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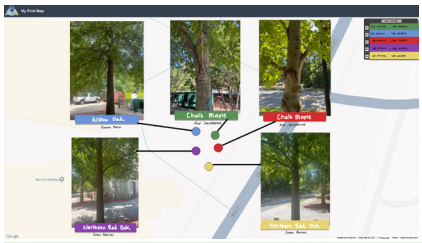
CourseSource

Lesson

Counting Caterpillars on Campus: Engaging Students in Setting Up a Phenology Site for Participatory Science

Peggy Brickman[1*]

[1]Department of Plant Biology, University of Georgia



Abstract

Climate change has been shifting spring temperatures that coax tree budding and the myriads of insects that fuel entire ecosystems. This activity engages undergraduates in setting up a monitoring site to contribute to the participatory science project, Caterpillars Count! that charts the phenology (the study of the timing of seasonal changes in the biological world) and abundance of arthropods in forest ecosystems. Once the site is established, subsequent classes with as few as a dozen to upwards of hundreds of students can enter data to inform this project, allowing students to directly measure the impact of rising temperatures on their community. This activity was developed for a small (<30 students) general education course for non-science majors that fulfills an environmental literacy requirement. However, it is equally well-suited for a small-enrollment introductory biology course for majors, or as a project for a student-led environmental group, or ecology courses at the introductory level.

Primary Image: Counting Caterpillars on Campus: Engaging Students in Setting Up a Phenology Site for Participatory Science. Example site map created by students.

Citation: Brickman P. 2025. Counting Caterpillars on Campus: Engaging Students in Setting Up a Phenology Site for Participatory Science. CourseSource 12. https://doi.org/10.24918/cs.2025.17

Editor: Katie Burnette, University of California Riverside

Received: 12/13/2024; **Accepted:** 5/12/2025; **Published:** 7/23/2025

Conflict of Interest and Funding Statement: This work was funded by an NSF DUE/IUSE Award #2120459 Undergraduate Student Experiences with Citizen Science. The author has no financial, personal, or professional conflict of interest related to this work.

***Correspondence to:** 2502 Miller Plant Sciences, Athens, GA 30602; brickman@uga.edu

Learning Goals

Students will:

◊ help collect data that supports authentic scientific research.

◊ From the Ecology Learning Framework:

» What is the relationship between phenology and biodiversity?

Learning Objectives

Students will be able to:

◊ recognize biological and environmental consequences of rising greenhouse gas levels.

◊ connect datasets from Caterpillars Count and phenology data from the National Phenology Network and then utilize them as evidence in scientific communication (1).

◊ explain data from graphs and maps indicating changes in species distribution over time in response to climate change.

◊ utilize evidence from observed patterns of data to communicate how seasonal timing is shifting due to climate change.

◊ recognize common groups of insects, trees, and birds.

◊ understand how ecological community interactions affect ecosystem stability.

◊ discuss how data collected by participants differs from data collected by other methods including the types of errors that might be more frequent in participants' data.

◊ From the Ecology Learning Framework:

» predict the implications at the local and global scale for observed changes in phenology.

» relate changes in phenology to local and/or global disturbances.

INTRODUCTION

Participatory science (also referred to as citizen science, community-engaged, or community-academic partnerships) provides unique opportunities for volunteer participants to engage in authentic scientific practices (2). Beginning with Wells W. Cooke's North American Bird phenology program in the 1800s (3), technological advances have made large-scale data collection efforts for environmental monitoring more accurate and affordable, and scientists have been eager to capitalize on the public's interest in addressing local community concerns about environmental impacts (2).

Example Participatory Science Projects with Ecological Monitoring:

- Alliance for Aquatic Resource Monitoring
- Audubon Christmas Bird Count
- Caterpillars Count!
- Hudson River Eels Estuary Project
- Monarch Larva Monitoring Project

Post-secondary educators have been increasingly incorporating participatory science in both lecture and lab settings to investigate ecological/environmental issues and to offer opportunities for students to collect and submit scientific data that advances knowledge in the field (4). Educators tout the opportunities for students to engage in authentic scientific practices and the observed increase in engagement. However, most instructors cited challenges dealing with logistics of implementing the project (*e.g.,* timing during the semester or finding relevant projects and assessments) (4).

