Plasticine Caterpillar Predation Experiment

September 6, 2016

Contents

List of Figures

1 Rationale

This investigation describes an actual experiment conducted by scientists at Hubbard Brook. This project is ideal for middle and high school students because it provides them with an engaging opportunity to participate in authentic science and develop the science and engineering practices as set forth in the Next Generation Science Standards: asking questions, developing hypotheses, conducting investigations, analyzing, representing and interpreting data, constructing explanations and designing solutions.

It aligns with the NGSS disciplinary core ideas in life science of interdependent relationships in ecosystems and cycles of matter and energy transfer in ecosystems. It also provides opportunities to highlight several cross cutting themes of science, namely energy and matter, and stability and change. (See NGSS alignment information - section 7)

2 Introduction

Caterpillars are a very important part of the ecosystem. Caterpillars consume large amounts of plant matter like leaves and are food for birds and other animals. It can take 6,000 to 9,000 caterpillars to raise all the baby birds in a single nest of chickadees! Other animals, such as predatory invertebrates like spiders and small mammals like mice will also eat caterpillars.

Scientists often want to understand how different organisms interact, like birds and caterpillars. But it can be hard to study actual caterpillars, because they're hard to find and we don't know what happened when they disappear. They could have been eaten, but we don't know by who, or they could have moved to another location to continue eating or to build a chrysalis/cocoon to grow into a butterfly or moth. Instead, we make model caterpillars from plasticine, a type of clay, and see what happens!

Plasticine is relatively soft and doesn't harden over time, so that when something tries to eat it, teeth, beak, or pincer marks are left. These caterpillars can be used to compare predation rates between different locations, vegetation, years, or other questions. Predation rates are similar between plasticine and real caterpillars, but it is not recommended to use the caterpillars to estimate actual predation rates since there are too many possible dissimilarities between them and real caterpillars.

3 My Experiment

I'm studying the effects of ice storms on forest food webs, and am using the caterpillars to compare predation rates at different intensities of experimental ice storms. To do so, I put 50 caterpillars in each plot and checked them every other day. I also connected bird predation to an index of bird activity in the plots to see if the two are connected. Currently, I have both pre- and post-experimental data and am working on the analyses to see what it means. This experiment is taking place at Hubbard Brook Experimental Forest in the White Mountains of New Hampshire. This forest pioneered watershed-level research and was the first location to discover acid rain, so it's pretty neat!

4 Questions and Hypotheses

What question would you like to investigate? Teachers may wish to simply give students a question to investigate, or they may wish to use this as an opportunity to practice and refine asking scientific questions.

Sample questions

- What percentage of my caterpillars will be predated? (Descriptive study)
- Which location will have a higher predation rate? (compare 2 sites)
- At what heights are predation rates greatest? (compare 2 or more heights in one location)
- On which plants are predation rates greatest? (compare 2 or more plants)
- In what time of the year are predation rates the greatest? (compare 2 sampling times)
- What types of predators exist for caterpillars in local parks, and what were the rates of predation? (Descriptive study)
- What is the effect of caterpillar color on the rates of predation? (compare 2 or more colors)

If you are asking a comparative question, what is the dependent variable? What is the independent variable?

What is your hypothesis? A hypothesis is an explanation for what you think will happen. Examples:

- If the plasticine caterpillar is located on a tree or tall shrub, then the effect on the rates of predation will be greater than those not located on a tree or tall shrub.
- If the plasticine caterpillar is located high on the flora, then the effect on the rates of predation will be greater than those located low on flora.
- Caterpillars with camouflaged coloring (i.e. green, brown) will be predated more than caterpillars with bright colors (i.e. red, orange).
- More plasticine caterpillars will be predated in fall than in winter.

How will you test your hypothesis, to answer your question? What are your methods/procedures? Be sure to include the 5 jobs that follow in your procedure.

Once you've collected your data, how will you graph it? What will be the best type of graph to use, to answer your question? The Graph Choice Chart is a good resource (see last page).

