

# WildCam Lab: Inquiry and Data Analysis Using Trail Camera Data from Gorongosa National Park, Mozambique

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Researchers in Gorongosa National Park (GNP) in Mozambique are using trail cameras to document the recovery of the park's wildlife after a decades-long civil war decimated many animal populations. Using WildCam Gorongosa, an online interactive platform, citizen scientists can identify species in trail camera photos to help researchers document their distribution. We present an inquiry-based laboratory exercise that enables students to use WildCam data to propose and test their own hypotheses while developing data analysis and graphing skills using Excel. We implemented this exercise in a first-year undergraduate introductory biology course for majors. Students gained experience mining and manipulating large data sets, discussed the benefits and limitations of using trail camera data to test ecological questions, and were exposed to authentic citizen science.

**Keywords:** inquiry-based learning, trail camera data, Gorongosa National Park, Excel data analysis, WildCam

## Introduction

We present a laboratory exercise that guides students through the steps of scientific inquiry using an online interactive platform called WildCam Gorongosa ([www.wildcamgorongosa.org](http://www.wildcamgorongosa.org)) that provides access to trail camera data from Gorongosa National Park (GNP) in Mozambique, Africa. This exercise was implemented with first-year biology students at Mount St. Mary's University, and is a modification of a teaching activity originally developed by HHMI BioInteractive (<http://www.hhmi.org/biointeractive/scientific-inquiry-using-wildcam-gorongosa>). In the exercise, students learn to identify animals photographed by trail cameras, develop a hypothesis that can be tested using trail camera data, and download and analyze the data necessary to evaluate their hypothesis.

As written, the exercise is best suited for introductory-level biology students (major or non-majors), but could be adapted for students in upper-level courses by increasing the complexity of the research questions and

requiring statistical analysis of the results. It can be completed within a 2-hr lab period, but a 3-hr lab period would allow more time for sharing and discussing results. To prepare for the lab, instructors should familiarize themselves with the online platform and data analysis techniques. No physical set-up is required. Students will need access to an internet-connected device (e.g., tablet, laptop, or desktop computer) that can support a browser and a spreadsheet program such as Microsoft® Excel or Google Sheets.

The focus of this exercise on African animals in their native ecosystems is expected to keep students engaged and motivated as they learn the steps of scientific inquiry and gain technical skills in data analysis and graphing. Students will also benefit from a discussion about the limitations of real data sets and from the experience of participating in authentic citizen science, which is an increasingly important avenue for contributing to the advancement of scientific knowledge (Bonney et al, 2009).

## Student Outline<sup>1</sup>

### Objectives

- Identify animals captured by trail cameras in Gorongosa National Park
- Develop a hypothesis that can be tested using trail camera data
- Download and analyze trail camera data to test your hypothesis and reach a conclusion
- Discuss the benefits and limitations of using trail camera data to test ecological questions

### Introduction

Gorongosa National Park is a 1,570-square-mile protected area in Mozambique. Lion researcher Paola Bouley and her team use motion-detecting trail cameras to learn more about Gorongosa's lions. Lions are not the only animals captured by these cameras. The photos provide valuable information on a variety of different animals, including their numbers (to help estimate population sizes), their behaviors, and interactions with other animals. The public has identified animals and collected data from the photos on a citizen science website called WildCam Gorongosa ([www.wildcamgorongosa.org](http://www.wildcamgorongosa.org)). The WildCam Lab is a section of WildCam Gorongosa where you can view trail camera data on a map, filter, and download the data to investigate scientific questions.

The process of science is iterative and adaptable. The first step in scientific inquiry typically consists of **making observations** about the natural world. Observations can inspire questions about phenomena to gain understanding about how nature works. For scientists to answer a question, it must be testable, meaning that it could be answered by designing an experiment and/or collecting data. After identifying a **testable question**, the scientist may form a **hypothesis**, which is an explanation for the observed phenomenon, based on observations and/or prior scientific knowledge. Before collecting data, the scientist may also **predict** the expected results of the investigation if the hypothesis is supported. The scientist can **test the hypothesis** through experimentation or further observation, followed by an analysis of the data collected.

In this activity, you will learn firsthand what it is like to be an ecologist studying Gorongosa's wildlife. You will use actual trail camera data to generate a testable question, form a hypothesis and prediction, and choose and analyze the appropriate data to answer your question from the WildCam Lab. The results of your investigation may contribute to the conservation effort in Gorongosa National Park.

### Procedures and Questions

#### *Part 1: Making Observations and Asking Questions.*

1. Visit WildCam Gorongosa ([www.wildcamgorongosa.org](http://www.wildcamgorongosa.org)) and create an account or sign in with your existing account. Click the "Get Started" button and read through the tutorial.
2. With a partner, spend 10 minutes observing and identifying animals. Record your observations and questions in the table on the following page. As you work, consider the following questions and make notes in the two boxes below:
  - What do you notice? What do you wonder?
  - Which animals have you identified in the pictures? How many?
  - What are they doing? What environment are they in?
  - If there are pictures with no animals, what other observations can you make? What questions do you have?

