INQUIRY & INVESTIGATION

# Predation on Plasticine Model Caterpillars: Engaging High School Students Using Field-Based Experiential Learning & the Scientific Process

NABT BioClub RECOMMENDATION

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## Abstract

*Engaging students in hands-on inquiry helps them develop skills associated with the scientific process. Development of simple experiments using model caterpillars can provide an experiential demonstration of the scientific process and ecological principles for high school students. Caterpillar models are formed from plasticine, a nontoxic, nondrying modeling clay, and are an excellent tool for quantifying relative predation rates by birds, small mammals, and invertebrates. Lifelike surrogate larvae are glued to vegetation for short periods (one week) and retain identifiable marks (beak, teeth, mandible imprints) following predator attack. This technique is simple, inexpensive, and provides rapid and clear results, rendering it a highly effective method of inquiry for high school students. Students can use these methods to ask a variety of research questions, such as comparison of predation in nearby habitats (park vs. backyard), vegetation (tree vs. shrub), season (spring vs. fall), or coloration (aposematic vs. camouflage). For many students, this may be one of few opportunities at the high school level to investigate science "in the field" and integrate scientific practices, such as the scientific method and inquiry, in an authentic research experience. Participants develop their scientific reasoning skills through creation of research questions and interpretation of results. They learn experimental technique, build field skills, and work collaboratively. This experiment aligns with the Next Generation Science Standards.*


**Key Words:** *Ecology; experiential; field skills; predation; scientific inquiry; scientific method.*

## Introduction

Involving students in hands-on inquiry is important for their understanding of science as a process and not just as a collection of facts (Gormally et al., 2009; Schultheis & Kjelvik, 2015). Experiential learning, particularly when students have ownership of the process, can improve understanding and retention of scientific concepts (Gormally et al., 2009; Minner et al., 2010). Exposing students to the entire scientific method can help build thought processes and facilitate learning skills such as data analysis, graphical presentation of outcomes, and interpretation of their results (McDonald, 2012; Schultheis & Kjelvik, 2015). Here, we present a simple experimental technique using plasticine model caterpillars as a resource for illustrating these core scientific activities. This scientific inquiry project provides high school students an opportunity to use the scientific process while exploring key ecological principles.

Plasticine model caterpillars are an important tool in ecological research for comparison of predation between localities, habitats, vegetation types, colors, morphologies, or years (Roslin et al., 2017). Plasticine is a nontoxic, nondrying modeling clay. It can be formed into shapes yet remains malleable and can retain imprints of attempted predation events (beak, mandible, teeth imprints). These lifelike surrogate larvae are glued to vegetation for short periods and then collected and assessed for evidence of predation. This simple, inexpensive technique provides rapid and clear results, making it an effective introduction to experimental design for high school students. The experiment allows students to ask questions, develop hypotheses, and conduct investigations; analyze, interpret, and present data; and construct explanations and design solutions, in alignment with the *Next Generation Science Standards* (NGSS) Science and Engineering Practices. The concepts in this experiment most closely relate to the "Interdependent Relationships in Ecosystems" (LS2.A) and "Cycles of Matter and Energy Transfer in Ecosystems" (LS2.B) disciplinary core ideas. For many students, this may be one of few opportunities at the high school level to investigate science "in the field" and integrate scientific practices, such as the scientific method and inquiry, in an authentic research experience.

> *"Caterpillars are an ideal study organism to investigate interactions among predators and prey."*

## Ecological Background

Predator–prey interactions are an important and fascinating part of ecology. Prey species have evolved behavioral, morphological, and physiological adaptations to reduce predator pressure (Campbell & Reece, 2004; Greeney et al., 2012). For example, some prey species have developed toxins

*The American Biology Teacher*, Vol. 81, No. 5, pp. 334–339, ISSN 0002-7685, electronic ISSN 1938-4211.  DOI: https://doi.org/10.1525/abt.2019.81.5.334.

that make them unpalatable to predators (Dyer, 1997; Hero et al., 2001; Smith et al., 2012). Many of these organisms, such as monarch caterpillars and poison dart frogs, are brightly colored (aposematic) to warn predators not to attack them (Smith, 2000; Campbell & Reece, 2004; Inbar & Lev-Yadun, 2005). Palatable species like inchworm (geometrid) caterpillars use camouflaging colors and morphological mimicry to blend into their surroundings (Campbell & Reece, 2004; Smith et al., 2012). These species are found on plants with features that match the caterpillars' camouflage patterning or morphological mimicry (Campbell & Reece, 2004; Smith et al., 2012). Others have adapted to live on a certain part of a plant, such as under the leaf, near the ground, or higher in the canopy (Tvardikova & Novotny, 2012). Predator species also specialize by foraging on a particular plant species, on groups of species (i.e., deciduous or coniferous trees), or on locations within a plant (MacArthur, 1958).

