Data Activity: Student Handout

Is bigger always better? An investigation on the effect of drought on different sizes of trees

Introduction

Forests are vital ecosystems for our planet as they provide food and shelter to a vast diversity of organisms. Humans greatly benefit from forests because they provide us with many goods (e.g., lumber and food), services vital for life (e.g., carbon sequestration and oxygen production through photosynthesis), as well as cultural and aesthetic benefits. To protect these important benefits, it is essential that forests remain intact and be fully functioning ecosystems. Scientists are working to identify factors that threaten forest survival and integrity.

One aspect of a forest that creates the variety of benefits listed above is the structural complexity of the forest, which describes the three-dimensional structure in a forest. For example, vegetation of varying heights provides greater variation in three-dimensional structure. Structural complexity is enhanced with increased diversity of tree species of different age/size classes in the forest. The natural distribution of tree sizes in a forest is often skewed, where there are many individuals that are small and few individuals that are large. Despite the low abundance of larger trees, they can have greater impact in the forest than smaller trees. For example, since large trees are established in the forest canopy, they can change the microclimate around themselves by providing shade and reduced temperatures. Large trees can also be reliable fruit producers, and they create their own disturbance when they fall by opening large patches of higher light availability. When some individuals have a greater impact than their abundance would dictate, these individuals are referred to as keystone individuals. Given their influence, larger trees are important for maintaining a functionally diverse forest ecosystem.

The occurrence and type of forest will depend on the environmental conditions of a region. Although random events, like drought, can cause mortality, that mortality will not be significant in the long-term health of the ecosystem if those events are short-lived and infrequent. Conversely, the shifting, or long-term changing of environmental variables can play a vital role in the survival, and distribution, of a species, especially when they cannot relocate to a more hospitable environment. When species are sessile, like plants, they have to either adapt to the new conditions or risk death. Additionally, biotic interactions within the forest can also change with the environment, which may cause further negative effects.

To begin this activity, you will first watch the HHMI's Scientists at Work video following Liz Hadley, a scientist who has been studying biodiversity in Yellowstone National Park for 30 years. During this time, she has observed significant changes to the abiotic and biotic environment as a result of climate change. Increased temperature has resulted in prolonged dry periods causing some ponds to shrink or disappear, thereby having a huge negative impact on amphibian diversity and abundance. Additionally, increased temperatures are allowing for expansion of the Mountain Pine Beetle's distribution and preventing annual winter beetle die-off, resulting in higher rates of beetle infestation in the area. Increased temperature and drought are not isolated to the National Park, but are pervasive problems throughout the western United States.

After you watch the video, you will then investigate the effect of drought on the mortality and growth of various-sized trees in a diversity of forests. Data were collected from different drought events in different locations around the world. You will analyze the data to determine if these events had a significant effect on the size distribution of trees in forests. You will then extrapolate this information to draw inferences about the effect of long-term drought conditions, which is one effect of climate change.

Background

To explore the effects of drought on forest structure, you will be analyzing data from the Bennett et al. (2015), which compiled data from various worldwide drought events. and their subsequent tree mortality and growth rate. The tree-size data have been compressed into tree size *categories* based on tree diameter at breast height (DBH; Figure 1), a common measurement of tree size. The data includes tree mortality and growth rate, as well as the presence or absence of bark beetles to examine the role insects have in tree survival.

