TIPS, TRICKS & TECHNIQUES

Using Life History Data to Examine Trade-Offs in Body Size and Reproductive Ability

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Abstract

Life history trade-offs provide an opportunity for students to learn about concepts in ecology, evolutionary biology, and natural history. Here I present a simple activity that I created to help students use data from museums and online life history databases to explore the relationship between body size and reproductive ability in birds. This activity, which guides students in hypothesis development and testing, data collection, and statistical analysis, is applicable to students at the high school and undergraduate levels. In addition, although I focused on birds, this activity can also be applied to other taxa where life history data are available.

Keywords: *life history; ecology; body size; reproduction.*

○ Introduction

Foundational research over the past century in ecology and evolutionary biology has shown that life history traits in many organisms are often negatively associated with each other (Stearns, 1989; Zera & Harshman, 2001). These negative associations, which are called trade-offs, are thought to result from differential evolutionary strategies that animals employ to maximize their reproductive fitness and survival (Partridge & Harvey, 1988; Zera & Harshman, 2001; Engen & Saether, 2016). For example, classic life history trade-offs include negative associations between parental investment and number of offspring an organism has, and between the lifespan of an organism and the earliest date that they can begin to reproduce (Stearns, 1989; Royle et al., 2012; Santos & Nakagawa, 2012).

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To help students explore the basics of life history trade-offs, I have developed an activity that can be employed in either high school or undergraduate science classrooms. This activity introduces students to the concept of hypothesis formation by starting with a discussion on life history trade-offs in vertebrates, and then concluding with an activity in data collection and analysis using either a natural history museum collection or an online life history database. For this activity, I focused on life history trade-offs that exist in birds, but this project can work well with other taxa including mammals, reptiles, and amphibians, if these collections or data sources are more readily available.

○ Activity Overview

To help facilitate discussion and the formation of initial hypotheses from students, this laboratory activity can start out with a lecture that introduces the basic concepts of life history trade-offs. In this lecture, students and the instructor can discuss how traits can be negatively associated with each other (as described above) and how this can affect the lifespan and reproductive success of different types of organisms. This is a common theme in many biology and ecology textbooks. One example that I have discussed in my past classes, which worked well and received positive feedback from students, is the trade-offs in parental investment vs. reproductive output—e.g., elephants rear young and produce few offspring that have relatively high survival rates, whereas salmon have no parental care and produce lots of offspring with minimal numbers that survive.

Following the completion of this mini-lecture, I would suggest that instructors place their students into groups to discuss the next

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steps of the activity. When I have previously taught this laboratory, I explained to each group that our goal for the activity is to determine whether there are life history trade-offs in birds with regard to body size and reproductive output. With this question in mind, we discussed how there are many different bird species that vary in size and abundance worldwide, and how life history trade-offs may facilitate this diversity. I then usually take time to discuss the secondary goals of this activity: to develop skills in hypothesis formation and testing, to familiarize themselves with data collection using museum specimens and online databases, and to conduct simple statistical tests to examine patterns in their data.

Another important step is for students to talk about data collection and what types of data sources and information we have on bird body size and reproductive abilities. In doing so, I have focused on explaining how all high school and college science classrooms have two options for collecting information that can be used to look at life history trade-offs. The first is collecting field data on species, though we often discuss how this may be beyond the scope of a simple laboratory activity. We also discuss how we can collect pre-existing data accessible through natural history museums and online databases.

Life History Data in Museums and Online Databases

After discussing the collection of online data on birds, I then introduce students to several databases that have life history data on bird body size and reproductive output. The best example is All About Birds, www.allaboutbirds.org, which is a product of the Cornell Lab of Ornithology. Other natural history museums also have bird and/or vertebrate life history databases; for examples, see Smithsonian Institute of Natural History for links to databases; http://vertebrates.si.edu/birds/birds_links.html.

Using the All About Birds website as a guide, I then work with each group of students to examine how they can identify birds and observe their physical characteristics or search by their body shape (https://www.allaboutbirds.org/guide/browse). In addition, I show each group that each individual bird species' profile includes a link to their life history data, including average length, wingspans, weights, and clutch size, which are all useful for our examination of trade-offs between body size and reproductive output.