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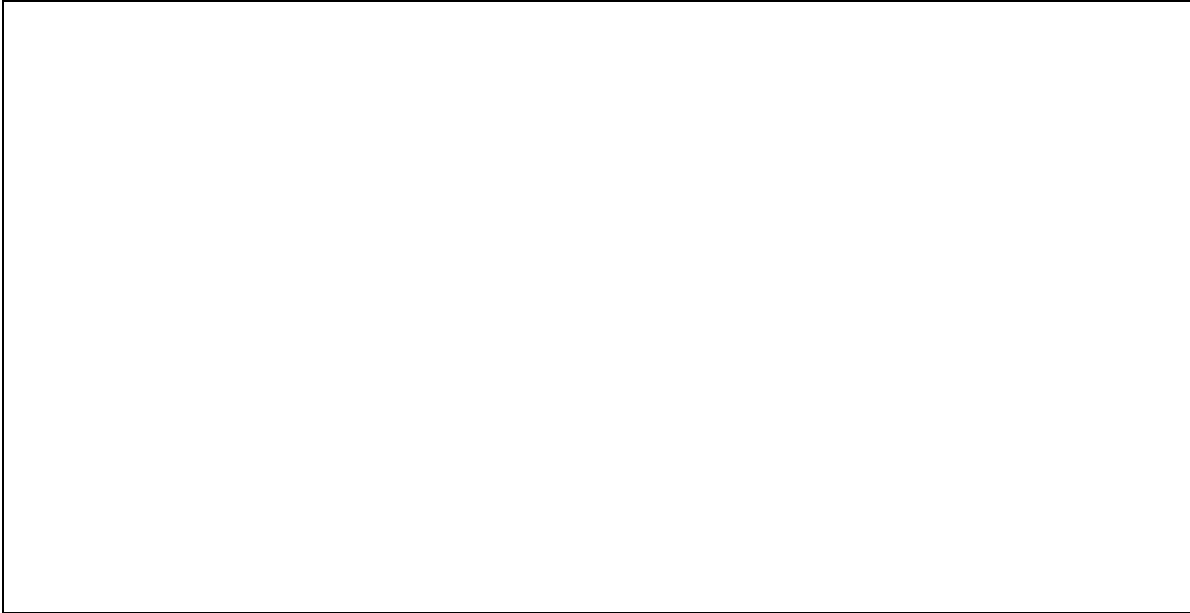
<sup>1</sup> This outline is a modification of the original student guide developed by HHMI BioInteractive, which is available at <http://www.hhmi.org/biointeractive/scientific-inquiry-using-wildcam-gorongosa>

<b>Observations</b>
<b>Questions</b>

*Part 2: Testable Questions*

A good research question is one that can be answered by performing an experiment, collecting data, or analyzing existing data. In order to determine which questions you can answer, you need to know which kinds of data can be gathered from the trail camera photos.

3. With your partner, brainstorm which kinds of data you can gather from the trail camera photos. Write your list in the space below:



4. Assess whether the following question is testable given the types of data you could collect from the trail camera images, based on the list you generated above.

*During which season is the highest abundance of animals present in the limestone gorge vegetation type?*

Is this question testable using the data from the trail camera images? If so, what information would you include in your analysis from the images? If not, what additional data would you need to test this question?

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The spreadsheet in Figure 1 shows data for 6 images downloaded from the WildCam database. The column headings indicate the types of data recorded for each image. Much of this information is called **metadata**, or data that are useful in providing the context for each photo, such as when and where the photo was taken. For example, useful metadata include the date the photo was taken and the GPS position of the camera, which make it possible to know the season and the type of vegetation that the camera was in.

	A	B	C	D	E	F	G	H	I	J	K	L
1	image_id	camera	longitude	latitude	date	month	year	season	time_period	veg_type	human_structure	distance_human_m
2	681504	C15	34.5406	-18.9522	11/17/2013	Nov	2013	DryWet Oct-Dec	Day 0623-1709	Floodplain Grassland	Road	4
3	687882	C08	34.3215	-18.9672	8/10/2013	Aug	2013	Dry Jul-Sep	Day 0623-1709	Mixed Savanna and Woodland	Road	3
4	688612	C21	34.676	-19.0319	9/24/2013	Sep	2013	Dry Jul-Sep	Day 0623-1709	Limestone Gorge	Ranger Outpost	6466
5	695637	D35	34.5001	-18.9262	9/15/2013	Sep	2013	Dry Jul-Sep	Day 0623-1709	Floodplain Grassland	Road	17
6	696736	C06	34.3416	-18.9785	9/1/2013	Sep	2013	Dry Jul-Sep	Day 0623-1709	Mixed Savanna and Woodland	Road	2

M	N	O	P	Q	R	S	T	U	V	W
water_type	distance_water_m	species	species_c	percentage_resting	percentage_standing	percentage_moving	percentage_eating	percentage_interacting	young_present	horns
River	222	Warthog	1	0	0.2	0.2	0	0	FALSE	
River	3677	Warthog	1	0	0.1	0.1	0	0	FALSE	
River	16	Baboon	1	0.047619048	0.047619048	0.047619048	0.047619048	0	FALSE	
Lake	2300	Elephant	1	0	0.045454545	0.045454545	0.045454545	0.045454545	FALSE	
River	1777	Baboon	1	0	0.045454545	0.045454545	0	0	FALSE	
River	195	Baboon	3	0.041666667	0.041666667	0.041666667	0	0.041666667	TRUE	

**Figure 1.** Partial data set downloaded from the WildCam database.

- After reviewing the types of data available from the camera photos, consider which of the research questions you wrote for question 2 above are potentially testable using these data. Star each question that you think you could answer. Spend five minutes with your partner modifying your questions or writing more questions in the space below that could be answered with data from WildCam pictures.