Caterpillars are important prey species because they are abundant and diverse in many ecosystems, play a vital role in food webs and nutrient cycling, and support a rich community of parasitoids and vertebrate and invertebrate predators (Stange et al., 2011; Poch & Simonetti, 2013). For example, caterpillar densities and abundance affect behavior and reproductive success of breeding birds (Moorman et al., 2007; Townsend et al., 2016). Predatory invertebrates and small mammals will also eat caterpillars (Ostfeld & Keesing, 2000; Hooks et al., 2003). Therefore, caterpillars are an ideal study organism to investigate interactions among predators and prey.

Direct assessment of predation on caterpillars is challenging because it is hard to track live caterpillars in natural habitats, making it nearly impossible to determine whether predation occurred. Thus, plasticine model caterpillars offer an excellent alternative for quantifying relative predation rates by birds, small mammals, and invertebrates (Howe et al., 2009; Low et al., 2014). Plasticine is a soft modeling clay that does not harden over time and is available in a variety of colors. Many predators are initially fooled by plasticine model caterpillars, and a durable legacy of their attack is imprinted in the plasticine. Examination of recovered models after attack yields impressions left by teeth, beaks, or mandibles of predators.

## ○ Objective

The goal of this experiment is to introduce students to the scientific method using hands-on experiential learning. Students will follow the scientific process, beginning with asking questions through making conclusions and considering future research. Predator–prey interactions will be assessed directly by observation of predation marks on plasticine model caterpillars. Through their questions, students will investigate whether factors such as color or location drive predator–prey dynamics.

## ○ Setup & Plasticine Model Caterpillar Deployment

The first step is to have students develop specific questions that use plasticine model caterpillars to investigate predation. Teachers can provide students with a topic or prime more independent investigation with a few options to help them along (Table 1). Questions could evaluate aposematic vs. cryptic coloration, location of larvae on plants, different habitats or locations, and more. Independent variables (i.e., location, height, plant, color) and dependent variables (i.e., predation rate for each type of predator) should be determined for their question. They should also develop a hypothesis, prediction, and experimental design to address their question (examples in Table 1). These steps let students work through questions 1–4 of the assessment that accompanies this lesson (Appendix 1).

Plasticine (or plastalina) can be found in most craft stores. Lengths of plasticine should be rolled out to ~3.5 mm in diameter, and cut to ~25 mm lengths to mimic the size of some caterpillars while still being large enough to handle (Figure 1). Each piece of clay should be bent slightly in the shape of an arc to simulate a geometrid (inchworm) caterpillar. Other sizes, shapes, and colors can simulate different types of caterpillars depending on the students' questions. To prevent inadvertent damage and marking to the plasticine model caterpillars, they can be transported in Tupperware containers divided by layers of wax paper. Some plasticine model caterpillars will get marked by fingernails or dropped during deployment, so it is important to have extra models on hand. The number of plasticine model caterpillars attacked by predators can vary substantially. Several studies report predation rates of 15–30%, although lower (e.g., 5%) and higher (e.g., 50%) predation rates have also been observed (W. Leuenberger, unpublished data; Ruiz-Guerra et al., 2012; Bereczki et al., 2014; Roslin et al., 2017). Thus, deployment of ≥50 plasticine model caterpillars should be considered for meaningful assessment of predation attempts.

Superglue is used to affix plasticine model caterpillars to vegetation. To limit mess, we recommend using a gel control variety of superglue, and instructors should have nail polish remover to clean

**Table 1. Sample hypotheses, experiments, and predictions for plasticine model caterpillar experiments.**

| Hypothesis | Prediction | Experiment |
|---|---|---|
| Caterpillar color affects predation. | Camouflaged caterpillars will suffer higher predation than aposematically colored caterpillars. | Set out green and red caterpillars. |
| Plant type affects predation. | Caterpillars on shrubs will have higher predation than caterpillars on trees. | Place caterpillars on trees and shrubs. |
| Predation differs between habitats. | Caterpillars in an open area will have higher predation than those placed in the forest. | Deploy some caterpillars in a forested area and others in an open area. |
| Predation is different for caterpillars placed at different heights. | Caterpillars located 0.5 m above ground will experience greater predation than caterpillars located 1 m above ground. | Place caterpillars 0.5 m and 1 m above ground. |

