Fundamentals of Ecology

Spring 2015

Laboratory Reference

Authors: EVSC 3201 Lab

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How to use this reference:

This is a reference for the website. The website and communication from your instructor are the primary sources for information related to this course, and therefore supersede information contained in this document. The material in this document may change and an updated weblog of changes will be maintained at this webpage.

Where possible, sections headers of this reference are hyperlinked to the associated web page on the laboratory website.

Your instructor's expectations and due dates may differ from those listed here.

This is reference is intended to help provide a document accessible offline that can assist with background information for your lab reports and assignments.

Please notify aslatosky@virginia.edu about any typos or errors you encounter! Provide the section title and header and an image or copy of the text in question.

This syllabus is subject to change by your instructor

Syllabus: Fundamentals of Ecology Lab

EVSC 3201

Section ___ Sessions____

Spring 2015

Instructor: _____ **Office**: _____

E-mail: _____ **Office Hours:** _____

or by appointment

General Information:

This is a laboratory course companion to EVSC 3200, Fundamentals of Ecology. Although the courses are related, the topics we will be investigating in the lab are not coordinated with the lecture topics. You will earn a separate grade for the lab, which has no effect on your lecture grade.

How to get an A	How to get a poor grade or worse
• Attend lab and have fun! • Do all pre-lab assignments well before they are due, foster your own interest in the subject matter • Read journal articles carefully, noting word usage, use of citations and use of statistical analyses • Proof-read your own work and offer to proof-read peers' work. • Seek help from your T.A. when you struggle	• Arrive late to lab, or miss lab • Wait until the last minute for pre-lab work or ignore it. Complain to yourself and others about what you "have to do" • Only scan journal articles or ignore them completely • Wait until the last minute to do your writing assignments • Don't use the resource you have in your T.A., who wants to see you do well.

Field Labs:

Field labs will be conducted rain or shine so bring appropriate gear. It is a good idea to bring a small notebook and pencil into the field. Be on time so you don't get left behind! If you know you cannot make a lab, we need to make plans well before the day of the field trip.

Grading:

Category	Category Points	Detailed Point Distributions	
Pre-Laboratory Work and Participation	35%	5%	Attendance and In-Lab Participation
		15%	Assessments of pre-lab materials
		15%	Rough Drafts
Forest Labs	25%	5%	Journal Article Assignment I
		20%	Forest Lab Report
Stream Labs	40%	10%	Journal Article Assignment II
		30%	Stream Lab Report
Total		100%	

HONOR CODE:

Copying, plagiarism, or the use of old reports will not be condoned. Your T.A. will state clearly when work is allowed to be turned in as a group. You should otherwise assume that each assignment is to be written in your own words. You are expected to pledge all assignments longer than two paragraphs, or your work will not be graded.

Laboratory Exercise Schedule

Lab	Week	Pre-Lab Module	Topics	Due at Start of Lab
1	Jan 26-30	Scientific Writing Excel & Statistics	Scientific Writing Overview & Library Research* Descriptive Statistics*	Due: Assessments (*)
2	Feb 2-6	Scientific Writing Excel & Statistics Forest Ecology	Introduction; Literature Cited; Hypothesis Development* Hypothesis Testing Clements Vs Gleason; First Journal Article Assignment	Due: Assessments (*)
3	Feb 9-13	Scientific Writing Excel & Statistics Forest Ecology	Methods Installing/using StatPlus Data Collection- Meet in Lab, then we go to Observatory Hill	Due: First Journal Article Assignment
4	Feb 16-20	Scientific Writing Excel & Statistics Forest Ecology	Results Regression in Excel, Figures in Excel* Data Collection- Soils, in Lab	Due: Assessments (*)
5	Feb 23-27	Scientific Writing Forest Ecology	Discussion and Abstract Owl Model	
6	Mar 2-6	Scientific Writing	Literature Cited*, Peer Review	Due: Full Draft + Abstract; Assessment (*)
		~❁ Spring Break! ❁~		
7	Mar 16-20	Scientific Writing Stream Ecology	Introduction, Literature Cited Stream Data I, River Continuum Concept	Due: Forest Lab Report
8	Mar 23-27	Stream Ecology	Stream Data II	Due: Second Journal Article Assignment
9	Mar 30- Apr 3	Scientific Writing Excel & Statistics Stream Ecology	Methods Introduction to t-Tests, Comparing t-Test and Regressions Biotic vs Abiotic Interactions(*)	Due: Assessments (*)
10	Apr 6-10	Scientific Writing Excel & Statistics Stream Ecology	Results How to do a t-Test in Excel*, Comparing t-Tests and Regressions Food Webs*, Water Quality	Due: Assessments (*)
11	Apr 13-17	Scientific Writing Excel & Statistics	Discussion and Abstract Misleading Figures	Due: Full Draft
12	Apr 27-May 1	No Class		Due: Stream Lab Report

Contacts

TA	Office	Email	Lab Section	Lab Location
Itiya Aneece	Clark 348	itiya_aneece@virginia.edu	Wednesday	Monroe
Lilian Aoki	Clark 172	lra5vx@virginia.edu	Tuesday	Clark
Alex Bijak	Clark 174	alb5bd@virginia.edu	Monday	Clark
Brynn Cook	Clark 194	bsc8tn@virginia.edu	Thursday	Clark
Amber Slatosky	Clark G074	aslatosky@virginia.edu	Wednesday	Monroe
Allisa Vincent	Clark 174	cav3gh@virginia.edu	Friday	Clark

** DO NOT switch labs without checking first. Room is often limited and it may be possible to arrange a trade with another student. If you need to switch a lab, e-mail your TA **and** the TA of the lab you wish to attend in advance.

Policies

Tips for Success:

1. Early on in the semester, familiarize yourself with UVA's library catalog, Virgo, and research platforms such as Web of Science to assist your search for articles. Also consider utilizing RefWorks (http://guides.lib.virginia.edu/content.php?pid=562375&sid=4635663), an online reference management to easily collect and organize citations, or another type of citation manager offered free of charge through the UVA Library (i.e. EndNote).
2. Before starting your first write-up or partial write-up, skim several articles published in ecology journals (i.e. Journal of Ecology, Global Environmental Change, Conservation Biology, etc.) to better understand the writing format and style you are expected to imitate. Do not worry about understanding all of the scientific content presented in the articles, instead focus on what type of information is included in each section of the article and how it is organized.
3. Avoid procrastination. When possible, complete all assignments during the scheduled lab time so you may ask questions regarding the data analysis and interpretation. While most calculations/analyses will seem straightforward immediately following the lab exercise, they may not be as clear several days later.
4. Leave time for revision and do not turn in an assignment that you have not yet edited. This course fulfills the second writing requirement for the College of Arts and Sciences, so successful students will pay attention to writing style, grammar, and spelling. Write-ups should be cohesive, meaning that each section is linked and there is a logical flow of ideas.

General Information:

This is a laboratory course companion to EVSC 3200, Fundamentals of Ecology. Although the courses are related, the topics we will be investigating in the lab are not coordinated with the lecture topics. You will earn a separate grade for the lab, which has no effect on your lecture grade. This course utilizes the flipped-classroom method in which students review lecture material outside of class and ask questions, discuss, and participate in exercises pertaining to the lecture material in class. Students are expected to take an active role in their own learning in this method; such an active role promotes meaningful learning and retention of skills to be used outside of class.

Learning objectives:

1. Students will learn fundamental ecological concepts and test them in the field.
2. Students will use ecological concepts and literature to assess real-world situations.
3. Students will practice scientific writing and data analysis and interpretation.

Expectations:

1. Successful students will attend class and participate with the TA and peers.

2. Successful students will complete pre-lab modules and assessments well before class. Pop quizzes may be used to test preparedness (part of participation points). Print out and bring what you will need to class (i.e. lab instructions and datasheets), or bring your laptop.

3. Successful students will submit what they have completed at the end of the lab period even though it may be only a rough draft. The final drafts of assignments must be submitted by the beginning of the following lab section with a 10% penalty for each day late. TAs will allow one free late day one time given notification before the assignment is due. If there are any extenuating circumstances (illness, family emergency, etc.) please contact the TA as soon as possible before the assignment is due to discuss extensions.

4. Many of the lab exercises involve fieldwork. Successful students will be on time and dressed appropriately for weather. Appropriate attire will be discussed prior to the lab. It is a good idea to bring a small notebook, datasheets, and a pencil or pen into the field. If you know you cannot make a lab, we need to make plans well before the day of the field trip to discuss attending another lab section.

5. Successful students will be courteous to fellow students and to the TA. Off-task use of laptops or cellphones prohibits learning of others as well as the user and conveys disrespect towards the TA.

6. In addition to these graded assignments, there may be several forms of assessment that students will partake in during class. These will not be graded but will be used to assess learning and the pace of the class.

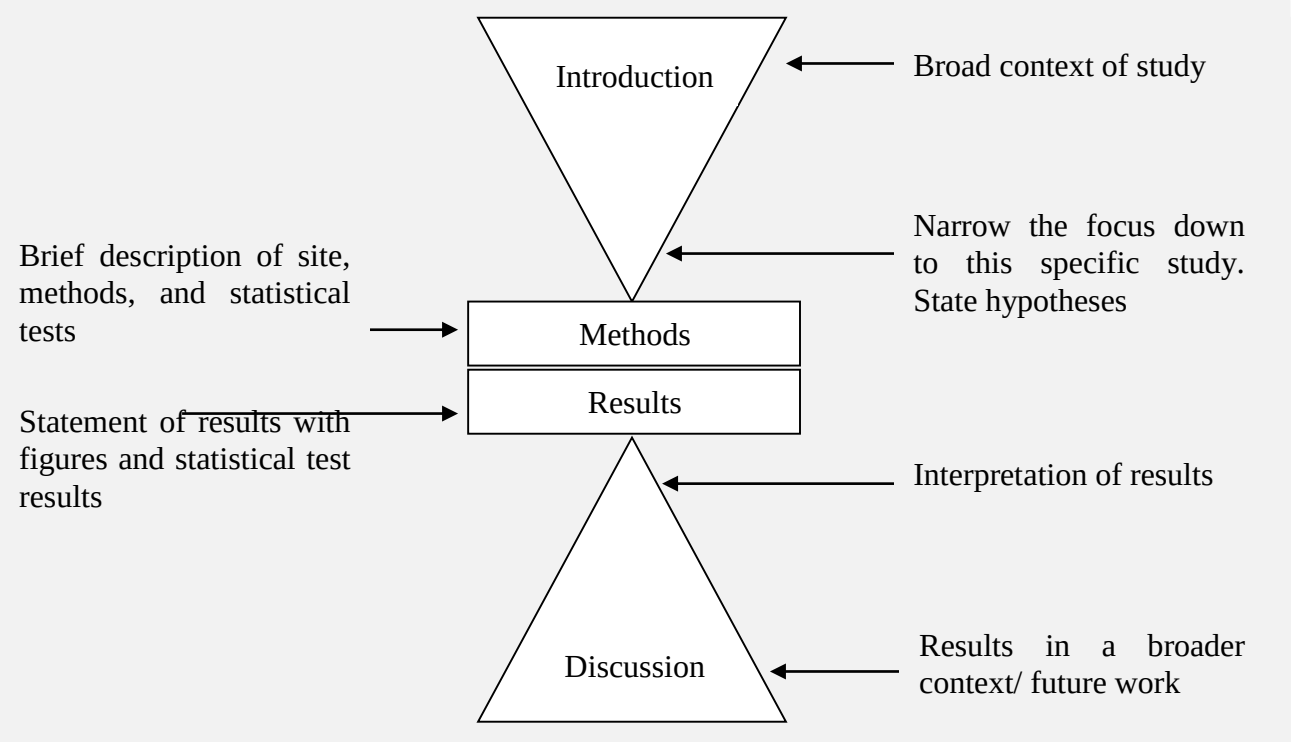
Introduction to Scientific Writing and Library Research

Overview

This course fulfills a writing requirement course through increasing your scientific writing literacy. Full lab reports for this course should contain all of the sections of a scientific paper: abstract, introduction, methods, results, discussion, and references. Below is a more detailed guide to the structure of a lab report which you should read carefully and refer back to when completing your assignments throughout the semester. The main tool that you will learn about in the library research portion of this first lab is "Web of Science." "Web of Science" is a powerful search engine and will be invaluable to you when it comes to searching for references for your lab reports.

Lab Report Guidelines

These guidelines are adapted from J. D. Herod, J. Colosso, G. Wilkinson, and R. Manderino. Below is an outline of the overall structure of a lab report. The use of triangles for the introduction and discussion highlights the importance of starting out with broad statements at the beginning of the introduction, narrowing to the hypotheses (introduction) and interpretation of results (discussion) of your study, and then broadening out again at the end of the discussion.



Below are the basic guidelines for writing full lab reports. There are no hard and fast rules, but, in general, a full lab report should be at least 6 pages and no more than 10 pages, 1.5-spaced. See the provided grading rubric and writing guidelines for more suggestions and information.

Header and Lab Report Title (6 lines):

- The header should include your name, course number and section, T.A. name, the date, and your pledge either right or left aligned. After the header, you should give a descriptive title for your lab report, centered on the page. Both the header and lab report title should appear at the top of the first page of your lab report.

Abstract (7–10 sentences):

This section is an overview of the entire lab report and it should stand on its owns such that the reader will grasp the important aspects of your report without having to read the report in its entirety. Well-written abstracts include all of the following:

- Introduction statement that frames why the study is important.
- Statement of hypothesis.
- Brief statement of methods: when, where, and how the study was performed.
- Statement of key findings. Directly describe the results and implications. Include data with statistical support in brief when possible.
- Conclusion statement: summarize what was found and why it is important.

