ACTIVITY 9.2 – HOW DOES VARIATION MATTER?

What Will We Do?

We will analyze data about the peppered moth in order to figure out what caused the change in the population.

Procedure

1. Your teacher will assign your group one of the studies in this activity. Circle or highlight the number and title of the study that your group is assigned.
2. Carefully read the study your group is assigned.
3. There is a chart on the last page of the activity sheet. Find the row for your study and summarize the patterns you found in the data. Record your interpretations of the data in the last column.
4. When your group has finished, jigsaw with people from each of the other studies. Record their information in the chart at the end of the activity. When you finish, you should have information about each of the studies.
5. Take detailed notes about what the other groups discover. You will need all of the information in order to write an evidence-based explanation in Activity 9.3.

Studies of the Peppered Moth

Beginning in the 1950s, scientists began to study the peppered moths. Their goal was to figure out why the carbonaria form of the moth had become more frequent than the typica peppered moth during the late 1800s. Before that time the carbonaria form had been very rare.

Biologists had some hypotheses about what might have been going on. The next sections contain four collections of studies. The studies look at different types of interactions between the moths and the abiotic and biotic factors in their ecosystem. These studies provide clues that can help figure out why the populations of peppered moths have changed over time.

The four groups of studies and the questions they are trying to answer are:

1. **Group A: Pollution Studies #1 and #2**: Does pollution have anything to do with the proportions of the carbonaria and typica peppered moths?

2. **Group B: Predation Experiments #1 and #2**: Do birds prey on one variation of the peppered moth more easily than the other?

3. **Group C: Study of pollution reduction**: How did the proportions of carbonaria and typica moths change in the last 50 years?

4. **Group D: Inheritance Experiment**: Is the color of the moth inherited, or is it something that happens to the moth due to its environment?

1. Group A: Pollution Studies #1 and #2

Research Question: Does pollution have anything to do with the proportions of carbonaria and typica peppered moths?

A major change in the environment in England was underway in the 1800s caused by the Industrial Revolution. Population sizes in urban centers were increasing dramatically. Coal was now being used in homes and in factories. Smoke, sulfur, and other pollutants from the coal were common in the industrial areas. Pollution was also high in urban areas where many people used coal in their homes for heating and cooking.

The woods near these urban and industrial areas also suffered. Tree bark became blackened with soot, and many of the lichens that grew on trees in the woods died. Scientists wondered if somehow the increased numbers of carbonaria had something to do with the observation that the woods were becoming polluted.

Pollution Study #1

To investigate this idea, scientists compared the proportion of carbonaria and typica peppered moths in different parts of England.

Method

Data were gathered from woods in England during the spring and summer when the adult form of peppered moths is active. To count insects that are active at night, like the peppered moth, scientists set up traps called light traps. The moths fly toward a bright light above a box with a small opening and get caught in the box. The next morning, the scientists collected the moths, classified and counted them, and then released them. The scientists set up the traps for several nights. They collected at least 25 moths and sometimes as many as 300.

Scientists collected the data from three different areas of England.

- Industrial – These areas had the greatest concentration of industry. The nearby woods also showed the most pollution, including darkened bark of trees and loss of lichens on trees.
- Intermediate – These were urban areas with less industry. However, they showed evidence of pollution from the use of coal in homes.
- Rural – These were areas away from the industry and cities and were relatively pollution free.

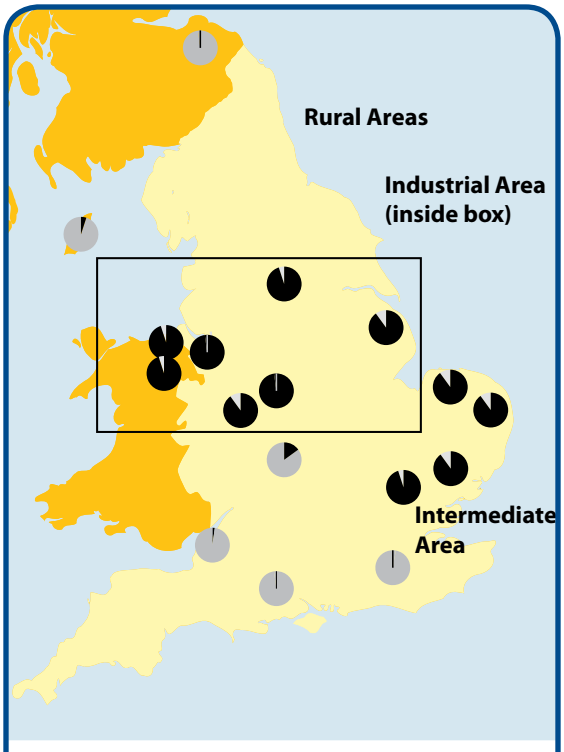

Fig. 1: Proportion of carbonaria and typica peppered moths in different areas of England 1952–1956

Results
The data for each site are shown as two-color pie charts on the map.

