K-12 Partnership Lesson Plan

What to do with all these data?

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Overview

This session gives teachers the tools they need to analyze data collected on the plots – both graphically and statistically. Using treatments from the Long Term Ecological Research (LTER) sites at KBS that parallel our schoolyard BEST Plots, this lesson will use raw data to answer scientific questions - how does nitrogen fertilization affects plant diversity and productivity? We will compare nitrogen fertilization plots and control plots with no fertilization additions and analyze plant diversity and productivity, and how this relationship changes over time. During this session, we will cover the steps of the scientific method, including data collection, analysis, and interpretation.

Objectives

At the conclusion of the lesson, students will be able to:

- Test hypotheses using data collected from scientific experiments
- Understand the importance of replication in experimentation
- Use Excel to calculate averages, variances, and standard errors
- Use Excel to plot graphs (bar graphs and scatter plots)
- Analyze data statistically using t-test and correlation/regression
- Interpret experimental results and draw conclusions from their data

Length of Lesson

This lesson will take two class periods, or about 2 hours

- First class period:
    - 25 minutes of background
    - 35 minutes plotting graphs in Excel
- Second class period:
    - 30 minutes conducting statistical analyses
    - 15 minutes to work as groups and discuss results
    - 15 minutes to discuss results as a class

Grade Levels

This lesson is appropriate for a variety of grade levels, including upper middle school and high school classes. The level of statistics could be tailored to the class and age group. Graphing exercises could be used for middle school, and more advanced statistics could be added for high school classes or AP classes.

Standards Covered

B1.1B Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis,

logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.
B1.1E Describe a reason for a given conclusion using evidence from an investigation.
B1.1h Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.
B1.2D Evaluate scientific explanations in a peer review process or discussion format.
S1.2.1 Calculate and interpret measures of center including: mean, median, and mode; explain uses, advantage and disadvantages of each ensure given a particular set of data and its context.
S.1.2.3 Compute and interpret measures of variation, including percentiles, quartiles, interquartile range, variance, and standard deviation.
S.2.1.2 Given a scatter plot, identify patterns, clusters, and outliers. Recognize no correlation, weak correlation, and strong correlation.
S.2.1.3 Estimate and interpret Pearson's correlation coefficient for a scatter plot of a bivariate data set. Recognize that correlation measures the strength of linear association.
S2.1.4 Differentiate between correlation and causation. Know that a strong correlation does not imply a cause-and-effect relationship. Recognize the role of lurking variables in correlation.

Materials

- Raw data set from the LTER fertilization experiment or BEST Plots
- Computers with Microsoft Office Excel
- Statistics package for Excel

Background

It may seem obvious that as we apply fertilizer, such as nitrogen, plants will grow larger and produce more flowers and seeds. Plants need nitrogen for many of their cell structures, such as proteins, DNA, and chlorophyll. However, less obvious is the fact that plant's responses to fertilizer may not be the same among species. For example, grass species need high levels of nitrogen to grow at their peak levels; this is why corn crops need such high levels of fertilizer, and why we need to add so much fertilizer to our lawns to keep them healthy. Other plant species, such as legumes, have other sources of nitrogen and do not depend heavily on nitrogen in the soil. Legumes have symbiotic rhizobia bacteria living in their roots that can fix nitrogen from the atmosphere and trades it with the plant.

What will happen to diversity and productivity when we add nitrogen fertilizer to communities of plants? While fertilization should benefit all species, it will not benefit all species equally. We can now look at data from different functional groups of plants to see how diversity and productivity has changed over time.

In this lesson, students will have the opportunity to graph and perform statistical tests on two types of data: categorical data with data on functional group performance in 2003, and continuous data with the change in functional group performance over time. T-test is used to determine if two categorical groups are different (e.g. no nitrogen addition vs. nitrogen addition). Correlation/regression examines the relationship between two continuous variables (year vs. biomass).

Activities of the Session

1. Introduce the big questions in ecology that we can address with our data - diversity, productivity, and coexistence. How are many species able to coexist in a community together? Why don't certain species take over an ecosystem and lower diversity? What mix of species will make our plots most productive for bioenergy production?

