276	H	2
3	421	2	0.1	842	42.1	799.9	800	M	0.1
4	1221	2	0.1	2442	122.1	2319.9	2320		
5	3541	2	0.1	7082	354.1	6727.9	6728		
6	10269	2	0.1	20538	1026.9	19511.1	19511		
7	29780	2	0.1	59560	2978	56582	56582		
8	86362	2	0.1	172724	8636.2	164087.8	164088		
9	250450	2	0.1	500900	25045	475855	475855		
10	726305	2	0.1	1452610	72630.5	1379979.5	1379980		
11	2106285	2	0.1	4212570	210628.5	4001941.5	4001942		
12	6108227	2	0.1	12216454	610822.7	11605631.3	11605631		
13	17713858	2	0.1	35427716	1771385.8	33656330.2	33656330		
14	51370188	2	0.1	102740376	5137018.8	97603357.2	97603357		
15	148973545	2	0.1	297947090	14897354.5	283049735.5	283049736		
16	432023281	2	0.1	864046562	43202328.1	820844233.9	820844234		
17	1252867515	2	0.1	2505735030	125286751.5	2380448279	2380448279		
18	3633315794	2	0.1	7266631588	363331579.4	6903300009	6903300009		
19	10536615803	2	0.1	21073231606	1053661580.3	20019570026	20019570026		
20	30556185829	2	0.1	61112371658	3055618582.9	58056753075	58056753075		

### Step 5: Analyzing Patterns

Before we go on, it's time to answer some questions!

1. **Describe** what happened to the size of your population over 20 years. Use data from your model to support your answer.

The population exploded! It grew from 50 birds to billions in just 20 years!

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2. **Predict** what would happen to the size of the population over another 20 years.

It would keep growing faster and faster!

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3. **Describe** whether you think this is a realistic model of populations growth. Provide reasons and evidence from the model to support your answer. In your answer, **describe** if resources are limited or unlimited.

I do not think this is realistic. Populations can't grow this big this quickly. Resources in this situation are unlimited because the population doesn't stop growing.

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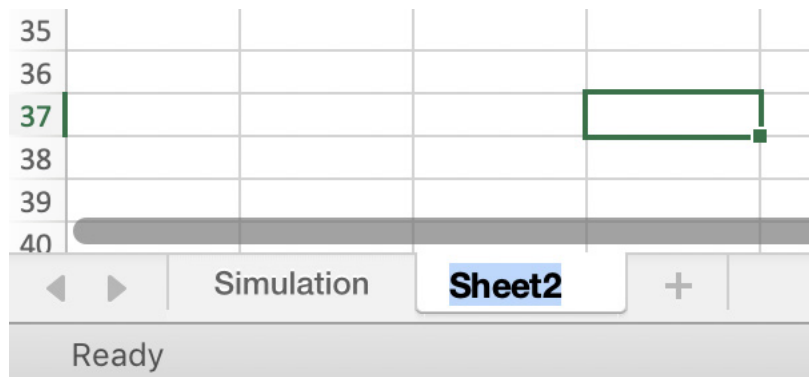
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### Step 6: Creating Graphs and Using the Model for Prediction

Now we need to be able to make graphs! To do this we will want to add another sheet to our project. That way, if we make a mistake, we still have our model on the "Simulation" tab that we can use again.

1. Rename the current sheet.
  - a. Double click on "Sheet 1" at the bottom.
  - b. Type "Simulation" to replace the name.
2. Click on the + next to "Simulation" to add another sheet.
3. Rename Sheet 2.
  - a. Double click on "Sheet 2" at the bottom.
  - b. Type "New Model" to replace the name.





Now we will have our data move to the “New Model” sheet automatically.