5 Methods

5.1 Preparation

Caterpillar creation is very simple and is one of those great Science/Kindergarten moments. I rolled out snakes of plasticine and cut them into caterpillars that measured 3.5 mm by 25 mm (Figure 1). These caterpillars are bent slightly in the shape of an arc to simulate a geometrid (inchworm) caterpillar. I put caterpillars into a tupperware container divided by layers of wax paper. It is important to make quite a few more caterpillars than needed for the experiment as some will get marked in the process of deploying them and have to be discarded.

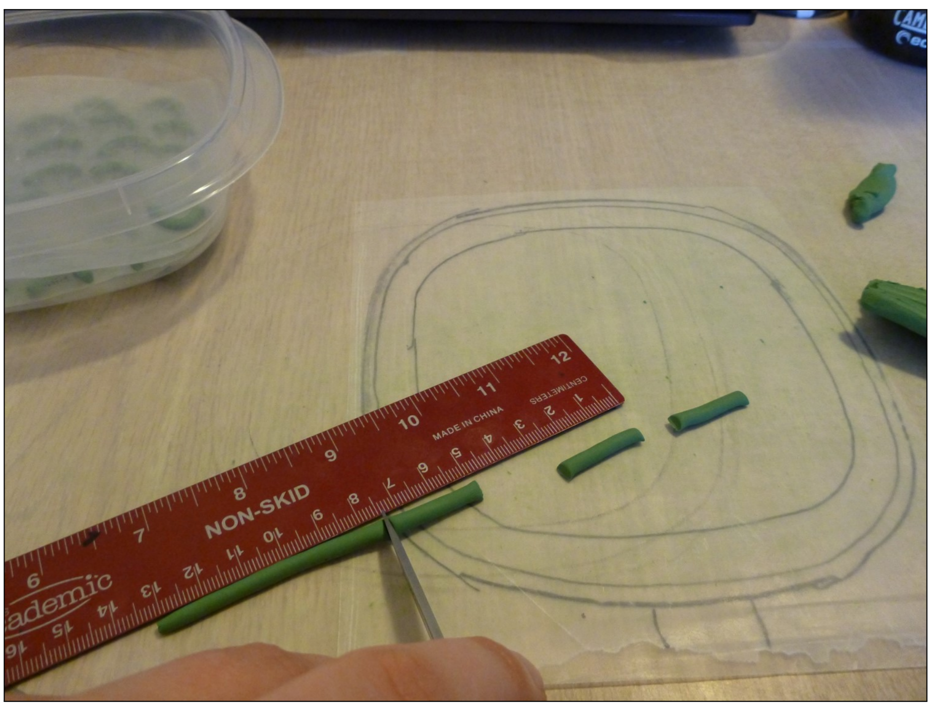


Figure 1: Measuring and preparing the caterpillars

Locations of where each caterpillar will go can be determined beforehand or when deploying. If in a large group, it would likely work well to do everything at once. If only working with a few students or only in short time intervals, deciding where to glue caterpillars beforehand would likely be smoother. For myself and 1 - 3 upper level undergraduates, it took about 3 person hours per 50 caterpillars. I would estimate longer for middle or high school students, but you probably have a better idea of how long than I do!

Data sheets should be prepared beforehand. At a minimum, I recommend that each caterpillar should have a specific number to identify it throughout the experiment. Plant species is one potentially important variable (or type of plant if species level is unknown, i.e. grass, shrub, sapling, tree). Height of the caterpillar is another that I recorded, and is particularly useful for re-finding caterpillars. Vegetation density, canopy cover, or other variables depending on the location and questions. It's good to include space to record whether a caterpillar was or wasn't predated on any given check. If predated, I mark whether I think it was predated by a bird, invert, or small mammal. It is possible for caterpillars to be predated by more than one type of predator, although it doesn't happen particularly often.

5.2 Caterpillar Deployment

There are essentially four to five main jobs when deploying caterpillars:

1. **Flagger:** One job is to flag the base of each tree/shrub/plant that a caterpillar will be placed on (Figure 2). It is important to place the flagging at the base rather than near the caterpillar so that birds/other predators do not associate the flagging with the caterpillar. This job can also include being the person to decide where each caterpillar will go. The flagger writes a number in permanent marker on the piece of flagging and ties it to the plant, while communicating the location/height to the data collector. This part can be done ahead of time if needed.

