Exploring Species Interactions with "Snapshot Serengeti"

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Abstract

Authentic learning experiences are a valuable way for students to gain an in-depth understanding of the scientific process. However, implementing such experiences in large enrollment courses can be challenging. Here, we present a community ecology lab module that uses data from a long-term camera trap study to allow students to design and conduct their own scientific inquiries. "Snapshot Serengeti" is a 10+ year wildlife monitoring survey in Serengeti National Park, Tanzania. Over 200 camera traps continuously collect fine-scale spatial and temporal data on the dynamics of ~50 animal species. The charismatic subject matter (large African animals) engages students, encouraging excitement about the topic, while the ample amount of processed data enables students to conduct real ecological research. In this lab, students collaborate in all stages of the research process. We present two lab variations: a four-week in-person and five-week remote-learning online option. From this module, students learn to generate testable research questions, produce and interpret graphs, participate in peer review, and communicate their results in both oral and written format. While originally developed for a 1000-level introduction biology course for non-majors, this material could easily be adapted to provide authentic hypothesis testing and data analysis experience to biology majors. In addition to a greater awareness of community ecology principles, students will come away from this lab with a better understanding of how exploratory research fits into the scientific process and confidence in their own ability to engage in the process of science.

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Supporting Materials: Supporting Files S1. Snapshot Serengeti – Suggested Learning Objectives; S2. Snapshot Serengeti – In-Person Instructor Guide; S3. Snapshot Serengeti – Online Instructor Guide; S4. Snapshot Serengeti – PowerPoint Week 1; S5. Snapshot Serengeti – Data File; S6. Snapshot Serengeti – In-Person Lab Manual; S7. Snapshot Serengeti – Image Sets; S8. Snapshot Serengeti – PowerPoint Week 2; S9. Snapshot Serengeti – PowerPoint Week 3; S10: Snapshot Serengeti – PowerPoint Week 4; S11: Snapshot Serengeti – Online Lab Manual; S12: Snapshot Serengeti – Vulnerable MegaBabies Portfolio; S13: Snapshot Serengeti – Carnivore Competition Portfolio; S14: Snapshot Serengeti – Mixed-Species Herding Portfolio; S15: Snapshot Serengeti – Experimental Design Worksheet; S16: Snapshot Serengeti – Peer Review Tutorial; and S17: Snapshot Serengeti – Peer Review Rubric.

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Learning Goal(s)

Students will:

- Become familiar with community ecology principles including how species interact with each other and their environment across time and space (learning objectives: species/habitat interactions, interactions within ecosystems, how matter and energy move through ecosystems, how organisms obtain and use matter and energy to grow).
- Gain an appreciation for African ecology and wildlife conservation issues.
- Discover new ways to participate in real research through citizen science.
- Actively engage in all parts of the scientific process by developing their own research inquiry (writing hypotheses and predictions, processing and analyzing data, interpreting and communicating results).
- Develop appreciation of the iterative process of science.
- Gain skills in interpretation of data and communication of scientific material.

Learning Objective(s)

Students will be able to:

- Engage in meta-cognitive learning.
- Develop and conduct an authentic scientific inquiry.
- Generate a testable research question based on observations.
- Evaluate different methods of visualizing data.
- Generate and interpret graphs to answer questions.
- Communicate the results of research and the nature of science in oral and written form.
- Place exploratory research into a larger context of the scientific process.
- Participate in citizen science initiatives.
- Collaborate with peers on a scientific task.

INTRODUCTION

Pedagogical Motivation

Active learning experiences such as engaging first-hand in scientific research improve student learning, engagement, and confidence in their ability to do science and interpret the scientific findings of others (1). As such, there has been an increasing emphasis on the development of authentic undergraduate research experiences for both biology majors (2) and non-majors (3). Here, our objective is to present students with an accessible and engaging research experience in order to demystify the scientific process and improve scientific literacy for non-biology majors.

