Example DryadLab Activity :
Why are there so many kinds of Galápagos finch?

Overview:
Students use morphological data from seminal papers to explore adaptive radiation and speciation in the Galápagos finches (*Geospinizae*).

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Derived from the BioQUEST BIRDD project (http://bioquest.org/birdd/index.php)

Instructional level:
Upper-level undergraduate

Keywords:
Subject: evolution, morphology, adaptive radiation, biogeography, competition, character displacement
Geographic: Galápagos Islands
Taxonomic: Geospiza (Galapagos finch)

Learning outcomes:
This activity is designed to give students practice in developing a hypothesis, visualization and statistical analysis of large datasets, and interpretation of the results. Students will apply their understanding of concepts in evolutionary biology, such as adaptive radiation and character displacement. In addition, this activity is designed to give students experience in group work and presentation of their work.

Duration:
120 minutes in class

Requirements:
One computer with internet access for each student group; basic data management, graphing and statistical analysis software (e.g. Excel) on each

Background:
The Galápagos finches, or Darwin's finches, are a classic model of evolution, and specifically adaptive radiation. There are 13 species of finch on the islands, but they are at once both so similar and so diverse that they have provided a fertile ground for exploring evolution since Darwin's 1835 visit. Darwin himself did not realize their role in explaining evolution until after ornithologists revealed the abundance of speciation to him; as a matter of fact, he was much more interested in the mockingbirds.

The finches are proposed to have arrived on the volcanic islands from the South American mainland and are now considered part of the tanager family rather than

the finch family. There are four genera recognized in the group, and the species occupy overlapping but distinct ecological niches. In the genus *Geospiza*, there are six species. In good times, they often eat the same foods, but in times of scarcity, each species has a specialized niche – large seeds, cactus fruits, etc. – on which they rely. Their mating behaviors, such as times and songs, differ greatly, maintaining the distinct species. The ecology of the different islands influences which species live on each island, and especially which species co-exist on an island. Gene flow between islands occurs with occasional immigrants depending on storms and the distance between islands.

This activity is based on a collection of resources called "BIRDD" assembled by the BioQUEST Curriculum Consortium. Although the original software for BIRDD is obsolete, the databases remain a valuable tool for student research. The BIRDD user manual is available in Dryad for additional information about the project including data sources, notes on measurements, and ideas for student activities. For all BIRDD content in Dryad, go to http://datadryad.org/search?query=BIRDD

This activity allows students to explore the compiled morphological data from several different studies, and provides a rich space for students to ask questions about the adaptive radiation and evolution of the Galápagos finches.

Description of activity

Students may work individually, in pairs or in small groups.

1. Give students background on Galápagos finches, possibly including activities from BIRDD: Getting to know the Galápagos Finches. [More detail needed]. Hand out:
    a. Names Used in the Darwin's Finch Data Resource
    b. How to Interpret Measurements
2. Remind the students that the Galápagos finches are notoriously difficult to tell apart by casual observation. Based on what they know about the birds' ecology and evolution, what traits might be used to distinguish between species and why? Have students propose evolutionary explanations for the diversity of Galápagos finches.
3. There are four morphological datasets at the students' disposal to test their hypotheses. Collectively, they include data on beak length, depth and width, sex, plumage, wing length, tail length, tarsus (leg) length, and middle toe length. These measurements were taken from specimens collected starting with Darwin's visit in 1835 through 1947 by different investigators. Give a background to the data in Dryad. [More detail needed]. Note that these are real data, and as a result, will be messy. Some data may be missing. Some data points may appear to be mistakes. Other data may not be helpful. Evaluating data to determine which points to keep, and what questions may be answered with the available information is an important part of this activity.