Modified or New Questions

*Part 3: Hypothesis and Prediction*

Now that you know the types of data that are available, it is time to select your research question and formulate a hypothesis and prediction. Then, you will make a plan for collecting data that will allow you to test that hypothesis.

Before you explore your own question, we will walk you through the process of making a hypothesis and a prediction using the following example question:

*During which season is the highest abundance of animals present in the limestone gorge vegetation type?*

In formulating hypotheses, it’s helpful to identify the variables involved in your question. An **independent variable** is the variable you are studying the effect of, and the **dependent variable** is the variable that is affected by (or depends on) the independent variable. For example, for this question, the independent variable is the season and the dependent variable is the number of animals found in the limestone gorge during each season.

Hypotheses are often generated in pairs: a **null** and **alternate hypothesis**. Remember that the null hypothesis is a negative statement of the expected results, generally predicting no difference or no effect of the independent variable (season) on the dependent variable (number of animals present in the limestone gorge vegetation type). The alternate hypothesis, on the other hand, predicts a difference or an effect of the independent variable on the dependent variable.

Null hypothesis: *Animal abundance in the limestone gorge vegetation type will not vary by season.*

6. What is the alternate hypothesis?

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But why is this question (and your paired hypotheses) biologically interesting? Why might we expect animal abundance to vary by season?

You may be able to answer this by exploring the Gorongosa National Park Interactive Map (<http://www.hhmi.org/biointeractive/gorongosa-national-park-interactive-map>). Visit the map, click on the limestone gorge and vegetation type layers, and read about the various vegetation types. You might discover that the limestone gorge vegetation type has streams that flow year-round and lush, green vegetation, even during the dry season. Vegetation typically dries out and dies in the other areas of the park during the dry season. A specific alternate hypothesis based on this new information would be:

**Alternate hypothesis:** *In the limestone gorge vegetation type, animals are most abundant in the dry season.*

This alternate hypothesis is useful and biologically interesting, because it specifically states that animals may be more abundant in the limestone gorge *in the dry season*. This expectation is based on background knowledge and, if confirmed, it can help you explain what factor(s) may be influencing the movement of animals to and from the limestone gorge. How does this alternate hypothesis compare with the one you wrote in question 6 above?

Before analyzing data, scientists will typically predict the results or observations that would be generated if the alternate hypothesis were supported (in other words, if the null hypothesis is rejected). In our example, a prediction might be:

**Prediction:** *I will find more animals in photos taken in the limestone gorge during the dry season than during any other season.*

If the alternate hypothesis were supported by the data, then a potential explanation for this observation (which could be tested in a later experiment) would be that animals are most abundant in the dry season in the limestone gorge vegetation type *because they are attracted to the water and green vegetation that is scarce in other areas.*

7. Choose one of the testable questions you generated in questions 2 and 5 above which you are the most interested in studying and write it below:

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8. List your null and alternate hypotheses.

Null hypothesis:

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Alternate hypothesis:

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9. What specific results do you predict to see if your alternate hypothesis is supported by the data?

Prediction:

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10. Explain why your question is biologically interesting. Use your background research and information from the WildCam photos you have seen so far to justify your answer and provide a biological rationale for your predicted results.

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11. Which variables from the spreadsheet (see the data column headings in Figure 1 for the possible variables) will you need to include in your analysis to test your hypothesis stated above?

Independent variable(s):

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Dependent variable(s):