This module was conceived of as a way to utilize student interest in charismatic African megafauna to teach community ecology concepts and involve students in authentic scientific inquiry. This lab series is intended to complement a corresponding lecture sequence covering topics such as community ecology, biodiversity, conservation, and environmental ethics (a list of suggested learning objectives and publicly-accessible reading assignments for lecture is provided in the lesson plan). We initially developed this module for a large non-biology major introductory-level class serving several hundred students per semester (in lab sections of ~24 students each) and later reworked the in-person laboratory experience to provide a remote-learning online option. These laboratory exercises meet the University of Minnesota's Liberal Education requirements for Biology with Laboratory, specifically, that students gain experience doing "the work of the field, exploring unanswered questions in biology, integrating mathematical thinking, handling and interpreting data, and confronting unexpected results."

In addition, the work parallels the active research of ecologists at the University of Minnesota and world-wide. The dataset used by students in this project is actively being analyzed by numerous research groups to study questions relating to carnivore coexistence, predator-prey dynamics, mutualisms, disease dynamics, and more (Zooniverse Publications; scroll down to "Snapshot Serengeti"). Highlighting these studies and providing opportunities for students to connect with the researchers themselves through the citizen science website and social media provides students further evidence that they are participating in the work of "real biologists."

Authentic Research Data

The Serengeti ecosystem in Tanzania is world-renowned for its diverse and dynamic wildlife community. Dozens of ungulates, iconic predators such as lions and cheetahs, and charismatic megaherbivores including rhino and elephant call the Serengeti home (4). Over two million wildebeest, zebra, and gazelle migrate across the vast plains of the Serengeti every year in the world's largest terrestrial mammal migration. Many of these animals are vulnerable or endangered, making the Serengeti a key biodiversity hotspot for maintaining populations of these species in the wild (5).

The "Snapshot Serengeti" camera trap monitoring survey was established in 2010 by the University of Minnesota's Serengeti Lion Research program (Figure 1) (6,7). Over 200 camera traps were deployed in the center of Serengeti National Park, Tanzania, capturing millions of images of ~50 wildlife species every year. These images contain vital information for ecology and conservation, enabling researchers to study changes in animal abundance, distribution, and behavior across vast spatial and temporal expanses. As the volume of camera trap data generated by the project was so enormous, the "Snapshot Serengeti" team partnered with the Zooniverse, an online citizen science platform, to crowdsource the image classification process to thousands of volunteers around the world. With the help of citizen scientists, the "Snapshot Serengeti" project has classified data from millions of images, giving researchers an unprecedented look into of the secret lives of Serengeti wildlife. These data are now publicly available for scientists and students to perform their own research inquiries - possibly even discover something new to science! In this lab, students help classify new images online and work with four years of processed data (over one million rows of data on 27 species) to ask and answer questions about patterns of species behavior across time and space.

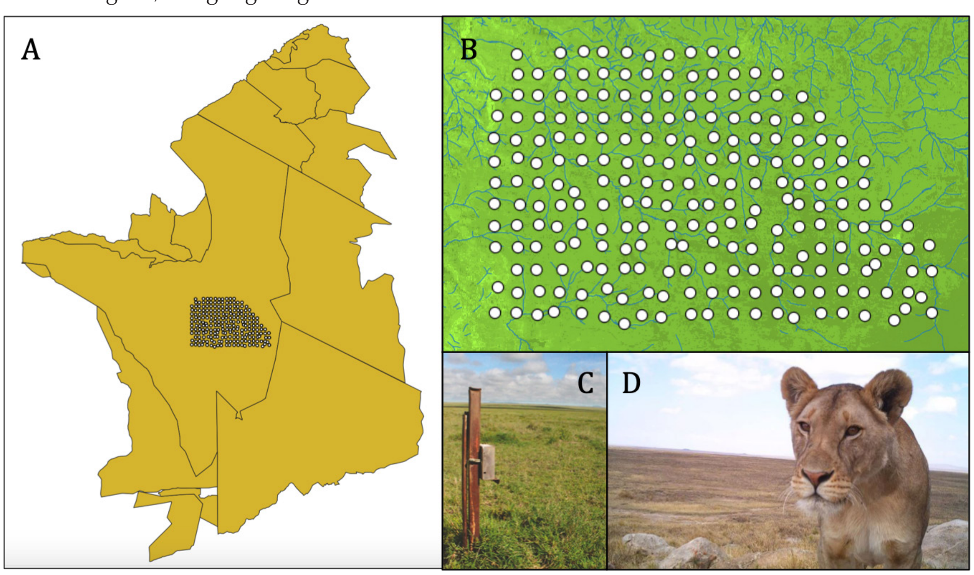

Figure 1. "Snapshot Serengeti" camera trap survey, located in Serengeti National Park, Tanzania (A). White dots represent the locations of over 200 hundred camera traps (B). Camera traps (C) on the ground are mounted on trees or poles, taking pictures (D) of passing wildlife.

