OVERVIEW

This activity complements WildCam Gorongosa (http://www.wildcamgorongosa.org), an online citizen science platform for identifying animals photographed by motion-detecting trail cameras in Gorongosa National Park. The WildCam Lab is a part of WildCam Gorongosa, where students can view trail camera data on a map, filter, and download the data to investigate scientific questions. In this activity, students will be guided through making observations about species diversity and calculating diversity indices (richness, Shannon diversity index, and evenness). Using a spreadsheet tutorial, students will then use these indices to measure the biodiversity of medium to large animals in different vegetation types in Gorongosa from a large data set of trail camera data that they download from the WildCam Lab and analyze their results. Students will then investigate the impact human activity might have on biodiversity by further analyzing information from this data set.

KEY CONCEPTS

- Biodiversity is the variety of life and can be measured on multiple scales including genetic diversity, species diversity, and ecosystem diversity.
- Indices that measure species diversity include species richness (the number of species in a given area) and evenness (similarity in the abundances of species).
- The location and abundance of animals are determined by the availability of resources and community interactions, such as competition, predation, and human influences.
- An ecological niche is the role of an organism in its environment, which includes the conditions under which it can live, what resources it uses, and how it reproduces.
- The diversity of an ecosystem, including soil, plant, structural, topographic, and climatic diversity, can positively impact animal species diversity.
- Human activities influence the abundance and distribution of living organisms.
- Proposing a claim and developing an explanation for a scientific research question requires the systematic analysis of relevant data.
- Thorough scientific research requires the careful and thoughtful interpretation of experimental results and analysis of all variables.
- Data can sometimes be used to make claims about scientific questions that were not foreseen when the data was collected, or to identify new questions to investigate.

STUDENT LEARNING TARGETS

- Calculate diversity indices (richness, Shannon diversity index, and evenness) by hand and using spreadsheet software (Excel or Google Sheets).
- Make predictions and use evidence to explain a difference in diversity among vegetation types.
- Explain the relationships between diversity indices.
- Predict how diversity could support ecosystem resilience.
- Propose a claim and explanation about a scientific research question supported by scientific evidence.
- Determine whether scientific results confirm or contradict a research question.
- Evaluate the methodology used to answer a scientific research question.
- Propose a scientific research question that can be investigated using available data.

CURRICULUM CONNECTIONS

Standards	Curriculum Connection
NGSS (2013)	HS-LS2-2, HS-LS2-7, HS-LS4-6, HS-ESS-3
AP Bio (2015)	2.D.1, 4.A.5, 4.C.4, SP2, SP3, SP5
IB Bio (2016)	4.1, 5.3, C.1, C.2, C.3, C.4
AP Env Sci (2012)	II.A, II.C, VII.C
IB Env Systems and Societies (2017)	2.1, 2.2, 3.2, 3.4
Common Core (2010)	ELA.RST.9-12.7, WHST.9-12.7 Math.N-Q.A.1, N-Q.A.3, S-IC.3, MP.2, MP.4
Vision and Change (2009)	CC5, DP1, DP2

KEY TERMS

claim, community, diversity, ecosystem, evenness, evidence, floodplain grassland, Gorongosa National Park, limestone gorge, richness, savanna, Shannon diversity index, species abundance, vegetation type, woodland

TIME REQUIREMENTS

- Two 50-min classroom periods or one 90-min block period. Part 1 may be assigned as homework (see Teaching Tips).
- Time requirements may differ depending on computer/internet access.

SUGGESTED AUDIENCE

- High School: Biology (all levels), Environmental Science (all levels)
- College: Introductory Biology or Ecology

PRIOR KNOWLEDGE

Students should

- be introduced to the WildCam Gorongosa website and perform some animal identifications prior to conducting this activity, as a way to engage and provide context.
- be familiar with the concepts of biodiversity, ecosystems, and species abundance.
- be comfortable using spreadsheets to organize information and calculators for simple calculations, including natural log (ln).

TEACHING TIPS

- Have students watch (for homework or in class prior to activity) "The Science of Camera Traps" from the 2015 Holiday Lectures on Science (https://www.hhmi.org/biointeractive/science-camera-traps).
- The Help and Ecology tabs on the WildCam Lab website (https://lab.wildcamgorongosa.org/students/ecology) provide additional background information on the geography and climate, water, vegetation, wildlife, and humans in Gorongosa.
- The Glossary and Help tabs on the right-hand menu on the Gorongosa Interactive Map can provide guidance and information for you and your students.
- Be prepared to display the WildCam Lab site on an overhead projector to demonstrate or facilitate parts of the activity for students.
- To gain more familiarity with the information available about Gorongosa, students can complete Part 1 as homework or on their own prior to the class working through the activity. If this option is selected, students would start working on Part 2 together in class.
- Ideally, students should work through the class activity in pairs or small groups.
- Each pair or group of students should have access to a computer/device with spreadsheet software.

- Depending on how you facilitate students working through the activity, you may want to project WildCam Lab to demonstrate how to view, filter, and download data. You can also project the spreadsheet for Part 3 to guide students through creating pivot tables and graphs.