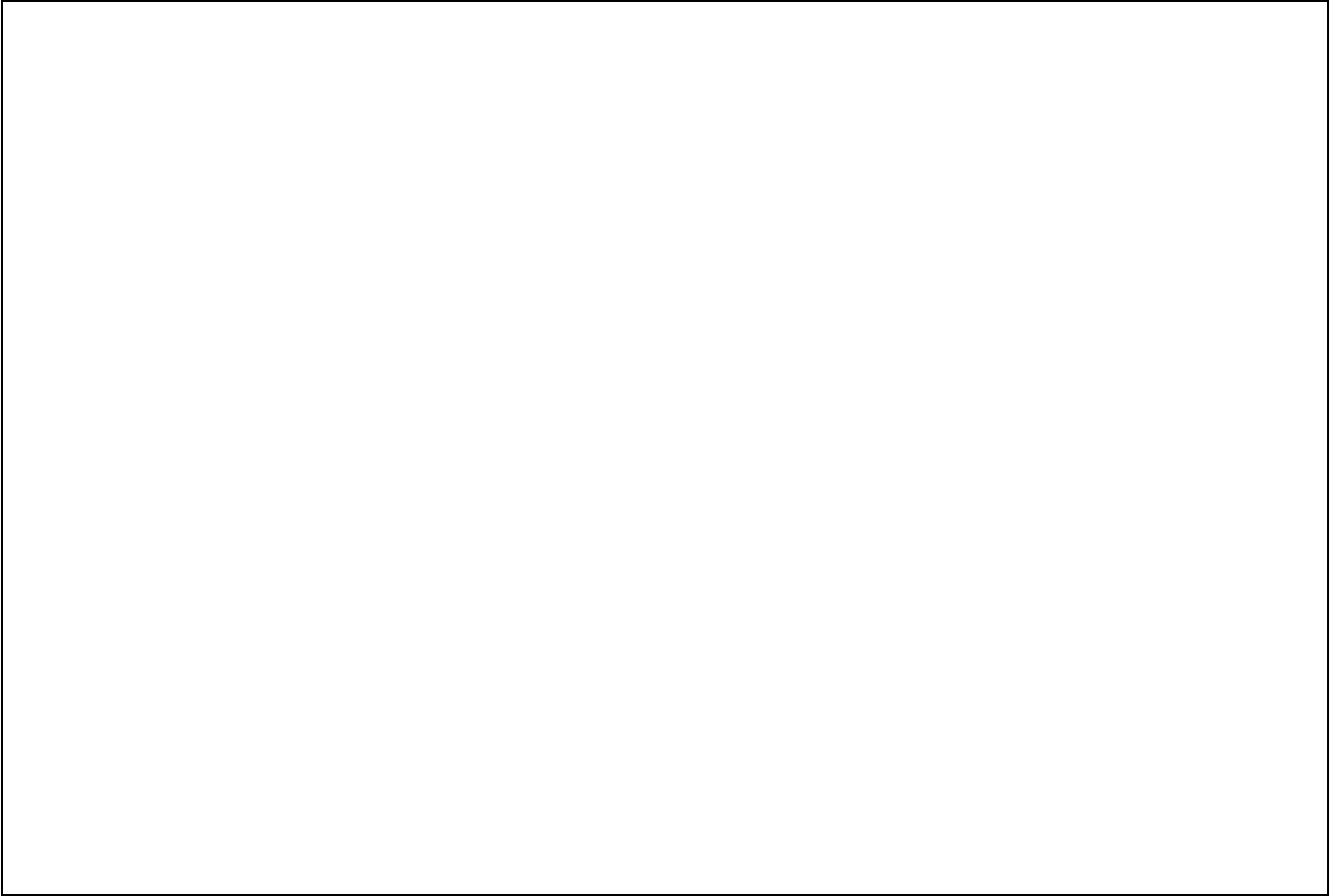
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*Part 4: Data Collection Plan*

You will now gather the data for your research question using the WildCam Lab.

12. Take notes in the space below as your instructor demonstrates how to use the WildCam Lab, focusing on the questions below:

- How do you use the filters on WildCam?
- What do you do with filters you do not need (for example, the “Season” filter, if your question is not looking at seasons)?





13. On the image below of the WildCam Lab, circle or write in the options you would select for each relevant filter to get the data needed to answer your question.

The image shows a digital interface for filtering data from the WildCam Lab. It consists of two main panels. The left panel is titled 'Species' and contains a list of 50 animal species, each with an unchecked checkbox. The right panel contains several filter sections, each with a title and a 'Viewing all' link. The 'Habitats' section has four options with unchecked checkboxes. The 'Seasons' section has four options with unchecked checkboxes. The 'Times of Day' section has four options with unchecked checkboxes. The 'Date' section has two input fields for dates in 'mm/dd/yyyy' format, separated by 'to'. The 'Distance to Humans (m)' section has two input fields, both containing the text 'Any', separated by 'to'. The 'Distance to Water (m)' section also has two input fields, both containing 'Any', separated by 'to'.

**Species** *Viewing all*

- Aardvarks
- Baboons
- Birds (other)
- Bushbucks
- Bushpigs
- Caracals
- Civets
- Cranes
- Duikers
- Elands
- Elephants
- Genets
- Ground Hornbills
- Hares
- Hartebeests
- Hippopotami
- Honey Badgers
- Hyenas
- Impalas
- Jackals
- Kudus
- Leopards
- Lion Cubs
- Lions (Females)
- Lions (Males)
- Mongoose
- Nyalas
- Oribis
- Otters
- Pangolins
- Porcupines
- Raptors (other)
- Reedbucks
- Reptiles
- Rodents
- Sable Antelopes
- Samango Monkeys
- Secretary Birds
- Servals
- Vervet Monkeys
- Vultures
- Warthogs
- Waterbucks
- Weasels
- Wildcats
- Wild Dogs
- Wildebeest
- Zebras
- Humans
- Fire!
- (Nothing)

**Habitats** *Viewing all*

- Limestone Gorge
- Floodplain Grassland
- Miombo Woodland
- Mixed Savanna and Woodland

**Seasons** *Viewing all*

- Wet (Jan-Mar)
- Wet-Dry (Apr-Jun)
- Dry (Jul-Sep)
- Dry-Wet (Oct-Dec)

**Times of Day** *Viewing all*

- Dawn (0557 - 0622)
- Day (0623 - 1709)
- Dusk (1710 - 1735)
- Night (1736 - 0556)

**Date** *Viewing all*

mm/dd/yyyy to mm/dd/yyyy

**Distance to Humans (m)** *Viewing all*

Any to Any

**Distance to Water (m)** *Viewing all*

Any to Any

14. Use the WildCam Lab ([lab.wildcamgorongosa.org](http://lab.wildcamgorongosa.org)) to filter the data and download a spreadsheet that will help you answer your research question. If you discovered, as you worked through the filter options, that you might not be able to filter the appropriate data to address your question, you may return to question 5 and either edit your question or pick a new one. Refining or changing your question based on the available data is a regular part of the iterative process of science.