Introduction (3-6 paragraphs):

This section provides information on the background and purpose of the study. A strong introduction will contain the following:

- A statement of the broad context and relevance of your study and an explanation of why the reader should care about your study.
- A description of other research that has been done that is *relevant* to your study. Make sure to cite at least two journal articles or books as references. Make sure that this part of the introduction provides enough background information to justify your objectives and hypotheses. Please note: any references to websites or the lab handout are in addition to the two journal/book references. DO NOT quote references directly; you should restate information from the references in your own words.
- A tailoring down of the background to the specific study. Describe the specific study system and the general processes undertaken to investigate the system.
- A brief description of the objectives and hypotheses of your study. This should be the last paragraph of your introduction and should be set up by the preceding paragraphs.

Methods (2-4 paragraphs):

This section should give a brief explanation of the procedures used in the study. Be sure to include the following:

- Brief description of the field site. Explain where (location can range from specific site coordinates, local area, region, and state) and when (month or season and year) the study was conducted. Emphasize features of the site that can or potentially influence the results of the study.
- Description of the field and/or lab methods used in the study. You should include enough information for someone else to be able to duplicate your work but you should not go into excessive detail, nor should you duplicate what is written in the lab handout. Where appropriate, state how and why you made any changes to the procedure described in the lab handout. A good rule of thumb is to be specific with tools and the description of their use only if an uncommon approach was utilized.
- Show and label important equations that were used and explain all variables in the equations. If you used a statistical test, you do not need to show the equation. Rather, you should state which test was used, give the alpha level, and include any other pertinent information about the test (*e.g.*, what the independent and dependent variables were for a regression analysis; what groups were compared with a t-test, etc.).

Results (2-4 paragraphs):

This section provides both a visual and a verbal description of the results obtained in your study. More information is contained in the section called "Data Presentation" in the introduction to statistics section of this lab reference. The results section should contain:

- Written description of results: DO NOT INTERPRET the results. This section describes the facts revealed by the methods without implying their greater meaning. Write these paragraphs as if no tables or figures are in the section – what would you say?
  Never begin a sentence with "Figure/Table X shows…" or some variant thereof. When writing about results a figure helps describe, refer to that figure parenthetically [e.g. "Orange mountains had the highest mean concentration of flying elephants, while purple mountains featured very few or no flying elephants (Table 1)."] If a figure or table is included, it must be referenced.
  Describe relationships between variables. For example, for a scatterplot graph, you should point out whether there is a positive or negative linear relationship, or another sort of relationship, between the variables. You should point out unusual (*e.g.*, outlying) or important data points.
  If a regression trendline is applied, describe what the accompanying equation means in terms of the variables. Remember to consider the intercept. Be sure to present the results of any statistical tests (*i.e.*, give the test statistic, p-value, and degrees of freedom) and whether or not you can discard the null hypothesis.
- Figures and tables: NO RAW, UNANALYZED DATA. Use figures (*i.e.*, graphs, charts, images) to help present your findings and be sure to provide any figures explicitly described in the lab handout. A graph should be used to visually present findings. Scatterplots are useful if a regression analysis is

"Figure labels go below the figure and table labels go above the table."

performed and bar graphs are useful to display the average values compared in a t-test. The axes of all graphs should be clearly labeled (with units as appropriate) and easy to understand. Tables are especially useful when presenting counts or calculated values. All tables should have column and row labels and be clear and easy to read. If multiple statistical tests are conducted, it is useful to present a table presenting the relationship tested, test-value, and p-value.

All figures and tables should have a descriptive caption and should be numbered (*e.g.*, "Table 1. Number of flying elephants collected by mountain type.") Figure labels go below the figure and table labels go above the table. Each description should be able to stand on its own, such that if it were removed from the paper, it would still be understood.

Discussion (4-8 paragraphs):

This section is very important; it ties together the hypotheses posed in the introduction and the information given in the results section, it lists the key findings of your study, draws conclusions from the results and applies them to the greater understanding of the system, points out weaknesses of the study, and suggests further research and questions. You should do the following when writing your discussion section:

- Return to the hypotheses that you gave in the introduction. Do your data support your hypotheses? Why or why not? Interpret your results and be sure to provide an explanation if your results do not match your expectations (*e.g.*, biases or confounding factors in the methods used, etc.).
- Have the data changed previous knowledge? Compare them to the results of others. Describe your main conclusions and why your findings are important. Describe a couple of ways in which your methods could be improved or further research that could be done to answer any questions raised by your findings.
- Discuss the consequences of the study's results in the greater scheme of understanding. How do the results change our knowledge of the system? How can they be applied?

Each lab covered in this course features discussion questions to help expand on ideas and apply new concepts. Use these questions as a tool to help develop this section, ***but do not rely on them to satisfy the requirements of the discussion*** *- make sure the points listed here are addressed.*

References:

Be sure to cite any books and journal articles from which you obtain information when writing your lab report. You should include both an in-text citation and a full citation (see examples below) to each reference in your report. The full citation should appear in a separate reference section at the end of your lab report. Notice that every line after the first for each reference is indented. For each lab report, you are required to have at least two book or journal article references. One may be your textbook. Be sure to cite any websites used but remember that a website does not count as one of your two required

references. Please DO NOT quote directly from the references; restate the information contained in the reference in your own words.

For this lab you will use a style guide that is commonly used for scientific journals.

General guidelines: https://owl.english.purdue.edu/owl/resource/560/01/

In-text citation format: https://owl.english.purdue.edu/owl/resource/560/03/

Reference list: general rules: https://owl.english.purdue.edu/owl/resource/560/05/

Citing journal articles: https://owl.english.purdue.edu/owl/resource/560/07/

Citing books: https://owl.english.purdue.edu/owl/resource/560/08/

Reference lists: handling multiple authors
https://owl.english.purdue.edu/owl/resource/560/06/

Citing the lab manual:

Lecture instructor last name, Lecture instructor initial. (Semester Year). Lab Manual for Fundamentals of Ecology: Lab title.

Example:

Aneece, I., Aoki, L., Bijak, A., Cook, B., Slatosky, A., & Vincent, A. (2015). *Lab manual for fundamentals of ecology*. Charlottesville, VA: University of Virginia

Things to Keep in Mind

The following represent mistakes commonly made by students when writing lab reports. Please try to AVOID making these mistakes.

1. Misuse of the word "trend". A trend represents a change over time. If you have two variables, say light and depth, and neither variable is time, then you should talk about the "relationship" between those variables, NOT trends in the variables.
2. Misuse of the term "experiment." An experiment is something that involves treatments and control of variation in the natural world. For example, if you want to look at the effects of different nutrient levels on plant growth, and you mark off plots of land, and apply specific amounts of fertilizer to each plot, that is an experiment. If, on the other hand, you just go out and measure in-situ nutrient levels in different areas that have different amounts or types of vegetation already growing there, that is NOT an experiment. Most of the exercises that you will do in this lab are NOT experiments; rather, they involve collection of data from the natural environment and are "observation-based" rather than "experimental" in nature.
3. Improper use of the term "significant." When talking about your results, DO NOT use the word "significant" unless you have run a statistical analysis on the data and the results of that test are significant. For example, in order to say that there is a

"significant difference" between two groups, you must have run a t-test on the data for those two groups and found that the p-value for that t-test was less than 0.05.

4. Incorrect use of the words "affect" and "effect." "Effect" is a noun and indicates that one variable influences, impacts, or changes another variable. For example, "Light has a strong effect on the amount of photosynthesis performed by a plant." "Affect" is a verb that means "to have an effect on". You should use this word when you mean to say that one variable had an effect on another variable. For example, "Light affects the amount of photosynthesis that a plant can perform."
5. Incorrectly assuming that the word "data" is singular. "Data" is plural, "datum" is singular, so be sure to use the correct term (usually "data" is the correct term; it is unlikely that you will only have one data point) and conjugate your verbs accordingly. For example, "The data show that…" or "The data were collected at…" or "The data are…".
6. Incorrect use of first vs. second vs. third person narrative, especially in the methods section. It is recommended that you use the first person (I/we) at the end of the introduction, when you state your hypotheses, and throughout the methods section. For example, when you state your hypotheses, you can say something like "I expected to see a positive relationship between…" or "I expected that trees would be taller in areas with more sunlight." In the methods section, you can say something like "We collected water samples…" or "We measured trees…" rather than saying "Water samples were collected" or "Trees were measured." Avoid using the second person (you) in your methods section. For example, don't say "You then weigh the samples…" or "You collect water at…"
7. Duplicating portions of the lab handout when writing your methods section or using informal language. DO NOT DO THIS. The methods section of your full lab reports should be written in your own words and should be written using formal language. **Duplicating portions of this lab manual is plagiarism and thus an honor offense.**

Remember that too little information is just as bad as too much information. The reader of your report should be able to easily follow 1) why you did a particular study, 2) how you did your study, and 3) what your main findings were.

Lab Report Rubric

Lab Report Rubric		Points	
I	**Abstract**	Possible	Awarded
1	Context of study, and importance	2	
2	Hypothesis clearly stated	2	
3	Brief description of methods and results	2	
4	Results in a broader context	2	
II	**Methods**		
1	Successfully establishes concept of the lab (present tense used)	4	
2	Explains the objectives of the experiment (Past tense used)	2	
3	States hypothesis that is based on research and/or sound reasoning (Past tense used)	3	
4	Hypothesis is testable (Past tense used)	2	
5	References cited in the body of the introduction	2	
III	**Methods**		
1	Past tense is used	1	
2	Methods are concise, in complete sentences, and do not read like a recipe	4	
3	Experiment is repeatable	3	
4	Methods are accurate	4	
5	Statistical analyses	2	
IV	**Results**		
1	Past tense is used	1	
2	Opens with effective statement of overall findings with results and data clearly recorded. Data are analyzed correctly.	4	
3	Tables have proper labeling, contain accurate data, and have captions.	4	
4	Figures have proper labeling, contain accurate data, and have captions.	4	
5	Tables are formatted correctly (see style guide)	2	
6	Figures are formatted correctly (see style guide)	2	
7	Tables and graphs are cited within the text (see style guide)	2	
V	**Discussion and Conclusion**		
1	Past tense is used	1	
2	The data and observations are interpreted accurately, trends are described	5	
3	Conclusions follow data (not wild guesses or leaps of logic)	4	
4	Based on the data the hypothesis is rejected or accepted.	4	
5	Describe possible limitations and shortcomings of the methods used	2	
6	Discuss applications of experiments (i.e. "real world" connections)	4	
7	Explain possible future avenues of research (future tense is used)	2	
8	References cited in the body of the conclusion	2	
VI	**References**		
1	Minimum of ___ references, used well.	4	
2	References are formatted correctly	4	
VII	**Style**		
1	Sections have headings	4	
2	Few, if any, spelling/grammar errors	4	
3	Introduction starts broad, then narrows to specific hypothesis	2	
4	Hypotheses are outlined and addressed in the methods and results in a consistent order	2	
5	Discussion and Conclusion starts with results of hypothesis tests and broadens to implications and future research	2	
	Total	100	

Useful Library Information

Dave S. Ghamandi, MSLS
Librarian for Environmental Science
Office: I-044 Brown Science & Engineering Library
E-Mail: dave@virginia.edu
Office Phone: 434-924-3845
Information Desk: 434-924-3628
Reference E-Mail: sciref@virginia.edu

LINKS OF INTEREST

Library Website:
http://www2.lib.virginia.edu/brown/
Subject Guides:
http://www2.lib.virginia.edu/brown/research/guides/
Environmental Science Subject Guide:
http://guides.lib.virginia.edu/envsci

RefWorks:
http://guides.lib.virginia.edu/refworks
Interlibrary Loan:
http://www.lib.virginia.edu/leo/borrowing.html
Off-Grounds Access:
http://www2.lib.virginia.edu/tools/offgrounds.html

BEST DATABASES TO BEGIN WITH

Web of Science/Web of Knowledge (1970-Present)
Large database covering all aspects of science. Includes Science Citation Index
Proquest: Biological and Environmental Sciences (1973-Present)
Includes multiple databases in areas such ecology, environmental sciences, water resources, and other natural science areas. Can search multiple databases at the same time.
Biological Abstracts (1985-Present)
Provides international coverage in areas such as genetics, botany, ecology, biomedicine, zoology, microbiology and biochemistry.
GeoRef (1933-Present)
Many kinds of information on geology and geophysics worldwide.
Academic Search Complete
Large general database of articles from scholarly journals and a few newspapers covering a wide range of topics.

Not finding what you need?

Try another database on the subject guide page, schedule a **Research Tutorial** or ask a librarian at http://www2.lib.virginia.edu/brown/research/sciencequestions.html

Journal Article Assignments

First Journal Article Assignment

Use library resources to find an article that you can cite in the introduction or conclusion section of your forest lab report. Do not use an article already cited by your instructor in pre-laboratory material.
Tip: Maybe some sort of animal or plant relies on forest health- maybe this is an underlying reason to understand forest structure and evolution? Perhaps you could find a paper describing a different forest or ecosystem that was examined in a similar way?
Make sure that the article adheres to the following criteria:

- It is recent- it has been published since the start of the year 2010
- It is an actual research article (not a review or a note). It should contain the sections of a paper that you have learned about.
- Be sure you can understand most of- or at least the gist of what is happening in the article.

Word of advice: Look at the number of pages for the article- a very *long* article might be difficult to work with for this assignment.
Once you have found this article you will write a journal article summary that will be graded according to the rubric found at the end of this transcript. Upload both the summary and a pdf of the article to Collab. If the paper you find follows several hypotheses, pick one of them and follow it through the article. *Number your answers according to the questions. Answer the questions in complete sentences. Try to keep the whole assignment under 4 pages in length, double spaced. If you go over this page length, see if you can make your work more concise. Please do not exceed 6 pages.*

Deadline: Feb 9-13 (Ask your instructor)

TURN IN THE ASSIGNMENT WITH A COPY OF THE RUBRIC PASTED AFTER YOUR TEXT or with a printed copy of that page of this handout.