- Dark Grey = the proportion of carbonaria (dark colored) moths
- Light Grey = the proportion of typica (light colored) moths

Making Sense
What can you conclude from this pollution experiment? On the chart at the end of this activity sheet, summarize the evidence and record your interpretation. How can this evidence help explain the population change in the peppered moth?

Pollution Study #2

The scientists studying the peppered moths wanted to investigate whether the pollution affected the plants and other organisms where the moths lived. If other organisms and plants were affected by the pollution, they wanted to see if that was connected to the increase in the carbonaria moths. Because sulfur dioxide is given off into the air when coal is burned, scientists tested the amount of it in the air in many different areas. They also examined the organisms in the area and the frequency of carbonaria versus typica moths in these same locations. They looked for a pattern between these three variables: amount of pollution, growth of organisms, and relative proportions of carbonaria versus typica.

They collected data to answer two questions:

- Does the amount of pollution affect the lichens and trees?
- Is the type of lichen on trees related to the types of moths found there?

The results of the experiments to answer these two questions are reported in the following graphs.

Results
Does the amount of pollution affect the lichens and the trees?

Scientists found a high correlation between the amount of air pollution (sulfur dioxide) and the growth of lichen on the trees.

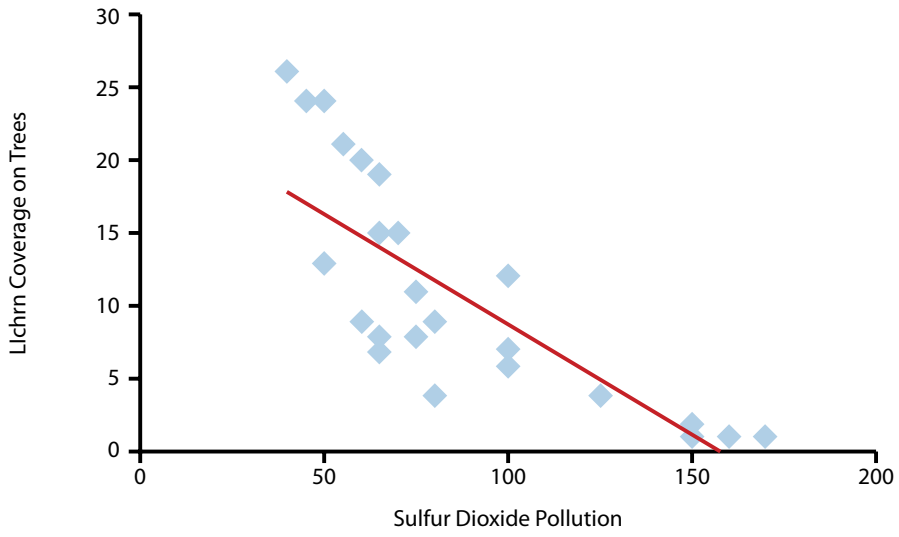

Fig. 2: The effect of sulfur dioxide pollution on the lichen coverage on trees. Each blue point shows a different site in England with varying degrees of pollution. The red line is the best-fit line through the center of the data points.

Is the type of lichen coverage on trees related to what types of moths are found there?

Scientists again found a high negative correlation between the amount of lichen coverage on trees and the proportion of peppered moths that were the carbonaria rather than the typica variation.