2. Discuss how nutrients affect plant productivity. It is clear that plants benefit from fertilization. Grow larger, produce more seeds and fruits, photosynthesize faster...
3. However, all plants do not respond the same way to fertilization. Some plants benefit more than others. We can break plants down into "functional groups" that respond to nitrogen fertilization in different ways:
    - Grasses - grow very quickly and require high amounts of nitrogen. This is why farmers need to apply high rates of fertilizer when they grow corn.
    - Legumes - have rhizobia mutualist growing on their roots that fix atmospheric nitrogen. Therefore, they do not rely exclusively on nitrogen in the soil and have another source compared to other functional groups. This means that legumes are not usually limited by nitrogen and do not benefit as greatly from fertilization.
    - Forbs - a variable group. Should have intermediate nitrogen needs compared to the other groups.
4. Discuss the question: If fertilization affects different groups of plants in different ways, what do you predict fertilization will do to species richness (# species)? Any prediction that students have at this point would be acceptable. A list of potential predictions is below:
    - Diversity will go up with nitrogen fertilization. The species that did well with low nitrogen will continue to do well, while even more species will be able to grow now that there are more resources available (ex. legumes will stay the same, while more grass species come in).
    - Diversity will stay the same when you add nitrogen fertilizer. Some plant species will do better, and some will do worse, but the overall number of species will stay the same (ex. legume species will become more rare while grass species become more common).
    - Diversity will go down with nitrogen fertilization. Some species will drop out of the community because they can no longer compete (ex. legumes will disappear from the community and grass species will stay at the same level).
5. Share the questions students will be able to address with the data we have from the LTER
    - How does nutrient addition affect diversity and productivity?
    - Does nutrient addition affect diversity and productivity of groups of plants in different ways?
6. Introduce the LTER experimental design. Point out there are six replicates, which are necessary for conducting statistical tests later. Discuss with students the importance of replication when conducting experiments (for reliability of results due to variation found in nature and measurement error, confidence in your estimate of the mean, and performance of statistical tests).
7. Optional: Discuss which treatments in the BEST Plots mirror the LTER. This will be useful when you are analyzing the plot data for nutrient addition plots
8. Introduce the LTER data set. Go over column headings and what is in each tab of the Excel sheet. Show the full data set, but then explain how that full data set has been condensed.
9. Introduce the question of the day to address as a group: Do grasses and legumes respond differently to N addition? Divide the class into four groups and each group will be responsible to analyze two sets of data (2003 data and 1989-2003 data). Four groups are: grass richness, grass biomass, legume richness and legume biomass.
10. Demonstrate how to plot bar graphs to examine each variable (richness or biomass) under nitrogen addition and no nitrogen addition treatment.
    - In Excel, show students how to calculate average and standard deviation.
    - In Excel, demonstrate how to plot bar graphs and how to add error bars.
11. Have each group work independently to calculate average and standard deviation of each response variable and plot bar graphs.
12. Ask students if they see any pattern, based on bar graphs and how we can tell if there are any differences between no nitrogen additions versus nitrogen addition plots. Also, discuss the importance of replication and the concept of outlier.
13. Explain the basic concept behind T-test and demonstrate how to analyze the data using T-test in Excel.

14. Have each group analyze their data using T-test and report the results to the class. Based on the data, draw conclusion about whether grasses and legumes respond differently to N addition.
15. Discuss if you expect this pattern to be consistent over time.
16. Using 1989-2003 data, demonstrate how to make scatter plots in Excel. Explain how to analyze the data using correlation and regression.
17. Each group plots the data in scatter plots and analyzes it using correlation/regression in Excel.
18. Discuss the results as a class and address the original question: “Do grasses and legumes respond differently to N addition?”

Resources

- Raw data from the LTER available upon request.
- Data from the BEST experiments available at”
    - *Plant biodiversity:* https://docs.google.com/spreadsheet/ccc?pli=1&key=0Aik4wLybTNMcdDhldnV2clJTcnViWG5fRERMS0VQRkE&authkey=CO6F6OsJ#gid=0
    - *Plant productivity:* https://docs.google.com/spreadsheet/ccc?key=0Aik4wLybTNMcdDBKNmJOblFXaVV6d3dtTmNOUlhPWGc&authkey=CNGu96sF#gid=0

Extensions and Modifications

This lesson can be modified for a variety of grade levels. Practice with hypothesis testing and graphing of data could be appropriate for any grade level. Focusing on the 2003 data alone would make this lesson appropriate for early middle school science classes. Focusing on the data over time could be used as a graphing exercise for upper middle and high school classes. Statistics could be introduced for high school and AP classes.

Additionally, this lesson could be modified to use data collected in the mixed prairie plots in the BEST plots. A comparable set of data from this experiment would be the mixed prairie *non-fertilized* non-harvested plots, versus the mixed prairie *fertilized* non-harvested plots.

Assessment

Student understanding can be assessed by their graphs, accuracy of statistical test output, and their interpretation of the results from the data. Have students print their graphs from Excel or email them to the teacher. Send statistical results and a paragraph about what those results mean for the scientific questions.