

ISSUES – DATA SET

Energy Balance and Trophic Status in Fish

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THE ECOLOGICAL QUESTION:

Do fish predators experience feast and famine?

ECOLOGICAL CONTENT:

animal energetics, energy balance, trophic status, feeding strategies, predator prey relations

WHAT STUDENTS DO:

Students use a spreadsheet to examine the relationship between fish with empty stomachs and their food sources.

SKILLS:

Using a spreadsheet to make a simple figure (less advanced students); sorting data and calculating simple statistics, such as mean and standard deviation (more advanced students).

ASSESSABLE OUTCOMES:

Written interpretation of a figure, and/or written explanation of the analysis results for explaining the relationship between fish with empty stomachs and their food sources, figure from spreadsheet data, written explanation of mean/standard deviation, written analysis of the published paper.

SOURCE:

Arrington, D. A., K. O. Winemiller, W. F. Loftus, and S. Akin. 2002. "How often do fishes "run on empty"? *Ecology* 83(8): 2145:2151. Ecological Archives E083-038-A1 www.esapubs.org/archive/ecol/E083/038/default.htm

OVERVIEW OF THE ECOLOGICAL BACKGROUND

This **Data Set** grew out of a similar one on lizards (Huey et al. 2001) in which proportion of animals with empty stomachs was used as an index of instantaneous energy balance. In that case, researchers wanted to know whether lizards alternate between states of feast or famine in contrast to keeping a positive energy balance.

In the present study Arrington et al. (2002) selected fish because these animals display a wide range of trophic specializations. The scientists measured the number of fish with empty stomachs in 36,875 individual fish of 254 species collected from Africa, South America, Central America, and North America. They only included samples with >10 individuals in the study; mean sample size was 145.

Arrington et al. found that percentage of piscivores with empty stomachs was significantly higher than percentages for omnivores, invertivores, and algivores/detritivores in each geographic location (ANOVA, $P < 0.005$). Invertivores had next highest proportions with empty stomachs followed by the other two categories, which were not statistically different from each other. Within the piscivores, a disproportionate number provided parental care (e.g. mouth brooding).

Arrington et al. conclude that animals able to put surplus energy into lipids and other storages can tolerate the energy costs associated with high-cost reproduction and also survive stress periods. They state that their results "reveal a potential influence of feeding frequency and energy balance on life history evolution".

In the Ecology paper Arrington et al. also include figures on Nocturnal/diurnal fishes (nocturnal fishes had more empty stomachs); African/Central & South/North American fishes (same pattern); and piscivore "biters" vs. "engulfers" (biters had fewer empty stomachs).

References:

Arrington, D. A., K. O. Winemiller, W. F. Loftus, and S. Akin. 2002. "How often do fishes "run on empty"? *Ecology* 83 (8): 2145:2151.

Huey, R. B., E. R. Pianka, and L. J. Vitt. 2001. How often do lizards "run on empty"? *Ecology* 82: 1-7.

STUDENT INSTRUCTIONS

Background information:

This is a data set from this paper: D. A. Arrington, K. O. Winemiller, W. F. Loftus, and S. Akin. 2002. "How often do fishes 'run on empty'? *Ecology* 83 (8): 2145:2151.

This study grew out of a similar one on lizards in which the proportion of animals with empty stomachs was used as an index of "instantaneous energy balance". In that study the researchers wanted to know whether lizards alternate between states of feast or famine in contrast to keeping a positive energy balance (which means they consume more energy than they use) all the time.

Arrington et al. (2002) wanted to look at the energy balance question with animals with different feeding modes - such as ones that eat insects vs. ones that eat other animals. They used fish in their study because these animals display a wide range of trophic (feeding) specializations. They measured the number of fish with empty stomachs in a very large data set - 36,875 individual fish of 254 species collected from Africa, South America, Central America, and North America. They only included samples with >10 individuals in the study; average sample size was 145.