Journal Article Summary Assignment

	Points Awarded	Points Possible
Article uploaded to Collab, .pdf format, on time*		**YES/NO**
Grammar and Spelling		**1**
Correct article type, length, and search parameter		**2**
Questions:		
1. What is something you learned in the introduction? What article was cited to support that information?		**3**
2. What is the hypothesis or major question in this article? How does this relate to the assignment prompt *"Use library resources to find an article that you can cite in the introduction or conclusion section of your forest lab report. Do not use an article already cited by your instructor in pre-laboratory material."*		**3**
3. What was a sampling method the authors used? In other words: How did they collect the data used to test the hypothesis?		**3**
4. How did the experimenters test the hypothesis? (*include statistical tests and why you think those particular tests were used)*		**4**
5. What evidence was gathered and how was the information displayed? *(example, were graphs, maps, tables, etc used?)*		**3**
6. What was one major conclusion? What do they describe as a possible future direction for research? How might you incorporate this information into your own lab report?		**4**
7. Provides the full and correct APA citation		**2**
Total _____% out of 5% of your overall grade		**25**

*Or according to whatever method your instructor asked for

*If multiple hypotheses are presented, choose **one** hypothesis and follow how that **same** hypothesis was tested, reported, and discussed.*

Second Journal Article Assignment

Use library resources to find an article that you can cite in the introduction or conclusion section of your stream lab report. Do not use an article already cited by your instructor in pre-laboratory material.

Make sure that the article adheres to the following criteria:

- It is shorter than 9 pages (excluding references)
- It is recent- it has been published since the start of the year 2010
- It is an actual research article (not a review or a note). It should contain the sections of a paper that you have learned about.
- Be sure you can understand most of- or at least the gist of what is happening in the article.

Word of advice: Look at the number of pages for the article- a very *long* article might be difficult to work with for this assignment.
Once you have found this article you will write a journal article summary that will be graded according to the rubric found at the end of this transcript. Upload both the summary and a pdf of the article to Collab. If the paper you find follows several hypotheses, pick one of them and follow it through the article. *Number your answers according to the questions. Answer the questions in complete sentences. Try to keep the whole assignment under 4 pages in length, double spaced. If you go over this page length, see if you can make your work more concise. Please do not exceed 6 pages.*

Deadline: Mar 23-27 (Ask your instructor)

Use the diagram after the rubric to help guide your reading and summarizing.

TURN IN THE ASSIGNMENT WITH A COPY OF THE RUBRIC PASTED AFTER YOUR TEXT or with a printed copy of that page of this handout.

Journal Article Summary Assignment

	Points Awarded	Points Possible
Article uploaded to Collab, .pdf format, on time*		**YES/NO**
Grammar and Spelling		**1**
Correct article type, length, and search parameter		**2**
Questions:		
1. What is something you learned in the introduction? What article was cited to support that information?		**3**
2. What is the hypothesis or major question in this article? How does this relate to the assignment prompt "Use library resources to find an article that you can cite in the introduction or conclusion section of your stream lab report. Do not use an article already cited by your instructor in pre-laboratory material.		**3**
3. What was a sampling method the authors used? In other words: How did they collect the data used to test the hypothesis?		**3**
4. How did the experimenters test the hypothesis? (*include statistical tests and why you think those particular tests were used)*		**4**
5. What evidence was gathered and how was the information displayed? *(example, were graphs, maps, tables, etc used?)*		**3**
6. What was one major conclusion? What do they describe as a possible future direction for research? How might you incorporate this information into your own lab report?		**4**
7. Provides the full and correct APA citation		**2**
Total _____% out of 10% of your overall grade		**25**

*Or according to whatever method your instructor asked for

*If multiple hypotheses are presented, choose **one** hypothesis and follow how that **same** hypothesis was tested, reported, and discussed.*

Introduction to Statistics

Introduction

Statistics is the tool that ecologists and other scientists use to determine if the effect, difference, relationship, or pattern that the scientist has hypothesized is really there. This lab is an introduction to the statistical analyses that you will be using throughout the semester. You will become familiar with both descriptive and inductive statistics. Descriptive statistics allow you to summarize your data (*e.g.*, mean, standard deviation). Inductive statistics involve hypothesis testing. Hypothesis testing is a method for using sample data to decide between two competing claims (hypotheses) about a population characteristic. This involves formulating a null hypothesis (a hypothesis of no effect) and testing it against an alternative hypothesis (that there is a treatment effect). We will learn how to use MS Excel to perform (1) a **t-test**, which allows you to test for a difference between two populations, and (2) a **regression**, which allows you to test for a relationship between two continuous variables. We will use a large fish dataset to perform an example t-test and a smooth cordgrass (*Spartina alterniflora*) dataset to perform a regression.

Definitions

1. Population: the subjects, items, elements, or units in a defined group. Usually the group definition includes explicit restrictions to a specified sampling area or "universe" limited in space or time (*e.g.*, all of the black bears living in the Shenandoah National Park (SNP) in 1990).

2. Sample: a subset of the subjects in a population which are chosen using a specific procedure (*e.g.*, all of the black bears live-trapped in SNP between 15 June and 15 August 1990).

3. Variable: an attribute that varies from subject to subject in a population or sample and can be measured for each subject of the population (*e.g.*, body weight or sex of black bears).

> *A. Continuous variable*: a characteristic that can take on an infinite number of values between a lower limit and an upper limit (*e.g.*, the body weight for each black bear in SNP).
>
> *B. Discontinuous variable*: a characteristic that can take only certain, fixed values, with no intermediate values in between (*e.g.*, the number of offspring for each black bear in SNP).
>
> *C. Ranked variable*: a characteristic that cannot be measured numerically, but which can be ranked by magnitude or order (*e.g.*, the order in which black bears are live-trapped).

4. Observation: a measurement or value recorded for a variable on a subject selected from the population (*e.g.*, the number of teeth, body weight, time of capture, or sex of the first black bear live-trapped in SNP on 15 June 1990).

5. Frequency distribution: an ordered listing of the qualitative or quantitative categories of a variable and the frequency of each category in the sample, where frequency is simply the number of observations that fall into that category (Figure 1).

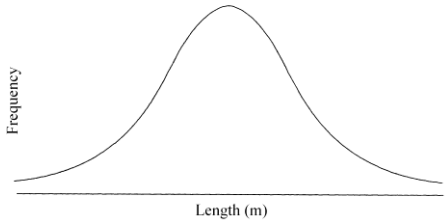


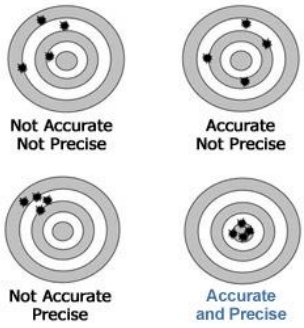
Figure 1. Example of a frequency distribution. This is a normal distribution and could represent length measurements taken on a wide range of different types of cars. This distribution shows that most cars have lengths within a fairly narrow range but there are a few very small (*e.g.*, smart car) and very long (*e.g.*, limo) cars.

6. Population parameter: a quantitative attribute of a population that is generally unknown and unknowable but can be estimated using sample statistics (*e.g.*, the mean body weight for all of the black bears in SNP).

7. Sample statistic: a quantitative estimate of a population parameter derived from a sample. Such statistics are based on independent random samples and are used to estimate population parameters (*e.g.*, the mean body weight for all the black bears live-trapped in SNP between 15 June and 15 August 1990).

8. Accuracy: the closeness of a measured or computed value to its true value (*e.g.*, how close the value of the sample mean is to the value of the population mean).

9. Precision: the closeness of repeated measurements of the same variable to each other.



10. Random sample: a sample selected in such a way that each subject of the population has an equal probability of being included in the sample.

11. Independent sample: a sample derived such that the selection of any subject does not increase or decrease the probability that any other subject will be sampled.

12. Dependent versus independent variables: In an experiment, independent variables are those variables that are manipulated or controlled, whereas dependent variables are

only measured. In an observational study, the independent variables are those that are likely driving variation in the dependent variable. For example, consider an experimental study where we are interested in the relationship between calories and weight in a population of humans. We can control the number of calories that the subjects of the experiment ingest and we would expect that variation in calories ingested (independent variable) would lead to changes in subject weight (dependent variable). As another example, consider an observational study where coyote abundance is measured in different habitat types. Here the independent variable, which may lead to variation in coyote abundance, is habitat type, and the dependent variable is coyote abundance.

Descriptive Statistics

Descriptive statistics are used to summarize a data set, to estimate population parameters, and to reduce a large body of raw information (observations) to a smaller body of summarized information. We can take measurements on a sample of subjects from a defined population and calculate the descriptive sample statistics. We then have estimates of population parameters and a standardized way to communicate what we know about the population we have sampled. The descriptive statistics that you will use during the semester are defined and described below, and the calculation procedure for each statistic is illustrated.

Example Data for Descriptive Statistics

Number of observations = n = 6
Raw observations: $X_1 = 3, X_2 = 5, X_3 = 2, X_4 = 4, X_5 = 2, X_6 = 4$

The following notations will be used in the examples that follow.

Sum of observations

$\Sigma X = X_1 + X_2 + \ldots + X_n$

$\Sigma X = 3 + 5 + 2 + 4 + 2 + 4 = 20$

Sum of squared observations

$\Sigma X^2 = X_1^2 + X_2^2 + \ldots + X_n^2$

$\Sigma X^2 = 9 + 25 + 4 + 16 + 4 + 16 = 74$

Sum of observations squared

$[\Sigma X]^2 = [X_1 + X_2 + \ldots + X_n]^2$

$[\Sigma X]^2 = (20)^2 = 400$

Where Σ means "the sum of," X_i refers to each observation, and n is the total number of observations in the sample (the sample size).

Measures of Central Tendency or Location

A measure of central tendency provides an estimate of a value about which all values in a population tend to clump. The primary measure that you will use is the sample mean.

Sample mean ($\bar{x}$):
Commonly called the "mean" or "average" of the observations in a sample. The mean is by far the most commonly calculated statistic. The mean is calculated by dividing the sum of all the individual observations by the number of observations in the sample.

Example of Sample Mean

$$\bar{x} = \sum_{i-1}^{n} \frac{X_i}{n} = \left(\frac{20}{6}\right) = 3.33$$

Measures of Variation or Dispersion

A measure of dispersion describes the spread of the observed values in a sample around some measure of central tendency. The two measures that you will use are standard deviation and standard error. Standard deviation is calculated based on variance, which is another measure of dispersion.

Sample standard deviation (s).
The standard deviation is calculated as the square root of the sample variance (s^2). The standard deviation is simply the spread of the individual observations about the arithmetic mean. To calculate the standard deviation for a sample, we must first calculate the variance. The variance is based on the deviations of the sample observations from the sample means. The formula for the variance is expressed in terms of squared deviates:

$$s^2 = \frac{\sum_{i=1}^{n} \left(X_i - \bar{X}\right)^2}{n-1}$$

Rearranging this formula so that it is arithmetically easier to calculate gives us the following equation:

$$s^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}\right)$$

Example of Standard Deviation

$$s^2 = \frac{1}{6-1}\left(74 - \frac{400}{6}\right) = \frac{1}{5}(74 - 66.67) = 1.466$$

The standard deviation (s) is then calculated as the square root of the variance:

$$s = \sqrt{s^2} = \sqrt{1.466} = 1.211$$

Standard error of the mean ($s_{\bar{x}}$)

The standard deviation is a measure of the variation of individual sample observations about their mean. There also is variation among the means computed from different samples of the individuals in the population of interest. For example, if we were to take five different samples of the SNP black bear population (from the earlier example), we would likely obtain five different means. The standard error of the mean, often referred to simply as the "standard error," is a measure of the variation among these different sample means. It may be regarded as a standard deviation among the means and is useful in computing confidence limits for a population mean and for determining the sample size required to achieve a specified sampling precision. Sample size greatly influences the standard error.

Example of Standard Error of the Mean

$$s_{\bar{x}} = \left(\frac{s}{\sqrt{n}}\right) = \frac{1.211}{2.449}0.494$$

The standard error decreases with increasing sample size, but the square root term limits the rapidity of this decrease; quadrupling the sample size only halves the standard error.

Inferential Statistics and Statistical Hypothesis Testing

Inferential statistics are used to make some judgment about the population of interest based upon the sample statistics. More specifically, inferential statistical analyses, such as t-tests and regressions, use data collected from randomly selected samples to test hypotheses about the populations from which the samples were drawn. T-tests are used to determine whether there are statistically significant differences between the mean values of two samples, and thus differences between the populations from which the samples were drawn. Regression analyses are used to assess the strength of the relationship between two variables.

When using statistical tests, you should always keep the null and alternative hypotheses associated with those tests in mind. The outcome of a statistical analysis tells you

whether or not you can reject the null hypothesis for the test that you have performed. In the case of a t-test, the null hypothesis is that the two samples being considered, and thus the two populations from which the samples were drawn, are the same. For a regression, the null hypothesis is that there is no relationship between the two variables being considered. Rejecting the null hypothesis provides support for the alternative hypothesis. For a t-test, the alternative hypothesis is that the two samples are different from one another. For a regression, the alternative hypothesis is that there is a relationship between the two variables.