2. **Data Collector:** This job involves collecting data as decisions are made. The caterpillar number needs to be linked to the correct vegetation information for the data to be accurate.

3. **Caterpillar Preparation:** We found that it works best for one person to have the tupperware with caterpillars and super glue and hand caterpillars individually to another (Figure 3). This job can involve putting glue on the ends of caterpillars, or that can be part of the next job.

4. **Caterpillar Placement:** This person is the one to actually glue to the caterpillar to the plant.

5. **Photographer:** Not necessarily one of the main jobs but a super important one! I generally had photographer be part of the data collector's job when I had a choice, but if there are more students, having some take turns as photographer would be good.

Figure 2: Flagging the base of an American beech seedling where a caterpillar will be deployed

Figure 3: Lily prepares the caterpillars with glue for the person gluing them to plants

Switching jobs throughout the process is really easy. Depending on how messy the glue gets, it may be necessary to switch whoever is on Caterpillar Placement particularly often so that the caterpillars remain as unmarked as possible. Having people rub some nail polish remover on their fingers afterward this task is helpful.

5.3 Caterpillar Checks

Caterpillars can be checked every day, every other day, or as logistics allow (Figure 4). Caterpillars should only be left out for about a week. Birds learn pretty quickly that the plasticine caterpillars aren't actually food so a longer experiment wouldn't produce better data. When checking, predated caterpillars are removed. A label is written for the caterpillar and both label and caterpillar are placed in a microcentrifuge tube or in another container or bag. It's important to keep track of the caterpillar's number when transporting them back to school so that information about the caterpillars location and height is linked with the caterpillar. The flagging for the caterpillar is removed.

Figure 4: Checking on the caterpillars

If a caterpillar isn't found right away, I went with a protocol of searching for 10 person minutes before declaring it gone. Two people searching seemed ideal as three got pretty crowded in a small area. Some caterpillars did get moved a couple meters either by wind or by a predator. As such, it is good to approach caterpillars carefully and to watch the ground so that none get stepped on. I continued to search for caterpillars that had been declared gone on consecutive checks and did recover a caterpillar later on that had been overlooked during the previous check. In total we only lost 8 out of 800 caterpillars, so these guys can be recovered at pretty high rates! We did not replace gone caterpillars, but we did reglue unpredated caterpillars that fell to the ground.

5.4 Caterpillar Takedown

On the last day, we brought out pre-labeled microcentrifuge tubes and took down all remaining caterpillars (Figure 5). All remaining flagging should also be removed.

Figure 5: Collected caterpillars are placed in microcentrifuge tubes for transportation and storage

5.5 Reviewing Caterpillars

I think it is important to go through the caterpillars afterwards and confirm field ID's. Some sort of magnifier would be particularly helpful here. One paper recommends having two people look at each caterpillar independently and then use the consensus. I will have a bunch of pictures and some demonstration caterpillars as reference, as do some published papers. When identifying predators, it is only possible to classify predators as birds, small mammals, or invertebrates (Figures 6, 7, 8).

Figure 6: Bird predation on one of the caterpillars

5.6 Data Analysis

Once you have identified which caterpillars have been predated, the next step is to look for patterns and see if your results match your hypotheses. Calculating the percent of caterpillars that were predated and graphing your data is a great way to visualize these patterns. Consider the Graph Choice Chart to choose which type of graph best suits the question of interest. What story do your data tell you? Do you see any patterns? Is there anything that stands out at you? How did your dependent variables affect the percent of caterpillars that were predated? Did certain predators respond differently than others? Are you able to answer your questions with the data you collected?

