



Hubbard Brook Research Foundation

Migratory Bird Math and Science Lessons



Red Eyed Vireo/Robert Royse

Lesson: Bye-Bye Birdie?

Avian ecologists (scientists who study the ecology of birds) at the Hubbard Brook Experimental Forest have been collecting data on birds for over 40 years. These data represent one of the longest-running bird studies ever conducted and have allowed scientists to try to answer questions such as: How do the population sizes of different species of birds change over time? What types of habitats do birds favor? What types of food do they prefer to eat? Which animals prey upon birds? How does climate affect birds? Using these data, scientists are able to learn more about what sorts of natural or human influences affect bird populations, and why. This is an excellent example of one of the benefits of long-term monitoring.

By graphing bird abundance data collected from the Hubbard Brook Experimental Forest from 1969–2010, students will identify population trends among birds, observe the value of long-term data collection and develop science process skills by designing additional studies to further investigate factors affecting bird abundance.

Specifically, students will analyze and graph data to answer the following questions:

1. How has the total abundance of birds at Hubbard Brook changed in the past 41 years? Have all of the different species of birds changed in this same way?
2. What might be the reason for this change in abundance? How could you test this to find out?
3. Is it really necessary to collect data for so long? Could we learn this same information by collecting data for a shorter time span?

Summary	Students graph long-term bird abundance data to determine trends in the bird population over the past 41 years at the Hubbard Brook Experimental Forest as well as to understand the value of long-term data collection. Additionally, students investigate whether all populations of bird species changed in this same way, seek possible explanation for population fluctuation, and develop an organized, logical approach for a future experimentation.
Subject areas	Biology, Environmental Science, Ecology
<u>Skill level</u>	Advanced
Objectives	<ul style="list-style-type: none"> • Represent data in graphs. • Interpret graphs to determine trends, if any are present. • Propose explanations and develop hypotheses for trends seen in graphs. • Identify variables affecting bird populations. • Propose testable ideas for future study.
<u>NH Science Framework Standards</u>	S:SPS1:8:4.1, S:SPS1:8:4.3, S:SPS1:11:4.1, S:SPS1:8:1.7, S:SPS1:11:1.1, S:SPS1:12:4.1 S:SPS1:8:5.3
Time	Two 40-minute class periods plus homework. If making pencil and paper graphs allow more time.
Materials	<ul style="list-style-type: none"> • Student Handout: Bye-bye Birdie? • Student Reading: Habitat Preferences of Four Bird Species • HBEF Bird Abundance Data 1969-2010.xls • Graphing software or graphing paper Optional: <ul style="list-style-type: none"> • Methods of Bird Research.pdf • Change in Bird Abundance graph.pdf • Habitat Preferences of Four Bird Species Slideshow.pdf • Paper and Pencil Graphing Instructions • Excel Graphing Instructions
Assessment	Student Handout

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Note to Teachers

Background information

The Hubbard Brook Experimental Forest (HBEF) is one of 26 “Long Term Ecological Research” sites in the United States. Located in a wide array of ecosystems, Long Term Ecological Research sites are places where scientists have collected ecological data for many years to help us understand our ecosystems, their biodiversity, and the services they provide. At Hubbard Brook, scientists began collecting precipitation, weather, and streamflow data in 1955 and since then have expanded to include studies of water and soil chemistry, vegetation, animals, soil microbes, and especially the interactions between these different components of the ecosystem. The data from Hubbard Brook are used to try to answer many different questions that help us understand how forests and the organisms living in them change over time and how the ecosystem responds to natural and human-caused disturbances, such as ice storms, forest cutting, acid rain, and climate change.

Avian ecologists (scientists who study the ecology of birds) at the Hubbard Brook Experimental Forest have been collecting data on birds for over 40 years. These scientists, along with their students and technicians, have gone out every summer since 1969 to monitor populations of over 30 bird species. This involves waking up every morning well before dawn and traveling to the far reaches of the forest to listen for, look for, and ultimately identify and count all the different birds seen in certain areas. The data collected throughout this time represent one of the longest bird studies ever conducted and have allowed scientists to try to answer questions such as: How do the population sizes of different species of birds change

over time? What types of habitats do birds favor? What types of food do they prefer to eat? Which animals prey upon birds? How does climate affect birds? Hubbard Brook researchers also mark and follow the lives of individual birds to learn about the number of eggs birds lay and how well the birds that hatch from these eggs survive into adulthood. Using these data, scientists are able to learn more about what sorts of natural or human influences affect bird populations, and why. This is an excellent example of one of the many benefits of long-term monitoring.