I sought to address the challenges listed by educators for setting up a participatory science project by building off the model developed by educators at Michigan State University who employed graduate teaching assistants to set up a long-term phenological data collection site (5). Data collection for this program has been ongoing since 2008 with students using diverse and innovative methods to collect data and troubleshoot problems (6). By definition phenology is the study of the timing of events in nature such as reproductive cycles of plants, animals, and other organisms (7). I was selected to develop materials for the Caterpillars Count! project based in North Carolina. Data is collected throughout spring and summer, and the topic provides opportunities for students to engage in environmental monitoring, data collection, and analysis of datasets. In addition, the lessons on engaging with Caterpillar's Count! data presented here could be used in a classroom to introduce climate change and phenology without the need to set up the site.

Intended Audience

First-year students at the college/university level who are taking a science course for majors or non-science majors.

Required Learning Time

Setting up the Caterpillars Count! site required two classroom sessions for introducing the project and 2 field-trip sessions for scouting sites (photographing and identifying trees and their GPS coordinates) and placing tree tags and conducting surveys.

Prerequisite Student Knowledge

Students will need to know how to use a web browser on their smart phone. Additionally, students may benefit from knowledge of how to navigate a campus map.

Prerequisite Teacher Knowledge

The instructor should have basic computer skills needed to create the site on the Caterpillars Count website. Access to the Internet is required. Instructors should be able to identify tree species on campus and be able to generate or annotate a campus map with tree locations and identifiable markers. A timeline is provided to help with navigating the online system used by Caterpillars Count. The site is designed for ease of use with extensive help available to novice users including fun quizzes to identify and estimate the sizes of arthropods. Instructors should understand biogeochemical cycles and climate change as well as familiarity with wooded environments on or near their campus. To prepare students to interpret figures and captions, instructors may wish to review one of the great lessons provided by Data Nuggets (8); Teaching Issues and Experiments in Ecology including provide practice questions (9).

SCIENTIFIC TEACHING THEMES

Active Learning

Throughout the lesson, students interact directly with course material with some guidance from instructors.

Peer learning: This lesson is based on pairs of students working together towards the learning objectives. Almost every step involves collaboration and discussion among students on how best to accomplish their goals. Peers have been shown to demonstrate changes in opinions about science when engaged with peers in a service-learning program (10) as well as improving collaborative engagement (11).

Inquiry-based learning: This lesson is a research exploration of changes in arthropod phenology in the students' local environment. They visualize course-collected data and develop work toward hypothesis formation (science argumentation) as well as data interpretation, visualization, and use these in communication. Active learning using case studies and problem solving that require students to read and interpret text and/or data and collaborate to generate an answer have been shown to improve critical thinking skills (12). Engaging in inquiry-based, learner-centered activities has been shown to long-term improvements in learning for science students (13).

Assessment

The lesson consists of multiple opportunities for reflection and self-assessment. Formative assessments opportunities include: (i) pre- and post-questionnaires to measure changes in knowledge and attitude about climate change; (ii) insect identification using the Caterpillars Count Arthropod ID quiz and virtual survey game. Reflective assessments include: (iii) an initial reflective discussion post in which they investigate and describe why a particular local bird species is meaningful to them, how it is predicted to be impacted by the climate crisis, and what efforts can be done to protect its environment; and (iv) a final discussion post in which they describe why students should care about arthropods, examples of arthropods and the

food they consume, and consequences to a warming climate for our ecosystem. Summative assessment includes (v) creation of three assessment questions that assess data interpretation skills using graphs and maps from Caterpillars Count or the National Phenology Network Visualization tool (example graph interpretation question: How many days earlier did spring arrive compared to 20 years ago?).

Inclusive Teaching

The lesson is a collaborative learning activity with all students collecting data for their group and consequently the whole course. Every student has the opportunity to collect, analyze, and visualize phenology data. The lesson encourages students to access their personal interests and experiences in investigating species of interest to them. Sites are tagged for accessibility (along paved parking lots adjacent to accessible bus stops) for students with mobility impairments and efforts should be made to include able-disabled pairs when possible (14). In addition, we recommend conducting a post-trip check-in and debrief to determine if students had additional issues with accessibility. Finally, be sure to include an access statement in the syllabus for your course, so that students are aware of requirements for field work and can advocate and plan accordingly.

LESSON PLAN

Pre-Semester Preparations

Prior to the start of the course, instructor(s) select sites that will be used in the lesson (Table 1). Students will select and identify trees and shrubs that form circles dictated in the site setup to ensure consistency in data collection for Caterpillars Count! Circles include 5 trees or shrubs at a 5-meter distance from each other (Figure 1). Sites can be selected based on multiple criteria. Caterpillars Count! advises selecting sites with newer growth trees since students will need to visually survey branches, and older trees tend to lack lower branches. Sites along roads that are within walking distance and/or access to paths and public transportation are ideal if your campus is large. Collection of data would be difficult in highly urban areas, and instructors must be prepared to collect data from late spring to early fall, so timing may not work for many courses.