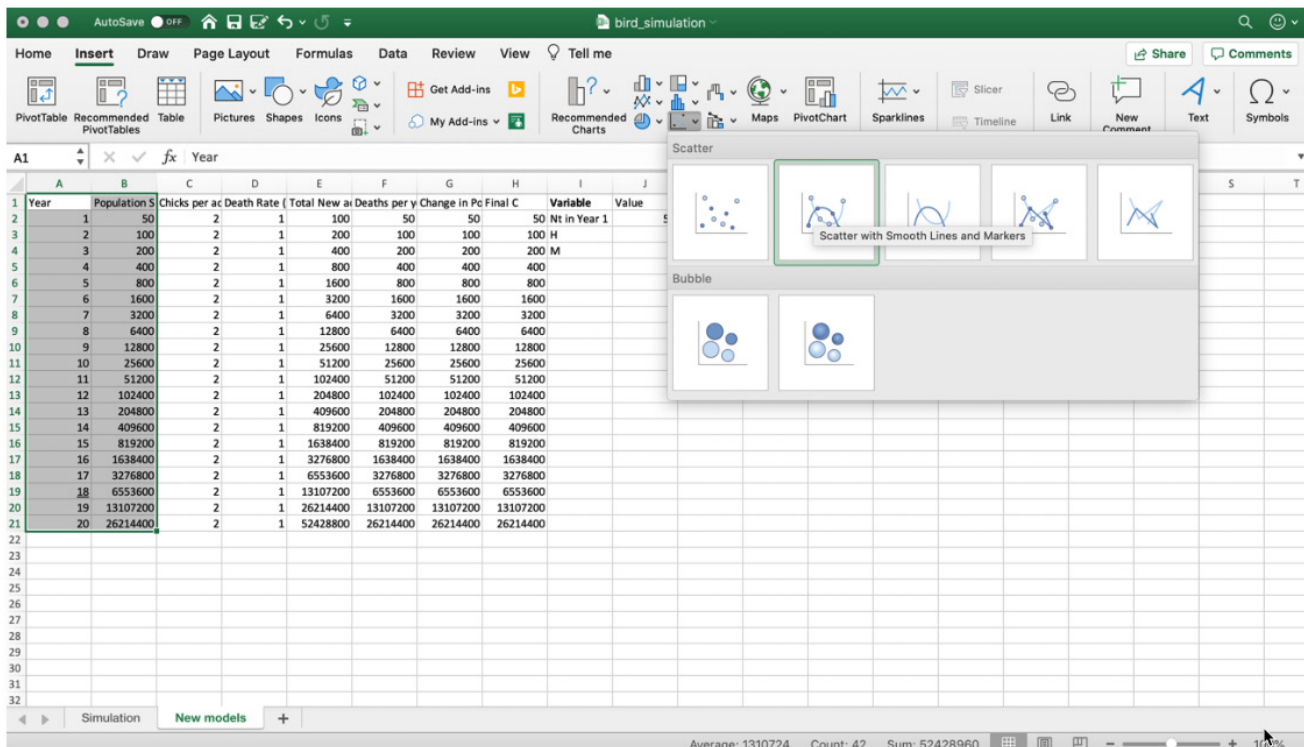
4. Click on the “Simulation” tab at the lower left.
5. Select cells A1 to J21. This will include everything you have typed or calculated on the page.
6. Go to the Edit tab at the top and click “Copy tab.”
7. At the bottom, click on the tab called “New Model.”
8. Put your cursor in cell A1.
9. Go to the Edit tab at the top and click “Paste.”

Now we are ready to make a graph.

