INQUIRY & INVESTIGATION

Clay Caterpillar Whodunit: A Customizable Method for Studying Predator–Prey Interactions in the Field

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Abstract

Predator–prey dynamics are an important concept in ecology, often serving as an introduction to the field of community ecology. However, these dynamics are difficult for students to observe directly. We describe a methodology that employs model caterpillars made of clay to estimate rates of predator attack on a prey species. This approach can be implemented as a field laboratory in almost any natural or seminatural setting, and is designed to allow educators to pursue any number of student-generated hypotheses representing varying degrees of scientific sophistication ranging from middle school to college level.

Key Words: *Ecology; predation; caterpillar; camouflage; field experiment; hypothesis testing.*

High school classes can benefit tremendously from the inclusion of experiments that allow students to build a solid understanding of the scientific process. Hands-on experiments reinforce topics learned in the classroom by introducing students to the scientific process and further engaging them in critical thinking. In the field of biology, such experiments are frequently limited to those that can be carried out on a small scale in a classroom setting, which often limits the exposure of students to ecological questions and hypotheses. Field experiments offer students the chance to be actively involved in ecological research, developing and implementing experiments to test one or multiple hypotheses. However, constraints of time, funds, adequate resources, and suitable field sites may restrict field activities from being incorporated into high school courses as frequently as teachers would like. The simple methods and flexibility of the experiment presented here facilitate the inclusion of variations of this experiment into the high school science experience. We expect that educators using this experiment will be able to expose their students to the following science skills:

- Understanding the components of a scientific inquiry
- Formulating and justifying hypotheses
- Designing experiments to test specific hypotheses
- Organizing and analyzing data to evaluate hypotheses
- Presenting research results

Hands-on experiments reinforce topics learned in the classroom by introducing students to the scientific process.

Predator–prey interaction is a fundamental concept in ecology and one that many students intuitively grasp from a young age. Furthermore, it is an ecological interaction that many students find interesting and exciting. From a conceptual viewpoint, predator–prey interactions are an important bridge between population ecology (the fluctuations in population size of a particular species in time and space) and community ecology (the interactions among species). Hands-on demonstrations of predation are difficult in the classroom or laboratory setting, and so the topic is often presented through the use of a few standard examples, such as the classic example of population cycles in the Canadian lynx and snowshoe hare (as presented in Odum, 1953, and now ubiquitous in introductory biology textbooks), or through the use of computer simulations such as Populus (Alstad, 2007).

We describe an experimental system using clay models of caterpillars that allows students to study predator–prey interactions in the field. The basic premise of the study is that the soft clay of the models will record predation attempts by wild predators in the form of distinct marks left on the model. The students place models in the field and return after some period (days to weeks) to collect them. Students then collect data regarding the rate of predation on the models and (in many cases) the identity of the predator based on the marks left in the clay.

Clay models offer a number of possibilities to study predation. Because clay is weather resistant and retains marks incurred during a predation attempt (Brodie, 1993), using clay models to represent prey items can serve as a valuable tool when teaching students how prey characteristics affect predation rates. Such models have been used to determine predation on model frogs (Saporito et al., 2007), snakes (Brodie, 1993), salamanders (Kuchta, 2005), eggs (Lewis et al., 2009), and caterpillars (Howe et al., 2009; Remmel & Tammaru, 2011).

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Table 1. A few examples of variations on the experiment.

Questions	Potential Experiments	Learning Areas
How do predators find and choose prey?	Students compare attack rates between differently colored caterpillars, caterpillars with different patterns, caterpillars of different sizes	Camouflage Aposematic coloration Mimicry Prey choice
What is the effect of habitat variation?	Predation rates are compared between different habitats, or within microsites in particular experiments (i.e., on the surface of branches or on trunks, low or high in the canopy, on the ground or on vegetation, on forest edges or in forest interior)	Predator community structure Habitat use Organismal niches
How does the distribution of prey in space affect predation?	Predation rates are compared between individuals that are grouped closely together and individuals that are more widely spaced, or between transects that have higher or lower concentrations of caterpillars	Predator learning Optimal foraging Search images

These studies included investigations of the importance of prey size, habitat, distance from predators, mimicry, and aposematism (warning coloration) on the rate of predation on the model organisms.

Clay caterpillars are an easy system for teachers to use. There is no wrangling of live animals, and because marks recorded in clay will persist until the model is collected from the field, the time frame for observing predation events can be modified to fit the instructor's schedule. Caterpillars (the larvae of the order Lepidoptera, the moths and butterflies) are, in our opinion, an obvious choice for the prey organism, because they are ubiquitous in natural systems that contain broadleaf vegetation and are preyed upon by a wide variety of animals. Furthermore, no particular artistic gift is required to form a clay caterpillar that would be suitable for these experiments.