This lesson has three parts. As such, the student procedure and handout are each broken into three distinct parts:

- Part A asks students to graph and interpret long-term abundance data to determine if bird populations have increased, decreased, or remained stable over the past 41 years.
- In Part B students will graph and examine a smaller portion of these data to see if the same trend can be observed over a shorter period of time. The purpose of doing so is to illustrate the value of long-term data collection.
- Part C asks students to look at the abundance of individual species of birds to see if individual trends match the overall declining trend in abundance. Students will be asked to hypothesize reasons for this decline as well as to design additional studies to further investigate factors affecting bird abundance.

Introduce Lesson to Students:

1. Teachers may wish to open lesson with the following: *Starting in 1969, a team of*

scientists at the Hubbard Brook Experimental Forest started collecting data to learn about the factors that affect the population sizes of birds. Optional: teachers may wish for students to view the slide show [Methods of Bird Research](#).

2. Teachers should ask students to brainstorm a list of things that could affect population size. *Possible ideas include changes in: food abundance, predator abundance, habitat; variation in weather, changes in vegetation as forest ages (succession), natural disasters, development, etc.*

3. Next, introduce the term **variable**: *These things are called **variables**, and scientists try to understand how these variables change in relation to one another. This helps them to answer their question(s). When scientists conduct long-term studies they collect large amounts of data to understand how variables change over time.*

Part A:

How has the total abundance of birds at the Hubbard Brook Experimental Forest changed since 1969?

Discuss with students before beginning the procedure for Part A:

1. Display the Excel file [HBEF Bird Abundance Data 1969-2010](#) (in Support Materials) overhead. Ask students to look at the data table (spreadsheet) to see if any trends in the numbers can be observed. It is unlikely that someone could spot the trend by just glancing at the numbers, which is why the next step is to portray the data visually.

2. Graphs allow data to be displayed visually and allow us to see if patterns exist. Seeing data in a graph format can be a very exciting moment for scientists because it is often the first time they can see patterns that may answer their questions.

3. Students will use the data from the Excel file to construct a graph that will allow them to answer the question: **How has the total number of birds at the Hubbard Brook Experimental Forest changed over time?** (Instructions for using Excel or paper and pencil to make graphs are included at the end of this lesson.)

- Students will graph the numbers of birds observed per 10 hectares within the bird study area at Hubbard Brook. One hectare equals a 100m x100m area. Ten hectares is roughly equivalent to 19 football fields.

- What type of graph should you make? There are many different kinds of graphs, and each is appropriate for different types of data. What type of graph would be most appropriate to make with this data? *A line graph is very useful for examining the changes in one variable over time.*

Bar graphs - suitable for making comparisons among data, uses data that fit into categories, not data that are continuous (i.e.: height or weight)

Histograms - suitable for showing data in equal intervals, uses data that are continuous

Line graphs - suitable for showing change over time

Pie graphs - suitable for showing data that are parts of a whole

Part B

What is the value of long-term data collection?

Discuss with students before beginning the procedure for Part B:

1. What is the value of long-term data collection? Is it really necessary to collect data for so long? Could we learn this same information by collecting data for a shorter time span?

2. Decide whether to have students work individually or with a partner, and assign each group a subset of the data.

For example, break the data into 5-year segments:

1969–1974; 1975–1980; 1981–1986; 1987–1992; 1993–1998; 1999–2004

Part C

Are all bird species declining at Hubbard Brook? What is the reason for the fluctuations in bird populations?

Discuss with students before beginning the procedure for Part C:

You have examined the patterns of total bird abundance for the Hubbard Brook Experimental Forest and determined that the total numbers of birds have declined since 1969, but is this true for every species of bird at Hubbard Brook? You will examine four species of birds to see if each of these species follows the overall trend. What do you think causes populations to fluctuate?

(The graph showing abundance for the four species is printed on the student handout. You may also display overhead using the [Change in Bird Abundance graph](#) supplied in Support Materials. In addition, you may wish to show an optional slide show titled [Habitat Preferences of Four Bird Species](#) to provide students with images of these birds.)