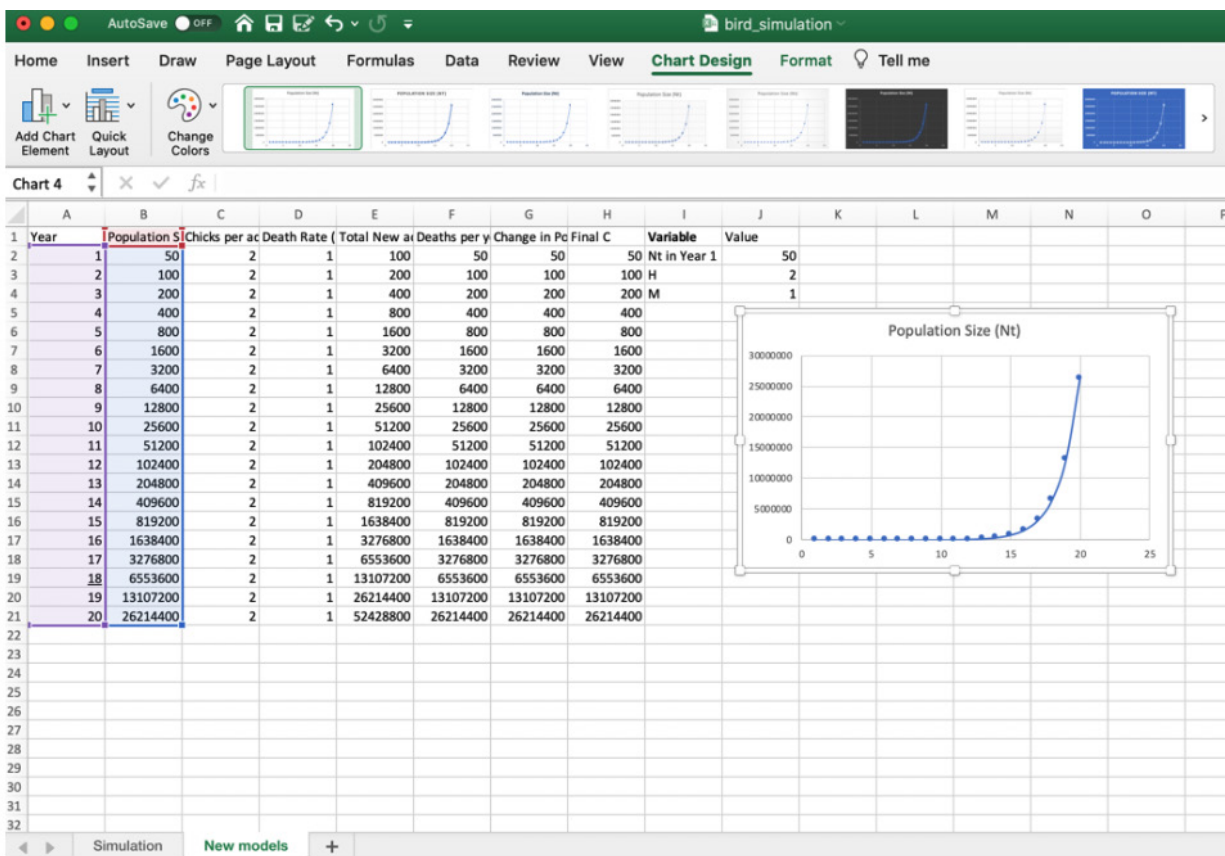
10. Highlight Cells A1 to B21.

Year	Population S	Chicks per ac	Death Rate	Total New a	Deaths per y	Change in Pc	Final C	Variable	Value
1	50	2	1	100	50	50	50	Nt in Year 1	50
2	100	2	1	200	100	100	100	H	2
3	200	2	1	400	200	200	200	M	1
4	400	2	1	800	400	400	400		
5	800	2	1	1600	800	800	800		
6	1600	2	1	3200	1600	1600	1600		
7	3200	2	1	6400	3200	3200	3200		
8	6400	2	1	12800	6400	6400	6400		
9	12800	2	1	25600	12800	12800	12800		
10	25600	2	1	51200	25600	25600	25600		
11	51200	2	1	102400	51200	51200	51200		
12	102400	2	1	204800	102400	102400	102400		
13	204800	2	1	409600	204800	204800	204800		
14	409600	2	1	819200	409600	409600	409600		
15	819200	2	1	1638400	819200	819200	819200		
16	1638400	2	1	3276800	1638400	1638400	1638400		
17	3276800	2	1	6553600	3276800	3276800	3276800		
18	6553600	2	1	13107200	6553600	6553600	6553600		
19	13107200	2	1	26214400	13107200	13107200	13107200		
20	26214400	2	1	52428800	26214400	26214400	26214400		

11. Click on the Insert tab at the top of the page. Then click on the scatter plot, which is the icon that shows a graph with dots on it (see picture). Select the graph that has smooth lines and markers on it.



12. Click on your graph and move it next to your data.



13. **Describe** how the population grows over time.

It grows more quickly each year.