When deciding whether or not to reject a null hypothesis on the basis of a statistical test, four outcomes are possible:

		Reality: H_o is	
		FALSE	TRUE
Test Result: H_o is	REJECTED	Good	Type I Error (α)
	ACCEPTED	Type II Error	Good

1. The null hypothesis is rejected when in fact it is false (this is good).
2. The null hypothesis is rejected when in fact it is true (this is bad, and is termed **Type I error**).
3. The null hypothesis is not rejected when in fact it is true (this is good).
4. The null hypothesis is not rejected when in fact it is false (this is bad, and is termed **Type II error**).

The probability of Type I error is denoted by α and is commonly referred to as the significance level of the test. The alpha level is predetermined by the researcher. It is most common to use $\alpha = 0.05$. If you say that a test was significant at $\alpha = 0.05$, this means that there is a 5% chance that the null hypothesis was rejected improperly. Another way of saying it is that you are 95% confidant that your rejection of the null hypothesis is proper.

The p-value (also called the observed significance level) of a test is something that is commonly reported in the literature and refers to the probability that the result you have obtained for a particular test is due to random chance. P-values are between 0 and 1. A low p-value, less than 0.05, would indicate that the researcher can be very confident in rejecting the null hypothesis as there is a very low probability that the difference between the two samples is due to chance. A p-value below 0.05 is typically considered a statistically significant result (we are 95% certain that the result we obtained is not due to chance).

Please remember that if you reject the null hypothesis, it DOES NOT MEAN that you have "proved" the alternative hypothesis to be correct; you can never "prove" an alternative hypothesis, you can only find support for it.

T-tests

To apply a t-test to compare two populations, one assumes that the subjects in each population were sampled independently and at random, and that the variable being measured for each population is normally distributed. The frequency distribution for normally distributed data looks like a bell shaped curve, with a single peak at the mean and tails that extend infinitely in both directions from the mean (Figure 1). Further assumptions concerning the variance in each population are also required, but for our purposes we will not examine the assumptions about variance in detail.

An example of the type of data that could be examined using a t-test is the distribution of lengths of leaves on White Oak (*Quercus alba*) and Red Oak (*Quercus rubra*) trees in a forest. We could measure the length of leaves on *n* trees of each species and then use a t-test to determine whether the mean leaf length is significantly different for these two oak species. The extent to which the sample means differ relative to the standard error of the difference in means can be used to decide if the observed difference in sample means is statistically significant. The t-test statistic (t) is the ratio of the difference in means to the standard error of the difference between means (see below).

$$t = \left(\overline{X}_1 - \overline{X}_2\right) \Big/ se_{(\overline{X}_1 - \overline{X}_2)}$$

Where $se_{(\overline{X}_1 - \overline{X}_2)} = \sqrt{s_1^2/n_1 + s_2^2/n_2}$

and s_1^2 and s_2^2 are the variances of samples 1 and 2, respectively, and n_1 and n_2 designate the sizes of the samples used to estimate the attributes of the two populations (*i.e.*, the number of White Oak and Red Oak trees sampled).

If the null hypothesis is true, this ratio follows the probability distribution known as the Student's t-distribution. If the t-test statistic is large, the difference between the means is large relative to the standard error of the difference in means and the difference between the two oak species is significant. If this ratio is small, the difference between the means is not significant and is considered to be caused by chance variations in sampling.

The significance of t is determined by comparing the t-test statistic computed using the sample leaf length data to the "critical values" from the Student's t-distribution. A table of these critical t-values is shown in Appendix 1. To find the critical t-value appropriate for comparison to your computed t-test statistic, you must first calculate the number of degrees of freedom. Degrees of freedom (df) is a measure of variability expressing the number of options available within a variable. For example, if you have six containers to fill, only five can be filled arbitrarily (5 df); the order in which the last container is filled is fixed because the other five containers are already filled. Degrees of freedom for the t-test is calculated using the formula:

$df = n_1 + n_2 - 2$

$$df = \frac{(V_1+V_2)^2}{\frac{V_1^2}{n_1-1}+\frac{V_2^2}{n_2-1}} \text{ where } V_1 = \frac{s_1^2}{n_1} \text{ and } V_2 = \frac{s_2^2}{n_2}$$

Example t-test

Below are leaf length values measured for 10 White Oak and 10 Red Oak trees.

Table 1. Leaf lengths, in cm, for leaves of Red Oak and White Oak trees.

Red Oak Leaves (cm)	White Oak Leaves (cm)
10.5	25.2
13.2	15.8
13.5	23.1
10.3	11.6
11.1	10.6
13.4	13.8
11	16.6
12.8	16.9
15.8	17.5
12	20.1

The following output can be generated in Excel by using the leaf length data shown above and a two-tailed t-test assuming unequal variances. We are selecting the t-test assuming unequal variances rather than the t-test assuming equal variances because as noted earlier, we are not examining assumptions about variance, and thus we cannot assume that the two populations we are comparing have equal variance. Please note that the variables that you should always report when you do a t-test are shown in bold (df, t-test statistic, p-value). Also, Excel sometimes miscalculates the degrees of freedom and thus displays the wrong critical t-value. The correct values are shown below but the degrees of freedom were calculated and entered by hand and the correct critical t-value was obtained from Appendix 1. You should always double check the results given by Excel by calculating the value for degrees of freedom of a t-test using the formula shown above.

Table 2. Results of a t-test looking at leaf lengths in Red vs. White oaks.

	Red Oak	*White Oak*
Mean	12.36	17.12
Variance	2.93	21.79
Observations	10	10
Hypothesized Mean Difference	0	
Df	**18**	
t Stat	**-3.03**	
P(T<=t) two-tail	**0.01**	
t Critical two-tail	2.10	
P(T<=t) one-tail	0.01	
t Critical one-tail	1.80	

As you can see from the Excel output, the degrees of freedom for the test is 18, and the t-test statistic is equal to 3.03 and is larger than the two-tailed critical t-value (2.10). This indicates that the difference in leaf length between Red Oaks and White Oaks is larger than expected for samples with a total of 18 degrees of freedom from two populations that are not different from one another. Please note that we can disregard the negative sign on the t-test statistic value because we are conducting a two-tailed test and are thus interested only in the magnitude of the difference between the mean values. We would pay attention to the negative sign if we were doing a one-tailed test and were thus interested in whether one species has a longer or shorter leaf length than the other.

The two-tailed p-value is 0.01, which means that the probability of improperly rejecting the null hypothesis is less than 1%. We can reject the null hypothesis that there is no difference in oak leaf length between White and Red Oaks as the p-value is less than 0.05. To double check these results, you can use the table of critical t-values (Appendix 1) to determine whether the t-test statistic calculated by Excel is greater than the critical t-value given for 18 degrees of freedom.

Regression

A regression problem involves determining whether there is a relationship between two variables. The results of a regression analysis include an equation that can be used to estimate the value of one variable (the dependent variable) from the value of a second variable (the independent variable). To perform a regression analysis, experimentally-determined values for the variables of interest are plotted with the independent variable being shown on the x-axis and the dependent variable on the y-axis. A scatterplot is obtained and a line is fitted to the points using a simple mathematical procedure called the method of least squares. The method of least squares fits a line to the data in such a way that the sum of the squared differences between the observed y-values and the y-values predicted by the fitted line is minimized.

A linear, or straight-line, relationship can be described mathematically by the equation:

$$y = mx + b$$

Where:

$y =$ the computed line value of the y-axis variable
$x =$ the line value of the corresponding x-axis variable
$m =$ the slope of the line
$b =$ the intercept of the y-axis or y-intercept

To obtain the value of a slope (m) for a straight line fitted by the method of least squares, the following equation can be used:

$$\frac{\sum XY - \bar{X}\sum Y}{\sum X^2 - \bar{X}\sum X}$$

The y-intercept, the value of the dependent variable that corresponds to X=0, can then be solved for by rearranging the equation of the line and using both the calculated value for the slope (m) and the average values for x ($\bar{X}$) and y ($\bar{Y}$).

$$b = \bar{Y} - m\bar{X}$$

The equation for this "regression" line permits prediction of the values of one variable based on values of the other variable.

In addition to calculating the y-intercept and slope of a linear equation via the method of least squares, a regression analysis yields a number, called the coefficient of determination (R^2), that gives the proportion of variation in y that can be attributed to an approximate linear relationship between x and y. Values of R^2 range from 0 to 1. R^2 values closer to 1 tell us that much of the variation in y is explained by the given linear relationship, and thus the relationship between x and y is strong. If the R^2 value is closer to 0, then relatively little variation in y is explained by the linear relationship and therefore the linear relationship between x and y is weak. The coefficient of determination is calculated by squaring "r," the sample correlation coefficient, which is a quantitative assessment of the strength of the relationship between the x and y values in a set of (x,y) pairs.

To calculate R^2, we must first calculate r using the following equation and then take the square of the resulting value:

$$r = \frac{\sum[(X - \bar{X}) \times (Y - \bar{Y})]}{\sqrt{\left[\sum(X - \bar{X})^2 \times \ [\sum(Y - \bar{Y})^2]\right]}}$$

Example

Below is data on the height above ground and dry density of 1-meter segments of a tree trunk.

Table 3. Height above ground and dry density data for 1 m tree trunk segments.

Height (m)	Dry density (kg/m^3)
1	20.68
2	16.46
3	14.76
4	13.95
5	12.35
6	12.54
7	12.17
8	8.78
9	9.07
10	9.01
11	8.53
12	6.81
13	6.43

You can use Excel to generate a scatterplot of these two variables (height above ground and dry density), as well as the equation of a regression line and R^2 value (see below).

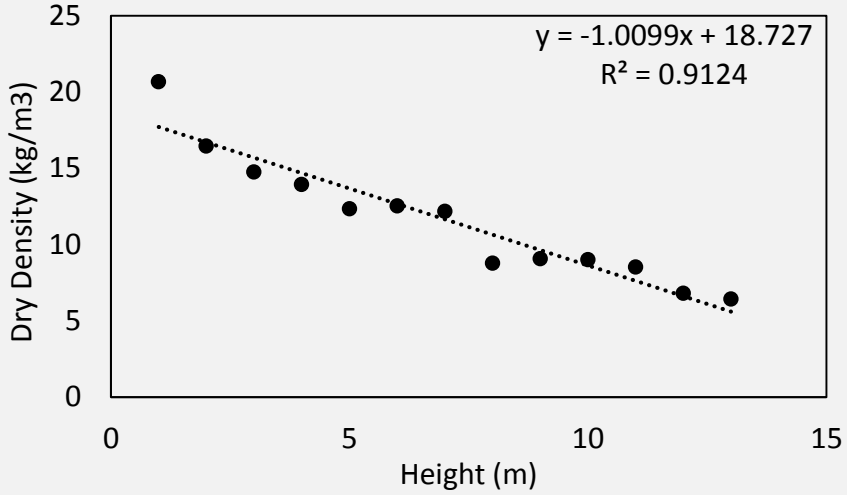


Figure 2. Scatterplot of height above ground vs. dry density for 1 m tree trunk segments. There is a strong, negative relationship between the two variables.

Excel can also be used to generate the following regression analysis output. Please note that the values that you should report are shown in bold (R^2, p-value, equation for the regression line) and that some of the information provided by Excel is not shown here.

Table 4. Results of the regression analysis of height above ground vs. dry density for 1 m tree trunk segments.

Regression Statistics	*Value*
Multiple R	0.96
R Square	**0.91**
Adjusted R Square	0.90
Standard Error	1.27
Observations	13

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**18.73**	0.75	25.00	0.00
X Variable 1	**-1.01**	0.09	-10.70	**0.00**

Please note that the R Square value matches the R^2 shown on the scatterplot. Furthermore, the intercept coefficient matches the value for the y-intercept (b = 18.73) in the regression line equation shown on the scatterplot and the X Variable 1 coefficient matches the value for the slope (m = -1.01) of the equation. The null hypothesis for this analysis is that the slope of the line is equal to 0, which would mean that there is no relationship between the variables. The p-value for the slope indicates the probability that we would see a slope other than 0

by chance. Since the p-value is less than 0.05, we can reject the null hypothesis and say that we are 95% confident that the slope is, in this case, less than 0. Please note that the direction of the linear relationship (positive or negative) is indicated by the sign of the slope (*i.e.*, X Variable 1 coefficient) and is, for this example, negative. Also, please keep in mind that the p-value for the slope, 0.00, is rounded to two decimal places but that it is actually greater than 0. This would be apparent either if more decimal places were shown or if a scientific notation were used.

Practice Assignment

You will need to use the Excel file posted in the practice resources tab on Collab.

T-test Procedure:

Use the data analysis tools in Excel to perform a t-test on the fish data listed in the "t-test" worksheet in the Excel file posted on Collab. Follow the steps outlined below. Please note that these steps are written for Excel 2007 and that the titles of tabs, sub-tabs, options, and dialogue box components in Excel 2007 are shown in bold. Also, please note that the fish dataset is based on Arrington et al. (2002).

1. Go to the "t-test" worksheet in the Excel file on Collab.

2. Go to the **Data** tab, find the **Analysis** sub-tab, and select the **Data Analysis** option.

3. Select **t-Test: Two-Sample Assuming Unequal Variances**. In the dialogue box for this test, select the "Percentage with empty stomachs values" for all algivores/detritivores for the **Variable 1 Range**. For the **Variable 2 Range**, select the Percentages for all piscivores. Set the **Hypothesized Mean Difference** to 0. Do NOT check the **Labels** option. (Please note: you would check this option if you had put the values for Variable 1 and Variable 2 in two separate columns, given each a separate text column heading (*e.g.*, Algivore/Detritivore, Piscivore), and had included these column headings when selecting the two variable ranges.) Keep **Alpha** at 0.05. Select a cell removed from the columns containing your data for the **Output Range**. Click **OK** when you are ready to have Excel run the t-test analysis.