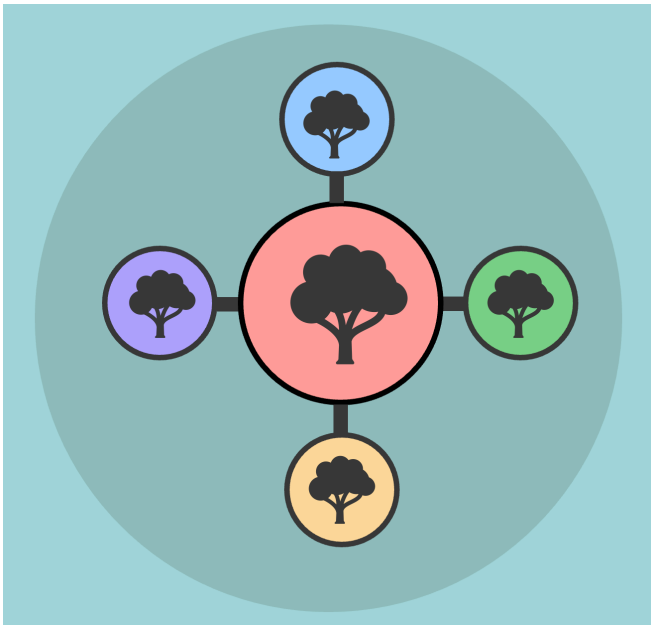


Figure 1. Caterpillars Count! circle.

Student Groups

If this activity falls in the first few weeks of the semester, you might want to assign pairs of students to groups based on similar majors or interests. For students with mobility impairments, Chasen *et al.* (14) recommend making efforts to include able-disabled pairs. We formed groups of two students based on similar majors as a way for students to get to know someone with similar interests in the course. This guide provides evidence-based recommendations for forming peer groups to ensure high quality collaborative interactions (15).

Week 1: Introduction and Site Creation Preparation

This week involves two in-class meetings to introduce students to climate change and phenology (Table 2). The **Day 1** activity begins with students taking a survey to uncover their beliefs about climate change from the Climate Change and the American Mind Survey from the Yale Program on Climate Change Communication (Supporting File S1). This can be delivered online through your learning management system or google forms, or class time can be devoted to completing it on paper. The instructor does not immediately discuss results and instead waits to compile and present them to the students in the next second session.

The instructor then presents a short lecture introducing the Caterpillars Count! Project and the decline in insect populations and the importance of insects for humans as pollinators and for the ecosystem as food for birds and many other species (Supporting File S2). Students complete an assignment in which they investigate one bird species from the Audubon society site and the insects that their bird eats (Supporting File S3). Students describe why this bird is meaningful to them, how it is predicted to be impacted by the climate crisis, and what efforts can be done to protect its environment. Instructors have their students reflect on the importance of the particular location and place for this project as well as the role of collective action to solve the complex issues of climate change. This assignment is graded for completion.

In preparation **Day 2**, students review the Caterpillars Count! Arthropod ID guide and Dichotomous key to learn some of the most common arthropod orders found on trees and shrubs. They then practice by taking the Arthropod Photo ID quiz to test their knowledge until they can consistently get at least 9/10 correct. During the class session on **Day 2**, students investigate existing data from Caterpillars count! and the National Phenology Network Visualization tools (Supporting File S4). They explore maps and graphs in class (filter by month or particular tree species) and start investigating the types of questions that can be answered with the data (Supporting File S5, S6). As an assessment, they create questions related to phenology, for example, how many days earlier did spring arrive compared to 20 years ago to test their understanding of the concepts and to determine when insects would be present on the site and when birds would be consuming them. Most questions were graphical in nature and replicated the example that was provided, but it

was clear that students could master the NPN data exploration process. Questions also help the students and instructor realize the feasibility of collecting data on active arthropods for the timing during the semester.

In the **Day 3** activity, students will meet at the future sites (Table 3). Before they meet, students review the requirements of the sites (one center tree/shrub and four additional trees/shrubs) in all cardinal directions at 5-meter distance from the central tree found on the Caterpillars Count! site. Students mark potential trees and take preliminary photos of trees and conduct photo ID using iNaturalist. They then complete a homework assignment in which they check their identifications and create a map of their circle to identify each tree species and indicate latitude and longitude (Supporting File S7). The instructor will need to enter this data on the Caterpillars Count! site management before students can conduct their first visual survey as well as printing out and laminating the branch survey code tags.