Notes for specific questions:

Question 10: Students are asked to think about why the abundances of some species of birds have increased while others have sharply declined. Provide students with copies of the short reading *Habitat Preferences of Four Bird Species* (included in this lesson), which provides relevant information that will help students propose an explanation to the question asked.

Questions 11 and 12 may be eliminated or offered as “Questions for Further Study.”

Question 11 asks students to reword their idea into a hypothesis. This may be approached either from the age of the forest or from the species of bird, and should be a testable prediction (So students should make sure it is fairly specific; i.e., focus the hypothesis on one of the four bird species illustrated in the graph and described in the reading).

Question 12 is designed to help students learn how to develop a logical approach to an investigation. Field studies are incredibly complicated and teachers can decide how much depth they want for students here depending on their goals.

Part C of Question 12 asks students to list relevant variables and explain why they need to be measured. The explanation is what is important as it provides practice in identifying the relevant variables. For example, if students hypothesize that change in vegetation will affect bird abundance they should say that they need to document vegetation and number of birds. However, they also should include food abundance or temperature as other related variables to measure. When students begin to realize that many variables need to be measured to identify causes, they start to understand the strength of the scientific experiment as a tool of discovery.



Student Procedure

Part A

How has the total abundance of birds at the Hubbard Brook Experimental Forest changed since 1969?

1. Graph the data

A. Access the file [HBEF Bird Abundance Data 1969–2010](#), which contains data collected by scientists at Hubbard Brook.

B. Create a line graph that represents how the bird abundance changed over the entire study period.

2. Analyze the Graph

Examine the graph by looking at the how the slope of the line changes as the X axis increases. Use the graph to answer Questions 1 and 2 on Part A of the Student Handout.

Part B

What is the value of long-term data collection?

You will select or be assigned different time spans of data to graph, either by yourself or with a partner.

1. Graph the data

A. Access the file [HBEF Bird Abundance Data 1969–2010](#), which contains data collected by scientists at Hubbard Brook. You will only graph the data for the years you have been assigned.

B. Create a line graph of the data that represents how the bird abundance changed during your assigned date range.

2. Analyze the Graph

Examine the graph by looking at the how the slope of the line changes as the X axis increases.

A. Use the graph to answer Question 3 on the Student Handout.

B. Share your graph with the rest of the class by describing what you observe, then answer Questions 4–6 on the Student Handout.



Answer questions for Part B on page 9 before continuing with Part C of the procedure.

Part C

Have all of the populations of different bird species changed in this same way? What is the reason for the fluctuations in bird abundance?

1. Analyze the graph

Examine the graph provided on the student handout and answer Questions 7–10.

2. Design further investigations

The results of a scientific study do not supply all the answers, but serve as a starting place for more questions. Propose ideas for future bird studies at the Hubbard Brook Experimental Forest by answering Questions 11 and 12.



Student Handout: Bye-Bye Birdie?

Name _____

Part A: How has the abundance of birds changed at the Hubbard Brook Experimental Forest in the past 41 years?

1. Examine the graph you created. You will notice that there are periods of years in which abundance changes rapidly and that there are periods of years in which abundance remains relatively constant.

A. List a span of years for which you notice a rapid change in bird abundance.

B. Describe what you observed in the graph to determine this.

C. List the span of years for which you notice a slow, gradual change in bird abundance.

D. Describe what you observed in the graph to determine this.

2. In Question 1 you examined the details of the graph. Now look at the overall trend. Has the abundance of birds at Hubbard Brook increased, decreased, or remained the same during the 41-year time-span described by the graph? Describe what you observe in the graph to determine this.



*Go back to Procedure Part B on page 6
before answering the following questions.*

Part B: What is the purpose of long-term data collection?

3. A. For the time span you just graphed, do you notice a change in bird abundance?

B. Describe what you observed in the graph to determine this.

4. Look at the other graphs made by the class. Do all of the graphs show similar trends?

5. Is the 'picture' you get about bird abundance any different in the shorter-term from the longer-term data set? Describe the similarities and/or differences between the two graphs.