We present a simple example of an experiment in which students examine two factors: the nature of the predator community that attacks the models and the influence of color on predation rate. In this example, students compare typically colored models (green, and thus relatively camouflaged) vs. a highly contrasting color, such as orange or bright yellow. Students might hypothesize that camouflaged caterpillars are harder to detect by predators and, thus, are attacked at a lower rate. An alternative hypothesis might be that brightly colored models are not recognized as prey items by potential predators and, thus, are attacked at a lower rate. A more sophisticated hypothesis might be that camouflaged caterpillars are attacked at a lower rate, but only by visually oriented predators such as birds (as opposed to tactile- or chemical-oriented predators such as many arthropods). Some research questions to which the experiment can easily be adapted are presented in Table 1.

These experiments are low cost, easily scaled to different class sizes, and adaptable to a range of schedules and alternative field sites, while allowing a great deal of flexibility for students and instructors to design their own experiments to pursue a variety of student-generated hypotheses.

○ Materials

- An accessible ecosystem that contains birds and insects (forest, urban area, park, etc.)
- Clay (we recommend Sculpey III brand)
- Paper and pencils for recording data
- Large trays (such as baking sheets or dissecting trays)
- Waxed paper to place models on
- Transport containers (such as fly or tackle boxes)
- Permanent markers for adding patterns to clay models
- Weather-resistant superglue
- Flagging tape or other easily seen marking
- Dissecting scopes or magnifying glasses for viewing attacked caterpillars

○ Making Clay Model Caterpillars

It is best to use new clay to make model caterpillars that are approximately 5 cm long and 1 cm in diameter. We found it easiest to divide packages of clay into uniform sections that resulted in correctly sized models when hand rolled (if using Sculpey III, separate each package of clay into approximately 20 sections).

Because sweat or food residues on hands are easily transferred to the clay, it is important that those involved wash their hands prior to rolling; otherwise ants and other insects may be attracted to salts and sugars that were accidentally incorporated into the clay. Care should be taken to smooth models as much as possible so that caterpillars begin the experiment without existing marks that might later be mistaken for predation attempts. If students develop hypotheses that involve differently patterned caterpillars, permanent markers can be used to draw patterns on the caterpillars. As models are completed, they can be placed on trays covered with waxed paper. To transport caterpillars to the field, tackle boxes (like those used to carry fishing flies) can be used.

○ Placing Caterpillars in the Ecosystem

We advise choosing a location that is easily accessible to students, but also where the models are unlikely to be disturbed by passersby. Our experiment was conducted along transects in a national park, and we placed five caterpillars each at focal points equally spaced along a 25-m transect. We replicated these transects within and among different forest types. Transect size and the level of replication can be adjusted to fit the situation. After marking the center of the location where caterpillars will be placed using flagging tape, caterpillars should be glued with weather-resistant superglue in places where they can easily be observed and collected by students. After ensuring that a caterpillar is secured, the caterpillar should be smoothed a final time to remove any marks that have been made during placement.

Figure 1. Typical marks made by the most common predators of caterpillars in the field. Note that some caterpillars were "striped" with black marker in this experiment.

It is very useful to have a student draw a basic map of where the caterpillars are located in relation to the flagging tape, because they can be surprisingly difficult to find again. The map should indicate the color of the caterpillar, an estimate of its direction from the flag, and an estimate of the height above ground at which the caterpillar is placed.

○ Collecting Data

During our experiment, data were collected over the course of 3 weeks. After placement of the caterpillars, the students returned after 2 days to complete an initial assessment. Using the map to find the caterpillars, they examined the caterpillars for any markings that indicated they had been attacked. If a caterpillar showed signs of attack, it was considered "dead" and removed from the field. Attacked models were carefully placed in fly boxes to be taken back to the lab and further examined. We repeated this examination and removal procedure after 1 week and after 3 weeks and collected all models after the final examination. The choice of time interval is entirely up to the instructor; the best interval will likely vary depending on the intensity of predation at a particular site and the hypothesis being tested.

Examples of attack marks are shown in Figure 1. Depending on where the experiment is completed, potential predators will vary. Before and during the experiment, students should be encouraged to consider what types of predators may attack the model caterpillars. As they collect caterpillars from the experiment, they will have to make determinations of what type of predators (e.g., mammal, bird, insect, unknown) marked the models. Not shown in Figure 1 are some of the smaller marks that arthropods may make, including puncture holes from bee or wasp stingers or ovipositors. Once models have been removed from the field and are back in the lab, they can be examined more closely using a dissecting scope or magnifying glass to see some of these more subtle marks. Additional close lighting is helpful for this step.

○ Recording Data

Development of a data sheet before data collection forces students to think about exactly what information they need to collect from each model. Leading students through the process of organizing data allows them to realize the importance of properly constructing spreadsheets, a skill that is useful in many fields besides science. Depending upon the hypotheses that students develop, they may need to organize data in slightly different ways. An example data sheet is presented in Table 2.

Table 2. An example data sheet for a simple experiment.

Transect	Point	Caterpillar	Color	Attacked	Predator
1	3	1	Green	Y	Bird
1	3	2	Green	N	—
1	3	3	Orange	Y	Arthropod (spider?)
1	3	4	Orange	Y	Bird
1	4	1	Green	N	—

○ Data Analysis

Although both middle school and introductory high school biology classes may favor a simpler method of analyzing the predation results collected in this experiment, the following discussion includes descriptions of statistical tools that could be employed by both advanced high school and undergraduate biology courses.