Once the instructor has all the survey codes printed and each circle has been entered by the site manager, students can return to their sites on **Day 4** and hang their survey code tags and conduct their first survey. Caterpillars Count! provides a video of students completing a survey using their app. The site manager can showcase their totals on the app and highlight those students with the highest arthropod counts. Students then complete a final reflection on what they have learned from participation which has been shown to promote learning (Supporting File S8) (16).

TEACHING DISCUSSION

General Observations

This lesson was implemented in the Fall of 2024, and 30 students were able to successfully establish 15 circles and record 84 observations from 12 different arthropod groups for a total of 420 organisms in approximately 2 weeks. Overall, student feedback was positive. They enjoyed selecting their sites and entering their data, and most felt a greater appreciation for arthropods, their importance as a food source, and the role of native plants in supporting ecosystems. In their final reflections, students also reported improvements in visualizing and interpreting data in the context of phenology. Students also found interpreting data to be easiest using graphical representations of time series on the Virtual Phenology Network (see Supporting File S6). Students who do experience difficulties interpreting data could be provided with some of the examples that are provided in that document with instructors providing steps in identifying the variables and discussing the conclusions that they would draw.

Pre-Post Changes in Climate Change Awareness and Attitudes

After participating in the Caterpillars Count! site set up and monitoring, students made gains in their awareness of climate change (Supporting File S9). Some of the largest gains were seen in questions that asked about their belief that most scientists think that global warming is happening (63% pre to 94% post) and that it is caused mostly by human activities (85% pre to 94% post). There was also increased agreement with statements like, "I have personally experienced the effects of climate change" (41% agree or strongly agree pre to 62% post). Students also increased their level of disagreement with statements like, "It's already too late to do anything about global warming" (15% pre to 28% post) or "The actions of a single individual won't make any difference in global warming" (40% pre to 67% post).

Logistical Constraints

There were several issues with students understanding the constraints of the circle selection. For example, some students erroneously believed that all the trees had to be the same species in the circles. Other students had trouble imagining distance—15 feet is the distance suggested between trees, but many students selected trees that were 2–3 feet apart. The addition of some meter tape measures would be useful. With 15 pairs of students, it was challenging to check over their sites during field trip meeting 3. Our campus grounds resisted the use of the metal tags that Caterpillars Count! suggested, so students used colored yarns as an initial way to mark their trees and then replaced this with the final printed tags using biodegradable jute string. After just a few winter months, half the tags were missing, so, if possible, it is preferable to use metal or plastic tags as recommended by Caterpillars Count!

Potential Additions to the Lesson

This exercise could also be an excellent summer outreach program for K-12 students. The first two class sessions could be modified to small lessons on data interpretation without the need to complete the field trip lessons to create a Caterpillars Count! site. I also found that students were curious to learn more about solutions to climate change after participating in the lesson. I added a class session engaging in a World Climate Simulation. This simulation was developed by the think tank Climate Interactive, in partnership with the MIT Sloan School of Management and the UMass Lowell Climate Change Initiative (17), who demonstrated statistically significant gains in three areas: (i) knowledge of climate change causes, dynamics and impacts; (ii) affective engagement including greater feelings of urgency and hope; and (iii) a desire to learn and do more about climate change. This activity was completed in one 50-minute session. All materials needed to teach the Climate Simulation are freely available (18).

Phylogenetic Exercise

If your course objectives include phylogenies and cladograms in the course. Students could use the tree or arthropod species in a phenology lesson to create a phylogeny and explain patterns of relationships among species.

Institutional Review Board Approval

This project was reviewed by UGA's IRB and determined to be exempt (PROJECT00011122).

SUPPORTING MATERIALS

- S1. Counting Caterpillars – Climate Change Survey [Instructor view only]. The items in this survey are derived from the Climate Change and the American Mind Survey from the Yale Program on Climate Change Communication. Instructors can access graphs of survey responses from US citizens to compare their students' responses to.