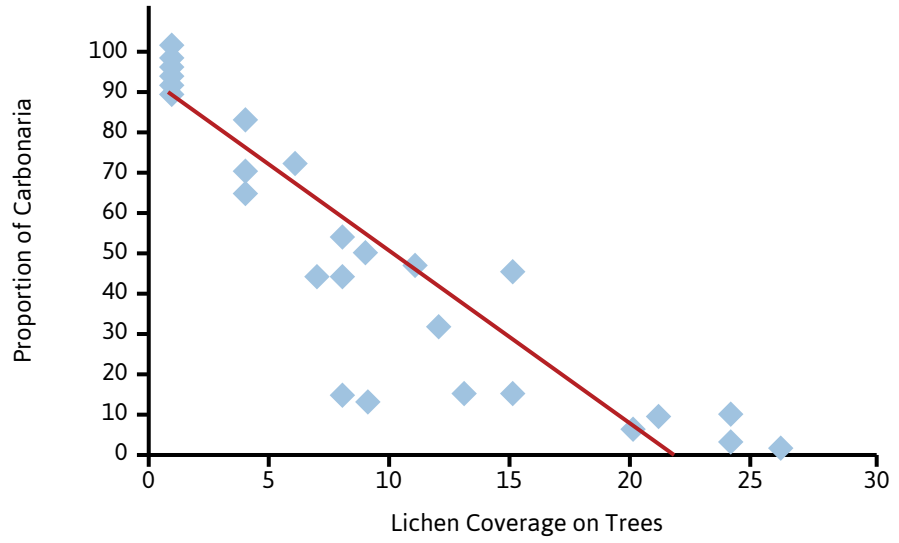

Fig. 3: The relationship between the lichen coverage on trees and the frequency of carbonaria peppered moths. Each blue point shows a different site in England with varying degrees of lichen coverage. The red line is the best-fit line through the center of the data points.

Making Sense
What can you conclude from these two pollution experiments? How can this data help explain the population change in the peppered moth? On the chart at the end of this activity sheet, summarize the evidence and record your interpretation.

2. Group B: Predation Experiments #1 and #2
Research Question: Do birds prey on one variation of moth more easily than the other?

Scientists were excited by the findings that pollution influenced the plants that grow on trees where peppered moths rest during the day. They wondered whether the carbonaria and typica moths might differ in how easily predators could find them in polluted woods. It was difficult to test this idea through observations, so scientists tried a number of different kinds of experiments.

Predation Experiment #1: (1953–1955)
Methods
This experiment compares what happened to moths in two different woodlands. One was heavily polluted (Birmingham) where the trees were almost totally free of lichens. The other was a non-polluted woodland (Dorset). They tried two methods (Figures 4a and 4b). One method involved observing the predation on released moths (Figure 4a). In the second method the scientists marked moths so they could be identified. They then released the moths each day and the counted the survivors (Figure 4b).

Results

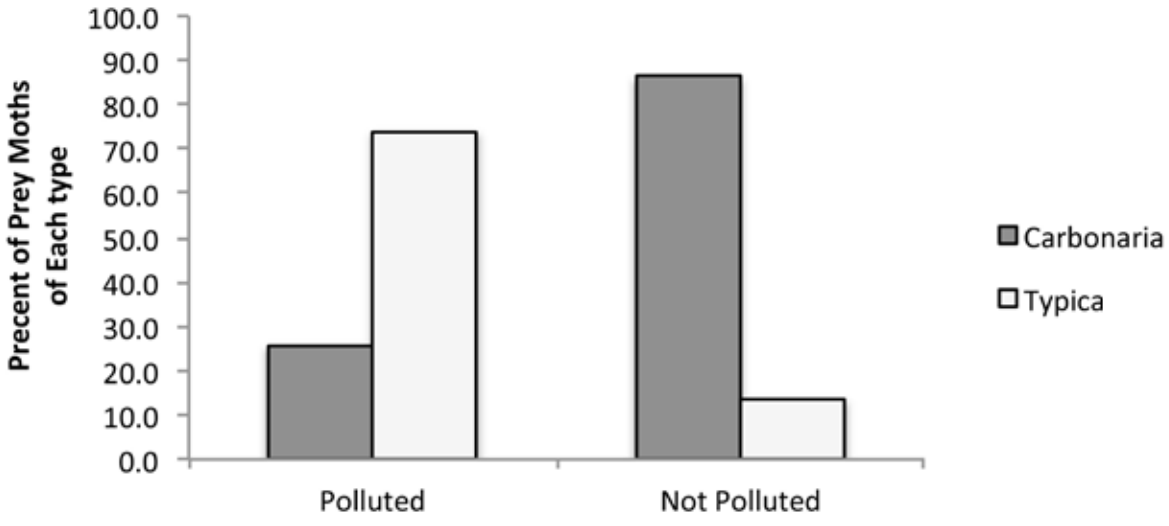

Fig. 4a: Did the birds eat carbonaria or typica moths?