The researchers examined the relationship between "trophic status" (what an animal eats) and number of fish with empty stomachs. (Since they were looking at the feast vs. famine question, they were interested in fish with empty stomachs). They classified fish into 4 categories - piscivores (carnivores that eat other fish), omnivores (eat everything), invertivores (eat invertebrate animals), and algivores/detritivores (eat algae and detritus).

They also looked at reproductive behavior of the fish and found that within the piscivores a disproportionate number provided parental care (e.g. mouth brooding - the fish takes care of baby fish in its mouth! This certainly would limit what the fish could eat).

Arrington et al. conclude that animals able to put surplus energy into lipids and other storages can tolerate the energy costs associated with high-cost reproduction and also survive stress periods. (Under which of the four feeding strategy would fish more likely be able to store fats? Which fish have "high-cost" feeding strategies). They state that their results "reveal a potential influence of feeding frequency and energy balance on life history evolution."

With the instructions below you will be able to make your own figure (graph) of the empty stomach/feeding strategy data.

Using the Excel file to make a simple figure:

1. Go over the Excel spreadsheet to make sure you understand the headings, the terms, and the question that the scientists were asking.
2. Next, highlight the columns from the words "Trophic Category" and Percent" down to the end of the numbers.
3. To make this bar graph figure, click on "Chart Wizard" and select Column and then Clustered Column with 3-D.
4. Label the x and y axis; increase the font size so that you can read it well.
5. After the figure appears on your sheet, widen it by using the "stretch-out" feature at the top and bottom right side of the graph; also get rid of the "series" box by clicking on it and selecting "delete".
6. Now examine the figure to interpret the data. What are your conclusions? Is there anything more you would like to know? How else could you plot these data to make a "neater" graph.

NOTES TO FACULTY

How to use this data set in a class:

This is a good data set to use in a discussion of feeding "strategies," e.g., trade-offs for predators vs. herbivores. The data concern energy balances in animals that have different feedings behaviors (diurnal/nocturnal) and different diets (e.g., carnivore/detritivore) - and therefore with different feeding-behavior strategies and life history evolution. It is also useful for instruction about the use of Excel to make figures because the data set is not very large.

In regard to sampling and statistics, these data can also lead to discussion about means, standard deviation and standard error, and statistical differences. Despite the wide range in the data, piscivores were statistically different than the rest because of the large sample size. As a specific Excel skill, students could also learn how to sort with the unsorted data.

There are four Excel files:

- Complete Sorted Data Set (fishdata1.xls): lists Order, Family, Species, Collection location, Nocturnal/Diurnal feeding behavior, trophic category (insectivore, omnivore, algal/detritivore, piscivore), Number of individuals analyzed, and Percent with empty stomachs.
- Simplified Students' Data Set (fishdata2.xls); lists Nocturnal/Diurnal feeding behavior, Trophic category, Number of individuals analyzed, and percent with empty stomachs.
- Very Simplified Students' Data Set (fishdata3.xls): lists Trophic category and Percent with empty stomachs.
- Faculty Data Set Version (with figure; fishdatafaculty.xls); lists Trophic category and Percent with empty stomachs; includes table with mean percent for each of the 4 trophic categories, standard deviation and standard error plus figure showing means and standard deviations.

If you want your students to learn how to sort data and calculate standard deviations and standard errors, give them the complete sorted data set (no. 1 above). Otherwise give them one of the sorted data sets (no. 2 or 3 above) or rework the file (e.g. calculate standard error) as you wish.

To introduce your students to standard deviation and/or standard error, the Resources section of this Data Set list websites that explain these statistics. You can use them to make a hand-out for your students or you can direct them to a site that you like. To save time in class or lab, have students learn to use Excel to calculate mean, stdev. and s.e. as homework.

Making and Using Figures:

The Resource section includes URLs for a variety of Excel tutorials. Because it took me a long time to figure out how to make standard deviations on a Mac, I include these directions here.