You could talk to students about how this type of growth is called exponential growth. It is the type of growth you will see if there is no limit on the population.

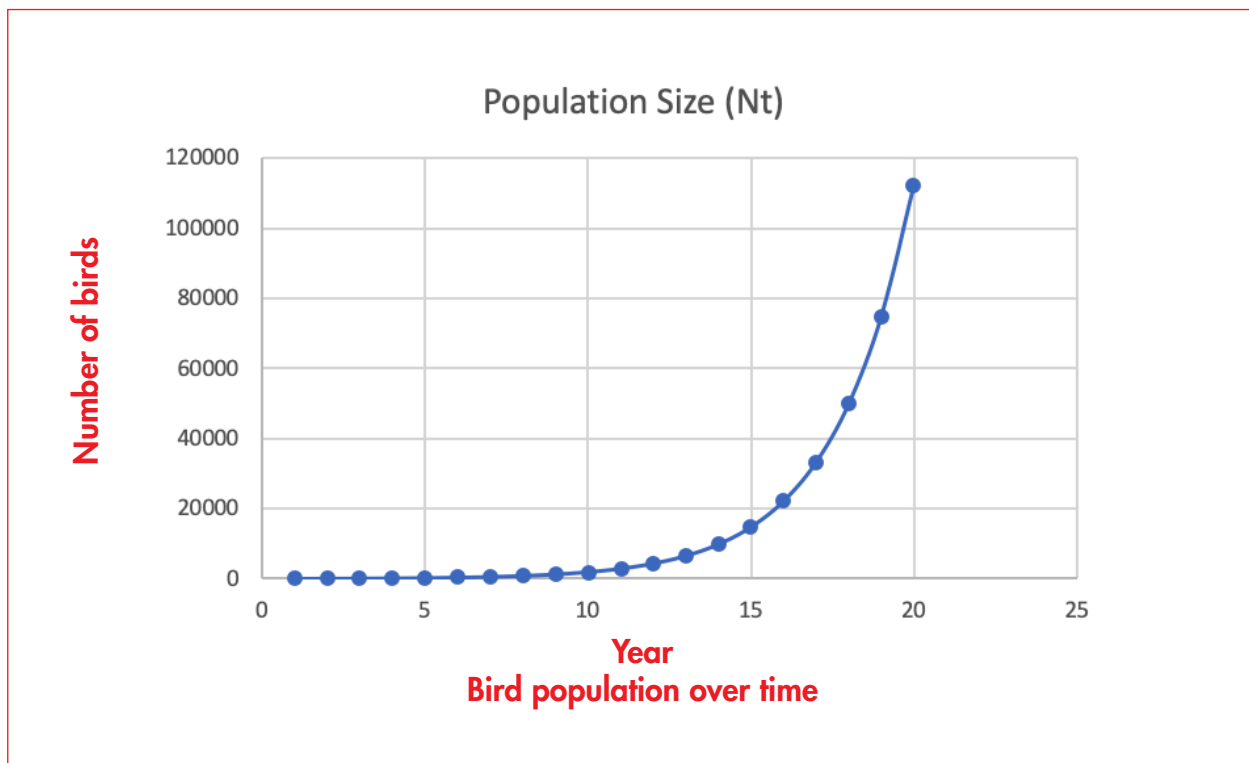
**Step 7: Using the Model to Explore**

Now, let’s see what happens to the population if we assume there are fewer chicks and a more dangerous habitat.

Let’s explore what happens if each individual only produces one chick each year and all of the adults die at the end of the year. To do this:

- a. Go to the tab “New Model.”
- b. Change H (cell J3) to a value of 1.
- c. Change M (cell J4) to a value of 1.
- d. The numbers in your model and the graph should have changed!

1. **Paste** or **redraw** the graph below. Be sure to add labels to the axes and add a figure caption.



2. **Describe** what happened to the population.

It stayed the same.