Intended Audience

This learning module is targeted at non-biology major undergraduate students in large-enrollment introductory courses with options for in-person or remote learning. This module could easily be used with smaller classes or adapted for ecology or biology majors by expanding the focus on the authentic research experience and increasing the complexity of the statistical tools employed (see "Teaching Discussion" for elaboration on possible modifications for biology majors or upper-division students).

Required Learning Time

We designed labs to last two hours per week for either four (in-person option) or five (online option) weeks. Students will spend four to five hours outside of class preparing the presentation and writing their essay or video report (summative assignments) and half an hour to an hour preparing for lab each week reading the manual and answering comprehension questions (formative assignments).

Prerequisite Student Knowledge

Students do not need prior knowledge of biological topics or the scientific process; this lab module is designed to complement a lecture series on community ecology topics that will inform student's activities in the lab. Experience with data analysis programs such as JMP is not required.

Prerequisite Teacher Knowledge

Instructors should be generally familiar with concepts in community ecology, especially those highlighted in the lab manual, and may want to familiarize themselves with the datasets and covariates provided for students' independent studies. Instructors should have a working knowledge of data visualization and analysis using JMP or similar statistical software. Instructional video links are provided to guide instructors in the use of JMP (see "Lesson Plan").

SCIENTIFIC TEACHING THEMES

Active Learning

Outside of lab: Students conduct independent research, answer comprehension questions, search for informative materials (videos, tutorials, research papers), and engage with their peers in-person and online. Students provide peer review and constructive feedback on others' assignments. Students are also encouraged to participate in online citizen science initiatives, in which they gain real research experience by helping scientists process actual field data from on-going research and conservation initiatives.

During lab: In small groups (in-person or online), students collaborate to brainstorm an authentic research inquiry, process camera trap data and perform data analysis, and present an oral summary of their work. All students engage in whole-class discussions and activities.

Assessment

Formative: Students are assessed through weekly homework short-question assignments, participation in online activities, and are given in-lab feedback on the development of their research project both from their instructor and peers. Students are encouraged to reflect on their own understanding.

Summative In-Person: At the end of the module, groups of students give a research presentation to the class. In addition, each student writes a final "popular science" essay aimed at informing non-scientists about the scientific process. Students also evaluate each other's group participation.

Summative Online: At the end of the module, students are allowed to revise their individual research based on feedback and submit either a written report or a video presentation of their project.

Inclusive Teaching

This lesson provides multiple ways for students to engage with the topic material:

- Students classify data individually at home and in lab, engage in small groups to develop projects and learn from one another, and participate in class activities and discussions.
- Students learn from both their instructor and peers. They are additionally encouraged to seek additional information online.
- Students access information in multiple ways, including instructor delivery, reading, and watching videos.
- Students engage in all roles of a scientist, from collecting and classifying image data to analyzing and interpreting processed data.
- Students share their knowledge and ideas through a variety of media, including oral presentation, written reflections, graphs, and essays. Students are able to choose the graphical representation of the data that makes the most sense to them.
- The system itself (African vertebrate fauna) and medium of data presentation (photographs) are charismatic and engaging to students, encouraging participation and excitement.
- The lesson provides an opportunity for students with disabilities that may limit them from participating in physical field work or lab activities to engage in real ecological research using only a computer.
- This lesson broadens participation in STEM by providing students that may not have the financial resources to gain biology field experience (e.g., could not afford the costs of travel, field equipment/clothing, or similar) the opportunity to engage in real ecological research using only a computer.

