

A Web-Based Study of Darwin's Finches

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Abstract: This is a Web-based laboratory exercise based on the research of Peter and Rosemary Grant with the finches on Daphne Major in the Galápagos Islands. A portion of the Grants' database forms a computer program developed for the Biology Guided Inquiry Learning Environments (BGuILE) project at Northwestern University. The program can be downloaded from the website <http://www.iqwst.northwestern.edu/finchesdownload.html>. Students use actual field data and develop hypotheses to explain survival rates of birds under various climatic situations from 1977 and 1978, a period during which there were extreme climatic events on the island. Students compare their hypotheses with those published by the Grants in *Science* (Boag and Grant, 1989).

Introduction

Laboratory exercises that study evolution are some of the most challenging to develop. Frequently, teachers must resort to simulations. This activity is a Web-based laboratory exercise in which students use actual field data and develop hypotheses to explain survival rates of birds under various climatic situations.

Since 1973, the research team led by Peter and Rosemary Grant has studied the population of finches on one of the smallest Galápagos Islands, Daphne Major. During their study, they have tagged thousands of finches, primarily *Geospiza fortis* and *G. scandens*. The researchers have taken measurements of numerous morphological features of the birds, observed mating and foraging behaviors, documented offspring and recorded deaths. Their research has been reported in numerous journal articles and was described in the Pulitzer Prize winning book by Jonathan Weiner, *The Beak of the Finch* (1994).

A portion of the Grants' database is the focus of a software program developed for the Biology Guided Inquiry Learning Environments (BGuILE) project at Northwestern University. This website provides an opportunity for students to work with actual field data to study evolution. Students learn how to access information in the database. Then they study the data from 1976 through 1977, a period of extreme climatic events on the island. Students compare their hypotheses with those published by the Grant research team in *Science* and *Nature*.

This laboratory exercise provides an introduction to the topic of evolution. Students can easily see how certain traits enable birds to survive under particular climate conditions. This is not how most of

them thought about evolution prior to the exercise. In addition, it tells a good story—the work of the Grant research team is one of the most compelling ongoing research projects in biology. The exercise illustrates the organization of institutional research, showing undergraduates how the work of graduate students plays a key part of the investigative process. It can be used as a springboard to introduce genetics and systematics. Students who are interested in going beyond this exercise can read other materials, including *The Beak of the Finch* (Weiner, 1994).

This exercise is appropriate for introductory level biology classes or for non-majors biology classes. Preparation time involves downloading the program (and accompanying Teacher's Tutorial manual) from the website before the lab. The download site for the website is: <http://www.iqwst.northwestern.edu/finchesdownload.html>. Some campus networks have built-in restrictions that prevent such actions without authorization or explicit involvement of IT staff. The entire exercise as presented here can be completed in about five hours.

The objectives of this laboratory exercise are

1. to provide students with an opportunity to analyze actual field data from a large database;
2. to provide students with an opportunity to integrate data from numerous sources.

Notes for the Instructor

1. The Teacher's Tutorial for the Galápagos Finches program is included when you download the program.
2. As preparation for the laboratory exercise, students are given a short section of background and a few follow-up questions (Background Information on Daphne Major in the Student Outline section below) to read prior to lab. Although there are many websites that explain the geology and climate of the Galápagos Islands, the instructor may not want to use them explicitly to avoid accidentally exposing the students to the “answer” to the laboratory exercise.
3. The laboratory exercise begins with the viewing of a portion of the video *What Darwin Never Saw* that documents the research done by Rosemary and Peter Grant on Daphne Major. (Note: You may be able to digitize the sections of *What Darwin Never Saw* that are pertinent and burn them to a DVD. Because the extracted segments amount to less than 10 minutes, this is acceptable under the fair use practice of AV materials.) The video presents the students with the physical environment of the island and the actual work carried out in the Grants' research. Students are also provided with some initial information about the island: a map that details its primary features (Boag and Grant, 1984; Grant and Grant, 2003: 970), rainfall and temperature data (Grant, 1985), and its principle inhabitants—various species of *Geospiza* (Grant and Grant, 2003: 968). Class discussion at this point can focus on the following points:
 - What types of data do the Grants collect?
 - Why did the Grants take so many measurements of so many birds?
 - How do precision and accuracy fit into their measurements?

