 ***Evolution in Action:***

**OVERVIEW**

This activity serves as a supplement to the film [*The Origin of Species: The Beak of the Finch*](http://www.hhmi.org/biointeractive/origin-species-beak-finch) and provides students with the opportunity to develop their quantitative skills by analyzing a small sample of data collected by Princeton University evolutionary biologists Peter and Rosemary Grant. We will start by watching the film together. Then you work through this workbook. I will leave important hints *in italics and red* that may be helpful especially when coding in R. **You are expected to perform all analysis and visualizations in R.** *Refer to the slides adn the example R script to help guide you if you get stuck. Please make graphs nice by changing axis labels, adding color etc.*

The Grants have provided morphological measurements for a sample of 100 medium ground finches (*Geospiza fortis*) born between the years of 1973 and 1976 on the island of Daphne Major in the Galápagos archipelago. The complete data set of 100 birds, including wing length, body mass, and beak depth, is available in the csv file.

**\*You will need to submit this packet and your R script to earn credit for this lab\***

**I suggest highlighting your answers so it is easier to find in the word document.**

**KEY CONCEPTS**

Evolution by means of natural selection can only occur if heritable traits vary among individuals in a population.

Under specific environmental conditions, individuals with one form of a trait may be able to better exploit some aspects of the environment than individuals with other forms of the trait can.

Natural selection involves the differential survival and reproduction of individuals with different heritable traits.

Evolution occurs when inherited traits in a population change over successive generations.

Scientists use graphing and statistics to summarize research data and readily identify patterns, frequency distribution and trends in the data, including in ecological and population data.

**STUDENT LEARNING TARGETS**

Describe patterns in data representing the distributions of beak depth measurements in two groups of finches.

Propose hypotheses to explain the trends illustrated in the graphs, based on an understanding of natural selection.

Use descriptive statistics (mean and standard deviation) to compare and contrast two sets of similar data.

Construct scientific explanations using data in graphs as evidence for how and why some characteristics may be adaptive in certain environments.

Graph primary research data to compare two populations and appropriately label all graph components, including title, axes, units, and legend.

Identify the adaptive traits that are most important to survival under specific environmental conditions.

BACKGROUND

In 1973, Princeton University evolutionary biologists Peter and Rosemary Grant began studying the finches of the Galápagos archipelago, a group of islands about 600 miles off the coast of Ecuador. They collected thousands of measurements every year to track changes in the physical characteristics of finch populations over time. One of their major goals was to collect enough data to identify associations between environmental and evolutionary changes in finch populations.

For their study, the Grants focused on the medium ground finch (Geospiza fortis), a seed-eating species of finch on the island of Daphne Major. Every year, the Grants measured physical characteristics like wing length, body mass, tarsus length (the section of leg between the ankle and knee), and beak depth (a measure of beak size) for hundreds of individual medium ground finches (Figure 1). Small differences in these characteristics can be important for survival in different environments. In addition, these characteristics tend to vary widely within finch populations.

A bird standing on the ground

Description automatically generated with medium confidence

**Figure 1.** Diagram showing four physical characteristics that were measured in the finches.

In early 1977, a drought began on Daphne Major. This drought caused the type and abundance of food available to the finches to change rapidly. Medium ground finches prefer to eat the small, soft seeds of a bushy plant called chamaesyce (*Chamaesyce amplexicaulis*). But during the drought, chamaesyce seeds became very scarce. One of the only remaining food sources for the finches was the seeds of a plant called caltrop (*Tribulus cistoides*). Caltrop seeds are much larger and harder than chamaesyce seeds and are covered with pointy spines.

The drought lasted for 18 months and killed over 80% of the 1,200 medium ground finches on the island. The Grants were interested in determining whether there were any differences between the finches that survived the drought (survivors) and the finches that did not (nonsurvivors) — in particular, whether any physical characteristics were key to survival. To answer this question, the Grants compared the average values of different characteristics in the survivors to the average values of the same characteristics in the nonsurvivors. They then used statistical methods to determine whether the differences they found between the two groups were likely to have affected survival or just occurred by chance.

To see whether the differences you expected are supported by the data, you will explore one of the Grants’ data sets. This data is available as a .csv file for easy read in into R.

1. Describe the major environmental change on Daphne Major that took place in 1977.

Daphne Major experienced a drought in 1977, which altered the resources available to the finches on the island. Small seeds produced by vegetation such as chamaesyce became scarce which left the large, spiky seeds for the finches to eat.

1. What types of medium ground finches were more likely to survive the environmental change you described?

Ground finches with larger beaks were more likely to survive the drought because their beaks allowed them to crack open the larger seeds. Finches with smaller beaks struggled to open the seeds and therefore died off.

Load the data into R and view the data. Each column should make sense. *band\_id is a unique value for each individual we will ignore the sex of the bird for this lab.*

Do you see any patterns in the data at first glance? *Note you can click on the column headers to quickly sort data. Look for differences among morphological features.*

Non-survivors had beaks lengths that were smaller than survivors

Birds with higher body masses survived more often than birds with smaller body masses

This is a sample of only 100 birds, but we know from the film that the Grants collected data on almost the entire population of medium ground finches on Daphne Major. Most researchers typically collect data from samples rather than the entire population. Why do you think that is? What are some advantages and disadvantages of using samples in research? Note: The birds in this sample data set consist of a mix of males, females, and birds of undetermined sex.

Collecting data from samples is easier than collecting data from the entire population; it takes less time and resources. Sometimes the entire population of a species won’t be in the same location. The sample data won’t obviously match the population perfectly, but it provides a reasonable estimate.