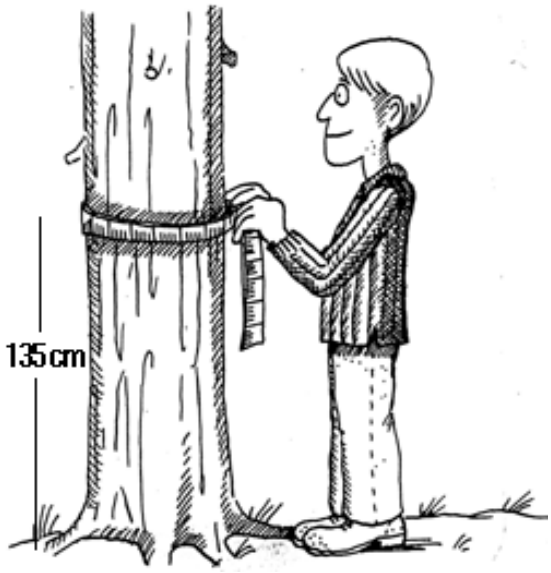

Figure 1. Demonstration of the diameter at breast height (DBH) measurement. The circumference of the tree is measured approximately 4.5 feet (135 cm) from the ground and then converted to a diameter (source: archive.epa.gov)

Video and Questions

Video: Liz Hadley tracks the impact of climate change in Yellowstone

After watching the video, answer the following questions:

1. Dr. Liz Hadley has been studying biodiversity in Yellowstone for 30 years. What is a benefit to a long-term study such as this?
2. Why is the whitebark pine important to the grizzly bear?
3. How do grizzly bears access the seeds of the whitebark pine?
4. Describe what the mountain pine beetle does and why the species is of concern.
5. How has climate change affected the survival of the mountain pine beetle?
6. Describe the effect of drying ponds on wildlife. What species are most affected?
7. Write a brief paragraph on the importance of national parks at both the local level and the global level.

Activity Assignment

Using authentic data, you will analyze the mortality rate by tree size, mortality rate by bark beetle presence, and growth rate by tree size. You will first visualize the data by creating graphs and calculating standard deviation and standard error, and then analyze the data to determine if there is a statistically significant difference between the tree size categories.

1. Using the information from the video, formulate a hypothesis to describe mortality rate based on tree size.

2. Based on your hypothesis above, draw a graph of what you predict to see in the data.

3. Using Microsoft Excel, import the data and review it. From the File menu, select Import for a CSV file. The data is delimited by comma. You should have five columns of data.

   How many variables are there? Are the variables continuous or discrete? What units are used? Make sure you understand what was measured.

4. Once you view and understand the data, you can start to condense and visualize it. Before making a graph, however, you need to sort your data by size category. I recommend using the "Sort" option under the Data tab, then copying the data for each size category into separate columns (see example below).

Example of sorted data:

1	10	20	30	40	50
3.19	3.35	3.7	3.28	6.9	56.79
4.14	9.71	10.7	44.36	19.3	19.54
10.57	4.54	5.5	6.54	5.4	12.48
13.85	8.88	10.69	5.25	10.51	2.96
2.6	1.84	3.36	1.8	3.94	3.6
2.18	2.33	43.95	80.1	12.74	3.07
18.92	27.45	6.11	15.79	7.03	3.09
25.26	2.8	3.21	3.16	15.26	1.38
1.7	2.15	2.1	26.32	4.21	2.8
2.19	2.98	73.91	50	14.29	15.2
0.81	1.81	81.45	27.15	40	14.96

Using the Insert - Chart function in Microsoft Excel, create a graph of the mortality rate for each size class of tree. Don't forget to add labels to your X- and Y-axes! You can do this in Excel using "Add Chart Element" under the "Chart Design" tab.

Which type of graph (bar/line graph) is best for this visualization? _____

Which variable is the dependent variable? _____

Which variable is the independent variable? _____

Describe any pattern or trends you see in the graph.

5. Now we want to examine the *variation* in the data, or the spread of the data around the mean. Standard deviation provides this measurement. If the data is variable, then there is low precision. Calculate and record the standard deviation for each size category (if you need additional help please see pages 8-11 in Data and Error Analysis in Science).

   Size category: 1 = _____, 10 = _____, 20 = _____, 30 = _____, 40 = _____, 50 = _____

   Does there appear to be low or high variability in the data? Explain.

6. Another common data measurement is standard error. This calculation provides an estimate of how close your sample mean is to the actual mean, or in other words, the accuracy of your data (for further description see page 12 in Data and Error Analysis in Science). Calculate and record the standard error for each size category.