4. The video shows blood being drawn from the finches in the study. An explanation of how the Finch Unit has analyzed these samples can be found in Weiner (1994: 214-221). More technical information can be found in these sources: Chapter 10 of *Ecology and Evolution of Darwin's Finches* (Grant, 1986); Sato, A., Tichy, H. O'hUigin, C. Grant, P.R., Grant, B.R., and Klein, J. (2000); and Vincek, V., O'hUigin, C., Satta, Y., Takahata, N., Boag, P.T., Grant, P.R., Grant, B.R., and Klein, J. (1997).
5. Students are introduced to the major components of the database and develop familiarity with it by working in groups of two or three to find the answers to a list of questions (Introduction to the Database in Student Outline section below). These questions serve two purposes:
 - To provide students with an opportunity to learn how to use the database;
 - To focus students' attention on some aspects of the data that they might overlook later when they're working independently.

Although the Grant team conducted research on both *G. fortis* (the medium ground finch) and *G. scandens* (the cactus finch) on Daphne Major, this database only deals with *G. fortis*. For background information about the 13 species of finch found in the Galapagos, see Weiner (1994: 40-42); see also Chapter 3 of *Ecology and Evolution of Darwin's Finches* (Grant, 1986.)

6. There are some problems in the Environment section of the database. Some of these are more significant than others.
 - The amount of rainfall listed for Wet'77 is incorrect. It should be 0.25 cm, not 25 cm.
 - There is not a consistent use of significant figures.
 - There is no unit of measure provided for seed abundance. For an explanation of how the abundance of seeds is calculated, see Boag and Grant (1984). In Appendix III of that report, some of the numbers correspond with the values given in the Environment section; others don't. The unit of measure is not the *number* of seeds, but the mass of seeds in g/150m². That interpretation seems to correspond best with the Grant data. A picture of the seedcracker that was used to measure the force needed to crack a seed can be seen in *Ecology and Evolution of Darwin's Finches* (Grant, 1986: 141, Plate 44).
 - A full listing of the plants found on Daphne Major can be found in Boag and Grant (1984: 467).
 - *The Beak of the Finch* (Weiner, 1994) contains useful explanations of some of these points. There is a good explanation of how the Finch Unit carried out the seed measurements in pp. 56-58. In addition, pp. 60-65 describes the finches' problems with *Tribulus* seeds and p.74 describes their problems with *Chamaesyce* seeds.
7. Background information on finch reproduction can be found in Weiner (1994: 71-72) and Chapter 4 of *Evolutionary Dynamics of a Natural Population* (Grant, 1989).

The Grant team bands the finches as soon as possible after they are hatched and measures them when they reach adulthood. The table below identifies when the 90 finches in the database were tagged.

Table 1. Banding year of finches included in Galápagos Finches database.

Time Period	Finches Banded
Wet'73	1-45
Dry'74	46-49
Dry'75	50-54
Wet'76	55-83
Wet'78	84-90

The following finches have field notes: 1, 5, 6, 9, 10, 14, 18, 19, 20, 26, 36, 40, 42, 47, 49, 52, 54, 60, 63, 65, 69, 71, 73, and 83.