Calculating Descriptive Statistics

You will now calculate descriptive statistics for physical characteristics in this sample of finches. **Descriptive statistics** are numbers that summarize the features of the data and their distribution. The below table lists three types ofdescriptive statistics: Sample size, mean, and standard deviation. As you’ll see by doing the calculations below, these statistics are related to each other and can reveal information not only about the sample, but also the entire population from which the sample was taken.

*I would use dplyr and group\_by to calculate the mean and standard deviation.*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Nonsurvivors** | |  |  | **Survivors** | |  |
|  | Body | Wing | Tarsus | Beak | Body | Wing | Tarsus | Beak |
|  | mass (g) | length | length | depth | mass (g) | length | length | depth |
| **Descriptive statistics** |  | (mm) | (mm) | (mm) |  | (mm) | (mm) | (mm) |
|  |  |  |  |  |  |  |  |  |
| Sample size (n) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Mean | 15.7 | 67.8 | 19.0 | 9.11 | 17.0 | 69.3 | 19.3 | 9.67 |
| Standard deviation (*sd*) | 1.36 | 2.28 | 0.837 | 0.880 | 1.76 | 2.33 | 0.858 | 0.842 |

Graphing the Data

Let’s compare the means you just calculated for the two groups using graphs. A bar graph is often a good choice for comparing a single numerical value among different groups. Make a graph for each variable and include standard deviation error bars and paste below. You should have four graphs. One for each variable: mass, wing length, tarsus length, and beak depth. Modify the graphs from default and make them look nice.

*Paste Graphs Below*

Chart, bar chart

Description automatically generated

Chart, bar chart

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*Chart, bar chart

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1. Summarize the differences between non-survivors and survivors that you observed from your graphs. Make sure to consider each of the four physical characteristics and the error bars from the previous question.

Drought survivors had two main differences. They had a bigger body mass and a bigger beak depth, but the standard deviations for these characteristics were large. Survivors also did have slightly bigger wing lengths and tarsus lengths, but the standard deviations for these characteristics were relatively smaller.

Statistics

Calculating *t* Test Statistics

We want to know whether there is a significant difference between the two means for each variable. Therefore, we will use a t-test. Perform a t-test for each variable between the birds who survived and those who did not. *We need to use the raw data to calculate these statistics (before you calculate the averages i.e., the data sheet you read into R). I recommend performing a t-test. Refer back to the previous R lesson for help and example code. Record the output in the table below. Bold and highlight any significant statistics. Remember P should be <= 0.05 to be statistically significant. Traditionally if the P value is very small you can change how you record it as follows:*

*P<0.01, p<0.001, P<0.001 This is often more accepted than writing in scientific notation.*

|  |  |
| --- | --- |
| **Characteristic** | **P Value** |
| **Body mass** | p < 0.0001 |
| **Wing length** | p < 0.01 |
| Tarsus length | p = 0.07186 |
| **Beak depth** | p < 0.01 |

Which traits are significantly different? Based on your graphs and the statistics write a sentence for each variable. ex: **“Birds that survived the drought had a larger mass than birds who did not survive (t-test, P <0.001)”.** The sentence structure is important. The subject of the sentence is bird and **not** the statistic. First describe the relationship and then put the statistics in parenthesis. Scientific writing is difficult, but following this method will make your writing more clear.

Birds that survived the drought had a larger body mass than birds who did not survive. (t-test, p < 0.0001)

Birds that survived the drought had a longer wing length than birds who did not survive. (t-test, p < 0.01)

Birds that had large tarsus lengths and birds that had small tarsus lengths both equally survived the drought. (t-test, p = 0.07186)

Birds that survived the drought had a bigger beak depth than birds who did not survive. (t-test, p < 0.01

Answer the following questions about the finches based on your analysis of the data.

* + Which of the four physical characteristics do you think were important for the finches’ survival during the drought? Explain your reasoning.

I think body mass, wing length, and beak depth were important for the finches’ survival during the drought. All had p-values that indicated that they were significant statistics.

* + Suggest a biological reason for the differences you found between the non-survivors and survivors.

Birds with bigger body masses and longer wing lengths may have been more likely to have bigger beaks, which allowed them to break open the larger, spiky seeds left by the drought.

*Is wing length related to beak depth in the survivor group? Create a figure and perform the appropriate statistical analysis. Write one sentence describing the relationship you found. If there is no relationship state that in a sentence. Both wing length and bill depth are numeric data. Based on your previous lessons how do you graph two numeric data? What type of statistic is commonly employed to test for relationships between two continuous or numeric variables? Paste your graph and report the p value and r 2 here. Make Beak depth the x variable and wing length the y variable.*

Chart, scatter chart

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p-value: 5.347e-08; p < 0.0000001 r-squared: 0.4522

Based on your results, is there an association between beak depth and wing length in this group of finches? Why or why not?

Yes, there is an association between beak depth and wing length in survivors because the p-value is extremely small, and the r-squared value suggests that 45% of wing lengths can be explained by beak depth.

Suggest a biological reason for the presence or absence of an association between beak depth and wing length in this group of finches.

Bigger beaks suggest bigger birds, which suggests bigger wing lengths. The bigger the bird, the bigger their wing lengths must be.

Imagine that the abundance of small, soft seeds resumed after the drought ended in 1978. Predict what would happen to **body mass** in this finch population over later generations. Explain your answer. (*Hint*: Think about whether and how body mass could be associated with beak depth and wing length. You can make another graph or do additional calculations to check your expectations.)

The body mass in the finch population would decrease over time because they would get outcompeted by the smaller birds. They would struggle to meet the food demands required for their size.