The steps to the completed figure (for a Mac) are:

1. Sort the data by trophic category
2. Calculate mean percent for each category and create new 4 row table on the spreadsheet (see C and D6-D9).
3. Use STDEV command to calculate standard error for each mean.
4. Calculate standard error as standard deviation/square root of N.
5. Select first trophic category and respective mean (e.g. 2 cells), then select Chart Wizard and Column subtype. On the new figure place the mouse at the top of the column to get the "Format Data Series" menu; select Y Error Bars. Then select "Custom" and type in the standard error values in the + and - boxes. Repeat for each trophic category one by one.
6. Label axes.

You can have students discuss their figures in a variety of ways. For instance students can work together in small groups (2-3) with Excel to create the figure and then discuss its implications together. In a small-medium size class each group can present their ideas and questions to the class; for larger classes or to take less time you can call on a group randomly to start off the discussion.

Student figures.

The Student Instructions show students how to make the simplest figure in which each individual data point is shown. For this they do not need to calculate mean or standard deviation. If you have little time, this figure will allow discussion of the main finding and also variability in the data and how to address this in general.

To use the data for a class on mean, standard deviation, and standard error give students the table with these data. Alternatively they can do the sorting and the calculations if you give them the equations.

Questions for discussion

1. Arrington et al. say in their conclusion "...our results reveal a potential influence of feeding strategy and energy balance on life history evolution." Explain.
2. What further questions do you have after examining this data set and what follow-up research would you suggest to address these questions?.
3. What are the advantages/disadvantages for fish of a diet of algae and detritus vs. carnivorous diet?
4. Arrington et al. looked at over 35,000 individual fish in this study. How does this large sample size influence interpretation of the data and also statistical analysis? How might the conclusions be different if the sample size was much smaller?

Assessment

To assess your students' learning you need to figure out what you most want them to learn (e.g. how to use Excel, the definition and utility of standard deviation, trade-offs for animals from different trophic levels.). A rich discussion on this topic appears elsewhere in TIEE in a paper on Assessment and Evaluation.

Assessable tasks include written answers to one or more of the questions above or creation of new figures with Excel.

Resources to Help Students Analyze these Data Sets

Sites with Excel tutorials:

- www.usd.edu/trio/tut/excel/ - basic information - how to use functions, filling down, formatting, inserting, graphs and graphing
- homepage.cs.uri.edu/tutorials/csc101/pc/excel97/excel.html - basic - from "what is excel?" to "creating charts"; copyright of University of RI Computer Science Dept.
- www.fgcu.edu/support/office2000/excel/ - Florida Gulf Coast University; basic - includes visuals.
- www.baycongroup.com/el0.htm - a lot of introductory information; BayCon Group - commercial site.

Standard Deviation and Standard Error Tutorials:

- www.beyondtechnology.com/tips016.shtml - How to calculate SD on Excel; Beyond Technology site.
- score.kings.k12.ca.us/lessons/standdev.html - SD internet tutorials for students; SCORE mathematics.
- mathcentral.uregina.ca/RR/database/RR.09.95/weston2.html - SD - Math Central, University of Regina.
- mathforum.org/library/drmath/view/52739.html - SD - Ask Dr, Math: The Math Forum @Drexel University.
- www.footballguys.com/shickstandard_1.htm - SD -football example: footballguys.com.
- davidmlane.com/hyperstat/A103397.html - mean, SD, SE; HyperStat Online Contents.
- www.animatedsoftware.com/statglos/sgstdev.htm - SD, SE: Internet Glossary of Statistical Terms - cute but visual.
- faculty.vassar.edu/lowry/dist.html - SE, Vassar Stats exercise.
- www.utexas.edu/cc/faqs/stat/general/gen9.html - SE with tree example; U Texas.

Ecological Archives:

- www.esapubs.org/archive/