**Figure 1.** Plasticine model caterpillar (left) next to a real notodontid caterpillar (right).

fingers as needed. A drop of glue should be placed on each end of the plasticine model caterpillar. The plasticine model caterpillar should be held on a twig or leaf petiole for a few seconds until the glue bonds. Brightly colored plastic flagging can be tied to the base of a plant with plasticine model caterpillars to aid in collecting them at the end of the experiment. We recommend placing the flagging at the base of the plant rather than next to the caterpillar so that birds and other predators are not likely to associate the flagging with the caterpillar and either avoid or seek out other flags. Each plasticine model caterpillar should be assigned a number, which is written on the flagging with permanent marker and linked to a data sheet. The data sheet should contain information about the caterpillar location, height, plant type, or other information needed to answer the students' questions. Plasticine model caterpillars should be left in situ for about a week before collection. Collected plasticine model caterpillars should be placed individually in a container or bag that prevents additional marks and labeled so that they can be linked to the data sheet. Most predation is readily visible on the caterpillars in the field, although magnifying glasses or dissection microscopes may be helpful. "Wounding" can be broadly classified as bird, small mammal, or invertebrate predation, but finer characterization (i.e., large or small bird) is not possible (Figure 2; Low et al., 2014). Low et al. (2014) provides an excellent photographic collection of predation marks.

**Figure 2.** Imprints left on plasticine model caterpillars by birds (top), invertebrates (middle), and small mammals (bottom).

## ○ Analyzing & Understanding Results

Calculating the percentage of plasticine model caterpillars preyed on by each group of predators provides insight into differences among groups. Graphing data is a great way to visualize these patterns, and we recommend the graph choice chart to help students decide on graph type (Webber et al., 2014). These results and graph correspond to questions 5–6 on the assessment (Appendix 1).

Interpreting these results requires students to look for patterns, such as whether plasticine model caterpillars at one location or of one color were preyed on more frequently than another. The patterns they look for should match their research question and help assess whether their hypothesis was supported by their data. The three predator groups (birds, small mammals, and invertebrates) may respond differently, so each predator group should be assessed separately. When writing their conclusion (question 7; Appendix 1), students should reference their results and think about why particular patterns occurred. For example: "We saw more predation on green caterpillars than red caterpillars in our experiment, which might be because predators thought that red caterpillars were distasteful or toxic."

As experiments often raise new questions and help students learn what they can do differently, questions 8–9 (Appendix 1) assess improvements and extensions of the experiment. Question 8 requires students to describe an improvement to their experiment. Then, students apply what they have learned to a hypothetical continuation of this experiment by thinking of a new question, hypothesis, and way to test that question using plasticine model caterpillars. After completing the experiment and assessment, students will have participated in a complete research experience.

## Teacher Responses

Two schools used this experiment with their students during the past two years. Experiments were conducted by sophomore biology students at Johnson-Brock Public School in Johnson, Nebraska, and with after-school Science Club students at Millard South High School in Omaha, Nebraska. For their experiments, students analyzed predation types based on location (different local parks) and seasonal effects (spring and fall). Students collaborated using Google Sheets and created pie charts and line graphs to represent predation (Figure 3). They determined that the urban park had more bird predation while the rural park had more invertebrate predation and that predation was higher during fall than spring.

Teachers from both schools indicated that their students gained valuable skills and insights into the scientific process. Participating students learned that data are often not as clean as they see in a typical "boxed lab" and felt that the exercise improved their ability to recognize patterns. Once they analyzed their data, students developed logical inferences to explain the patterns. Students also learned to work collaboratively and ask deeper questions.

Several students from Millard South High School presented their research outside of their Science Club. Three students received second place in their category at the local science fair. Two students presented their work to teachers, parents, and local scientists at an open-house event. These experiences taught students about communicating science, a vital and often overlooked part of the scientific process.