   Size category: 1 = _____, 10 = _____, 20 = _____, 30 = _____, 40 = _____, 50 = _____

   Does the data appear to be accurate? What could a scientist do to reduce the amount of standard error in a data set?

7. Let's visualize *standard error* on your graph. In Excel, go to "Add Chart Element" under the "Chart Design" tab. In the Error Bars tab, select "more options" in order to choose your Custom standard errors that you calculated.

8. Visualizing the data can provide an idea of what groups might be different but a statistical test is the only way to determine *significant* differences. *Data significance* means that the differences between groups is not due to chance and could be biologically relevant. One challenge of analyzing data is to choose the correct statistical test. In this case, the data is comparing mortality among multiple groups (tree sizes). Because we are comparing multiple groups, a common test to use is an Analysis of Variance (ANOVA).

   In the Data Analysis add-on for Excel, choose ANOVA: Single Factor test. Your input range is the data that you organized into columns for each size category (from Question 4). Make sure the Columns option is selected to describe how the data is grouped. Keep the Alpha value at 0.05, as is standard in biology. The alpha value is also called the significance level, and represents the probability of rejecting the null hypothesis when it is true.

   Fill in the values below with the results of your ANOVA.

   df = _____, F-value = _____, p-value = _____

   Based on the results of your ANOVA, what can you conclude based on your hypothesis? Is there a statistically significant difference in mortality among the tree size categories?

9. Now you will examine tree mortality with the additional variable of bark beetle presence. As you saw in the Liz Hadley video, bark beetle infestation can have a considerable effect on the health of the trees in an ecosystem. Using Excel, create one graph that separates mortality rate by tree size category between those locations with bark beetles present and those locations where they are absent. Make sure to calculate the standard error for each average and add them to the graph.

10. Explain the mortality pattern you see in the graph between trees with bark beetles and trees without bark beetles. Do you think bark beetles play a substantial role in tree mortality?

Mortality is an obvious negative consequence to environmental change. However, if the drought is not so severe as to cause mortality, a tree can be impacted in other way such as in their growth or reproduction. Slower growth is predicted during environmentally stressful conditions, of which drought can be considered as a stressful condition. In this section, you will examine the impact of drought on tree growth rate and determine if there is a difference based on the size of the tree.

11. Using the same data set but focusing on the **Growth** rate values instead of the Mortality values, sort the data based on tree size category as you did in Question 4. Create a graph of the average growth rate per size category and describe any patterns you see.

12. Now, calculate standard error and add the error bars to your graph. Does your data appear to be reliable?

13. List the sample size for each size category.

    Size category: 1 = _____, 10 = _____, 20 = _____, 30 = _____, 40 = _____, 50 = _____

14. If the low sample sizes were increased, predict how the graph may look instead.

Conclusions

Using your knowledge on the importance of a structurally diverse forest, what can you infer from your analysis regarding the future of the forest structure with respect to prolonged drought? In your answer, consider tree size and beetle presence. What impact could change to the forest structure have on forest animals?

Using your local habitat, design an experiment that would allow you to more directly measure the effect of long-term drought on forest health.

Create a conservation management plan to protect large trees in light of impending climate change.

References

Bennett, A.C., McDowell, N.G., Allen, C.D., Anderson-Teixeira, K.J. 2015. Larger trees suffer most during drought in forests worldwide. *Nature Plants.*

Bennett AC, McDowell NG, Allen CD, Anderson-Teixeira KJ Data from: Larger trees suffer most during drought in forests worldwide. Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.2v8p8

Figure 1. United States Environmental Protection Agency. Virtual Field Reference Database. https://archive.epa.gov/esd/land-sci/lcb/nrb/VFRDB/web/html/glossary.html

Liz Hadly tracks the impact of climate change in Yellowstone. HHMI BioInteractive Scientists at Work. https://www.biointeractive.org/classroom-resources/liz-hadly-tracks-impact-climate-change-yellowstone