Figures:

1. Make a table that lists the values of the following: degrees of freedom, t-test statistic, t-critical value, and two-tailed p-value for your t-test. Be sure to make a table that looks like the ones in this handout; it should have a thick, dark line at the bottom; a single, thinner line at the top; and a double line under the column headings. To make these lines, select the bottom row of your table in Excel, go to the **Home** tab, **Font** sub-tab, and **Borders** option. Select **Thick Bottom Border**. Then select the top row of your table and select **Top and Double Bottom Border** under the **Borders** option.

2. Make a bar graph that shows the mean values for percentage of fish with empty stomachs for algivores/detritivores and piscivores. Be sure to not only label the axes of the graph but to provide error bars that show +/- 1 standard deviation around the mean values. Use the stdev function to calculate the standard deviation values for each group of fish (algivores/detritivores and piscivores). To use this function, type "=stdev()" into a cell removed from the data, put the cursor in-between the parentheses, and then select the cells containing the data for one group of fish (*e.g.*, algivores/detritivores). The number that Excel generates should be the standard deviation for that group. Convert standard deviation to standard error for each group of fish by dividing standard deviation by $\sqrt{n}$ for each group. To make the bar graph, select the two values you are graphing (it's easier to do this if you type the two values in adjacent cells, one on top of the other) and go to the **Insert** tab, **Charts** sub-tab, **column** option. Select the first **2-D Column** option. Select the chart that is generated

and go to the **Design** tab and **Chart Layouts** sub-tab. Select **layout 9** (or another layout that has axis titles and a legend). Delete the **Chart title**. Replace **Axis Title** with the appropriate axis labels; include units where appropriate. To add in error bars, select the chart and go to the **Layout** tab and **Error Bars** sub-tab. Select **More Error Bars Options…**In the **Format Error Bars** dialogue box, make sure the **Vertical Error Bars** option is selected and check **Both** under **Direction** and **Cap** under **End Style**. Check **Custom** under **Error Amount**, click the **Specify Value** button, and then select the two standard error values (one for each fish group) for both the **Positive Error Value** and the **Negative Error Value**. Make sure that the standard error values are listed in the same order as the means (*e.g.*, value for algivores/detritivores in top cell, piscivores in bottom and adjacent cell). Click **OK** in the **Custom Error Bars** dialogue box and then **Close** in the **Format Error Bars** dialogue box when you are ready for the error bars to be generated.

Thought Questions:

1. What are the null and alternative hypotheses for this t-test?

2. Based on the p-value and the size of the t-test statistic relative to the t-critical value, do you reject the null hypothesis? Why?

3. What can you conclude based on the results of the t-test? Do these results make sense? Why?

Regression Procedure:

Use the following steps to perform a regression analysis on the cordgrass (*Spartina alterniflora*) data in the "Regression" worksheet in the Excel file on Collab:

1. Go to the "Regression" worksheet in the Excel file on Collab. Please note that the names of the different worksheets should appear at the bottom of the workspace in Excel.

2. Go to the **Data** tab, **Analysis** sub-tab, and select the **Data Analysis** option.

3. Select **Regression**. Select data for the dependent variable for the **Input Y Range**. Select data for the independent variable for the **Input X Range**. Check the **Labels** option if you include the text headings for the dependent and independent variables in your Y and X ranges. Check **Confidence Level** and keep it at 95%. Select a cell removed from the columns containing your data for the **Output Range**. Check **Line Fit Plots**. Click **OK** when you are ready to have Excel run the regression analysis.

Figures:

1. Make a table that lists the slope and line intercept for the linear equation generated in the regression analysis, as well as the R^2 value and p-value for the analysis. Again, make sure the table looks like the tables in this handout.

2. Make a scatterplot of the cordgrass data. Be sure to label the axes clearly and put the independent variable on the x-axis and the dependent variable on the y-axis. Add in a linear trendline and make sure you display both the R^2 value and trendline equation on the scatterplot. To make the scatterplot, you can modify the line fit plot generated by the regression analysis as follows: Delete **predicted Y** data series and the **title** from the line fit plot. Right click on **Y** data series and select **Add Trendline**. Select

linear option. Check **Display Equation on chart** and **Display R-squared value on chart**. Make sure that the axis labels are correct and change them as needed.

Thought Questions:

1. What is the independent variable for the regression analysis? What is the dependent variable?
2. What is the null hypothesis of this analysis? What is the alternative hypothesis?
3. What can you say about the relationship between these two variables based on the results of the regression analysis? Is it a strong relationship? What is the direction of the relationship? Does the direction of the relationship make sense? Why?

Bonus question: Based on the equation of the linear trendline, how much cordgrass productivity, in $g/m^2/yr$, would you expect to see at 4 cm above mean high tide level?

Appendix 1. Table of critical t-values. Please note that df = degrees of freedom and all critical t-values correspond to a probability of type I error (α) of 0.05.

df	t-critical	df	t-critical	df	t-critical	df	t-critical	df	t-critical
1	12.707	21	2.0796	41	2.0196	61	1.9996	81	1.9897
2	4.3026	22	2.0739	42	2.0181	62	1.999	82	1.9893
3	3.1824	23	2.0686	43	2.0167	63	1.9983	83	1.9889
4	2.7764	24	2.0639	44	2.0154	64	1.9977	84	1.9886
5	2.5706	25	2.0596	45	2.0141	65	1.9971	85	1.9883
6	2.4469	26	2.0555	46	2.0129	66	1.9966	86	1.9879
7	2.3646	27	2.0518	47	2.0117	67	1.996	87	1.9876
8	2.306	28	2.0484	48	2.0106	68	1.9955	88	1.9873
9	2.2621	29	2.0452	49	2.0096	69	1.995	89	1.987
10	2.2282	30	2.0423	50	2.0086	70	1.9944	90	1.9867
11	2.201	31	2.0395	51	2.0076	71	1.9939	91	1.9864
12	2.1788	32	2.0369	52	2.0066	72	1.9935	92	1.9861
13	2.1604	33	2.0345	53	2.0057	73	1.993	93	1.9858
14	2.1448	34	2.0322	54	2.0049	74	1.9925	94	1.9855
15	2.1314	35	2.0301	55	2.0041	75	1.9921	95	1.9852
16	2.1199	36	2.0281	56	2.0032	76	1.9917	96	1.985
17	2.1098	37	2.0262	57	2.0025	77	1.9913	97	1.9847
18	2.1009	38	2.0244	58	2.0017	78	1.9909	98	1.9845
19	2.093	39	2.0227	59	2.001	79	1.9904	99	1.9842
20	2.086	40	2.0211	60	2.0003	80	1.9901	100	1.984

References

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

Data Presentation Checklist

Adapted from a guide by JE Fultz 2013

- **Scaling Graphs** - the graph should be scaled so that trends are not distorted (as in Figure 1), but are displayed in the way that makes the most sense to the reader. To make best use of space, axes do not necessarily have to start at zeros (Figure 2). This method is sometimes used in the media to exaggerate trends.

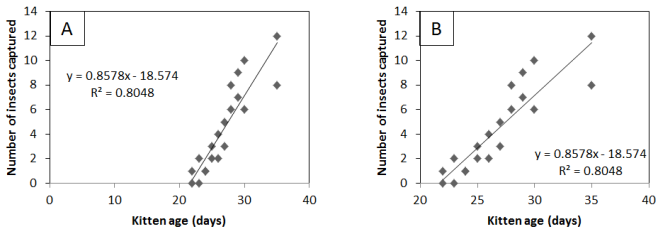


Figure 2: Example of conserving space by scaling axes. Relationship between the age of kittens and the number of insects they caught. A) has axes starting at zero, while B) has the x-axis starting at two weeks of age.

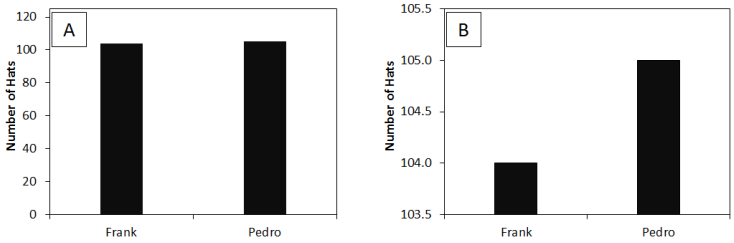


Figure 1: Example of manipulating scaling of the y-axis. The number of hats owned by Frank and by Pedro. A) has axes starting at zero, while B) has axes skewed to make the difference look much larger.

- **Axis Labels** - each axis should have a label describing the type of data displayed and the units in which it was measured. You add axis labels by selecting (highlighting) the graph, and then clicking on chart tools: layout: axis titles. For the x-axis click on primary horizontal axis title: title below axis. For the y-axis, click on primary vertical axis title: rotated title. Change font size for the entire graph by right-clicking outside of the axes, clicking on font, and selecting a font size. Use the shortest most descriptive title possible for axes or for legends describing treatments (Figures 1 & 2).
- **Tick Labels** - too many ticks and tick labels make the axis hard to read. Correct this for an axis by right-clicking on the axis, clicking on format axis, and adjusting the major unit to a larger interval (so fewer ticks).

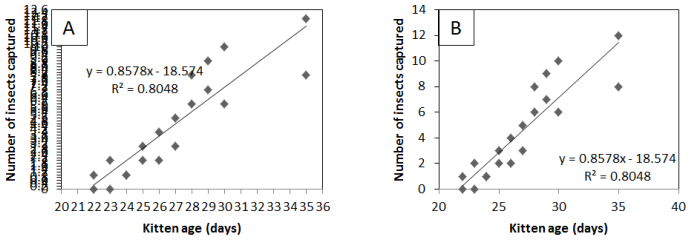


Figure 3: Example of controlling the number of tick marks. Relationship between the age of kittens and the number of insects they caught. A) has too many tick marks, while B) has fewer tick marks.

- **Legend** - for graphs that have more than one data series, a legend distinguishing the shading in bars, points, or lines may be necessary (see example 4a). However, this information can also be

given descriptively in the figure caption. The legend should neither crowd the figure, nor be too small.

- **Figure Caption** - a figure caption immediately below the graph summarizes the purpose of the graph. If your graph includes error bars, mention whether they refer to standard deviations, standard errors, or confidence intervals. Add the figure caption after pasting the figure from EXCEL into a WORD document. Sample figure captions are given throughout this laboratory reference.
- **Fonts** - Fonts (such as times new roman) can look blurry when reduced or magnified in size. For figures, use fonts sans serif: e.g., arial, tahoma, or calibri. Correct this for the entire graph by right-clicking on the graph outside of the axes, clicking on font, and selecting a font that is sans serif.
- **Color** - for printed work, use distinct stippling, lighter & darker shading, and/or different line patterns to distinguish different data series. Unfortunately, EXCEL has default colors that may not look different when printed in black and white. To change formatting, right-click on the columns/points/lines of a given series (all the columns/points of a series should be selected), and clicking on format data series, where you can change the fill, border color, line color, or line style. An example of how this can be problematic is found in figure 4.

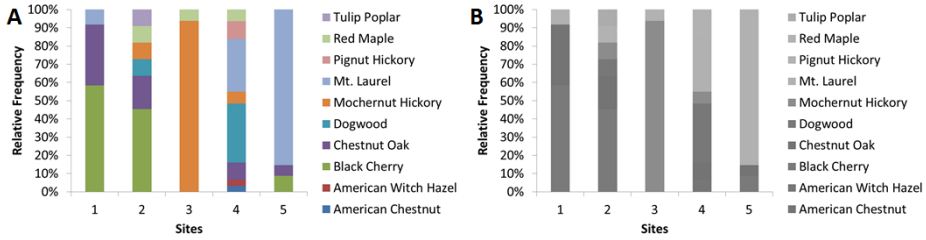


Figure 4: Example of print-color error. Relative frequency for species of tree at five locations along a transect on observatory hill. A) looks very nice, but if printed without color (B) it is impossible to interpret.

- **Background Shading** - make your graphs on a white or transparent background. Shading photocopies badly, and makes columns, points, and lines harder to see. To eliminate shading in the plot area (the area containing the data), right click within it (but do not select the columns/points). In the window that opens, select format plot area: fill: no fill.
- **Do Not Use Outside Borders** - this looks bad and is unfortunately created by default in EXCEL. To eliminate it, right-click on the figure outside of the axes, and select format chart area: border color: no line. See Figure 6 for an example.
- **Do Not Use Gridlines**- these usually clutter the figure. Select (highlight) them and click the delete key to eliminate them (these are shown in figure 6B).

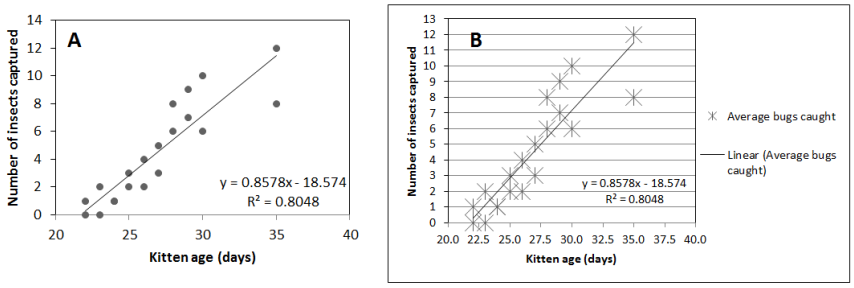


Figure 6. Comparison of a clean graph versus a busy graph. A) follows the checklist outlined above, while B) contains too many axis ticks, horizontal gridlines, difficult to interpret marks, small font, an outside border, and a legend for a single data series.