8. The introductory activity is followed by a brief discussion that includes these points:
 - Consideration of students' answers and the data they chose to address each question. Students have the opportunity to debate whether a particular data set best answers each question.
 - Discussion of the type of graphs that are used to represent the data:
 - Individual Differences—xy scatterplot; x axis is individual finches
 - Distribution—histogram
 - Relations—xy scatterplot; x axis is one of the two variables being compared
 - Number—pie chart
 - Discussion of the two query boxes:
 - The upper box that specifies HOW you want to compare data
 - The lower box that specifies WHAT you want to compare.
 - Clarification about the database. The Grants' actual database extends to over 5000 birds. The 90 birds in this exercise are a representative sample of the larger set of data.
9. This is also a time in which students can be shown how to organize their Data Log. The Data Log lets students organize the data by categorizing it with the "Category" popup menu. The categories are: Baseline, Environmental Stress, Variation and Reason for Advantage. More details about these categories are provided in the Teachers' Tutorial.
10. Once these preliminaries are completed, students are introduced to the actual research questions (Research Questions in Student Outline section below).
 - a. The first task is to develop the 1976 baseline data for three components of Daphne Major's ecosystem: rainfall, available food and finch population, including breeding and foraging behaviors of the birds. They use the data extracted from the database to compose an introductory paragraph with figures to illustrate key points.
 - b. The second task is to develop a hypothesis to explain what occurred during 1977 for the same three components of the ecosystem: rainfall, available food, and finch population. Again, they use the data from the database to compose a paragraph with illustrative figures.
 - c. The third task is to develop a hypothesis to explain what occurred during 1978, using the same components and composing a similar paragraph with illustrative figures.
11. After the students have submitted their essays, they are assigned the following article: Boag, P.T. and Grant, P.R. (1981). Intense natural selection in a population of Darwin's finches (Geospizinae) in the Galápagos. *Science*, 214, 82-84. Their assignment is to carefully read the journal article,

paying particular attention to the table and figures. They are asked to compare the conclusions reached by the authors to their own conclusions for the 1977 drought period. In the next class period, small groups of students are each assigned either a paragraph from the journal article or a table/figure. They are given some time to prepare their presentation of that segment of the report. Then, in the sequential order of the article, they explain their part of the report to the class. The point of this activity is not for them to completely understand the journal article, but to learn how to “walk an audience through the data” in a presentation.

12. As a follow-up activity, students are asked to hypothesize what would occur among the finch population if there were an increase in rainfall during a given year. Then they are assigned the following article: Gibbs, H.L. and Grant, P.R. (1987). Oscillating selection on Darwin's finches. *Nature*, 327, 511-513. In this article, the authors explain the events on Daphne Major after an exceptionally powerful El Niño event that deposited 10 times more rain on the island than normal. (Alternatively, students can read: Gibbs, H.L. and Grant, P.R. (1987). Ecological consequences of an exceptionally strong El Niño event on Darwin's finches. *Ecology*, 68, 1735-1746. This is a longer and more detailed manuscript of the same event.)
13. There is extensive primary literature reporting the Grant team's research. In addition to the sources mentioned above, the following also provide good background information: Abbott et al. (1977), Grant (2003), Grant (1981), Grant (1991), Grant and Boag (1980), Grant and Grant (1983), Grant and Grant (1993), Grant and Grant, (2002), Grant et al. (1985).



Figure 3. Daphne Major of the Galápagos Islands.



Figure 4. Aerial view of Daphne Major of the Galápagos Islands

Climate

Although the Galápagos Islands lie directly on the equator, their climate is not excessively hot. The daytime temperature in the lowlands typically reaches only 30° C (85° F). The reason for the dry and moderate climate of the islands is the Humboldt Current that carries cold water northward from the Antarctic. As it passes northern Peru, the Humboldt Current turns westward, bathing the Galápagos in cool water. From June to December, when the winds blow in a southeasterly direction, the shores of the southern islands are bathed in cool waters, chilling the air and creating unusually cool conditions for equatorial islands. During this period, rain is scarce in the coastal regions. In December, the ocean currents change, bathing the Galápagos in the warm Panama Current from the north. The rainy season, which lasts from December to June, is marked by decreased winds and warmer sea currents. The days are warm and the seas are calm during these months. The following generalization can be made about the climate of the Galápagos: June to December cool, cloudy and dry season; December to June, warm, sunny and wet season.