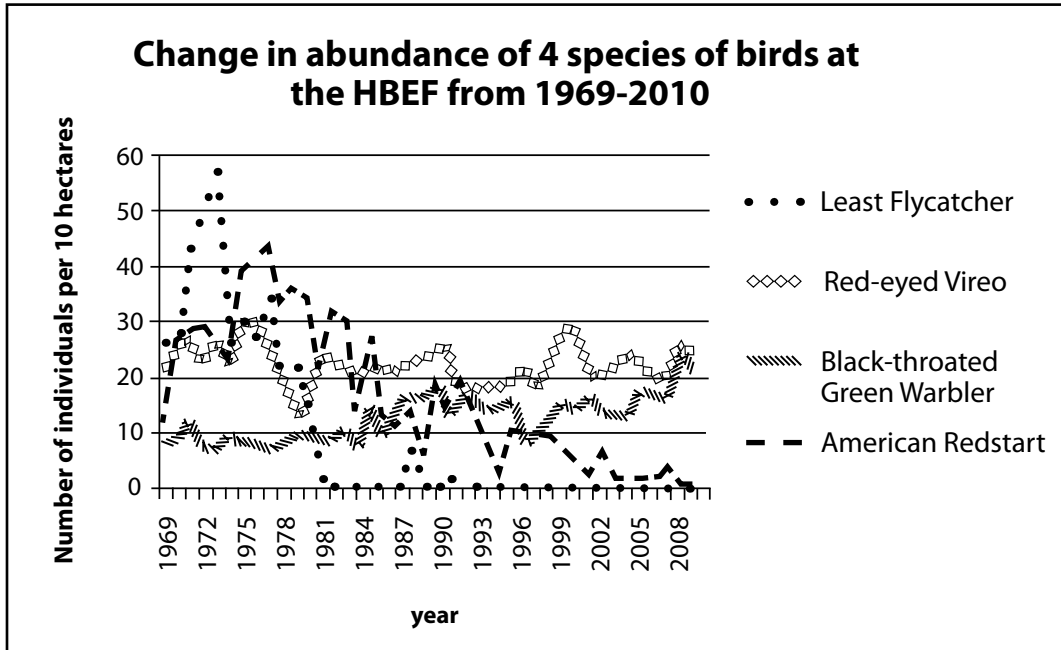
6. Think about the implications of your data analysis. What does it tell you about the importance of short-term vs. long-term data collection?



Go back to Procedure Part C on page 7 before answering the following questions..

Part C. What is the reason for the decline in bird abundance? Have all species of birds at the Hubbard Brook Experimental Forest in fact declined?

Examine the graph below, which shows patterns of bird abundance for four species of birds. Remember to notice the changes in the slope of the line.



7. In terms of overall abundance, which species have declined? Describe what you observe to determine this.

8. In terms of overall abundance, which species seems stable? Describe what you observe to determine this.

9. In terms of overall abundance, which species has increased? Describe what you observe to determine this.

10. Why do you think the abundances of some species actually increased while others have sharply declined? Read *Habitat Preferences of Four Bird Species* and use this information to support your answer.

Questions for Further Study

11. State your answer to Question 10 as a hypothesis.

12. To really understand what is going on with birds, scientists are still trying to learn why certain species of birds prefer particular habitats. What is it about a younger, shrubby forest that makes life nice for a Least Flycatcher? And why might a Black-throated Green Warbler prefer an older forest? Questions such as the following might help us understand why the abundances of different species of birds change over time:

- What types of habitats do birds favor?
- What types of food do they prefer to eat?
- What methods do they use to obtain these foods?
- Which animals prey upon birds, and how abundant are these predators?
- How does climate affect birds?
- What factors affect the reproduction of birds?

A. What is one question that you would like to investigate if you were an avian scientist at Hubbard Brook? (Either choose one question from the list above, or develop your own.)

B. Form a hypothesis to predict how this might affect bird numbers. Recall that a hypothesis predicts what you think might happen and why you think it. Also remember that this hypothesis must be testable by an experiment.

C. What variables must be measured to test your hypothesis? Choose at least three.

a. For each, explain why you included it and how it could be measured.

b. Identify the independent and dependent variables.



Student Reading

Habitat Preferences of Four Bird Species

The Hubbard Brook Experimental Forest

The Hubbard Brook Experimental Forest is a 7,800-acre tract of forest in the White Mountains of central New Hampshire that is owned and managed by the USDA Forest Service for scientific research. It was heavily logged in the early 1900s, but the most of the forest has remained relatively undisturbed since around 1915, when logging operations ended. The forest that grew up after the logging operations ended is called *second-growth forest* and contains a mixture of deciduous (about 80–90%; mostly beech, maples, and birches) and evergreen (about 10–20%; mostly hemlock, spruce, and fir) trees.