Statistics Cheat Sheet

Descriptive Statistics

Mean: "x-bar"- the sum of all sample values divided by the number of samples

$$\bar{x} = \frac{\Sigma x}{n}$$

x-bar: Mean
Σx: sum of all sample values
n: Number of samples

Median: the middle value of an ordered set of values

Mode: the most frequent value in a group of values.

Frequency Distribution: graphical display (histogram) of a distribution of observed frequencies of occurrence of the values of a variable

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Measures of Variation/Dispersion:

Range: the difference between the largest value of a variable and the smallest value.

$$\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{n - 1}}$$

x-bar: Mean
x: observation
n: number of observations
Σ: sum

Standard Deviation (σ): measure of the spread of observations about the mean.

Variance: the standard deviation squared. Weighs each observation by its distance from center of distribution.

Coefficient of Variation: used to compare measures of variation between sample groups with largely different means but the same metric (ie. length).

Standard Error: the standard deviation divided by the square root of the number of observations. Can be used to indicate the size of the uncertainty in the calculated mean.

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

s: standard deviation
n: number of observations

Hypothesis Testing and Significance:

Type I Error: False positive- observing a difference when there is not one

Type II Error: False negative- observing no difference when there is one.

α-significance: the probability of a type I error. If the result is significant at the 0.05 level, you are 95% confident that the results are not due to chance alone (you are not observing a difference when there is one).

P-value: the probability of error involved in accepting the observed results as valid. A p-value is used to measure the significance of a given result at a specific α-level (ie. α=0.05, so p-value < 0.05 is significant).

Test statistic (calculated using the observations from a population) is compared to a **critical value** (calculated for the degrees of freedom and α-level specified, maximum possible test statistic allowed to be significant).

Statistical Tests

t-test: used to compare the mean of two populations. Note the formula to the left will calculate the test statistic to be compared to the critical value based on the degrees of freedom and α-level of significance.

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

x-bar: mean of population
s^2: variance of population
N: number of observations

Chi-square test: used to compare the difference between what is expected and what is observed

Regression: used to analyze relationships between variables.

Coefficient of Determination (R^2): measure of the goodness of fit of a linear model. The coefficient ranges between 0 and 1, with 1.0 being the best fit.

$$X^2 = \sum \frac{(o-e)^2}{e}$$

O= observed value
e= expected value
x^2= test statistic

Least Squares Method: minimizes the sum of squared residuals, a residual being the difference between an observed value and the fitted value provided by a model.

Microsoft Excel Shortcut Cheat Sheet

Table 1. Keyboard shortcuts.

ctrl s	saves document/workbook
ctrl a	select all (the entire worksheet)
ctrl x	cut
ctrl z	undo the last thing you did
ctrl c	copy
ctrl y	redo the last thing you did
ctrl v	paste
ctrl shift <	reduce font size
ctrl b	bold
ctrl shift >	increase font size
ctrl i	italic
ctrl =	makes text subscript
ctrl u	underline
ctrl shift =	makes text superscript

Books constitute capital. A library book lasts as long as a house, for hundreds of years. It is not, then, an article of mere consumption but fairly of capital, and often in the case of professional men, setting out in life, it is their only capital
-Thomas Jefferson

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Forest Ecology I: Examining Forest Patterns along Environmental Gradients

Introduction

Many of the concepts presented in this lab have been at the center of remarkably divisive struggles within ecology (Smith 1996). Some of these issues are still unresolved, even after more than eighty years of, at times, acrimonious debate (Shugart 1998). What sorts of topics could serve to so greatly agitate ecologists? Amazingly, they are fundamental ideas about the nature of vegetation dynamics, ideas like **community**, and the contrast between the **individualistic approach** and the **organismic approach** to plant ecology. Although the term **community** has many meanings (Smith 1996), we will use the following definition: *an assemblage of plants in space and time with a complex network of interrelationships, both direct (*e.g., *competition for locally scarce nutrients) and indirect (*e.g., *effect of shading on soil surface temperatures, and thus soil moisture).*

The **organismic approach** to plant ecology is exemplified by the views of F.E. Clements (1916), one of the founders of the perspective, and a hugely influential ecologist (Shugart 1998; Smith 1996). Clements believed all of life was organized at increasingly larger physical scales, and that the community was itself a kind of **super-organism**, a completely integrated whole which 'lived' in a certain type of environment. The scales of organization ranged as follows: cells organized to form tissues, which aggregated as organs, systems of organs composed organisms, which when assembled formed communities. He championed the idea of a **climax** community, with a static series of developmental stages, which he termed **succession**. To Clements, growth and changes in the composition of a forest over time (*e.g.*, after the abandonment of a tract of farmland), was merely the development (directly analogous to the embryology of an animal) of a mature organism (*i.e.*, the climax or mature community, for example an oak-hickory forest) that would perpetuate itself if left to its own devices. The species components of these communities were tightly prescribed (*i.e.*, an oak-hickory forest is composed of species x, species y, *etc.*). Although the organismic perspective held nearly complete sway in ecology until at least the early 1960's, the individualistic perspective of plant ecology has supplanted it (Austin 1985; Shugart 1998; Smith 1996).

The **individualistic approach**, associated with the works of Ramensky (1924) and Gleason (1926), is fundamentally different in its conception from the organismic approach. Instead of seeing the community as a self-organizing super-organism, as did F.E. Clements and his intellectual allies, individualists argue that plant distributions are controlled on an individual species basis by the genetic differences between species (*e.g.*, species-specific response functions for productivity at various soil moisture levels), as well as the stochastic nature of dispersal. Any 'community' that is observed (*e.g.*, oak-hickory forest), is merely a coincidence in space of overlapping individual species distributions (Figure 1, right side) along some kind of environmental gradient. As you can see (Figure 1), there are various places where specific assemblages of plants exist, and these assemblages could be interpreted as communities; however, it is really the underlying pattern of response to altitude that controls the observed distributions, not some inherent capacity for self-organization. Many studies, empirical as well as

simulation, have reinforced this idea: it is primarily the species-level, genetically based, differences in responses to various environmental factors (*e.g.*, temperature, moisture, *etc.*) which explain the distribution of plants (Austin and Smith 1989; Shugart 1998). This is a simple, powerful, and attractive model of vegetation dynamics.

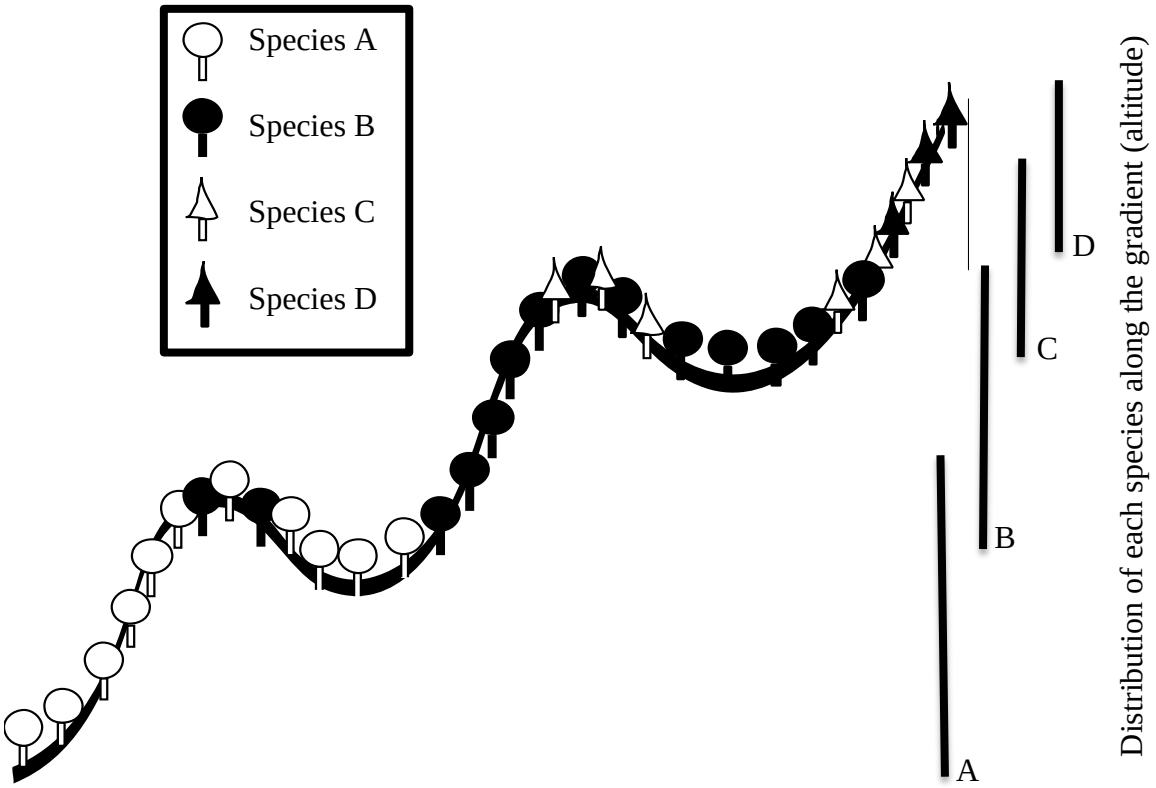


Figure 1. Hypothetical patterns of spatial distributions of four tree species along a complex environmental gradient (*i.e.*, altitude). The species have a regular and clear distribution range, but this produces a complex pattern of communities along the landscape (after Figure 5.15; Shugart 1998).

Austin and Smith (1989) suggest that there are three different types of gradients:

1. **Resource gradients** are differences in the abundances of resources, which are consumed by plants, and are required for survival (*e.g.*, light, moisture, *etc.*)
2. **Direct gradients** are differences in some factor which has direct influence on plant metabolism, but which is not consumed (*e.g.*, temperature, soil pH, *etc.*)
3. **Indirect gradients** represent a complex combination of observed responses to both direct, and resource gradients (*e.g.*, response to altitude is a combination of responses to moisture differences, which represents a resource gradient, and responses to temperature differences, which is a direct gradient)

In this lab, we will be examining patterns of species dominance (Smith 1996, p. 602) as we move along environmental gradients. More specifically, we will be looking at a transect along a small ravine at O-Hill, which has one slope oriented with a south-facing aspect, and an opposing slope with a north-facing aspect. Along the bottom of the ravine is a small seasonal stream, which indicates a more mesic site. The upper ends of both slopes are much more exposed, suggesting more xeric conditions. We would expect the patterns of species dominance to shift as we move from the top to the bottom of the ravine, or the north- to the south-facing slope, as a result of the genetically-driven differences between species in their response to environmental gradients along the transect.

It is important to note that there is more than one gradient along our transect at O-Hill. We will collect data on one gradient (organic horizon thickness) this week, and will also collect soil samples this week that will be analyzed in lab next week in order to obtain data on three more gradients (*i.e.*, soil texture, soil pH, and soil moisture). There are three other gradients, which we will not measure in the field, but which affect species distributions. There is a resource gradient (*i.e.*, sunlight) and a direct gradient (*i.e.*, temperature) running from a maximum along the south-facing slope, to a minimum along the north-facing slope. And there is an indirect gradient (*i.e.*, altitude), with 2 upper slope stations, two lower slope stations, and a bottom station. As mentioned above, moisture levels and temperatures vary with altitude, with higher elevation sites tending to be drier and, at least at O-Hill, warmer as a result of being more exposed to sunlight and less shaded by trees.

Objectives

The main objective of this exercise is to collect data on tree species at each of 5 stations, and collect soil samples that will be used to assess key environmental variables at these stations. The soil data and tree species data will then be combined in order to assess species distribution patterns, as well as multiple gradients underlying these patterns.

Materials

- Nylon rope
- Dichotomous key/field guides
- DBH tape
- Datasheets
- Meter stick
- Trowel
- Sharpies
- Plastic bags (for soil samples)

Exercise: Field Data Collection

Overview

The transect, which runs from one ridge-top, down the slope to the stream, and back up the other side of the ravine, is composed of a linear series of five sampling stations. Each station is a plot 10m x 10m ($100m^2$), and is clearly delineated. The stations perimeters are approximately 40m apart, thus the centers are approximately 50m apart. There are two stations each along the north and south facing slopes, and there is one station at the bottom of the ravine. We start our sampling on the south facing slope (station 1) and end at the north facing slope (station 5).

Tree species identification

Upon arrival at a new station, the first task is two divide the plot in half using the nylon rope; this will allow for a number of people to work in the same area and not repeat counts. The class should roughly divide in half, with each half going to a side of the plot, and then each half can further subdivide in order to make sure that everyone knows who is counting what. You definitely want to communicate with your neighbors in order to make sure that every stem is identified and measured ONLY ONCE.

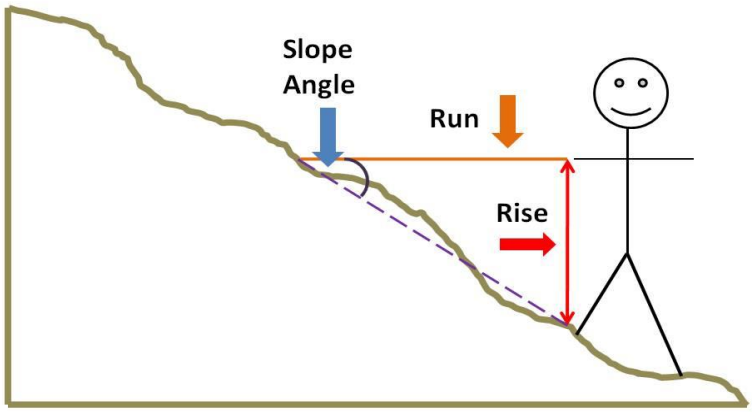
Tree species identification will be facilitated by the use of a dichotomous key, and a tree identification handout that contains pictures of leaves, bark, and seeds or flowers of several of the tree species found on O-Hill. The dichotomous key has been specially constructed to aid in the easy identification of species found at O-Hill (*i.e.,* superfluous species are excluded). Keys will be handed out and explained in class. If you are having a problem identifying a species, you can use the expanded winter twig key in one of the available field guides. Remember, a key is just a tool, and it has its maximum power when the user is employing it systematically, and intelligently: don't be afraid to look at several aspects of a particular tree in order to be sure about its identity.

