Population Changes

Overview

In this activity students act as predators and observe and count changes in the population of different forms of a 'species' (colored toothpicks). Several generations are captured, counted and analyzed as the population changes. This is a simulation of natural selection.

North Carolina Standard Course of Study

Science

7.03 Explain how changes in habitat may affect organisms.

7.06 Investigate processes which, operating over long periods of time, have resulted in the diversity of plant and animal life present today:

- Natural Selection
- Adaptation

Computer/Technology Skills

2.04 Use spreadsheet terms/concepts and functions (e.g., median, range, mode) to calculate, represent, and explain content area assignments.

2.05 Modify/create and use spreadsheets to solve problems by performing calculations using simple formulas and functions (e.g., +, -, *, /, average).

2.06 Create/modify simple content area spreadsheets to enter/edit, calculate, organize, and display content data for class/group assignment/project, citing resources.

Textbook References

McDougal Littell

Unit D, Chapter 2, Section 2.1 (pp 45-53) and Section 2.3 (pp 63-69) discuss population changes. The North Carolina Handbook section of the Teacher's Edition (pp NC2 – NC6) has a detailed explanation of natural selection.

Prentice Hall

Chapter 11, Section 3 (pp 402-409) introduces students to natural selection and adaptation.

Background

Industrial Melanism

In the 1950s, H. B. D. Kettlewell ran a series of experiments that are now regarded as classics in the study of evolution and natural selection. (This particular account is taken from *Ecology*, by Robert E. Ricklefs, Chiron Press, 1973, but descriptions of this work can be found in most biology textbooks.) In Great Britain, there has been a long tradition among enthusiasts of making collections of butterflies and moths. In the early 1800s, these collectors would be especially pleased when they found a melanistic form of the common Peppered Moth (*Biston betularia*). The usual Peppered Moth was mostly white with little black spots (the 'pepper'). The melanistic form was just the opposite; it was mostly dark, with little white spots. And these melanistic individuals were quite rare. However, as the decades of the 1800s passed, the collectors noticed that the melanistic moths were becoming increasingly common, especially in and around cities known for their industrial development. This was, after all, the industrial revolution in Great Britain, and cities like Manchester, Birmingham, and Liverpool were thriving. By the mid-1900s, the melanistic moths made up close to 100% of the population in some of these areas and the normal (white) forms were the rare ones. On the other hand, the white forms were still the most common ones in other areas.

Through crossbreeding experiments, geneticists had determined that this melanism was an inherited trait. Therefore, Kettlewell considered the spread of the trait to be an example of evolution and an opportunity to look for evidence of natural selection. He hypothesized that something in the environment near the industrial centers was changing to give the dark moths an advantage over the light ones in both survival and reproduction. How could he test this hypothesis?

Kettlewell collected more than 3,000 caterpillars, fed them in his laboratory, and allowed them to pupate and undergo metamorphosis into adults. While he was raising the caterpillars, he selected two forest tracts—one near an industrial center, the other in a natural area. When his adult moths were ready, he marked each one with a small dab of a special paint on the underside of its wing where it couldn't be seen by predators when the moth was resting on a tree trunk. He then released his moths, waited awhile, then set traps to recapture as many as he could.

There is an important difference here between Kettlewell's goals and the simulation we did with beans in **Estimating Populations: Mark-Recapture Sampling**. We were trying to estimate the total number of beans in our population. Kettlewell didn't really care about the total number of moths in his forests; he just wanted to know if there was a difference in the survival of the light and dark forms. Here are the results from one of his experiments, when he released moths near Birmingham, an industrial center:

	White moths	Dark moths
Number released	201	601
Number recaptured	34	205
Percent recaptured	16.0 %	34.1 %

Table 3 (polluted woods)

It looks like the dark forms survived much better than the light forms. But doesn't it make a difference that he released so many more dark moths? If he released more, it would make sense that he would recapture more. But it's the percentage that really counts here. He recaptured 34.1 % of the dark moths; that's more than twice the percentage of white moths recaptured.

Skeptics could argue that white moths were smarter and once released, they were less likely to be caught in Kettlewell's traps. Or perhaps, white moths were stronger, flew further from the release point, and thus were less likely to be recaptured. In order to account for these possibilities, Kettlewell ran a control experiment by releasing moths in a natural area, presumably unpolluted woods. Here are the results:

	White moths	Dark moths
Number released	496	473
Number recaptured	62	30
Percent recaptured	12.5 %	6.3 %

Table 4 (unpolluted woods)

Notice that this time, the white moths survived much better. This eliminates the possibilities of trap avoidance or differential dispersal.

These experiments confirmed for Kettlewell that the two forms of moths survived differently in the two habitats. But why? Who or what was the *agent* of natural selection? That is, who or what did the actual selecting? Kettlewell thought that in the industrial areas, soot from the coal-burning factories was settling on the tree trunks and turning them dark. As a result, the dark moths were better camouflaged in those areas and were less likely to be seen by predators, probably birds. Against normal bark, the white moths had the better camouflage. To test this hypothesis, he placed equal numbers of white and dark moths on tree trunks in natural and polluted woods. He set up a blind and simply sat and watched to see what would happen. Since Peppered Moths only fly at night, once placed on the tree trunks, they stayed right where they were. Here is what Kettlewell observed:

	White moths eaten by birds	**Dark moths eaten by birds**
in natural woods	26	164
in polluted woods	43	15

Table 5 (predator experiment)

Clearly, many more dark moths were eaten in the natural setting, and many more white ones were eaten in the polluted woods.