Observed Predation Method
- Released live moths of each form in early morning in trees.
- Observe birds eating moths during the day

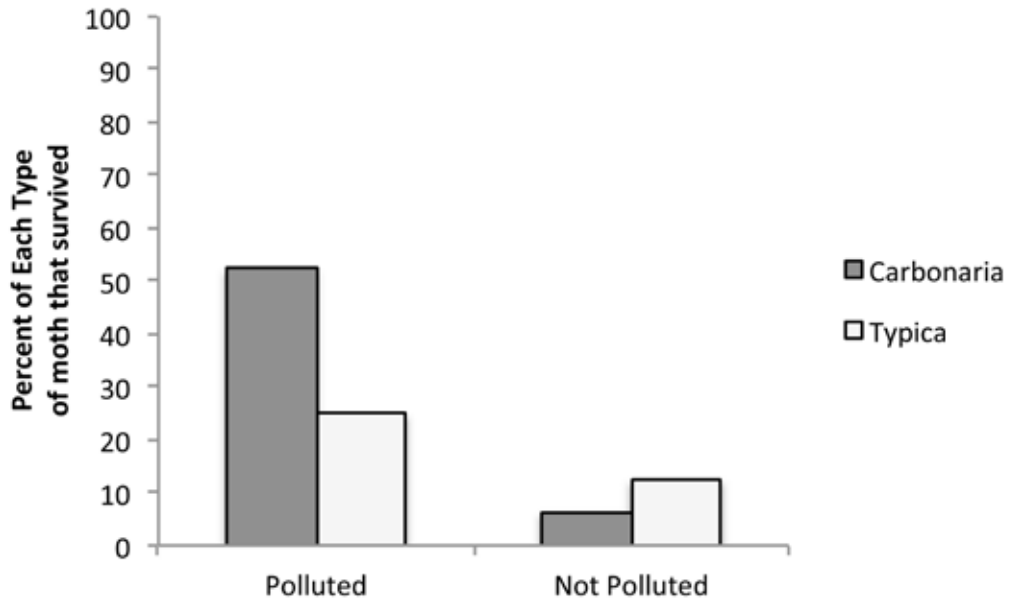

Fig. 4b: What proportion of moths survived?

Recapture Method

- Mark and then release live moths of each form early in the morning.
- Collect moths over the next few evenings in traps.

Predation Experiment #2: (1975)
Another method scientists tried to determine if predators could find one type of moth more easily than another, was to place moths on trees and collect them later. They could see which ones were missing, and therefore, may have been eaten.

Method
Scientists placed dead moths on trees in the places moths would normally rest. They put moths on various trees using approximately the total numbers that would normally occur. The scientists thought that since moths do not move from their resting positions on trees during the day, the number taken by predators would be similar to what would happen naturally. Scientists used wooded sites in more polluted and less polluted locations and compared them.

Results
Did the predators prey on the two variations of moths equally?