*Part 5: Data analysis*

You will now analyze your data and create a graph to represent your findings.

15. Use the spreadsheet tutorial provided at the end of the exercise to organize your data and create a graph.
16. Were you able to answer your question using the data you collected? If not, what additional data would you need to answer this question?

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*Part 6: Communicating Your Findings*

17. Describe the trends that you see in your graph.

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18. *[Optional]* Consult with your lab instructor to determine if your results can be analyzed statistically with a test you have already learned to do (e.g., chi-square, t-test, etc.). If so, report your findings here, using the format recommended by your instructor.

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19. Based on your graph (and the statistical results, if applicable), do you support or reject your null hypothesis? Explain your answer using evidence from the graph and/or statistical results.

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20. What are the potential limitations of trail camera data? Identify at least two potential biases of trail camera data (e.g., consider the placement of the trail cameras). To what extent might these biases affect your confidence in the results from your experiment? Explain.

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21. In this activity, the scientific process followed a linear sequence: observation, question, hypothesis, prediction, data collection/analysis, and findings. However, the process is typically iterative. Explain how new information might lead a researcher to go back and repeat certain steps in the scientific process, including asking different questions. At what stages in your process could you have obtained additional information from the scientific literature or other sources to inform or revise your process?

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22. Based on the results of this investigation, what are some additional research questions that could be further investigated to gain a deeper understanding about the animals in Gorongosa National Park?

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## PC Excel Tutorial

### A. Overview

This tutorial provides instructions for creating Pivot Tables to analyze and graph data downloaded from the Gorongosa WildCam Lab. The version of Excel used in this tutorial is Excel 2013 for PC. Not all features and functions may work the same way in other versions of Excel. Tutorials for PC and Mac are also available at <http://www.hhmi.org/biointeractive/scientific-inquiry-using-wildcam-gorongosa>.

In this tutorial we will use the example research question from the lab exercise: *During which season is the highest abundance of animals present in the limestone gorge vegetation type?*

The data used in this example were obtained using the WildCam Lab (<https://lab.wildcamgorongosa.org/>), filtering the data to include only photos taken from cameras in the limestone gorge vegetation type. A screenshot of the first few rows and columns of the resulting Excel spreadsheet with the data is shown in Figure 2.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	camera	longitude	latitude	date	month	year	season	time_period	veg_type	human_structure	distance_human_m	water_type	distance_water_m	species	species_count
2	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	5
3	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	2
4	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Human	1
5	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Human	1
6	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	3
7	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	1
8	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	1
9	D23	34.6172	-18.9591	12/5/2013	Dec	2013	DryWet Oct-Dec	Day 0623-1709	Limestone Gorge	School		5385 River		81 Baboon	1

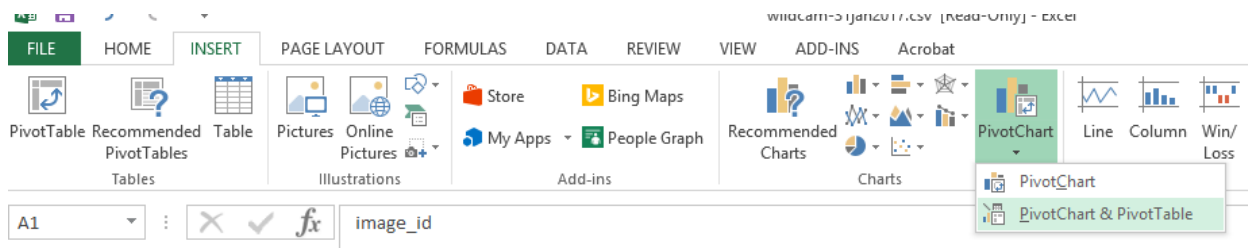
**Figure 2.** Partial view of the data set used in this tutorial.

To analyze the data to address the research question, we will create a bar graph showing the total number of animals captured in trail camera photos in the limestone gorge in each of the seasons.

### B. Make a Pivot Table and Bar Graph.

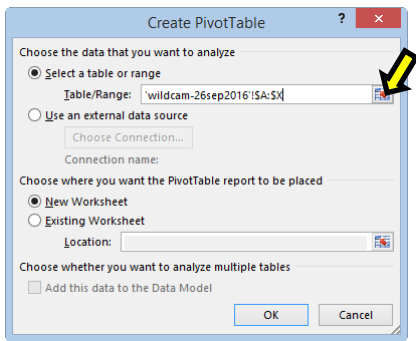
For research questions in which you need to sum the number of animals in a particular category (e.g., number of animals in each season), creating a **pivot table** is a quick and easy way to analyze your data. Excel can also automatically generate a bar graph based on the pivot table. *Note: it's possible that your research question is substantially different enough that a pivot table may not be appropriate, or that you will need to use methods to create your pivot table other than the ones illustrated here. Consult your instructor for guidance.*

1. Click the **Insert** tab and click on the **PivotChart** button. Choose the PivotChart and PivotTable option (Figure 3).