ACCESSING DATA SETS ON WILDCAM GORONGOSA

To show your students how to access the data sets for this activity, they will first need to set up a Zooniverse account. Optionally, you can also set up a "Classroom" for your students which will allow you to monitor which students join the site.

- If you do not yet have an account on Zooniverse, you will need to create one first via this website: https://panoptes.zooniverse.org/users/sign_up
- Launch the WildCam Lab website (http://lab.wildcamgorongosa.org) and enter as an educator.
- Create a "New Classroom."
- This will generate a unique url. Send this url to your students to invite them to join the classroom. Instruct your students that they must create a Zooniverse account first, then click the url to join your classroom.
- If you choose not to create a Classroom, you can simply have your students set up a Zooniverse account and enter the WildCam Lab website as an "Explorer."

MATERIALS

- Internet access, computers/tablets with spreadsheet software (Excel or Google Sheets)
- Student handouts
- Calculators that include natural log (ln)

PROCEDURE

Several online/supplemental resources are used in this activity:

- Gorongosa Interactive Map
- WildCam Lab for data sets
- Tutorial for analyzing data

ANSWER KEY

PART 1: Exploring Species Diversity in Gorongosa

Launch the Gorongosa Interactive Map (http://www.hhmi.org/biointeractive/gorongosa-national-park-interactive-map) for a brief tour and study of the natural features of Gorongosa National Park. After you explore, make some predictions about the following:

1. What elements are necessary to support a wide variety of life for a given region? Include specific examples that you read about in the interactive.
   Answers will vary but should include examples of the source of water, different types of food/plants, and habitats that could be used for shelter.

2. For this activity, we will be eliminating the Montane vegetation types (Montane Grassland, Montane Woodland, and Montane Rainforest), found only on Mount Gorongosa. Make predictions about the possible differences in biodiversity between the remaining different vegetation types and natural features you read about in the interactive. Include information you used to make your predictions.
   Answers will vary. Diversity in the vegetation should increase animal species diversity; therefore, vegetation types with a greater diversity of plant species and greater vertical structure (combination of grass, shrubs, and trees of varying heights) should have greater animal diversity. The savanna/woodland vegetation type is most likely to have the highest animal diversity, followed by the limestone gorge, and the floodplain grassland.

PART 2: Introduction to Diversity Indices (Measuring Diversity)

3. **Richness** (S) is the total number of species in an ecosystem. Richness does not take into account the number of individuals, proportion, or distribution of each species within the ecosystem. Based on the species list below, what is the richness of this ecosystem? S = ___*10*__

   Species: Wildebeest, Warthog, Elephant, Zebra, Hippo, Impala, Lion, Baboon, Warbler, Crane

4. Richness alone misses an important component of species diversity: the abundance (number of individuals) of some species may be low while for others it may be higher. The **Shannon diversity index** (H) accounts for species abundance by calculating the proportion of individuals of each species compared to the total number of individuals in the community (P_i). For most ecosystems, the value for H ranges from 1.5 to 3.5, with the higher score being the most diverse.

   $H = -SUM (P_i * \ln(P_i))$

   Where:

   P_i = species abundance/total abundance in the community

   ln = natural log

   a. Using the table below, calculate the total abundance in the community and the P_i value for each species. Next, calculate the natural log of P_i for each species ($\ln(P_i)$) and then multiply the two columns to calculate $P_i * \ln(P_i)$. Limit your numbers to three decimal places.

Species	Abundance	P_i	$\ln(P_i)$	$P_i * \ln(P_i)$
Wildebeest	3	***.041***	***-3.194***	***-.131***
Warthog	3	***.041***	***-3.194***	***-.131***
Elephant	2	***.027***	***-3.612***	***-.098***
Zebra	1	***.014***	***-4.269***	***-.060***
Hippo	1	***.014***	***-4.269***	***-.060***
Impala	4	***.055***	***-2.900***	***-.160***
Lion	1	***.014***	***-4.269***	***-.060***
Baboon	15	***.205***	***-1.585***	***-.325***
Warbler	25	***.342***	***-1.073***	***-.367***
Crane	18	***.247***	***-1.398***	***-.345***
Total	***73***			**-1.737**

   b. Calculate H by adding each of the values in the $P_i * \ln(P_i)$ column of the table above and taking the negative of that value. **H =** __*1.737*_____

5. **Evenness** (E) is a measurement to compare the abundances of each species in the community. Communities in which each species is more evenly represented are considered more diverse than communities in which a few species are very common and other species are very rare. Low values indicate that one or a few species dominate, and high values indicate that all of the species in a community have similar abundances. Evenness values range from 0 to 1, with 0 signifying low evenness and 1, complete evenness.