LESSON PLAN

This lab module can be completed in either four weeks (in-person option) or five weeks (online option) (Table 1) and is designed to be paired with a lecture series covering ecology and community ecology principles. As this lab could easily complement most introductory ecology courses, we do not provide specific lecture material here; however, we include a list of biology learning objectives and suggested reading materials that cover concepts touched on in this lab series (Supporting File S1. Snapshot Serengeti – Suggested Learning Objectives).

A rubric for grading both versions of the module is provided in Table 2. Instructors or teaching assistants provide feedback, teach data-processing and presentation skills, and grade assignments. In-depth instructions for instructors/TAs can be found in the Instructor Guide (Supporting File S2. Snapshot Serengeti – In-Person Instructor Guide; Supporting File S3. Snapshot Serengeti – Online Instructor Guide). Students will use JMP or a similar program to create bar graphs, scatter plots, and heat maps and Canvas or a similar course website for uploading assignments and online discussion.

Before each lab, students should be required to read that week's section in their respective lab manuals, and, for the in-person module, answer the corresponding 'Check Yourself' questions in the lab manual. Data used in this module were generated with the help of citizen scientists and it is valuable to highlight throughout the module that extra-curricular involvement in citizen science is an excellent way to gain experience with research and the scientific process.

In-Person Lab Module

Each lab period is divided into 2-3 parts (A-C).

Week 1 - Observations and Questions

Before Lab 1: Instruct students to search the internet for "Serengeti" videos and watch at least 20 minutes of informative clips.

Lab 1: Use Lab 1 slides with script (Supporting File S4. Snapshot Serengeti – PowerPoint Week 1). This lab is designed to introduce the notion that the scientific process is dynamic and iterative and to teach students how to come up with testable research questions. The lab also defines important concepts in community ecology and citizen science.

At the beginning of lab, students take a short quiz (slide 6, Supporting File S4. Snapshot Serengeti – PowerPoint Week 1).

In Part A, students load the "Snapshot Serengeti" data file (Supporting File S5. Snapshot Serengeti – Data File) into JMP or equivalent. Data fields are described in the lab manual (pages 7-8 of Supporting File S6. Snapshot Serengeti - In-Person Lab Manual). The lab instructor illustrates these fields using an example photo (slide 15, Supporting File S4. Snapshot Serengeti – PowerPoint Week 1).

In Part B, the class performs an exercise to help generate questions about patterns of animal behavior across time and space. Pairs of students receive curated sets of camera trap photographs (Supporting File S7. Snapshot Serengeti – Image Sets) that they classify and sort by location in the camera trap survey, season, and time of day to identify spatial and temporal patterns.

In Part C, students working in pairs classify real data collected by researchers on the citizen science website "Snapshot Serengeti." At the end of class, students answer "focus questions" about the images they have classified (page 12 of Supporting File S6. Snapshot Serengeti – In-Person Lab Manual) and start generating nine of their own questions within three thematic areas (page 13 of Supporting File S6. Snapshot Serengeti – In-Person Lab Manual). The themes are broader ecological relationships such as migration, predation, or predator avoidance.

Lab 1 Homework: Students post three of their nine "focus questions" to the course website and comment on at least one other student's post. Students watch a video tutorial on data visualization in JMP or a similar tutorial for the specific statistical program used in class.

Week 2 - Exploring and Visualizing Data

Lab 2: Use Lab 2 slides with script (Supporting File S8. Snapshot Serengeti – PowerPoint Week 2). This lab defines observational versus experimental studies and teaches the difference between questions, hypotheses, predictions, and justifications.

In Part A, students gain familiarity with the data visualization features of JMP by exploring the Serengeti data from Lab 1. Pairs of students answer guided inquiry questions (pages 18-19 of Supporting File S6. Snapshot Serengeti – In-Person Lab Manual) and graph their data. Questions and graphs are uploaded to the course website.

In Part B, the instructor goes through several uploaded graphs and the class discusses what the graphs represent and learn from each other various ways to visualize different questions.

In Part C, groups composed of four students work together and decide on a broad topic to perform an observational study using the Snapshot Serengeti data; within each group, two sets of partners explore a subset of that topic. Groups should discuss the questions they generated for homework from Lab 1 and come up with an overarching theme to investigate and three sets of hypotheses, predictions, and justifications relating to that theme.