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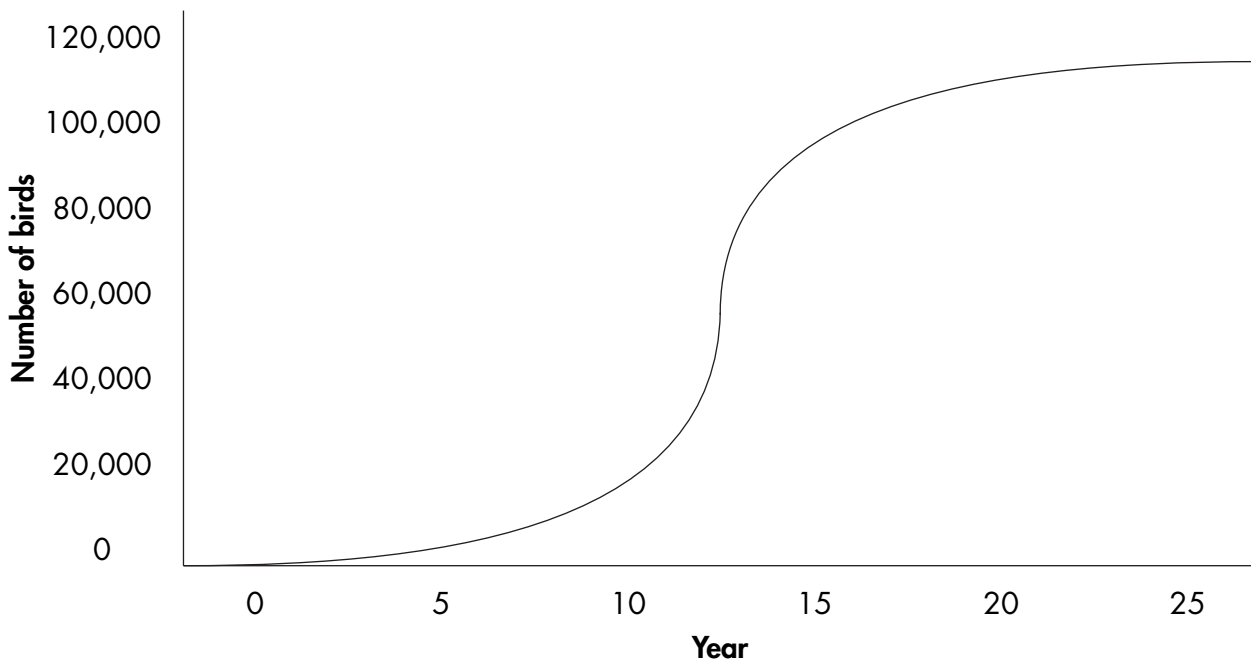
3. Using data from your model, **explain** why this pattern occurs. Hint: Use the information on total new birds and total deaths.

There were the same number of births and deaths. So, the population stays the same.

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**Extend the lesson:** Have students discuss why measuring birth rates and death rates is important for predicting changes in populations. Have them put new parameters (such as higher death rates) in their models to explore what happens to the population growth.

Population models can also help investigate limiting resources. Below is a graph of what bird population growth might look like if nest sites were limited.



**Bird population growth with limited nest sites**

4. **Describe** how you think the number of new birds hatching compares to the number of birds that die each year when the population is small and growing.

I think that birth rates are higher than death rates. In my model, the population grew when births were greater than deaths.

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5. **Describe** how you think the number of new birds hatching compares to the number of birds that die each year when the population is large and not growing at all. Use information from your model to support your answer.

I think that births are the same as deaths. When these were the same in my model the population did not grow.

6. **Predict** why a limited number of nest sites might result in the rate of population growth slowing and stopping.

I think it is because when all the nests are taken, no more chicks can be produced no matter how many adults there are. Getting exactly the right answer here is less critical than a plausible reason deaths would increase or births would decrease.

7. **Describe** other reasons a population might stop growing when the population is large.

Accept any plausible explanation. Possible answers could include: 1) predators start eating more individuals so death rates increase; 2) there is less food to go around so births would decrease, and more individuals might starve.

**Extend the lesson:** Have students conduct research on the Internet to learn about ways engineers and scientists use computer models. Have students choose one model and make digital presentations of their research results. They should include information on 1) why the model is created; 2) what the model represents in the real world; 3) how the model has helped scientists and engineers; 4) possible limitations of the model.