Two other pieces of this story help to add the finishing touches. In the polluted woods, it turns out that it wasn't really the soot that turned the trees black, but rather it was the other pollutants from the factories that killed the lichens that normally grew on the tree trunks. White moths with black specks look remarkably like lichens. In recent years, as Britain has introduced more stringent pollution controls, the lichens are coming back to the trees, and the white moths are becoming much more common again.

Secondly, one particular bird species, the Treecreeper, ate both types of moths in equal numbers in both types of woods. This particular bird species creeps around the trunks of trees and finds its prey by seeing their silhouettes sticking out from the bark. For them, white or dark color doesn't make any difference. The exception that proves the rule!

Materials

Materials for the whole class

- 8 boxes of flat toothpicks (750 per box)
- 1 set of food coloring
- 3 plastic trays
- Tape measure
- Surveyor flags
- String
- 2 clip boards
- 1 timer
- 2-3 student tally sheets for each class period (1 for each ‘generation’)
- 1 class tally sheet for each class period
- 1 summary tally sheet for data collected from all classes

Materials for individual students

- One 9-oz. cup
- Graph paper
- Photocopy of Hide Your Butterfly

Preparation

- A few days prior to doing the activity the tooth picks will need to be dyed using food coloring. Empty two boxes, 1500 toothpicks, into one plastic tray. In a 9-oz cup, pour ½ bottle of food coloring and fill the cup with water. Cover toothpicks with this colored solution. Place trays on a window sill for 2-3 days to let the water evaporate. Pour off any remaining water. Finally, spread the toothpicks out on cardboard to dry.
- The day of the lesson, lay out a 15 foot by 15 foot square using the flags. Use the string to make a border. This will be the hunting area.

Procedure

Part I.

- The following procedure will be done for each class. You will need to have one hunting area for each class.
- Inform students that they are going to "hunt" for toothpicks. The rules for the hunt are as follows:
    - Half the students in the class will conduct the first hunt, all at the same time. (The second half of the class will do the second generation).
    - Students may only take "baby steps." Both feet must always be touching each other.
    - Students should collect toothpicks into a 9-oz. cup.
    - Before the hunt begins, students should line up around the hunting space with their *backs to the hunting area* (so that they cannot see the toothpicks before they start).
- Ask students what they think will happen.
- Then go outside and gather the students around the hunting area. Inform them that you are going to put 50 of each color toothpick in the hunting area. Explain that each student will get to hunt, though in two separate groups.
- Divide the class into two equal groups.
- Have one group line up around the perimeter of the hunting area. Be sure all students have a cup and are facing away from the hunting area.
- Have students hunt for 15 seconds. After they hunt, have them sort, count and record their catch. After all students have recorded their results, total the number of each color toothpick.
- Explain to the class that the toothpicks that survived are able to reproduce. Therefore, match the number of toothpicks remaining for each color (50 minus the number captured) and add that number to the hunting area. [For example, since we started with 50, if 30 red toothpicks were captured, 50 – 30 = 20. So 20 reds survived to reproduce. Add 20 more red toothpicks to the hunting area,

bringing the new total to 40. Thus, the population of reds has decreased from 50 to 40 in this generation.

- Have the second group of students go through the same procedure with the new population numbers and record the number captured for each color.
- At this point, bring the class back inside and write the population sizes of each color toothpick on the board for year 1 and year 2. Here are some possible discussion questions:

    - What do you notice about the numbers for the various different colors?
    - How do these results compare to what you thought would happen?
    - What was the hunting like?
    - Were some colors easier to find than others? Explain.
    - What might you expect if you were to continue hunting for 4, 8, or 20 generations?

Part II.

- Part II of this activity is similar to Part I except only one hunting area is needed for all classes. Have each class do two or three generations (hunts), as time permits. The following class will start with the numbers left by the earlier class. After 4 or 5 classes have done the activity, you will have completed 8 to 10 generations. Collect and keep data for *all classes* throughout the day.
- The next day after the hunting is complete, have students graph the population changes for all four colors on one graph.
- On a second graph, have the students graph the entire toothpick population. It is better to do this on a separate graph since the numbers will probably be very large.

Reflection/Discussion

Some discussion questions:

- What did you notice?
- How does this relate to what happens in nature?
- How does this activity relate to the mark-recapture activity with the beans? In other words, how are predators similar to or different from scientists? [Predators remove their prey from the population. Scientists mark the animals they capture and then return them to the population. Predators eat their prey. Scientists are just counting them.]
- How does this relate to the **Oh, Deer!** activity?

Assessment

- Have students completed their graphs correctly?
- Each population started at 50. Explain why the different colors had different ‘survivals.’
    - Which increased? Explain?
    - Which decreased? Explain?

Extension

Hide Your Butterfly: Give each student one copy of the butterfly diagram. The challenge for them is to create and color a copy of this butterfly and then place it somewhere in the open so that it is camouflaged. One person will then have one minute to find as many butterflies as possible.

Date: ____________________ Class period: ________________ Generation: _______________

Student	Natural	Green	Blue	Red
TOTALS				

Date: Class Period:

Color	Generation 0 (G_0)	# Cap tured (C)	# Left ($G_0 - C = L$) # to replenish for G_1	Generation 1 ($L * 2 = G_1$)	# Captured (C)	# Left ($G_1 - C = L$) # to replenish for G_2	Generation 2 ($L * 2 = G_2$)
Natural							
Green							
Blue							
Red							
Total Population							

Date:

	G_0	C	L	G_1	C	L	G_2	C	L	G_3	C	L	G_4	C	L	G_5	C	L	G_6	C	L	G_7	C	L	G_8
Natural																									
Green																									
Blue																									
Red																									
Total																									

$G_0 - C = L$

$L * 2 = G_1$