Lab 2 Homework: Students finalize and submit the theme, hypotheses, predictions, and justifications for their group project (page 21 of Supporting File S6. Snapshot Serengeti – In-Person Lab Manual) and spend time outside of lab conducting background research for their project.

Week 3 - Hypothesis Testing

Lab 3: Use Lab 3 slides with script (Supporting File S9. Snapshot Serengeti – PowerPoint Week 3). This lab focuses on conducting original research. Instructors should reinforce the idea that, in real science, finding no trend or a trend that does not support your hypotheses is still a valid result. Students are encouraged to think about how the data collection process and scale of the study may affect their data or results.

In Part A, students continue working in groups using Snapshot Serengeti data to address (graph) their research question. Communication within and among groups to problem-solve issues and looking up answers or tutorials on the internet should be encouraged.

In Part B, students come together as a class to discuss everyone's graphs and the assumptions and implications of each groups' findings.

In Part C, in their project groups, students brainstorm how best to convey their findings to others; questions to guide this discussion are given in the lab manual (page 26 of Supporting File S6. Snapshot Serengeti – In-Person Lab Manual).

Lab 3 Homework: Each project group meets outside of lab to prepare a 10-minute presentation telling the story of their research. The presentation should include an introduction to the group theme, questions addressed by the group, summarized data with their interpretation, and overall conclusions drawn. The presentation should end with alternative interpretations and potential future research directions.

Week 4 - Interpretation & Communication

Lab 4: Use Lab 4 slides with script (Supporting File S10. Snapshot Serengeti – PowerPoint Week 4). Groups present their questions and results from the previous week. Each group member should speak during the talk. A rubric for grading presentations can be found in the lab manual (page 20, Supporting File S6. Snapshot Serengeti – In-Person Lab Manual).

Afterwards, students form new groups of 3-4 individuals and prepare for the homework assignment.

Lab 4 Homework: This week, students write a popular essay (similar to a blog or magazine article; 400-700 words) on something about the nature of science that they think the general public might not realize. They should use specific examples from their experience with the Snapshot Serengeti data to illustrate their main points. A rubric for grading the essay is provide in the lab manual (page 31, Supporting File S6. Snapshot Serengeti – In-Person Lab Manual). In addition, each group member should fill out a group evaluation to award participation points to their teammates.

Online Lab Module

Each week is divided into 2-3 tasks which students complete by following instructions provided in the lab manual (Supporting File S11. Snapshot Serengeti – Online Lab Manual). We recommend uploading the supporting documents (portfolios, worksheets) to Google Drive or similar and hyperlinking to these assignments at the appropriate point in the lab manual.

Week 1 - Observations and Testable Questions

This lab introduces students to the Snapshot Serengeti data and teach students how to develop testable research questions.

In Tasks 1 and 2, students participate in citizen science by classifying authentic camera trap images on the "Snapshot Serengeti" website; students should collect additional metadata on at least five images (page 10 of Supporting File S11. Snapshot Serengeti – Online Lab Manual).

In Tasks 3 and 4, students use real data to draw inference on the question, 'why do wildebeest migrate?'. Present students with spatial and temporal information from camera traps on wildebeest activity across the study site taken at two times of year. Students generate hypotheses to explain these patterns and work in groups to discuss and refine their answers. They then submit a single hypothesis with supporting evidence.

Week 2 – Visualize Wildebeest Data

This lab focuses on learning how to visualize (graph) data in order to address hypotheses about community ecology.

In Tasks 1 and 2, students familiarize themselves with the data visualization features of JMP using online video tutorials (or similar) and by plotting camera trap data from Snapshot Serengeti.

In Task 3, students work in groups to create graphs that address the guided inquiry questions (page 15 of Supporting File S11. Snapshot Serengeti – Online Lab Manual) and the hypotheses on drivers of wildebeest migration that they generated the previous week. Each student creates their own graphs and shares them with their group. The group then discusses the pros and cons of each other's graphing approach and as a team submit one final set of graphs to the course website.