Least Flycatcher

In New England, the Least Flycatcher prefers to live in semi-open, *mid-successional forests*. The term *mid-successional* refers to forests that are still growing back after a disturbance. These forests usually consist of trees that are all about the same age, have a dense, continuous canopy at the top with few gaps, an open middle canopy, and a denser shrub layer close to the ground.

New Hampshire has had one of the most drastic statewide declines in this species since the 1960s. Recent analysis of 30 years of data from Hubbard Brook shows that Least Flycatchers, once the area's most common forest bird in the early 1970s, declined annually at 17% and are now absent locally. Researchers at the Hubbard Brook Experimental Forest hypothesize that *secondary succession* is the major cause

Glossary of Terms

Canopy - the top-most layer of vegetation in a forest. Deciduous trees- trees that lose all of their leaves for part of the year. Examples include birches and maples.

Evergreen trees - trees that have foliage year-round. Examples include pines and firs.

Old-growth forest - a forest that has reached a great age and has grown for so long that there is no trace of past large-scale disturbance.

Second-growth forest - a forest that has re-grown after a major disturbance, such as fire, wind storm, or logging operation.

Succession - a series of natural changes that occur over time after a disturbance to an ecosystem. The biotic (living) components of the ecosystem change the abiotic (physical) components of the system, thus creating changes to the environment.

Primary succession - refers to a process in an area that is starting to support life, where there is no trace of preexisting vegetation (such as an area that has been covered by a lava flow).

Secondary succession - refers to the naturally occurring changes in vegetation that happen as a community ages, after it has been disturbed.

Early successional forest - a forest that has recently been disturbed and has started to grow back. These forests are typically dominated by fast-growing, shorter-lived species.

Mid-successional forest - a forest that is still growing back after a disturbance; it has not yet reached maturity. Dominance in these forests is transitioning between species dominant in an early successional forest and those dominant in a late-successional forest.

Late-successional (mature) forest - a forest

of population decline in New Hampshire. *Secondary succession* refers to the naturally occurring changes in forest structure that happen as a forest ages after it has been cut or otherwise disturbed. It is not really known why Least Flycatchers have responded so drastically to secondary succession: they seem to have an innate “preference” for forests of a particular structure or set of characteristics. What it is about forests of this age that Least Flycatchers really prefer is still a mystery!

American Redstart

In New England, the American Redstart generally prefers moist, *deciduous, second-growth* woodlands with abundant shrubs.

American Redstarts appear to reach peak abundance in forests about 10 to 40 years after the forest has been logged. After this time, they appear to decline in older forests. The most significant declines of this bird species have occurred in northern New England (NY, VT, NH and MA). This New England decline, which was most dramatic after about 1980, appears to have resulted at least in part from changes in the structure of the forest that occurred as part of succession of the hardwood forests in this region. The maturation of these forests reduced the suitability of habitat, for unknown ecological reasons.

Black-throated Green Warbler

In New England, the Black-throated Green Warbler occupies a wide variety of habitats. It seems to prefer the transitional area between deciduous and coniferous forests (the area where hardwood forests in lower elevations transition to coniferous forests in higher elevations), but it has also been found in both forest types. Although it seems to avoid *early successional* forests, it does inhabit both middle-aged and mature forests.

Indeed, population data on the Black-throated Green Warbler outside of New England agree with this: according to one study in West Virginia, its numbers increased as a forest matured: 5 years after a forest had been logged, researchers counted only 7 male birds. When researchers returned to count again 10 years after logging, they counted 99 birds. Upon return 15 years after logging, researchers counted 42 birds. The Black-throated Green Warblers are increasing, albeit slowly, at the Hubbard Brook Experimental Forest, too.

Red-eyed Vireo

The Red-eyed Vireo breeds in deciduous forests as well as forest that are mixed with deciduous and coniferous trees. The Red-eyed Vireo is more abundant deep in the interior of a forest than near the edge of a forest, and it seems to prefer unbroken tracts of forest. Although the Red-eyed Vireo can be found near small openings in the forest canopy, such as those created by windstorms or small clear cuts (2–10 hectares, or 5–25 acres), it avoids large clear-cuts and forest fragmentation, probably because environmental conditions at the edge of its habitat are less suitable. Following a disturbance such as a large-scale clear-cut or other event that fells large areas of trees, long periods of time are often required before the Red-eyed Vireo will re-colonize a site.