Questions:

1. Why would researchers select Daphne Major instead of one of the larger islands for the focus of their study?
2. What are the advantages of studying plants and animals found on an island as opposed to those on the mainland?
3. How might the organisms that colonize Daphne Major have arrived originally?
4. What precautions would researchers have to take when they conduct their work on an island such as Daphne Major?

Introduction to the Database

For each of these questions find the data that you think answers the question and determine the best way to present it. In some cases, the answer is available in the database; in other instances, you must carry out some calculations. With your partner(s), explore the database to find the answer to each question,

write out the answer in complete sentence format in Word, and insert appropriate data tables and figures where required.

Environment

1. How would you describe the rainfall pattern of Daphne Major? What is the average rainfall during the wet season on Daphne Major? Dry season?
2. Set up a table in Word that summarizes the physical characteristics of the seeds that are available to the finches on Daphne Major.
3. Contrast the availability of seeds in wet and dry seasons.

Individual Browser

Make sure you pay attention to where the cursor is on the finch identification line.

4. What is the mating history of gf 06?
5. When was gf 19 last observed?
6. What are some of the foraging behaviors that were observed for gf 47?
7. Construct a family tree for gf 20 and gf 63 and their offspring.

Compare Populations

For each of these questions, cut and paste the resulting figure into your document, using these steps:

- Right click on the row in the Data Log that you want to copy.
 - Go to File>Export Item as HTML.
 - In the dialog box, name the file specifically, click Save.
 - Right click on the graph in the box that opens. Click Copy.
 - Go to the document into which you want to add the figure. Click Paste.
8. What is the difference in weight between the finches in Wet '73 and in Dry'73?
 9. In the figure for #8, move the cursor to one of the red points on the graph. What does each red point represent? What does the green line represent?
 10. What is the difference in beak length for male and female finches in Dry '78?
 11. Compare the distribution of wing length among adult male finches who died in Dry'77 and those who survived.
 12. Compare the distribution of leg length among all adult finches in Dry'76 and Dry'77.
 13. What is the relationship between weight and beak length for fledglings and adults in Wet'77? (Fledglings are young birds that have recently acquired their flight feathers.)
 14. What is the difference between the total number of finches observed during Wet'76 and Wet'78?
 15. What is the difference between the number of male finches observed during Dry'77 and the number of females?
 16. What is the difference between the number of fledglings and adults observed during Dry'73?
 17. What is the individual beak difference between adult finches observed in Dry'77 and those in Wet'77?
 18. Compare the number of finches who survived Dry'77 and those who died in the same time period.
 19. What was the wingspan range of female finches in 1976 (Wet and Dry)?
 20. How many finches were born in Wet '78?
 21. Do females in general have bigger beaks compared to their weight than males?

Research Questions

For each of the three time periods described above, write one or two paragraphs. Be sure to include information from both the “Compare Populations” and the “Individual Browser” sections of the database to establish the baseline and to support your two hypotheses. You may also include information from the introduction that was emailed to you.

Determine the baseline situation for the finches in 1976. This includes:

- Climate conditions
- Food availability
- Population data (this includes information about breeding)

What climate event occurred on Daphne Major in 1977? How did this affect the following:

- Food availability
- The finch population (this includes information about breeding)

Develop a hypothesis that explains as specifically as possible which finches survived the climate event and which didn't.

What climate event occurred on Daphne Major in 1978? How did this affect the following:

- Food availability
- The finch population (this includes information about breeding)

Develop a hypothesis that explains as specifically as possible which finches survived the climate event and which didn't.

Materials

- Galapagos Finches software (including Teacher's Tutorial). Downloaded from <http://www.iqwst.northwestern.edu/finchesdownload.html>

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