Week 3 – Design Your Experiment and Investigate

This lab is intended to help students develop an original research topic and design an approach for answering their questions using the available data. A primary goal is to reinforce the idea that science is a dynamic and iterative process and that, as part of an authentic science experience, not finding the answers they were expecting is still a valid scientific result.

In Task 1, students explore 'portfolios' of current research topics of interest to the Snapshot Serengeti research team (Supporting Files S12. Snapshot Serengeti – Vulnerable MegaBabies Portfolio; S13. Snapshot Serengeti – Carnivore Competition Portfolio; S14. Snapshot Serengeti – Mixed-Species Herding Portfolio). Students can generate research questions using these dossiers or based on their own interests. Students conduct a primary literature search and generate specific research questions.

In Task 2, students fill out a draft guide for designing their own research project using the Snapshot Serengeti data (Supporting File S15. Snapshot Serengeti – Experimental Design Worksheet). In this document, students answer questions which help them refine their hypotheses and develop an approach to test their hypotheses.

In Task 3, students use JMP to graphically evaluate their hypotheses. They then submit these graphs with their completed Experimental Design Worksheet to the course website.

Week 4 – Peer Review

In this lab, students provide constructive feedback on each other's scientific writing. Emphasize that review and evaluation is an essential part of the scientific process.

In Tasks 1 & 2, students complete an online interactive peer review tutorial quiz (Supporting File S16. Snapshot Serengeti – Peer Review Tutorial) and review two project drafts submitted by other students. This task involves filling out a rubric (Supporting File S17. Snapshot Serengeti – Peer Review Rubric) and providing actionable suggestions to improve the analyses.

Week 5 – Revision and Final Report Submission

In this lab, students learn how to communicate the results of their scientific inquiries using different formats.

In Task 1, students revise their analyses based on peer review feedback. This may involve re-running their analyses or even starting from scratch. Emphasize that this is part of the scientific process! Instructors should advise students on how to address issues they are struggling with. Students write a response outlining how they addressed each specific issue raised by the reviewers.

In Task 2, students have the option to present their final research project as either a written report or video presentation. If they chose to write a report, it must include an Introduction, Methods, Results, and Discussion as outlined in the lab manual and associated grading rubric (pages 23 and 27 of Supporting File S11. Snapshot Serengeti – Online Lab Manual). For video presentations, students create a slideshow that includes each of the four sections mentioned above and record themselves presenting it. The presentation should be between 5-10 minutes long. The final report/presentation should be uploaded to the course website along with their response to reviewers.

TEACHING DISCUSSION

We have used the in-person Snapshot Serengeti lab in our non-majors biology course every Fall and Spring semester since Fall 2013 and the online lab every Fall and Spring Semester since 2017. These modules are a valuable addition to the science curriculum by providing an authentic science experience outside of the traditional wet-lab setting. Students are still able to engage in data collecting, processing, analysis, and interpretation of real scientific data and, with multiple years of research data available, there is little chance of a 'failed' experiment (e.g., all study organisms die or fail to grow/develop, derailing the student's major class project) which might discourage future participation in science. The charismatic study organisms and accessible questions pursued are engaging and easily comprehensible to non-science and science majors alike.

One issue that did arise with the implementation of the online course was that it was harder to assist students who had difficulties with JMP, the data visualization program. Getting students comfortable with the program is a major learning curve, and while TAs are present for the in-person labs to help students, it can take more time for the instructor and TAs to help struggling students online. To this end, we built flexibility into the online lab, which allows instructors the ability to grant students extra time when needed. Surprisingly, we found that this option actually became an asset as it promoted dialogue with the instructor and gave students more time to iterate on their ideas. Having the chance to engage more intensely with students during data exploration provided additional opportunities to destigmatize data evaluation and statistics - overcoming an important hurdle for engagement in the scientific process, particularly for non-majors. We clarify that we do not require students to perform statistical analyses in the non-majors introductory course, although we encourage faculty to highlight in lecture the importance of statistics and explain how to interpret p-values presented in the literature. Not using actual statistical analyses can be problematic in that students sometimes over-interpret trends they see in the graphs. We emphasize to students that they need to use care in their interpretations of the data and stress the importance of statistical analyses throughout the module.