   $E = H/H_{MAX}$

   Where:

   H = Shannon Diversity Index

   H_{MAX} = the highest possible diversity value for the community, calculated by **ln(richness)**

   a. Use the richness value you calculated in question 3 to calculate H_{MAX}. **H_{MAX} = ln(richness) =** __*2.303*___

   b. Use the Shannon diversity index value you calculated in question 4 and the H_{MAX} value you calculated above to calculate E. **$E = H/H_{MAX}$ =** ___*.754*_____

PART 3: Measuring Biodiversity in Gorongosa

Use the *Tutorial on Measuring Diversity in Gorongosa* to guide students in downloading the data (Part A of the tutorial) from WildCam Lab (https://lab.wildcamgorongosa.org). Then, guide them through making a pivot table and bar graph using the downloaded spreadsheet (Parts B, C, and D of the tutorial).

6. Following the directions in the tutorial, create a pivot table to produce a list of species within each vegetation type as well as their abundance. Calculate the values of diversity indices for each vegetation type and record your answers in the table below. ***Answers will vary.***

Vegetation Type	Floodplain Grassland	Limestone Gorge	Miombo Woodland	Mixed Savanna and Woodland
Richness				
Shannon Diversity Index				
Evenness				

7. Compare your calculated values to evaluate whether there is a relationship between richness, diversity, and evenness for each vegetation type. Explain your reasoning.
   The Shannon diversity index is calculated by taking the sum of Pi * ln(Pi) for each species. If more numbers are added based on the number of species present (or richness), then higher richness should increase the Shannon diversity index if the relative species abundance remains the same. Richness does not impact the evenness of an ecosystem. Evenness is calculated by dividing the Shannon diversity index (H) by the natural log of the richness (H_{MAX}). If the species abundances within a community are completely proportional (even), then H would be the same as H_{MAX}, so evenness (E) would be equal to 1 for that community. If two communities have even species abundances but richness is higher in one than the other, the evenness (E) would still be equal to 1 of each community.

8. Make a claim using evidence from this data about which vegetation type hosts the greatest diversity.
   Answers will vary.

PART 4: Human Impact on Biodiversity

Use the Gorongosa Interactive Map to note the degree of human activity in each vegetation type.

9. Name the layers that would be related to human activity.
   Ranger Posts, Community Education Center, Major Villages, Schools, Health Clinics, Sustainable Agriculture Projects, Tourism Areas, Chitengo Tourist Camp, Vinho Village, Major Regional Roads, Park Roads, Park Entrance Gate, E.O. Wilson Biodiversity Lab, Elephant Barrier

10. Which vegetation types appear to have the most human activity?
    Answers will vary.

11. Predict how human activity might affect biodiversity.
    Answers will vary; in general, there might be less biodiversity because of a change or impact to the native species habitat.

Now you will interpret data from trail cameras to determine whether species diversity changes with proximity to people. The data in WildCam can be sorted by "distance to humans" and structure type. A subset of the data was selected for analysis from three cameras at three different distances from the most commonly found human structure in the park, game drive roads. These are dirt roads used by tourists and staff for travel inside the park.

The cameras selected for data analysis were also filtered to be in the same vegetation type, mixed Savanna and Woodland, over the same four-month period, August through November.

12. Using the same process as in this activity, the Diversity Indices were calculated using the data captured by these three cameras and are displayed in the table below.

Distance to Human Structure	1 m	1,195 m	3,086 m
Richness	24	19	19
Shannon Diversity Index	2.373	1.812	1.649
Evenness	0.747	0.616	0.600

13. How does the diversity change as the distance to the human structure (road) increases?
Diversity decreases as the distance from the road increases. In particular, the one that is 1 m from the road has much higher richness, diversity, and evenness.

14. What might explain this change in diversity?
Answers will vary but could include that animals might use roads for their own ease of travel or that there might be benefits to being near humans, such as additional sources of food.

15. What are the limitations to only using the trail camera data from these three cameras for this investigation?

- *Trail cameras only take photos of animals that are large enough to be captured by the camera sensors. This technique omits smaller animals.*
- *More photos are taken of animals that spend a lot of time in front of a camera as opposed to animals that pass by quickly.*
- *Some individual animals visit the same area repeatedly, so individuals are counted multiple times.*
- *These cameras were only in one vegetation type, so results might not be indicative of all vegetation types. There were also only three cameras selected for analysis; additional camera data might produce different results for the diversity indices calculations.*
- *Cameras in open habitats may detect animals in a larger area than in habitats with dense vegetation.*

16. What else could you investigate to further study the impact of human activity on biodiversity? Consider the other variables in the data tables such as distance to water, season, and time of day.
Answers will vary but should include the analysis of additional cameras, different vegetation types, different human structures/activity, comparing across seasons, and access to water sources.

17. How might scientists in Gorongosa use the diversity indices to inform restoration efforts?
Biologists in Gorongosa might use diversity indices to prioritize their conservation and restoration efforts. Areas with the highest levels of biodiversity may get more resources allocated to them, such as antipoaching teams. Also, biodiversity can be monitored over time to detect changes that may signal an issue that needs to be remedied.

NOTE: This revised activity is a collation and synthesis of the following resources:
Measuring Biodiversity in Gorongosa
Human Impacts on Biodiversity

AUTHORS
Amy Fassler, Marshfield High School, Marshfield, Wisconsin; David Hong, Monrovia High School, Monrovia, California
Edited by Bridget Conneely and Aleeza Oshry, HHMI