Data Collection

Using the websites above, student groups then collect data that they can use to test their hypotheses about the relationship between body size and reproductive output. To facilitate this, I encourage each group to test simple hypotheses for which they do not know the outcome and that will be interesting regardless of the outcome. Depending on the class and its level, either students or instructors can generate the hypotheses. In addition, instructors can help guide which data they would like students to collect (e.g., birds from a specific area, a specific body type, or ones that are more closely related to each other), or this can be a student-generated activity.

One example that I often walk through with students is testing the relationship between body weight and the number of eggs produced each year. To date, students have reflected back in their evaluations that this was a relatively simple trade-off that they could easily understand based on looking at the bird bodies and size charts. When I teach this activity, I have student groups go to the All About Birds Search page (https://www.allaboutbirds.org/guide/search/) and collect data on the 16 most popular birds that are featured (i.e., the 16 pictures that pop up on that page). For each species, groups then collect information from the webpages and place it into a table that can be used for data analyses (see Table 1 for an example of how to do this).

Data Analysis

Following data collection, I introduce students to the concept of linear and non-linear regression and looking for correlations that may indicate if there are life history trade-offs. To do this, I explain the three basic trends that we could observe in these data: positive relationships, negative relationships, and no pattern. This discussion includes an overview of statistical correlations, an introduction to statistical programs (e.g., Microsoft Excel, R, JMP, or STATA), summary results including the coefficient of determination (R^2), and statistical significance (p-values). One potential example of the graphs that could be created can be seen in Figure 1.

Assessment Activities

Depending on the level of the activity and analyses that are completed by student groups, instructors can employ a variety of assessment tools to enhance student learning. In the courses that I have taught, I often required students to write lab reports that were formatted like mini-scientific papers. In doing so, students were challenged to find ways to incorporate relevant literature, explain why they were testing the hypotheses they chose, write methods sections that detail their research design, present results and statistical findings, and interpret these findings through a discussion

Table 1. Sample data for three of the sixteen most commonly searched bird species. I utilize median data because All About Birds lists ranges for body size and egg clutch measurements. All data collected from www.allaboutbirds.org, which is a component of the Cornell School of Ornithology.

Bird Species	Median weight of birds	Median number of eggs per clutch	Median number of broods per year	Total number of eggs per year
Northern Cardinal	45 g	3.5 eggs	1.5 broods	3.5 eggs × 1.5 broods = 5.25 eggs per year
Black-Capped Chickadee	11.5 g	7 eggs	1 brood	7 eggs × 1 brood = 7 eggs per year
Red-Tailed Hawk	995 g	3.5 eggs	1 brood	3.5 eggs × 1 brood = 3.5 eggs per year

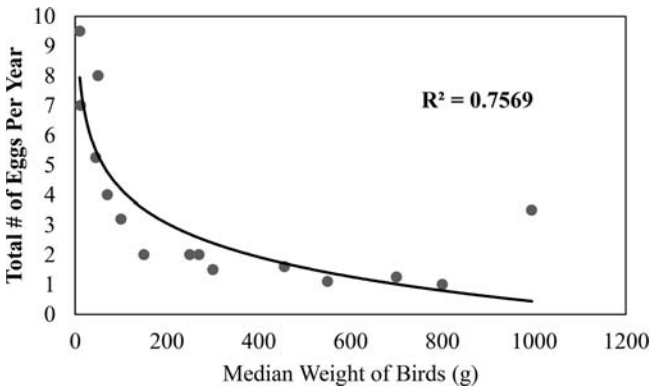

Figure 1. Hypothetical example of negative non-linear relationship between body size and number of eggs per year reproduced by bird species. Other examples could include positive linear or non-linear relationships or no relationship at all.

section. In doing so, I found that students were exposed to the process of scientific inquiry and to the idea that explaining their findings is just as important as investigating them. In lower-level courses, I have also found that quiz and test questions that require students to explain life history trade-offs and draw visual graphs or visual representations of them have been useful tools as well.

○ Conclusion

This activity has been integrated successfully into an introductory ecology undergraduate course at multiple universities and a freshman introductory biology course. In addition, a simplified version of this lab could be used in high school or upper-level ecology and evolutionary biology courses. I believe that examining these trade-offs in real species provides students with a better understanding of how different organisms may survive and coexist in their ecosystems. In addition, it helps introduce foundational concepts in ecology, evolution, and natural history. Finally, it gives students an opportunity to explore the basics of hypothesis formation and data analysis, which are critical skills for today's STEM students.

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