Figure 7: Small mammal predation on a caterpillar

Figure 8: Invertebrate predation on a caterpillar. Invertebrate marks are the paired pincer marks on the caterpillar's back. Other marks are indicative of bird predation

5.7 Paper/Presentation

The teacher can decide whether to have students write up a full scientific report or to have students instead concentrate on focused analysis and related questions. We recommend that students a data table and graph and answer some of the following questions:

- What percentage of your caterpillars were predated?
- Where (or when) were predation rates greatest?
- What was your question?
- What was your hypothesis?
- What did your data tell you? Did it support or refute your hypothesis? Do you have enough data to answer your question?
- Did your data surprise you?
- Did you encounter any problems? How might you improve or solve them, if you were to do this over again?
- What are some factors that may have given you inaccurate data?
- Based on what you know now, what is a question you would like to investigate next?

6 Materials

Part of the beauty of this experiment is its simplicity. The materials are as follows:

- **Plasticine:** Any type of plasticine (UK) or plastalina (U.S.) can work. The idea is to closely mimic the caterpillars of the area. Plasticine in the U.S. costs about $3 per pound, which would make 400-600 caterpillars. Colors could be used as is or mixed to better match the leaf color. I think mixing might take a lot of time though.
- **Super glue:** Super glue is used to attach the caterpillars to vegetation. I recommend Loctite® brand Super Glue Gel Control™. This type generally costs $3 - 4 per container (4 g) which lasts for a bit over 100 caterpillars. Other brands could work as well. I recommend avoiding liquid super glues as they are harder to work with and end up with more super glue on a person's fingers which adds time and unintentional marks on the caterpillars.
- **Nail polish remover:** I like having nail polish remover on hand whenever working with super glue. Nobody glued themselves to the forest during my experiment but we did use it to remove the build up of super glue on our fingers. Plus it's generally only $1 - 2 at any drug store.

- **Q-tips:** Useful for rubbing on nail polish remover.
- **Flagging:** It's important to have some method of keeping track of caterpillars. We tied plastic flagging to the base of trees/shrubs with a number on each. Flagging is about $2 per roll at Tractor Supply Co. or at a hardware store. One roll lasts for about 150 caterpillars.
- **Sharpies:** Useful for writing on flagging, $4 for five sharpies or so.
- **Data sheets:** Having some way of recording data while in the field is important.
- **Caterpillar containers:** Some way of keeping the caterpillars from getting marked while in transit is useful. I used microcentrifuge tubes, which are about $20 per 500. Other people have used petri dishes or Ziploc bags separated by paper towels. Other Tupperware should work as well.
- **Tupperware/Container:** Some sort of container is needed to store premade caterpillars before deploying. I could fit 150 - 250 caterpillars in a single sandwich sized tupperware. If purchasing is necessary, it would be only about $3.
- **Wax Paper:** I found wax paper useful for making layers between caterpillars in the containers and also as a surface for rolling caterpillars out on. Probably around $2 - 4.
- **Ruler:** Needed to measure out caterpillars. I'm assuming these are already in any science classroom though!
- **Magnifier:** Generally bird predation can be identified pretty accurately in the field, but invertebrate and small mammal predation can be a bit trickier. Any sort of magnifying glass will likely be sufficient. They seem to be about $10 each if not already available.

Overall, the initial cost for materials is likely around $25, with some variation depending on what materials are already available.

7 Next Generation Science Standards Alignment

This investigation aligns with these Next Generation Science Standards (NGSS) Science and Engineering Practices:

- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions

This investigation aligns with these NGSS Crosscutting Concepts:

- Cause and effect

  Cause and effect relationships may be used to predict phenomena in natural or designed systems; Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

- Systems and system models

  Models can be used to simulate systems and interactions - including energy, matter, and information flows - within and between systems at different scales.

- Energy and matter

  Energy drives the cycling of matter within and between systems; Energy cannot be created or destroyed - it only moves between one place and another place, between objects and/or fields, or between systems.

- Stability and change

  Small changes in one part of a system might cause large changes in another part; Much of science deals with constructing explanations of how things change and how they remain stable.

This investigation most closely aligns with these NGSS Disciplinary Core Ideas:
LS2.A - Interdependent relationships in ecosystems

- 6-8: Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared. *Bird predation upon caterpillars, affecting reproductive success (organism level).*

- 9-12: Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem.

LS2.B - Cycles of matter and energy transfer in ecosystems

- 6-8: The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.

- 9-12: Photosynthesis and cellular respiration provide most of the energy for life processes. Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle.