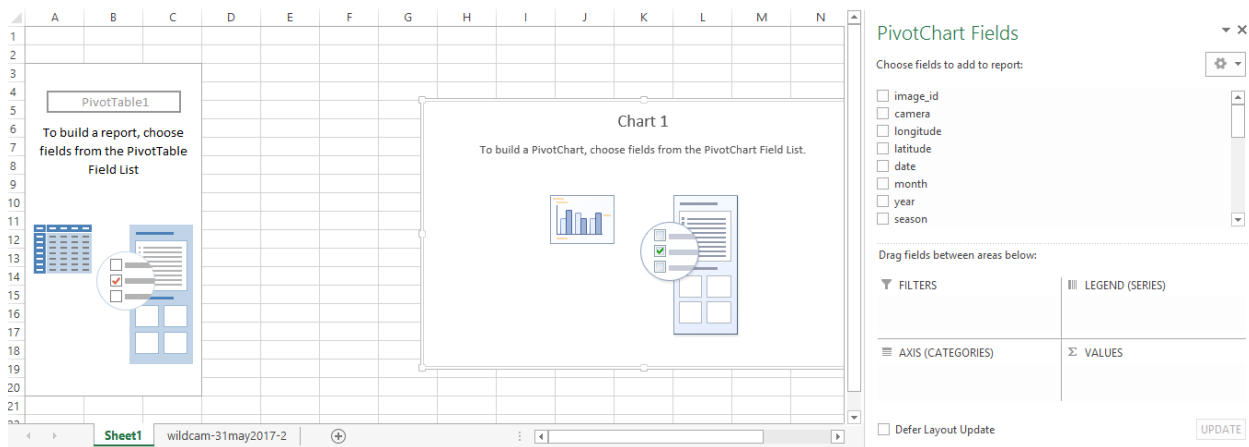
**Figure 3.** Inserting a PivotChart and Pivot Table.

2. Click on the button next to **Table/Range** (arrow in Figure 4). Navigate to your data and click on the letter “A” to highlight the first column. With the left mouse button held down, drag the cursor to the last column to highlight the entire data set. Under “Choose where you want the PivotTable report to be placed”, select **New Worksheet**. Click **OK** (Figure 4).



**Figure 4.** Selecting the range of data.

A new sheet will be added to the workbook (Sheet1) – see Figure 5. The next step is to build the pivot table so that it will analyze the data to answer the research question.



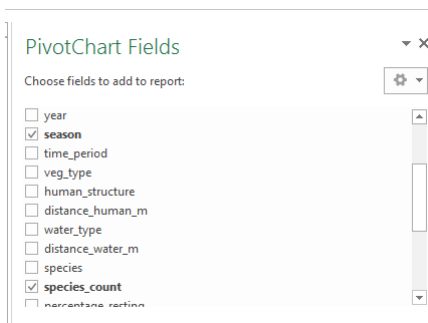
**Figure 5.** Initial output from creating a pivot table and chart in Excel.

A pivot table can be used to group data by certain variables. In this example, the numerical variable, “species\_count,” will be grouped by the categorical variable, “season.” To build the pivot table, you will follow the steps explained below to place the grouping variable (season) in the AXIS (CATEGORIES) area and the variable(s) being grouped (species\_count) in the VALUES area. You can group data by more than one variable and you can also group more than one variable.

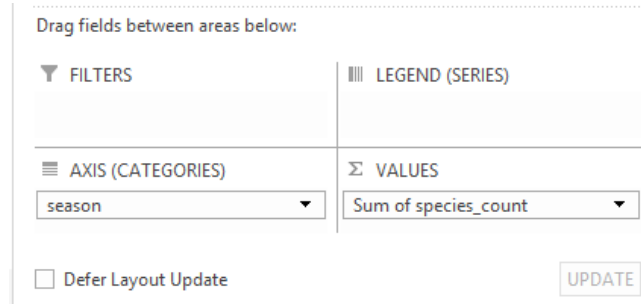
### C. Build the Correct Pivot Table

3. In order to create a bar graph that shows the number of animals in each season, you will need to select “season” and “species\_count” fields in the list of **PivotChart Fields**. Use the scroll bar on the right side of the list to view all of the field options (Figure 6).

4. By default, the season field will appear in the AXIS (CATEGORIES) field and the species\_count field will appear in the VALUES area. If, in your data set, these fields are not listed in the correct areas, you can drag the fields back and forth between the two areas as necessary. See Figure 7 for the correct arrangement of the fields.

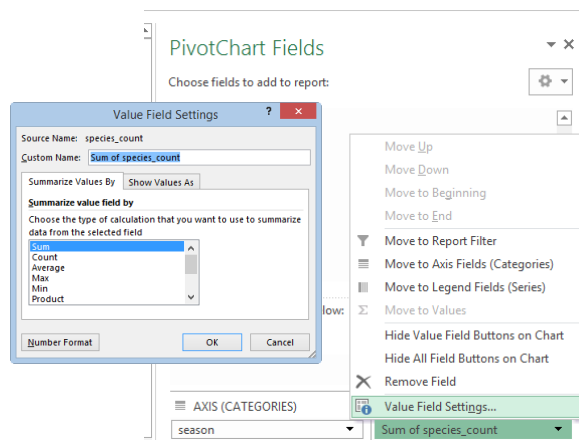


**Figure 6.** Selecting the fields to use in building the pivot table.



**Figure 7.** Arranging the fields in the correct areas of the pivot table.

5. In the VALUES column (`species_count`), make sure that the setting for your variable is appropriate for the dependent variable you have chosen. In this case, we want to sum the variable “`species_count`” because we want to total the number of animals observed in each photo. The default summary option (Sum) is appropriate in this example. To view the other summary options, click on the variable in the VALUES area (in this example, **Sum of species\_count**), and click on **Value Field Settings** and select “Summarize Values By” (Figure 8). Choose the option that works best for your research question and data (e.g., count, average, max, min, product, etc.).