Though the abundance of the Red-eyed Vireo has fluctuated at the Hubbard Brook Experimental Forest, overall it has remained fairly stable over the 41 years of study there.

References: The information above is from *The Birds of North America*, from the Cornell Lab of Ornithology and the American Ornithologists Union, accessible at <http://bna.birds.cornell.edu/bna/>.

Answer Key: Bye-Bye Birdie

Part A: How has the abundance of birds changed in the past 41 years?

1. Examine the graph you created. You will notice that there are periods of years in which abundance changes rapidly and that there are periods of years in which abundance remains relatively constant.

A. List a span of years for which you notice a rapid change in bird abundance.

Answers will vary.

B. Describe what you observed in the graph to determine this.

Steep slopes along the line these indicate a rapid change in bird abundance over a short period of time. There are large changes in values for Y axis and small changes in values for the X axis.

C. List the span of years for which you notice a slow, gradual change in bird abundance.

Answers will vary.

D. Describe what you observed in the graph to determine this.

Gradual change in the slope of the line indicates slow change over time. Students should refer to the slope of the line and perhaps include numbers to show the slow change over a long period of time. There are small changes along the Y axis and large changes along the X axis.

2. In Question 1 you examined the details of the graph. Now look at the overall trend. Has the overall total abundance of birds at Hubbard Brook increased, decreased, or remained the same during the 40-year time-span described by the graph? Describe what you observe in the graph to determine this.

Students should summarize the details they observed above to make a more general statement about the overall trend. Although there are periods of rapid change and periods of increase during the study period the overall trend shows a decrease in bird abundance.

Part B: What is the purpose of long-term data collection?

3. A. For the time span you just graphed, do you notice a change in bird abundance?

Answers will vary.

B. Describe what you observed in the graph to determine this.

Students should refer to how the slope of the line changes.

4. Look at the other graphs made by the class. Do all of the graphs show similar trends?

Students may or may not see trends, but there should be variety among students.

5. Is the 'picture' you get about bird abundance any different in the shorter-term from the longer-term data set? Describe the similarities and/or differences between the two graphs.

Answers will vary.

6. Think about the implications of your data analysis. What does it tell you about the importance of short-term vs. long-term data collection?

Data collected for a short period of time may show no pattern, or may even give an inaccurate impression of what is happening over a longer time period. Additionally, long-term data provide “background data” that can serve as a yardstick to compare current conditions to. This is important when trying to determine the effects of human or natural disturbance on an ecosystem.

**Part C. What is the reason for the decline in bird abundance?
Have all species of birds at the Hubbard Brook Experimental Forest in fact declined?**

7. In terms of overall abundance, which species have declined? Describe what you observe to determine this.

The abundances of the American Redstart and Least Flycatcher have declined. Answers will vary but should discuss the overall positive or negative slopes (trends) of the lines, as well as the ‘start’ point in 1969 and the ‘end’ point in 2010.

8. In terms of overall abundance, which species seems stable? Describe what you observe to determine this.

The abundance of the Red-eyed Vireo has fluctuated, but remained fairly stable overall.

9. In terms of overall abundance, which species has increased? Describe what you observe to determine this.

The abundance of the Black-throated Green Warbler has increased.

10. Why do you think the abundances of some species actually increased while others have sharply declined? Read *Habitat Preferences of Four Bird Species* and use this information to support your answer.

Changes in the kinds of trees and shrubs in the forest have occurred over time due to natural succession, providing different types of habitats. Because different species of bird prefer different types of habitats, the abundance of different species of birds changes over time as the forest ages. Certain birds (i.e., Least Flycatcher) prefer to nest in younger forests, which generally contain more shrubs. Other birds, such as the Black-throated Green Warbler, generally prefer middle-aged and mature forests. Some birds don’t have a strong preference, either way.