When included as part of a larger ecosystem unit, this investigation can help students develop the skills and concept needed to demonstrate competency for the following NGSS performance expectations:

- MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations
- HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

8 Acknowledgements

The lesson plan was written by Wendy Leuenberger (State University of New York College of Environmental Science and Forestry - SUNY-ESF). Jackie Wilson (Hubbard Brook Research Foundation) aligned the lesson with NGSS standards and helped make the plan useful for a broad audience. Students and teachers at Millard South High School (taught by Estefania Larsen) and Johnson-Brock Public School (taught by Jacob Leuenberger) piloted the lesson and provided valuable feedback. Dylan Parry (SUNY-ESF) also provided support for this project. Funding was provided by the Edna Bailey Sussman Foundation.

9 Contact Information

We would love to hear about your experiences with the lesson plan! Please feel free to contact Wendy Leuenberger at wleuenbe@syr.edu with any questions, suggestions, or comments. Good luck!

Graph Choice Chart

What question would you like to explore? Write your question as a complete sentence.

Does your question ask about the **variability** within a group of data points?

(i.e. the range of the data, the shape of the distribution, or what the center of the data is)

(one group, one variable)

— YES —

Examples:
1. Do all high tides rise to the same height?
2. How variable are windspeeds here?
3. What is the range and distribution of incomes in the United States?

— make a → FREQUENCY PLOT — either — DOT PLOT / HISTOGRAM / BOX PLOT

Does your question **compare two or more groups** to decide if the groups are the same or different?

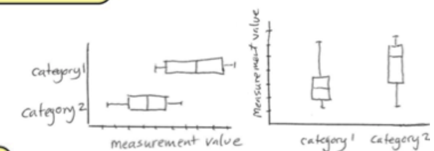
(two groups, one variable)

— YES —

Do you want to compare the **variability of all data points** in each group to decide if any difference between the groups is *meaningful?*

Examples:
1. Which of the two car designs is most consistently the fastest?
2. Is there a meaningful difference in the heights of fertilized and unfertilized bean plants?

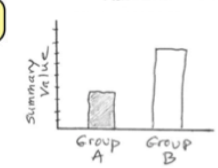
For each group make a → FREQUENCY PLOT



Are you comparing **single numbers** that summarize a group? (such as mean, median, or total...)

Examples:
1. Was the total snowfall greater this winter than last winter?
2. Do cats and dogs have the same average body temperature ?
3. How do the median incomes for the U.S. and Sweden compare?

— make a → BAR GRAPH



Does your question ask if **two numeric factors are correlated**?

(one group, two variables)

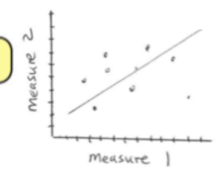
— YES —

Does it ask about how something changes through **linear TIME?**

NO —

Examples:
1. Is the fuel efficiency of a car related to its weight?
2. Are smoking rates correlated with median income?
3. Given a fixed volume, how are temperature and pressure related?

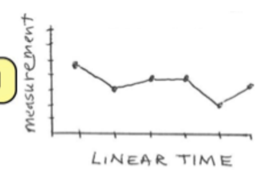
— make a → SCATTER PLOT



YES —

Examples:
1. Have summer lake water temperatures warmed over the last ten years?
2. How did my weight change over the last 3 months?

— make a → LINE GRAPH



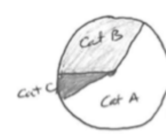
Does your question ask how a **total** is **proportioned** into sub-groups? (Or what proportion a sub-group is of a total?)

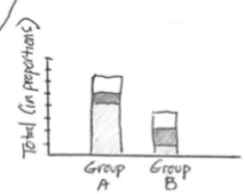
(one group with sub-groups, one variable)

— YES —

Examples:
1. Which circuit accounts for the largest proportion of the electricity use by our household?
2. What proportion of U.S. energy comes from wind?
3. What proportion of U.S. residents take public transportation to work?

— make either → PIE CHART / STACKED BAR CHART





The Maine Data Literacy Project -- Graph Choice Chart