**Figure 8.** Choosing how to summarize the VALUES field.

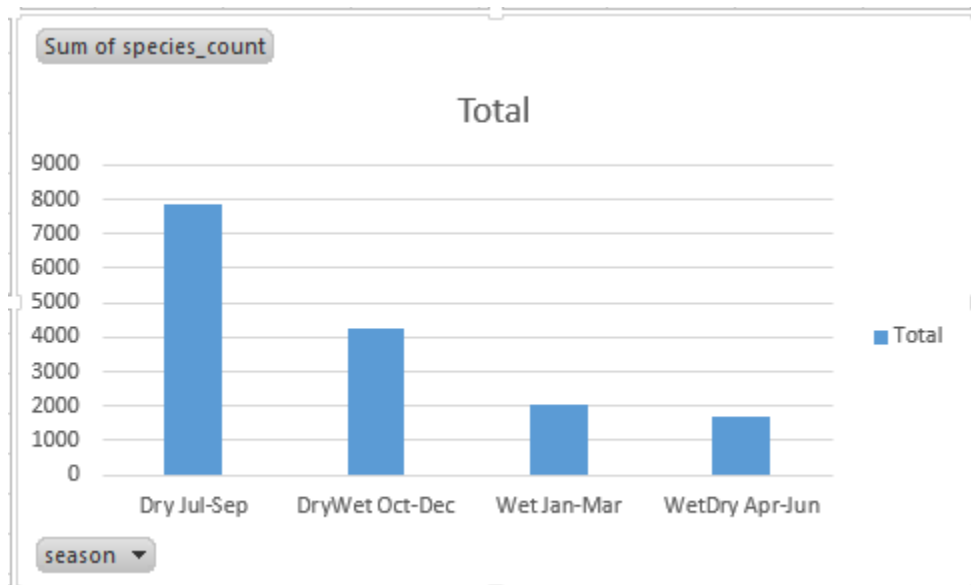
The completed pivot table is shown in Figure 9.

	A	B
1		
2		
3	<b>Row Labels</b>	<b>Sum of species_count</b>
4	Dry Jul-Sep	7857
5	DryWet Oct-Dec	4256
6	Wet Jan-Mar	2039
7	WetDry Apr-Jun	1713
8	<b>Grand Total</b>	<b>15865</b>
9		

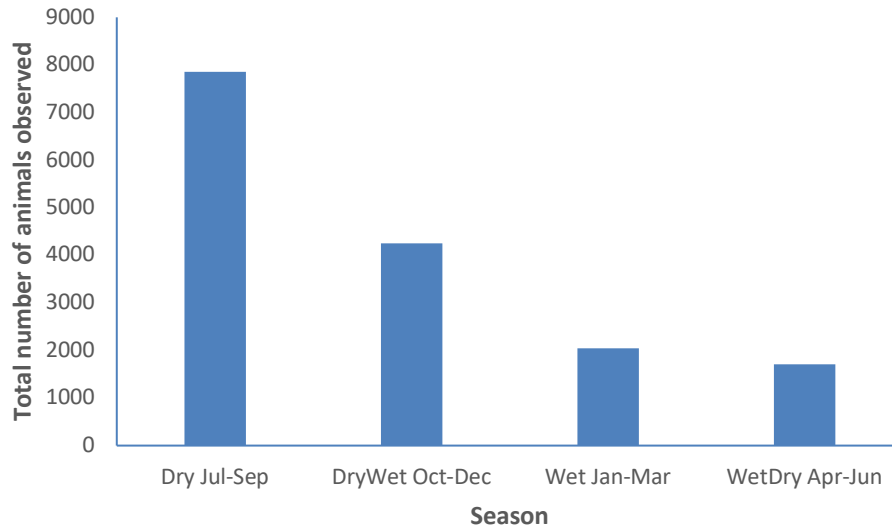
**Figure 9.** The completed pivot table.

*D. Build a bar graph*

Excel has automatically created a bar graph based on the data in the pivot table (Figure 10). You should customize your graph to meet your instructor’s guidelines for any report that is due from this activity (e.g., adding in axis labels and a figure caption; Figure 11). Hint: if you want to remove the field buttons from the chart, right click on one of them (e.g., season), and select **Hide All Field Buttons on Chart**. Click on the **DESIGN** button on the ribbon (under **PIVOTCHART TOOLS**) to explore the various options for editing the appearance of the chart.



**Figure 10.** The bar graph from the pivot table automatically generated by Excel.



**Figure 11.** Photos from trail cameras placed in limestone gorge habitat in Gorongosa National Park in Mozambique were analyzed to determine if the abundance of animals observed in the photos varied by season. Data from 8071 photos taken between Dec 31, 2011 and May 25, 2015 were analyzed.