11. State your answer to Question 10 as a hypothesis

The following may help students develop hypotheses:

- *Most of the time a hypothesis is written like this: “If _____, then _____.” (Fill in the blanks with an educated guess that has to do with the fact that different species of bird prefer different types of habitats. Use what you learned from the reading.)*
- *Your hypothesis should be something that you can actually test with an experiment or study. In other words, you need to be able to measure both the ‘if’ statement and the ‘then’ statement.*

Students might approach this from the age of the forest or from the species of bird; there are many possible variations:

- *If a forest is mature, then more Black-throated Green Warblers will be found there than Least Flycatchers.*

- *If many Least Flycatchers are observed in a forest, then that forest will be a younger forest.*
- *If a forest is middle-aged, then more American Redstarts will be found there compared to a nearby, older forest.*

12. To really understand what is going on with birds, scientists are still trying to learn why certain species of birds prefer particular habitats. What is it about a younger, shrubby forest that makes life nice for a Least Flycatcher? And why might a Black-throated Green Warbler prefer an older forest? Questions such as the following might help us understand why the abundances of different species of birds change over time:

- *What types of habitats do birds favor?*
- *What types of food do they prefer to eat?*
- *What methods do they use to obtain these foods?*
- *Which animals prey upon birds, and how abundant are these predators?*
- *How does climate affect birds?*
- *What factors affect the reproduction of birds?*

A. What is one question that you would like to investigate if you were an avian scientist at Hubbard Brook? (Either choose one question from the list above, or develop your own.)

Answers will vary

B. Form a hypothesis to predict how this might affect bird numbers. Recall that a hypothesis predicts what you think might happen and why you think it. Also remember that this hypothesis must be testable by an experiment.

Answers will vary

C. What variables must be measured to test your hypothesis? Choose at least three.

Answers will vary

a. For each, explain why you included it and how it could be measured.

Answers will vary

b. Identify the independent and dependent variables.

Answers will vary



Paper and pencil graphing instructions

1. Determine the independent variable and dependent variables. The independent variable is the variable that the scientist changes or predetermines.

Example: For the Bird Abundance study, “time” was predetermined by the scientists. For example, scientists have decided (determined) to count birds every year. The dependent variable represents the observed changes that occur as the independent variable changes. For the Bird Abundance study the dependent variable is “total bird abundance.” Scientists are measuring how bird abundance changes over time.

2. Label the axes. When making a graph the Y axis represents the dependent variable and the X axis represents the independent variable.

3. Make sure the axes are labeled with appropriate units. Axes should be labeled so that it is easy to understand what variables are represented on the graph.

Using the example above, the Y-axis should be labeled “Number of Individuals” and the X axis should be labeled “Year”.

4. Give the graph a clear title that explains what the whole graph represents.

For example, one title that clearly describes the graph would be “Total Bird Abundance Between 1969 and 2010 at the Hubbard Brook Experimental Forest”.

5. Decide what type of graph is most appropriate to use with your data (line graph, bar graph, etc.) and plot your data on the graph.

Excel Graphing Instructions for Mac and PCs

The directions for making graphs using Excel (version 2008) on a Mac are as follows:

- a. Highlight the data you wish to graph. Include the column headings.
- b. Under Insert in the toolbar, select Chart.
- c. A horizontal ribbon appears under the main toolbar. At the top of this ribbon are 12 small ovals with the main graph types (bar, bubble, column, scatter, etc). Choose the type of graph you wish to make.
- d. Subtype choices sometimes appear: select the most appropriate choice.
- e. The graph is produced as you soon as graph subtype has been selected. Check to see if things are making sense.
- f. To edit things like the title, use the right-hand sidebar, called the "Formatting Palette." Inside this palette are the "Chart Options." The chart title, x-axis, and y-axis labels all appear in one drop down menu near the top of the Chart Options section, under the label "Titles."
- g. You can choose to either imbed your graph in the current sheet or to place it in a separate sheet. You have to click on the chart and then press control and click at the same time. Now select "Move Chart." A dialog box appears asking if you want it inside an existing sheet or if you want the chart to occupy a new sheet all by itself.

The directions for making the graphs using Excel (version 2007) on a PC are as follows:

- a. Highlight the data you wish to graph. Include the column headings as you highlight.
- b. Under Insert in the toolbar go to Charts.
- c. Choose the type of graph you wish to make. Subtype choices sometimes appear: select the most appropriate choice.
- d. The graph is produced as you soon as graph subtype has been selected. Check to see if things are making sense.
- e. To label chart title, x-axis and y-axis, go to Chart Layouts and click "Layout 1." Now you can insert the titles by clicking in the area that you want to insert and typing the title.
- f. By default, the graph background should be set to white, but to save printer ink, be certain of this before printing. If background is not white, click in chart area, right click, and choose "Format Chart Area." You will see a toolbar: click on the 'paint bucket' icon and choose white.
- g. Be sure to click on the chart before you print, or you will end up printing the chart with the spreadsheet of data in the background.