For our example (and for most tests that students propose), the null hypothesis will be

Variables	Outcomes: Attacked	Not Attacked	Totals
Color 1	a= 28	b= 72	100
Color 2	c= 53	d= 47	100
Totals	81	119	N= 200

$$\chi^2 = \frac{(ad-bc)^2 \times N}{(a+b)(c+d)(a+c)(b+d)} = 12.97,\ p = 0.0003$$

Figure 2. A 2 × 2 contingency table for comparing observed and expected results with a chi-square analysis. In the example given, the result is statistically significant, as indicated by a p value less than 0.05.

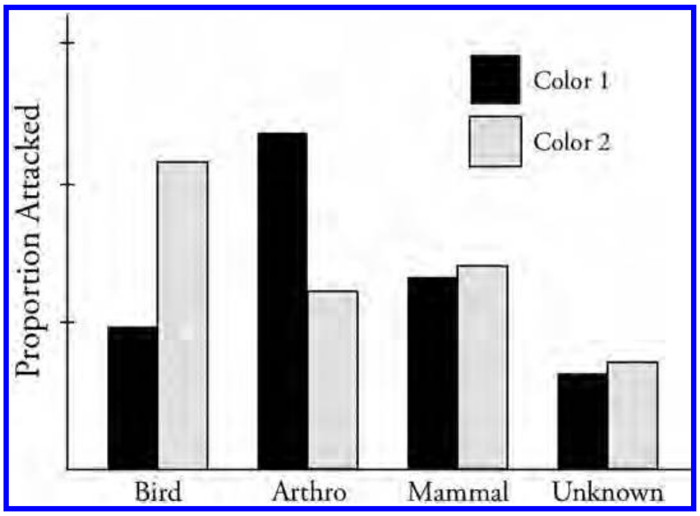

Figure 3. An example of a graphical representation of attack data when a simple variable is being employed. Note that the y axis is the proportion of attacks, which may be appropriate if the overall rate of attack is different between the two treatment groups.

that no difference exists between the treatment variables. Instructors should encourage students to make their null hypothesis as explicit as possible and to express that in terms of an expected outcome. For example, the null hypothesis for our experiment was stated as "We expect that the proportion of caterpillars that show evidence of predator attack will be the same for color 1 and color 2."

Because these experiments deal with discrete events (attacks by predators), they are well suited to be analyzed in a contingency table, which allows comparison of expected to observed outcomes. In the contingency table (Figure 2), we see that 40.5% of the models (81/200) were attacked overall. However, there was considerable variation between treatments; in this example, only 28% of color 1 (28/100) but 53% of color 2 (53/100) were attacked. Another way of stating this is to say that in relation to our null hypothesis of no difference, we observed that models of color 1 were attacked less frequently than expected, whereas models of color 2 were attacked more frequently than expected.

Contingency tables are also convenient if the instructor wishes to introduce statistical analysis into the lesson. A chi-square value can easily be calculated by hand and compared to a table of statistical values to determine significance. There are also online calculators for calculating χ^2 and determining significance, for example http://faculty.vassar.edu/lowry/newcs.html, which also allows users to calculate contingency tables more complicated than the 2 × 2 variety.

○ Student Assessment

Students should prepare a presentation of the results, modeled on the brief scientific talks given at professional meetings. Talks should consist of brief background and a literature review, a statement of question and hypothesis, a description of methods, and statistical analyses of data. Students should field questions from their peers and instructor following their presentation. At lower grade levels, it may be advisable to perform data analysis as a group, because students can easily get hung up on the calculation and interpretation of numerical data, which may detract from the larger goal of teaching the scientific process. For more advanced students or students at the college level, data analysis can be performed by the students themselves.

Depending on the amount of time available, groups of students may analyze different hypotheses. Using the data from our example experiment, one group of students might be assigned to describe differences in predation on the differently colored caterpillars, while another may focus on the diversity of predation marks encountered. An additional activity for more advanced students is to challenge them to develop strategies for how best to use graphs or images to represent their data (Figure 3). A college course that we taught using this method developed two separate hypotheses and designed an experiment to test both simultaneously. One group of students focused on the effect of caterpillars colored with warning coloration (red and black stripes). Another group examined the hypothesis that predation would vary among different forest types.

Alternatively, students could be expected to write a brief paper that outlines the experiment and clearly identifies the hypothesis, how experimental design allowed testing of the hypothesis, and the results.

Students at all levels should be encouraged and expected to identify shortcomings of the experiment and the challenge of uncontrollable variables. They should also be asked to propose potential follow-up and future projects related to predator–prey relationships, particularly questions that supplement their original experiment in which they may be able to control other variables. They should be reminded that rigorous scientific explorations may involve many complementary experiments that address a very specific question.

○ Conclusion

The use of clay models provides a platform for student-driven exploration of predator–prey interactions through hypothesis testing in the field. Students can and should be involved in every step of the experiment, from developing hypotheses and formulating the experiment to collecting, analyzing, and presenting the results.

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