What conclusion can you draw from this graph? Do the results support or reject the null hypothesis? Explain!

### *E. Answering your question*

In the lab activity, you came up with a testable research question using the trail camera data set. Now you will use the techniques from this tutorial to create a graph to explore your research question.

First, you should ask yourself: what graph do I need to create to help answer my question? Which variable(s) are grouping variables and which ones are values variables (i.e., variables that are being grouped)?

#### Step 1: Create a Pivot Table

Once you have downloaded the data from the WildCam lab, follow the instructions in Section B to create a pivot table exactly as you did for the example in the tutorial.

#### Step 2: Build the Correct Pivot Table

Use the instructions from Section C to build the correct pivot table. You will only select the variables that you need to create your graph. Drag the appropriate grouping variable(s) (your independent variable(s)) to the AXIS (CATEGORIES) area. Drag your dependent variable(s) to the VALUES area, and be sure to select the correct summary calculation (e.g., count, sum, average, etc.). If you are unsure which variables belong in which field, test it out and see if the pivot table makes sense. You can always drag variables back if you made a mistake.

#### Step 3: Create a Bar Graph

Use the instructions from Section D of this tutorial to guide you. Consult with your instructor to determine if a different type of graph is necessary to present your data.



## Materials

A computer with Internet access, a browser, and a spreadsheet program (e.g., Microsoft® Excel or Google Sheets) is required for at least each pair of students. The instructor can demonstrate data analysis and graphing using a projector attached to the instructor's computer.

## Notes for the Instructor

Many undergraduate students may not be familiar with African ecosystems and it can be challenging for them to develop biologically interesting or reasonable hypotheses to test in this exercise. Pre-lab assignments could provide useful background information, such as having the students read “Gorongosa: Restoring Mozambique’s National Treasure” (<http://www.hhmi.org/biointeractive/gorongosa-restoring-mozambique-s-national-treasure>) or review relevant resources on the HHMI BioInteractive website ([www.hhmi.org/biointeractive/gorongosa-national-park](http://www.hhmi.org/biointeractive/gorongosa-national-park)). The 34-min film “The Guide: A Biologist in Gorongosa,” available on the site, provides an excellent introduction to the park.

Students, working in pairs, generally take around 50 minutes to complete Parts 1-3 of the exercise. The instructor should practice identifying animals in the WildCam photos to be able to assist the students in Part 1 of the exercise. Students are sometimes reluctant to submit an identification because of the risk of making an error. Instructors can reassure the students that in citizen-science projects like this one there are adequate quality control protocols in place to ensure that the crowd-sourced identifications are accurate. Students should try to identify as many photos as possible during the 10 to 15 minutes spent in Part 1 of the exercise and not linger too long on any one photo.

Students will benefit from sharing their research questions in Part 2 (with the class or at least another group of students), to obtain feedback on the questions before proceeding to Part 3. Students tend to gravitate towards functional questions and hypotheses (i.e., *why* questions); they may need reminding that testable questions in this context are generally descriptive (i.e., *how*, *what* questions).

As students are developing their hypotheses and predictions, encourage them to utilize the available resources (e.g., the interactive park map) to develop a biologically meaningful rationale for their predicted results. Instructors should approve the students' answers to the questions in Part 3 before having the students move on to Part 4.

knowledge and scientific literacy. *Bioscience*. 59:977-984.

Students generally take the rest of the 2-hour lab period to complete Parts 4-6 of the exercise. Instructors should demonstrate the steps for filtering, downloading and analyzing trail camera data to address the model question in the exercise.

It can be challenging to troubleshoot data analysis and graphing problems encountered when students use different versions or platforms of spreadsheet programs. Conducting the exercise in a computer lab where all students are using the same program with a tutorial tailored to that program would alleviate this issue. Instructors may contact the authors for additional versions of the Excel tutorial (e.g., for Microsoft® Excel for the Mac or Google Sheets).

As students obtain their results, encourage them to consider alternative interpretations for any observed patterns in the data. Due to the nature of the data set, control over variables that would ideally be standardized is limited. For example, the trail cameras were not placed randomly or uniformly in the park because they were originally set up to help researchers locate lions. Some parts of the park (i.e., some vegetation types) have more cameras than others. In addition, the amount of time each trail camera has been operational is not currently available. An apparent difference in the abundance of a species between two vegetation types could be attributed to greater camera coverage in one vegetation type compared to the other, rather than an effect of the vegetation type on animal abundance. The ability to express animal counts in units of number of observations per camera hour would reduce the effect of this confounding variable; however, this functionality is not yet available in WildCam. It is beneficial for students to learn how to identify limitations in their data set and interpret their results accordingly. If time allows students to present their findings to the class, the instructor could facilitate a discussion to explore alternative explanations for the findings.

While this exercise is written for introductory level students (majors or non-majors), it could be adapted for upper-level courses. Instructors could focus the students' research questions on a particular topic in an upper-level course (e.g., competition, population growth patterns, predator-prey interactions), and require students to conduct statistical tests on their results. Students could then be required to develop and write a proposal addressing their research question in more depth, using their WildCam results as preliminary observations.

## Cited References

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