We are only interested in identifying and measuring trees that are greater in height than 137 cm (breast height). Any trees taller than 137 cm will be identified using the dichotomous key and tree identification handout, and will have their DBH (diameter at breast height) measured to the nearest 0.5 cm. Make sure that when you are taking DBH, you are actually doing it at 137 cm, that the DBH tape is straight and parallel to what would be normally flat ground, and that you are standing on the uphill side of the tree. In addition, if a tree has more than one stem, measure the DBH of each stem separately and add the values together to get the total DBH for that tree.

As you identify and measure the trees in a plot, make sure that the station data recorder (this role should alternate) is getting the correct data. All of the data will be recorded on the appropriate data sheets, on a station-by-station basis, and then assembled and distributed electronically by your TA.

Slope Measurements

Using the nylon rope and meter stick, have one person hold the nylon rope on the ground while another walks downhill until the nylon rope sits at a known height and is held level and tight (DBH height is an easy height to use). Using the meter stick measure the rope for the run length, and confirm rise length with meter stick as well. Measure the rise and run of the slope of each site and record the length and height in meters.



Soil sample collection and horizon measurement

A soil pit has been dug in each of the plots. At each station, care should be taken not to disturb the 'natural' soil horizons. Carefully remove the cover of the soil pit, and collect a soil sample from both the mineral and organic horizons. For each station, use a meter stick to measure the depth of the different horizons. Make sure the pit is re-covered after you have collected your samples and measured the horizons. Be sure to take notes on differences you observe among the stations.

Station ID	M Horizon (cm)	O Horizon (cm)
1 (South Facing Upper)		
2 (South Facing Lower)		
3 (Middle)		
4 (North Facing Lower)		
5 (North Facing Upper)		

Texture, soil pH and soil moisture

Samples collected from the mineral and organic horizons will be brought to the lab and stored in a refrigerator. Next week, we will be working in the lab to determine soil texture, pH, and soil moisture.

Data Analysis

For you calculations you will be completing an Excel worksheet to you help you calculate the correct values. Read through the descriptions of the calculations you will be making and then follow the directions on the worksheet.

1. Calculate a simplified **importance value** (Smith 1996) for the tree species at each sampling station using our stem counts and DBH measurements and the steps outlined below. This simplified importance value is merely an indicator of the dominance of a particular species at a site, which is a measure of how strongly the presence of that species controls the overall community structure. The easiest way to accomplish the following calculations is by using a spreadsheet program such as MS Excel.

    a. Calculate the **relative frequency** for each species at each station (Equation 1). Remember that the number of stems for either a given species (*i.e.*, species x) or for all species should be for a given station; do NOT combine data across all stations. The relative frequency varies between 0 and 1, and is useful for comparison of plants of different physical size.

$$\text{Relative frequency} = \left[\frac{\#\_of\_stems\_of\_species\_x}{total\_\#\_of\_stems\_of\_all\_species} \right] \text{(Eqn. 1)}$$

    b. Calculate the individual stem **basal area** for each individual of each species at each station (Equation 2). The individual basal area is simply the cross-sectional stem area of an individual tree at breast height, and can be calculated using the DBH measurements that we took in the field.

$$\text{Individual stem basal area} = \left[(\pi)(\frac{DBH}{2})^2 \right] \text{(Eqn. 2)}$$

    c. Calculate the basal area of each species at each station (Equation 3). A good way of visualizing the basal area of a particular species is if you took all of the trees of that species at one of the stations, and simply cut them all off at breast height. The cross-sectional area of these stumps would be the basal area of this species.

$$\text{Species basal area} = \left[\sum_{i=1}^{n} Individual\_stem\_basal\_area \right] \text{(Eqn. 3)}$$

    where Σ= the sum of; *i* = individual x of a given species, *n* = total number of individuals of a given species at a given station.

    d. Calculate the total basal area for each station (Equation 4).

$$\text{Total basal area} = \left[\sum_{i=1}^{n} Species\_basal\_area \right] \text{(Eqn. 4)}$$

    where Σ= the sum of; *i* = species x, *n* = total number of species at a given station.

e. Calculate the **relative dominance** of each species at each station (Equation 5). Remember that species and total basal area values should be for a given station; do NOT combine data across stations. Relative dominance values vary between 0 and 1, and are useful for comparison of plants of approximately equal size.

$$\text{Relative dominance} = \left[\frac{Species\_basal\_area}{Total\_basal\_area} \right] \text{(Eqn. 5)}$$

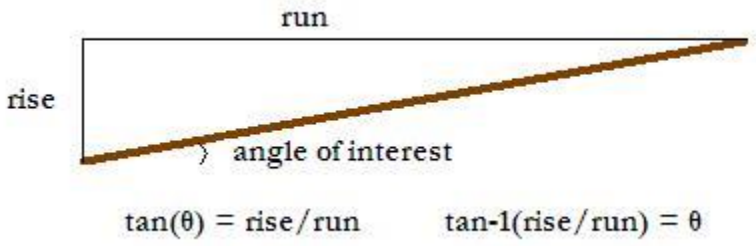
f. Calculate the **importance value** for each species at each station (Equation 6).

Importance value = Relative frequency + Relative dominance (Eqn. 6)

For example, imagine that at a particular station we calculate a relative frequency of white oak equal to 0.7 (*i.e.*, 70% of all the stems counted at the station were white oak stems), and a relative dominance of 0.85 (*i.e.*, white oak represents 85% of the basal area recorded at the station). The importance value of white oak at that station would then be equal to 0.7 + 0.85, or 1.55. As you can see, a species that is not present at the station would have an importance value of 0 at that station, and a monospecific station would have an importance value of 2 for the single species that is present. As none of our transect stations are monospecific in their species composition, we can expect our calculated importance values to vary from 0 to less than 2.

2. Calculate the slope of each site using the rise and run to calculate the angle.

Slope Angle (θ) = tan-1(rise/run) (Eqn. 7)



Discussion Guides

- Pick at least **two** of the species found in all, or most, of the stations on O-Hill. How would you expect the importance value of each of these species to vary along the transect? **Why**? Be sure to consider how you would expect at least **one** of the gradients along the transect that were described in this handout (*i.e.*, light, slope, temperature, or altitude) to affect each of the species. (Hint: look up information on the resource requirements, for example for light and water, of these species, and on the environmental conditions typical of the sites where these species are found.) Do your results match your expectations? **How**?

- Are there any species that only show up at one site? If so, **why** do you think that species is only found at that one site? Are there any species that have a high relative dominance but very low relative frequency? What does this say about the role that this/these species plays in the local forest community? Are there any species that have a high relative frequency but a low relative dominance? What does this say about the role that this/these species play in the local forest community?

- How do relative frequency and relative dominance differ as measures of abundance?

- Did we choose an appropriate sampling method for the kinds of questions we are asking, and the organisms being studied? **Why** or why not? Give at least **one** improvement that could be made to our methodology.

- How might an organismal ecologist, such as Clements, explain the patterns that we observed? Contrast this with an individualistic, or Gleasonian, explanation of the species patterns.

Write up Procedure

Your assignment is to create **figures** (see list below) that will help us to visualize and quantify any changes in community composition that occur among the different stations on O-Hill.

Please make the following figures:

1) A graph of the **Relative Frequency** for each tree species found along the transect. Make a 100% Stacked Column Graph by following the directions on the Excel worksheet (See Figure 2 for an example).
2) A graph of the **Relative Dominance** for each tree species found along the transect. Make a 100% Stacked Column Graph by following the directions on the Excel worksheet.
3) Your TA will select five of the tree species that you identified along the transect on O-Hill. For all 5 species, construct a bar graph that shows the **Importance Value** for all the species at each of the 5 stations in the transect by following the directions on the excel worksheet (see Figure 3 for an example).

Come to lab next week prepared to discuss the calculations you performed and the figures you made for this lab, as well as the discussion questions listed above.

Example Graphs

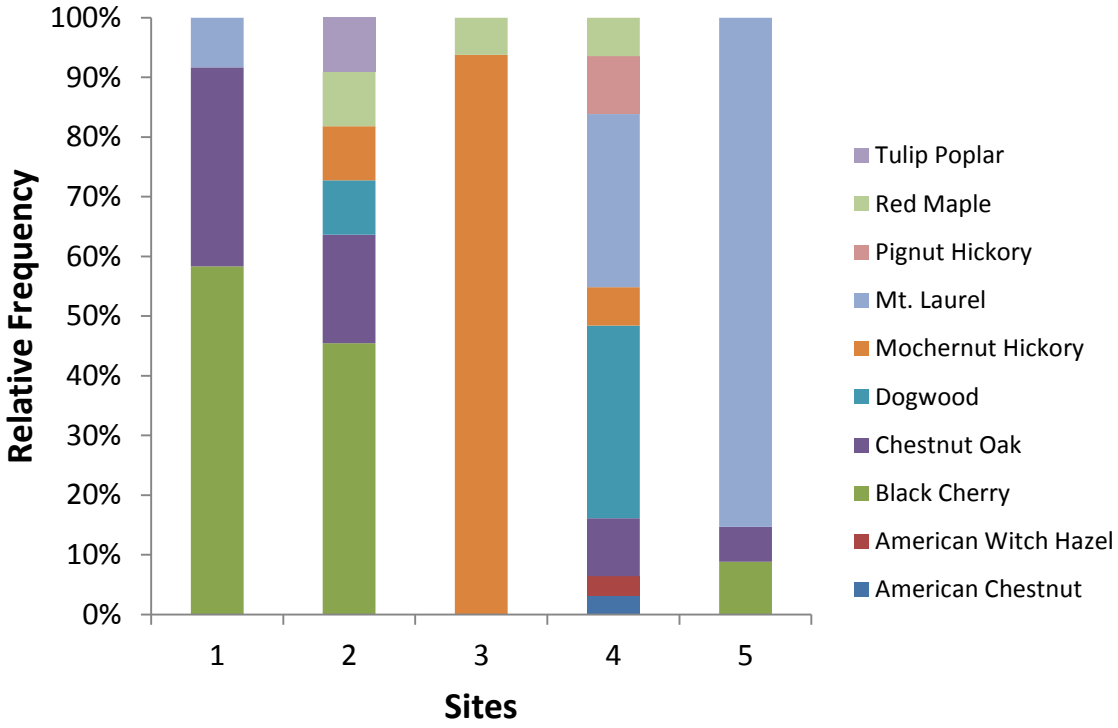


Figure 2: The percent relative frequencies of trees found on O'Hill along five sites (1 = south upper facing to 5 = north facing upper).

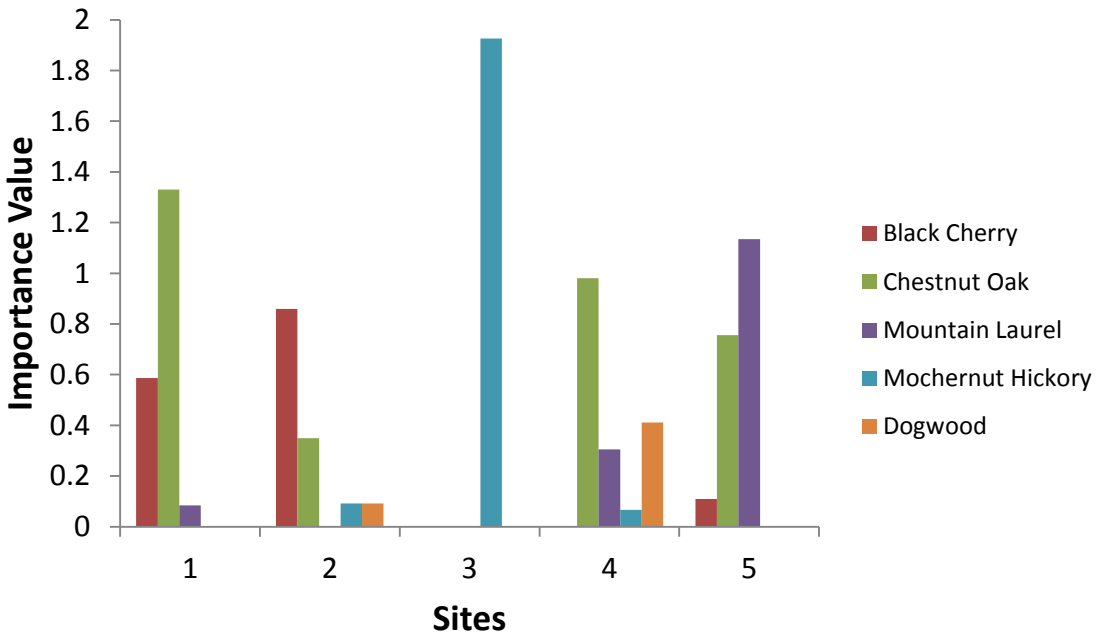


Figure 3. Importance values for 5 tree species found on O'Hill along 5 sites (1 = south facing upper, 5 = north facing upper).

Useful References

Austin, M.P. (1985). Continuum concept, ordination methods and niche theory. *Annual Review of Ecological Systems.* 16: 39-61.

Austin, M.P. and T.M. Smith. (1989). A New Model of the Continuum concept. *Vegetation*. 83: 35-47.