4. Provide a tutorial on performing a t-test and ANOVA in Excel [More detail needed]
5. Have different groups of students examine one or two characters from one or two species on one island. Potential questions for this activity include:
    a. What is the range of the characters for each species?
    b. Does the range vary significantly between the species?
    c. Does the range vary between members of the same species on different islands? If so, what conditions might set the range?
    d. Are there significant differences when species share territory versus where species have no overlap?
    e. [Note that the only character which has been found to be significant is beak size, however the differences between beak size in species such as *G. fortis* and *G. fuliginosa* may be quite small – on the order of millimeters, or fractions of millimeters. Differences are also highly influenced by the presence or absence of other finch species in the habitat.]
6. Have groups report their data back to the class by writing up their basic question and conclusions. Some will overlap, so combining similar questions and conclusions will help the discussion. Discuss the observations as a class before moving on to the next phase of research.
7. In the next phase, students should use the data from these datasets to explore the questions they have about the adaptive radiation and speciation of the finches. They might ask about correlations between beak and body size, the distribution of beak sizes within one species, or the differences in beak or body size of species occupying different ecological niches. Are there differences in species characters on islands where two species share territory versus islands where they do not?
8. Students should write up their results using the following prompts (available as a handout) [Questions with an asterisk (*) are aimed at DryadLab learning objectives]
    a. What question did you ask? Please specify species and island if appropriate.
    b. What data did you use to explore the question? Specify which dataset you used.
    c. ** What problems did you have with the dataset and how did you work around them?*
    d. ** What supplementary information is most important for you to be able to reuse these data effectively and with confidence?*
    e. What are your conclusions from your research? Include graphs and tables as appropriate.

f. Based on this work, how would you revise your original question or what different question would you ask?

9. Students should present their results to the class and class discussion should touch on the limitations of the data, choices of data use, analysis, or graphic representation and future directions. A suggested rubric for this activity is included in the handout.
10. After the presentations, the class might consider what kind of questions might be appropriate to ask next, and what kinds of data they would need to address those questions.

Grading Rubric

	1	2	3	4	5	Points
Group work	Individuals work independently. Little to no coordination.		Group functions, but does not exceed individual efforts.		Well coordinated efforts enhance individual contributions	
Individual work	Minimal effort, no exploration of the database options.		Good effort, exploration of database options.		Thorough exploration of the database options. Seeking additional outside information.	
Hypothesis	Unfocused question, not necessarily likely to be answered with the given data.		Thoughtful question, likely to be addressed with the given data.		Clear, focused question with multiple potential outcomes considered.	
Research	Minimal effort to address question.		Addressed question thoroughly.		Addressed question and explored different ways of analyzing the data.	
Write up	Addressed all the prompts in the form.		Clear, grammatically correct, no spelling errors.		Thoughtful, logical, well explained. No spelling or grammatical errors.	
Graphs and images	Inappropriate graph style.		Appropriate graphic		Multiple appropriate	

	Lacking or inappropriate legends and labels.		representation. Clearly labeled.		graphic representations, clearly labeled. Combination of multiple variables on graphs.	
Presentation	Lack of organization, unclear presentation. Flip or uninformed answers to audience questions.		Good presentation, appropriate images and graphs. Good responses to audience questions.		Clear, well thought out presentation. Graphs and images support argument, and are clear and well explained. Excellent presentation. Thoughtful and informed responses to audience.	
Class discussion	Basic information questions.		Thoughtful and appropriate questions about the presented research.		Questions that take the research question further or in another direction.	
Total						

Handouts:

1. Names Used in the Darwin's Finch Data Resource (from p68 BIRDD User Notes)
2. How to Interpret Measurements (from p52 BIRDD User Notes)
3. Measuring Evolution: Morphology and Adaptive Radiation in Galápagos Finches (A worksheet with questions for students to answer about their research questions, and a rubric for grading the projects).

Dryad datasets:

1. Sulloway, FJ (1982) Data from: The Beagle Collections of Darwin's Finches (Geospizinae). Bulletin of the British Museum (Natural History), Zoology series doi: 10.5061/dryad.154
2. Snodgrass RE, Heller E (1904) Data from: Papers from the Hopkins-Stanford Galápagos Expedition, 1898-99 XVI. Birds. Proceedings of the Washington Academy of Sciences doi: 10.5061/dryad.152
3. Lack D (1974) Data from: Darwin's Finches: an Essay on the General Biological Theory of Evolution. doi: 10.5061/dryad.150
4. Swarth HS (1931) Data from: The Avifauna of the Galápagos Islands. Occasional Papers of the California Academy of Sciences doi:10.5061/dryad.156

For additional information:

1. Weiner, J. 1994. *The Beak of the Finch*. Vintage Books. New York.
2. Sulloway, F.J. 1982. Darwin and His Finches: The Evolution of a Legend . J of the History of Biology Vol15(1):1-53. (http://www.sulloway.org/Finches.pdf)
3. BioQuest BIRDD User's Manual. URL