- S2. Counting Caterpillars – Caterpillars Count! Slides. Introductory instructional slides on phenology for class instruction.
- S3. Counting Caterpillars – Day 1 Assignment [for students]
- S4. Counting Caterpillars – Day 2 Slides. Instructional slides on Phenology Data Exploration to acquaint students with the data sets from Caterpillars Count! and the Virtual Phenology Network and have them practice visualizing data and developing questions.
- S5. Counting Caterpillars – Day 2 Assignment [for students]
- S6. Counting Caterpillars – Day 2 Assignment Key [Instructor view only]
- S7. Counting Caterpillars – Identify Trees Assignment [for students]
- S8. Counting Caterpillars – Post-Activity Reflection [for students]
- S9. Counting Caterpillars – Awareness of Climate Change [Instructor view only]

ACKNOWLEDGMENTS

This work was funded by an NSF DUE/IUSE Award #2120459 Undergraduate Student Experiences with Citizen Science. I am grateful for all the support provided by Allen Hurlburt as well as the critical feedback I received from Eric Hastie, Austin Heil, David Kirschtel, and Heather Vance Chalcraft. I also wish to thank the students of BIOL2103H who were willing to brave the searing August heat to scout sites, tag trees, and conduct surveys.

Table 1. Teaching timeline: Pre-semester preparation.

Activity	Description	Estimated Time	Notes
Scouting Sites			
Site requirements	Instructor considers questions and reviews a video	15 minutes	• Review Caterpillars Count! Host A Survey Site, which includes a convenient protocol quiz to ensure understanding of site requirements • Commit to surveying at least six times over the late spring (April) or summer (August)
Establishing a monitoring area	A few weeks before the semester, instructor scouts accessible locations that accommodate students with physical disabilities	45 minutes	• Area should contain representative vegetation of the common shrubs and trees at eye level • Routes along paved paths with public transportation access are ideal • Survey branches will be arranged in groups of five called "circles" 5 meters apart • Sites should have at least 10 (ideally 30 or more) survey tree locations • Choose a survey method (visual or beat sheet) • Notify your grounds department and check that they approve the tagging of trees
Site creation	Instructor registers the site	20 minutes	• Test your knowledge of Caterpillars Count! Protocols on the Survey Site • Register for an account • Create a new site using: – Site name – Short Description – Site Location – drag and drop on map – Number of survey locations you expect to support – Site password you will give to students to submit surveys

Table 2. Teaching timeline: Week 1, Lesson days 1–2.

Activity	Description	Estimated Time	Notes
Meeting 1: In-Class			
Pretest questions	Students respond individually to an online survey	10 minutes	• Collect and do not discuss • Do not allow students to talk or to use the Internet • Supporting File S1
Introduction to Caterpillars Count	Instructor presents brief introduction on the Participatory Science Group and issues	10 minutes	• Present slides 1–6 (Supporting File S2) • Video Warning about the effects of Climate Change on Insects
Why care about arthropods assignment	Students investigate birds of interest at the Audubon society website	25 minutes	• Present slide 7 (Supporting File S2) • Supporting File S3
Planning for site set up	Instructor presents brief overview of the next week	10 minutes	• Present slides 8–17 (Supporting File S2) • Show video of how to Conduct a Survey
Meeting 2: In-Class			
Pre-class homework	Students review insect categories and complete an arthropod ID quiz	25 minutes	• Arthropod Field Guide • Arthropod ID Guide • Arthropod Quiz
Introduction to data visualization tools	Instructor presents brief overview of the data that they will be collecting	10 minutes	• Present slides 1–14 (Supporting File S3)
Data visualization assignment	Students investigate phenology data from Caterpillars Count! and the Virtual Phenology Network	50 minutes	• Supporting File S4 • See Supporting File S5 for key • Present slides 15–29 • Maps and Graphs • Virtual Phenology Network

Table 3. Teaching timeline: Week 2, Site creation and observations.

Activity	Description	Estimated Time	Notes
Meeting 3: Field Trip			
Pre-class homework	Students ID bugs and estimate length online. Students download the app	15 minutes	• Instructions for conducting surveys • Data collection including paper data sheets/ App
On-site activity	Students meet on site and identify potential survey sites in pairs	50 minutes	• Review new site setup • Mark potential trees and take photos to conduct tree ID
Meeting 4: Field Trip			
Pre-class homework	Students identify the tree species from their potential sites	30 minutes	• What tree is it? • iNaturalist • Supporting File S7
On-site activity	Students hang site survey tags and submit observations	50 minutes	• Instructors Guide • Conduct a Survey with general sampling tips and a video
Post-activity reflection	Students reflect on the skills, knowledge, and future utility gained	20 minutes	• Supporting File S8
Post-test questions	Students respond individually to an online survey	10 minutes	• Collect and do not discuss • Do not allow students to talk or to use the Internet • Supporting File S1

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