Student response has been incredibly positive overall. In early implementation of this lab module, some students expressed that this activity did not feel like "real" science compared to conventional wet-lab activities. In response, we have worked to better communicate that this type of activity is typical of what many ecologists do, i.e., generating and working with large datasets. As research and media reports have come out describing new findings in animal ecology generated from this and other camera trap projects, we share them with the students. Students are also encouraged to follow new developments in on-going research detailed on the "Snapshot Serengeti" website and to connect with real researchers using these data through the citizen science platform and associated social media.

What students convey in their end-of-module "nature of science" essay suggests that this lab changes their perception of how science is done and that they have gained more appreciation for the scientific process. For example, students often express that they discovered that the process of doing science can involve more than test tubes and microscopes or that empirical investigations in which predicted relationships between variables are not found are still valid science. Students also improve in their data analysis and science communication abilities. Making data visualizations and interpreting graphs is a skill that is developed through several aspects of the lab, and students demonstrate improvement over the course in this area through these activities.

This activity could easily be adapted to upper-level biology courses: if statistical analysis and scientific writing skills were emphasized, the activity could be more thoroughly scaffolded to encourage students to do studies aimed at filling gaps in current ecological knowledge. We would suggest asking upper division students to develop and test a hypothesis using the data in multiple ways. For example, if a student hypothesized that predators are likely be active during narrow time frames during a day and that herbivores, in contrast, will have moderate activity spread throughout the day, we would encourage the students to look separately at different predator and prey species to see if this general trend holds up and to possibly find exceptions. One could also ask students to design a field or laboratory experiment they could do to further explore the hypothesis or theme they are exploring using the data. Another option would be to require students to contextualize their results in the literature, discovering and citing additional sources than those provided in class.

SUPPORTING MATERIALS

All images and figures pertaining to the Snapshot Serengeti project are open-source (available under a Creative Commons 4.0 International License); the remaining images are listed with attribution where found in the following materials.

- S1. Snapshot Serengeti – Suggested Learning Objectives
- S2. Snapshot Serengeti – In-Person Instructor Guide
- S3. Snapshot Serengeti – Online Instructor Guide
- S4. Snapshot Serengeti – PowerPoint Week 1
- S5. Snapshot Serengeti – Data File
- S6. Snapshot Serengeti – In-Person Lab Manual
- S7. Snapshot Serengeti – Image Sets
- S8. Snapshot Serengeti – PowerPoint Week 2
- S9. Snapshot Serengeti – PowerPoint Week 3
- S10: Snapshot Serengeti – PowerPoint Week 4
- S11: Snapshot Serengeti – Online Lab Manual

- S12: Snapshot Serengeti – Vulnerable MegaBabies Portfolio
- S13: Snapshot Serengeti – Carnivore Competition Portfolio
- S14: Snapshot Serengeti – Mixed-Species Herding Portfolio
- S15: Snapshot Serengeti – Experimental Design Worksheet
- S16: Snapshot Serengeti – Peer Review Tutorial
- S17: Snapshot Serengeti – Peer Review Rubric

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Table 1. Timeline of activities for the in-person (four-week) and online (five-week) "Snapshot Serengeti" modules.

In-Person Module			
Activity	**Description**	**Estimated Time**	**Notes**
Preparing for Lab 1			
Students	• Read lab manual Week 1 • Answer "Check Yourself" questions • Search for and watch internet videos of "Serengeti"	30-40 minutes	Lab manual with questions is Supporting File S1.
Lab 1: Observations and Questions			
In-class activities	• Part A: Explore "Snapshot Serengeti" data in JMP • Part B: Class camera trap photo activity • Part C: Engage in "citizen science" and generate research questions	2 hours	Slides with script are Supporting File S2. "Snapshot Serengeti" data are Supporting File S3. Image sets are Supporting File S4.
Homework	• Post focus questions online • Watch video tutorial for JMP • Read lab manual Week 2	15-20 minutes	Focus questions in lab manual.
Lab 2: Exploring and Visualizing Data			
In-class activities	• Part A: Graph data using JMP • Part B: Go through graphs as a class • Part C: Form project groups to come up with a theme and questions to investigate	2 hour	Slides with script are Supporting File S5.
Homework	• Finalize and submit theme, hypothesis, predictions • Conduct background research for project • Read lab manual Week 3	1-2 hours	Worksheets for final questions are in lab manual.
Lab 3: Hypothesis Testing			
In-class activities	• Part A: Work in project groups analyzing data to answer research questions • Part B: Groups discuss findings • Part C: Students brainstorm how to best convey results	2 hours	Slides with script are Supporting File S6.
Homework	• Meet outside of class to prepare 10-minute oral presentation of research	1-2 hours	
Lab 4: Interpretation and Communication			
In-class activities	• Student groups present oral reports • New groups prepare for homework assignment	2 hours	Slides with script are Supporting File S7. Presentation rubric in lab manual.
Homework	• Write a popular essay on something the general public might not realize about the process of science • Fill out group evaluation	2-3 hours	Essay rubric in lab manual. Group evaluation is Supporting File S8.