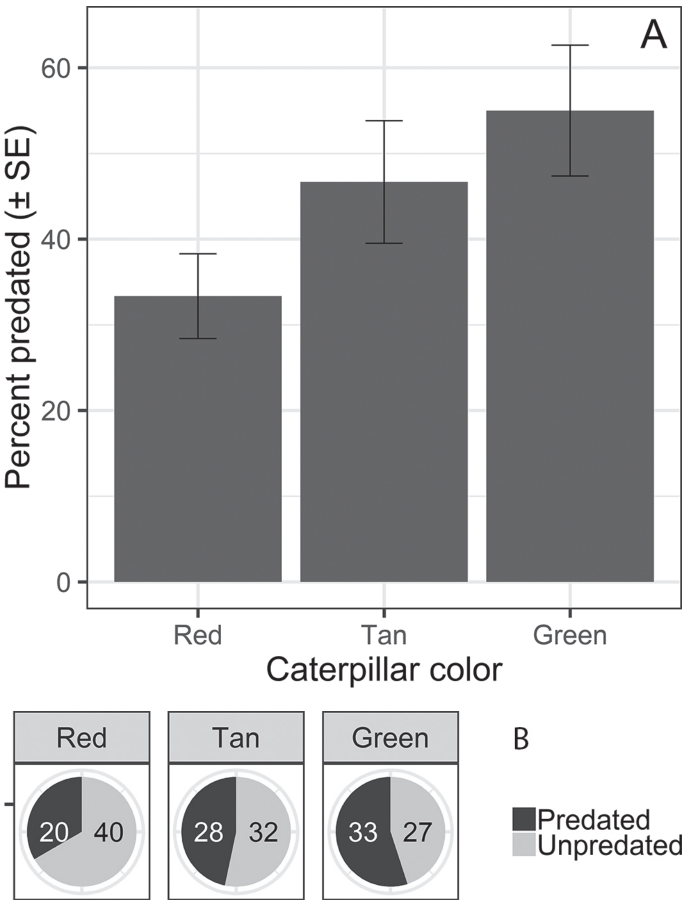


**Figure 3.** Examples of graphs depicting overall predation on plasticine model caterpillars of different colors.

## Conclusion

Through this experiment, participating students gained a thorough understanding of the scientific process. Imprints left on the caterpillars allowed students to observe consequences of predator–prey interactions. Each time this experiment is run, patterns in predation will not be identical due to natural variation, giving students a chance to explore authentic data. In all circumstances, students will learn about the process of designing and carrying out a scientific study. This experiment fits into an NGSS framework and is a hands-on and inexpensive way to teach students about science and ecology. Teachers can easily integrate this lesson into their science classes and build upon students' inquiry skills.

## Acknowledgments

We would like to thank students at Millard South High School and Johnson-Brock Public School for their participation. Jacqueline Wilson at the Hubbard Brook Research Foundation provided valuable guidance for NGSS standards. Example data were provided by Jeff Larkin and his BIOL 201 students at Indiana University of Pennsylvania. Feedback from Jonathan Cohen, Lindsey Rustad, Kimberly Wallin, and anonymous reviewers improved this lesson plan. Funding was provided to W.L. by the Edna Bailey Sussman Foundation and to D.P. by the State University of New York College of Environmental Science and Forestry Research Seed Grant.

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## Appendix 1: Questions & Grading Rubric to Accompany the Plasticine Model Caterpillar Predation Experiment

Predation on Plasticine Model Caterpillars – Assessment

1. What question are you testing with your experiment?
2. What is your hypothesis?
3. What do you predict will happen?
4. How does your experimental design address your question?
5. What are your key results?
6. Create a graph depicting your results. Consult the graph choice chart if needed to decide on a graph style.
7. What are your conclusions? Make sure to reference your results to justify your conclusions. Did you support or disprove your hypothesis?
8. What would you do differently to improve your experiment?
9. Think of another possible question you could ask using plasticine caterpillars.
    1. What is your question?
    2. What is your hypothesis?
    3. What is your prediction?
    4. How would you test your hypothesis?

| Assessment Item | Criteria | Needs Work (1) | Good Effort (3) | Proficient (5) | Comments |
|---|---|---|---|---|---|
| 1. Question | Question is clearly stated; specific; testable | One of three criteria | Two of three criteria | Three of three criteria | |
| 2. Hypothesis | Hypothesis is clearly stated; testable; pertains to the question | One of three criteria | Two of three criteria | Three of three criteria | |
| 3. Prediction | Prediction is clearly stated; testable; pertains to the hypothesis | One of three criteria | Two of three criteria | Three of three criteria | |
| 4. Experimental design | Experimental design is doable; directly addresses the question; directly addresses the hypothesis | One of three criteria | Two of three criteria | Three of three criteria | |
| 5. Results | Results are numbers (proportion or percentage of caterpillars predated); numbers are presented in a way that corresponds to the question; limited to descriptions of what was found (no interpretation included) | One of three criteria | Two of three criteria | Three of three criteria | |
| 6. Graph | Graph is an appropriate choice of graph type; clearly presented; includes necessary annotations (axes labeled, an informative title/description, and legend if needed) | One of three criteria | Two of three criteria | Three of three criteria | |
| 7. Conclusions | Conclusion accurately references results to justify statements; states whether the hypothesis is supported or not; clearly pertains to the question | One of three criteria | Two of three criteria | Three of three criteria | |
| 8. Suggested changes | Suggested changes are clear; relevant; inclusive of possible improvements to the experimental design | One of three criteria | Two of three criteria | Three of three criteria | |
| 9. Future project | Proposed question, hypothesis, prediction, and experimental design are clearly related; well stated; testable | One of three criteria | Two of three criteria | Three of three criteria | |