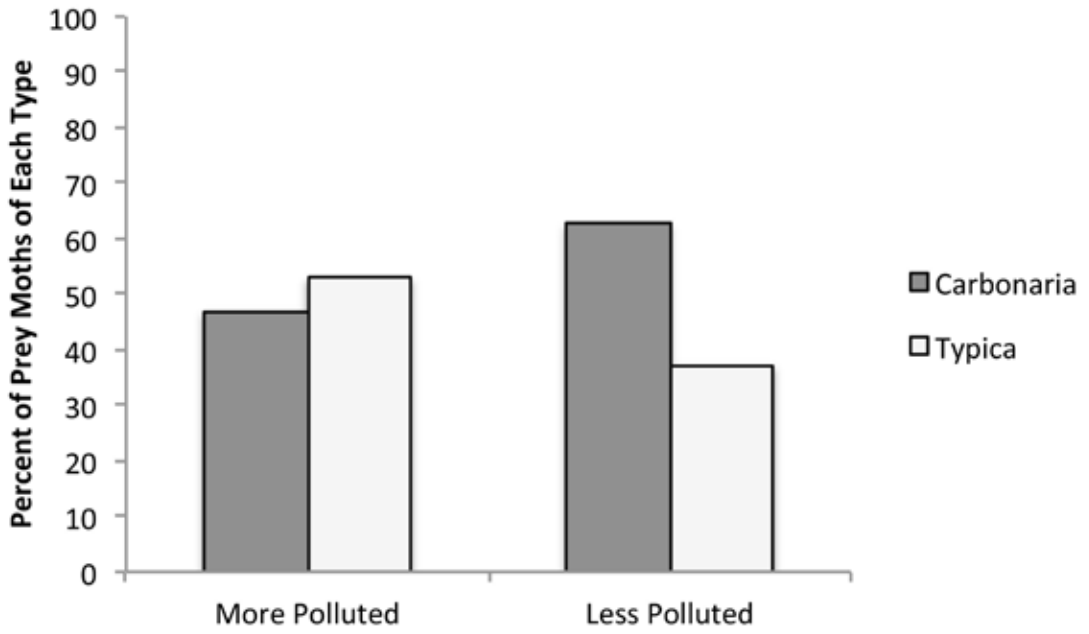

Fig. 5: The graph shows what proportion of moths eaten by predators were each type of moth, carbonaria or typica. Two different groups of sites are shown: a group of more polluted sites and a group of less polluted sites.

Making Sense
What can you conclude from these experiments on predators? How can this data help explain the population change in the peppered moth? On the chart at the end of this activity sheet, summarize the evidence and record your interpretation.

3. Group C: Study of pollution reduction

Research Question: How did the proportions of carbonaria and typica forms of the peppered moth change in the last 50 years?

England began to try to reduce air pollution in the 1950s. Clean air laws were put into effect. In addition, using coal as fuel for machines and homes was being replaced by electricity and oil. These were less polluting sources of fuel. Over the years from the 1970s to the present, the air has steadily improved. Scientists decided to track whether these changes had any effect on the peppered moths. They collected and analyzed data for almost 50 years.

Method
Data were gathered from woods in England during the spring and summer when the adult form of peppered moths is active. As in prior studies, scientists set up traps to catch the moths flying around at night. They classified them and then released them at the end of the study.

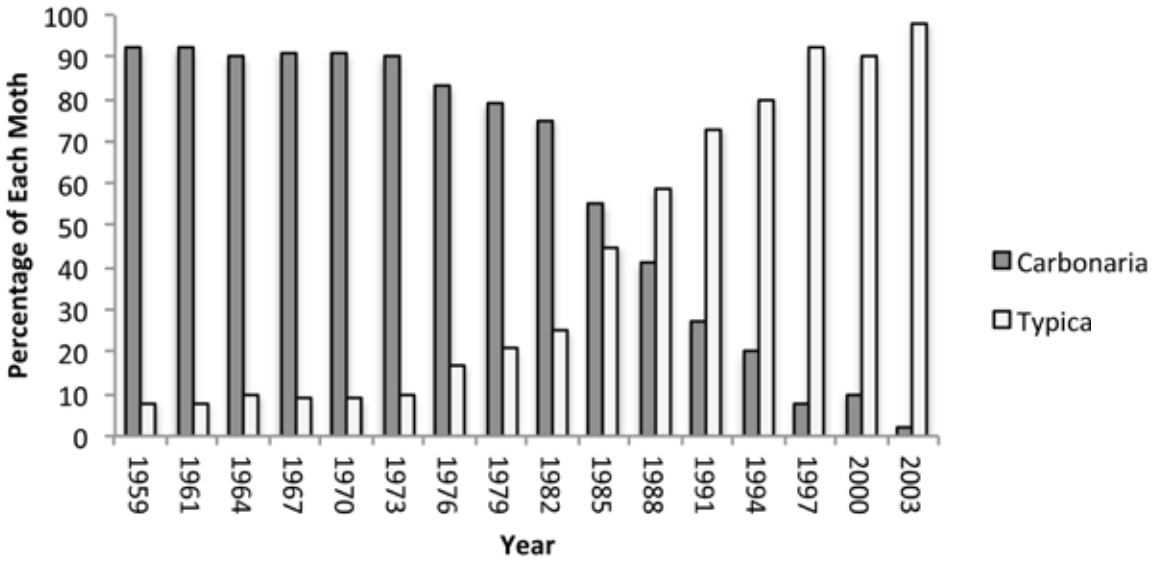

Fig. 6: Changes in the proportion of two varieties of the peppered moth between 1959 and 2003 in a highly polluted wooded area in England.

The scientists also looked at sites across the country. They separated them into groups: industrial, intermediate (urban), and rural. They wanted to see if these changes were happening in all environments across the country.