Online Module			
Activity	**Description**	**Estimated Time**	**Notes**
Preparing for Lab 1			
Students	• Read lab manual background and introduction • Complete lab manual Part 1 'Observations and Questions' • Download and install JMP	30 minutes	Lab manual is Supporting File 8. Instructor guide is Supporting File 9.
Lab 1: Observe and Hypothesize			
Tasks	• Task 1: Register with Zooniverse • Task 2: Classify animals on "Snapshot Serengeti" • Task 3: Wildebeest observations in time and space • Task 4: Form a hypothesis	2 hours	Metadata to collect from "Snapshot Serengeti" images on pg. 10 of Supporting File 8.
Submit	• Record additional data from "Snapshot" observations • Formulate wildebeest migration hypothesis • Provide explanation on how decided on hypothesis		
Lab 2: Observe and Hypothesize			
Tasks	• Task 1: Prepare to use JMP • Task 2: Visualize "Snapshot" data in JMP • Task 3: Visualize wildebeest data to answer hypothesis and guided inquiry questions	2 hours	Guided inquiry question on pg. 15 of Supporting File S8.
Submit	• Share and discuss graphs • Wildebeest graph assignment		
Lab 3: Design and Investigate			
Tasks	• Task 1: Research and select topic • Task 2: Design analysis to test hypotheses • Task 3: Begin to investigate hypothesis	3-6 hours	"Portfolios" of potential research questions Supporting Files S10, S11, S12. Experimental design worksheet is Supporting File S13.
Submit	• Fill out experimental design worksheet		
Lab 4: Peer Review			
Tasks	• Task 1: Complete peer review tutorial • Task 2: Review experimental design worksheets	2.5 hours	Peer review tutorial is Supporting File S14. Peer review rubric is Supporting File S15.
Submit	• Review worksheets from two other students		
Lab 5: Revision and Final Report Submission			
Tasks	• Task 1: Students revise analysis • Task 2: Students complete final report	2-4 hours	Grading rubric is on pages 23 and 27 of Supporting File S8.
Submit	• Submit final report		

Table 2. Rubric for grading the in-person (four-week) and online (five-week) "Snapshot Serengeti" modules. Specific rubrics for grading group presentations, essays, and final reports are located in the in-person and online lab manuals and instructor guides.

In-Person		Online	
Assignment	**Possible Points**	**Assignment**	**Possible Points**
Week 1		**Part 1**	
Start of lab quiz on Serengeti	2	Hypothesis discussion	3
"Check Yourself" questions	5	Null hypothesis tutorial	1
Serengeti classification worksheet	3	Wildebeest hypothesis assignment (team)	5
Focus questions	2	Lab manual check	5
Brainstorming page	2		
Canvas forum	2		
Week 2		**Part 2**	
"Check Yourself" questions	3	Graph discussion	3
Guided Inquiry questions/screen grabs	4	Wildebeest graph assignment (Team)	5
Week 3		**Part 3**	
"Check Yourself" questions	3	Experimental design worksheet draft	10
		Interpreting data tutorial	1
Week 4		**Part 4**	
Group presentation	15	Peer review tutorial	1
Homework: essay	15	Peer reviews	15
Group participation	4	**Part 5**	
		Final report	50
Lab Total		**Lab Total**	
	60		99