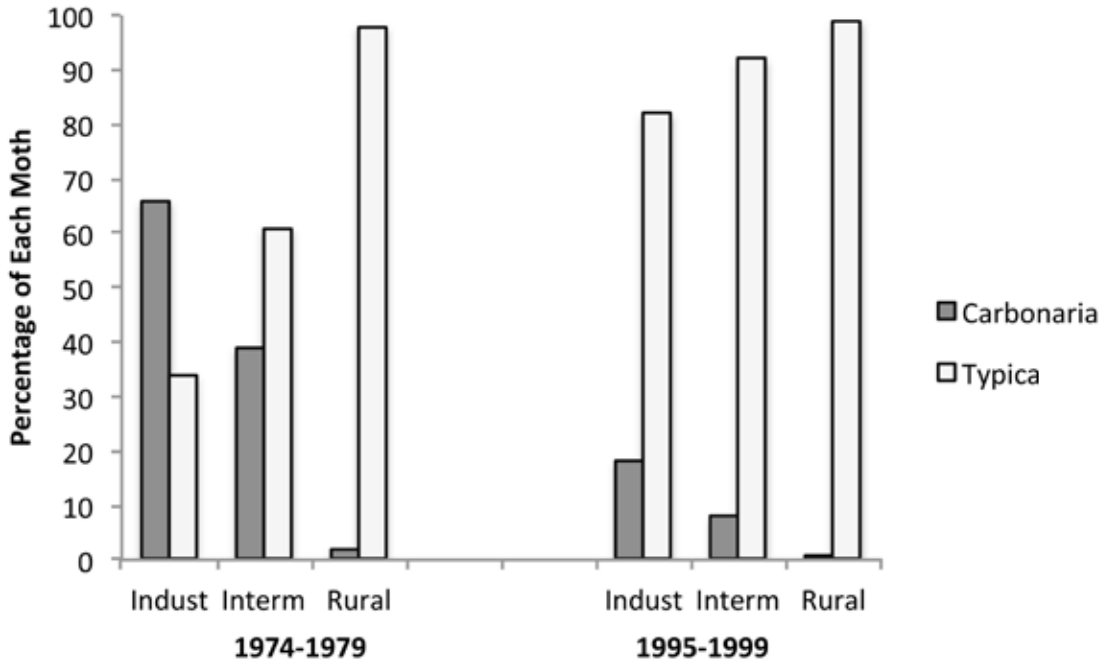

Fig. 7: Proportion of carbonaria peppered moths in three areas of England (industrial, intermediate, and rural) in two time periods, twenty years apart.

What can you conclude from these studies of the decline of the carbonaria? On the chart at the end of this activity sheet, summarize the evidence and record your interpretation. How can this evidence help explain the population change in the peppered moth?

4. Group D: Inheritance Experiment

Research Question: Is the color of the moth inherited, or is it something that happens to the moth due to its environment?

An important part in figuring out why the population of peppered moths was changing was understanding the moth's color. Since the carbonaria and typica moths have different variations of the color, scientists wanted to know if it was inherited. Is it like the purple versus non-purple plant stems or tasting or not tasting PTC? Or could living in a more polluted environment somehow affect a moth's color, turning it darker during its lifetime?

Method

Scientists thought that the trait was not environmental, because color in insects is usually an inherited trait. They tested their ideas to be sure. They tried breeding carbonaria and typica moths to see what offspring would be produced.

Results

	Parents		
Number of Offspring	carbonaria X carbonaria	carbonaria X typica	typica X typica
carbonaria	405	350	0
typica	110	152	509

This table shows a summary of the offspring produced by the three possible combinations of parent moths.

The results of this experiments reassured the scientists that the color of the moth was inherited. All of the moths were raised in the same environment in this experiment. However, they produced both types of offspring. This helped convince the scientists that the color variation was not caused by the environment.

They were also excited to see that two typica peppered moths had only typica offspring and no carbonaria. They took this as evidence that the color of the peppered moths was due to inherited traits and not influenced by the environment.

Making Sense

How can the finding that the peppered moth's color is inherited help explain why the population has changed over time? On the chart at the end of this activity sheet, summarize the evidence and record your interpretation.

Evidence Organizer

Type of Study	Evidence (Describe the Pattern In the Data)	Interpretation (What can you conclude from this evidence?)
Group A: Pollution studies #1 and #2		
Group B: Predation experiments		
Group C: Study of pollution reduction		
Group D: Inheritance experiment		

Making Sense

Using evidence from all of the studies, write out a chain of cause and effect that explains why the population of peppered moths has changed over time. Your chain of reasoning should include the following:

- Variation in the population
- Pollution
- Lichens and trees
- Predators
- Offspring and inherited traits