Clements, F.E. (1916). *Plant succession: An analysis of the development of vegetation*. Washington, D.C.: Carnegie Institute Publication no. 242.

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Forest Ecology II: Properties of Forest Soils

Introduction

When we examined forest patterns and spatial distribution of different tree species in the first part of this lab, we assumed that there were some environmental gradients controlling these distributions. These gradients are the result of environmental variables that vary in abundance, concentration, or quality along our transect at O-Hill. We are focusing on the spatial variability of various resources and other environmental variables that can affect the distribution of different tree species. However, it is important to remember that resources and other variables can change over time. It would however take a while for the distribution of long lived organisms, like trees, to change their distribution in response to temporal variation in a given variable. Thus, it is reasonable for us to assume that the gradients that control the patterns that we are observing only vary spatially.

Many of the resources that a plant needs to survive, grow, and reproduce are found in the soil. It follows that many of the gradients that control the spatial distribution of trees may be associated with various soil parameters and characteristics. To better understand the forest patterns we observed last week, we will measure several properties of the soil that may affect tree species distribution and abundance at O-Hill. Some of the parameters that may vary spatially along our transect, and thus help to explain the observed tree species distributions, are: **soil texture**, **soil moisture**, **organic matter content**, and **soil pH**. We will be measuring soil texture, soil moisture, and soil pH in lab today. We obtained an estimate of organic matter content in the field last week when we measured the depth, which is equal to the thickness, of the organic horizon. It is important to note that there are many other gradients that can impact vegetation patterns, such as light availability, air temperature, and soil temperature, which we will not be measuring.

Parameters of Interest

Soil texture

Soil texture is a measure of the particle size distribution of **clays**, **silts** and **sands** in a given soil. Clay consists of particles less than 0.002 millimeters (mm) in diameter, silt consists of particles 0.002 to 0.05 mm in diameter, and sand consists of particles 0.05 to 1 mm in diameter. Texture can be quantified by separating all the different particle sizes by sieving, gravimetric separation, hydrometric separation, or a number of other techniques. One can also obtain a useful soil texture value just by mixing the soil with water and feeling the soil with your fingers. Depending on the particle size distribution of the soil, the way it feels between your fingers will change. This can tell us if we have a sandy soil, or clay soil, or something in between.

Soil texture has a lot to do with soil properties and indirectly affects processes such as root growth, and the uptake of water and nutrients. A sandy soil will not hold much water, and its moisture content is strongly affected by local rainfall patterns and periods of drought. Sandy soils are also relatively infertile. A clay soil can hold large quantities of water, but, because of its tiny pore spaces, may not yield the water to plants during dry conditions. Silt is often incorrectly called clay because, like clay, it is sticky when

wet. Once the amount of sand, silt, and clay is known, you can give the soil a texture class name (Figure 1).

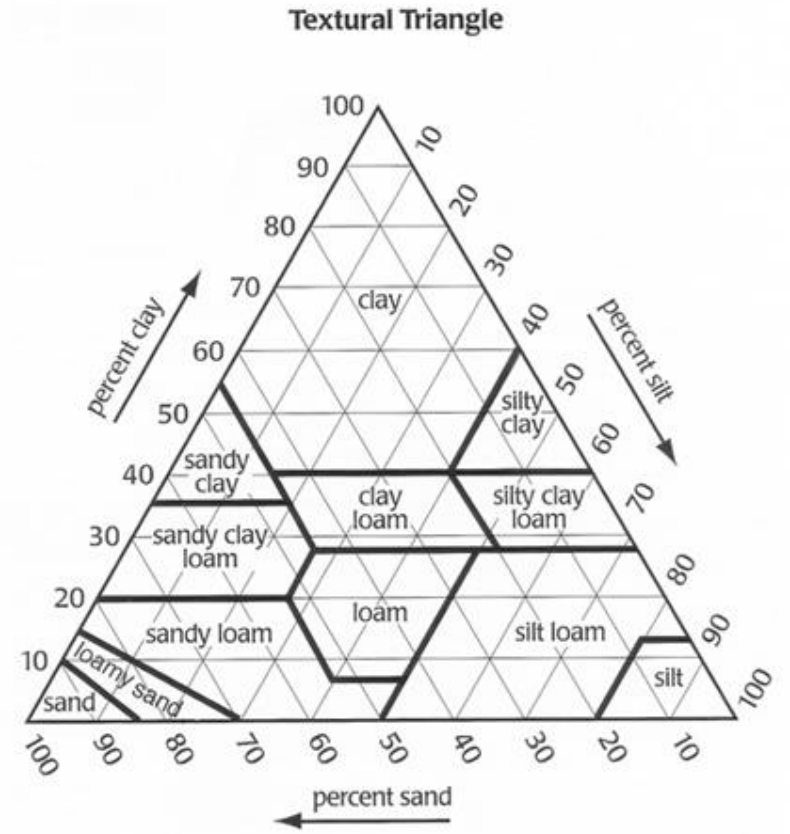


Figure 1. Soil texture triangle showing different soil textures that correspond to different combinations of sand, silt, and clay. Sand is a soil texture class with at least 85% sand, silt is a soil texture class with at least 80% silt, and loam is a mix of roughly equal parts of sand, silt, and clay.

Surface runoff on O-Hill is likely to take fine (*i.e.*, small) particles from the soils at high elevations and deposit them at lower elevations.

Soil moisture

Soil moisture is a measurement of the amount of water in the soil. Water is obviously a very important resource for plants, and the soil is the primary reservoir from which roots uptake water for the plant. Soil moisture can change with a number of variables, including: soil texture, precipitation, and proximity to the water table. A sandy soil will tend to drain more quickly than a clay rich soil, and subsequently create more arid conditions for the plant. Soil moisture can also change with organic matter content of the soil. Organic matter tends to act as a sponge, and thus the organic horizon is able to retain much more water than most minerals horizons. At O-Hill, the water table is much closer to the soil surface at the bottom of the transect, and subsurface flow is likely to take water from the high elevation to the low elevation sites. Additionally, the north-facing part of

the transect receives less sunlight, is cooler, and is thus the soil is typically moister than it is on the south-facing slope.

Organic matter content

As mentioned above, organic matter content is important for maintaining soil moisture. Organic matter also contains the remains of dead and decomposing organisms. The nutrients in the organic matter can be mineralized by bacteria and fungi, and can then be used by the plants. Organic matter content can also affect the soil pH, which in turn may control the types of plants that can grow on a given soil type. At O-Hill, surface runoff is likely to take organic matter from high elevation sites and deposit it at low elevation sites. The thickness of the organic horizon is also affected by local decomposition rates, and thus local temperatures. Decomposition of organic matter tends to happen more quickly under warmer, wetter conditions.

Soil pH

pH is a measure of the acidity and alkalinity of the soil. pH is based on a scale that ranges from 1 to 14; where 7 is neutral, less than 7 is acidic, and greater than 7 is alkaline. DI water is neutral with a pH of 7, lemon juice is very acidic with a pH of 2.6, and baking soda is very alkaline with a pH of 8.5. It is important to remember that pH is a logarithmic scale. This means that the difference between a pH of 7 and a pH of 6 is ten times the acidity, between 7 and 5 is 100 times the acidity, and between 7 and 4 is 1000 times the acidity. Thus, small changes in pH can have a major impact on the ability of plants to grow, especially since plants usually have a range of pH values at which they perform best. Outside its optimal range, a plant's performance may be physiologically constrained. Soil pH is used as an indicator of the availability of other nutrients in the soil, but only hydrogen ions are actually measured.

Objectives

The primary objective of this exercise is to examine the soils we collected last week at O-hill and measure three soil characteristics: 1) soil texture, 2) soil pH, and 3) soil moisture. We will then combine the data from this week with the information collected in the field last week to try and better understand the species distribution patterns on O-Hill.

Materials

- Eye dropper
- Beaker
- DI water
- Graduated cylinder
- Stirrer
- pH meter
- Scale
- Aluminum pan
- Drying oven
- Sharpie

Exercise 1: Soil Texture

For each station, or plot, on O-Hill, use soil samples from the **mineral** layer to assess the soil texture. Record your classifications of soil texture in table 1. Assess soil texture twice for the mineral soil at each station. Record the average or consensus of the two trials in the "consensus" column.

Table 1. Soil texture data.

Station ID	Texture 1	Texture 2	Consensus
1 (South Facing Upper)			
2 (South Facing Lower)			
3 (Middle)			
4 (North Facing Lower)			
5 (North Facing Upper)			

1. Place about two teaspoons of soil in the palm of your hand. Add water by the drop and knead the soil to break down clumps. The soil is the proper consistency when it is "plastic" and moldable like putty. If it's too wet, add more soil. The soil should be moist, but not quite glistening (Figure 2a). While working with the sample, note its malleability, stickiness, and stiffness. A high silt content makes a sample feel smooth and silky, with little stickiness or resistance to deformation. A soil with a significant sand content feels rough and gritty.
2. If the soil will not cohere into a ball and, instead, falls apart, then it is **SAND**.
3. If the soil forms a ball (Figure 2a), next try forming a ribbon. Place the ball of soil between your thumb and forefinger, gently push the soil with your thumb, and squeeze it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over your forefinger, until it breaks from its own weight (Figure 2b).

a)  b) 

Figure 2. a) Picture showing initial addition of water to the soil and formation of a ball. b) Picture showing the formation of a soil ribbon.

4. If soil forms a ball, but will not form a ribbon, then it is **LOAMY SAND**.

5. If soil forms a ribbon, but the ribbon is less than 2.5cm long when it breaks, consider whether the soil is:
    a. Very gritty, and a grinding noise is audible: **SANDY LOAM**.
    b. Very smooth, and no grinding is audible: **SILT LOAM**.
    c. Slightly gritty and smooth, and grinding is not clearly audible: **LOAM**.

6. If the soil exhibits moderate stickiness and firmness, and forms a ribbon 2.5-5cm long, consider whether the soil is:
    a. Very gritty, and a grinding noise is audible: **SANDY CLAY LOAM**.
    b. Very smooth, and no grinding is audible: **SILTY CLAY LOAM**.
    c. Slightly gritty and smooth, and grinding is not clearly audible: **CLAY LOAM**.

7. If the soil exhibits dominant stickiness and firmness, and forms a ribbon longer than 5cm, consider whether the soil is:
    a. Very gritty, and a grinding noise is audible: **SANDY CLAY**.
    b. Very smooth, and no grinding is audible: **CLAY**.
    c. Slightly gritty and smooth, and grinding is not clearly audible: **SILTY CLAY**.

Exercise 2: Soil pH

1. In a cup or beaker, mix DI water and soil in a 1 to 2 soil to water ratio (Figure 3a). Stir with a spoon or other stirrer until the soil and water are thoroughly mixed (Figure 3b).

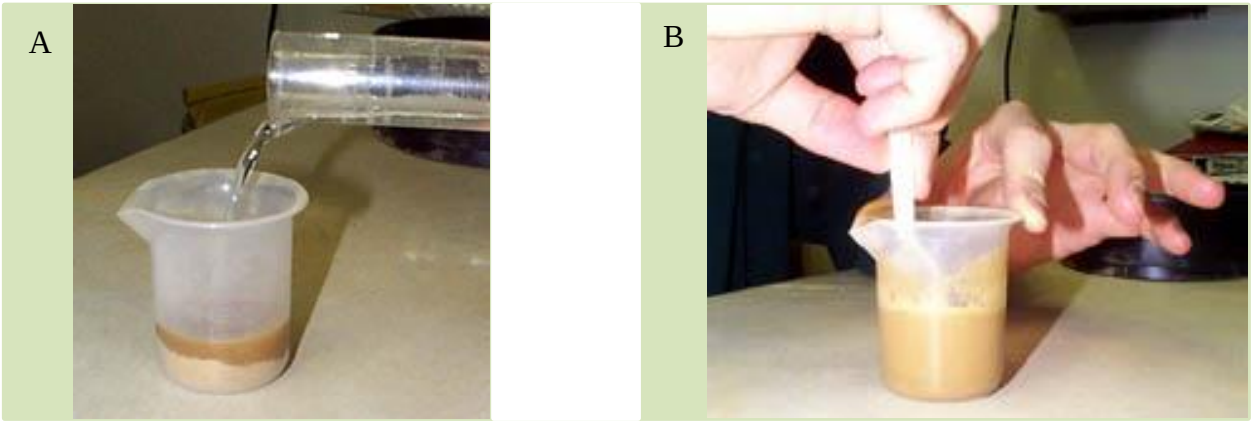


Figure 3. a) Adding water to soil. b) Stirring the water and soil until they are thoroughly mixed.

2. Stir the soil-water mixture for 30 seconds every 3 minutes for a total of five stirring/waiting cycles. Then, allow the mixture to settle until a supernatant (clearer liquid above the settled soil) forms. This should take about 5 minutes.

3. Measure the pH of the supernatant using the pH meter (Figure 4).

Figure 4. Measuring the pH of the supernatant with a pH meter.

4. Repeat this exercise twice for each soil sample at each station on O-Hill, and record the results in table 2. Record the average of the two pH measurements for each sample in the "average" columns.

Table 2. Soil pH data.

Station ID	Soil pH – Organic			Soil pH- Mineral		
	Trial 1	Trial 2	Average	Trial 1	Trial 2	Average
1						
2						
3						
4						
5						

Exercise 3: Soil Moisture

Soil moisture is measured by placing a known mass of moist soil into an oven and then evaporating off the water. The soil is then weighed again. The difference between the weight of the soil when it is wet and when it is dry is used to calculate the soil moisture (Equation 1). This process will be done by the TA but you should include it in your methods.

1. Place an aluminum pan onto the scale and record the weight. Then place approximately 15 g of moist soil into the pan, and record the exact weight of the pan and soil together.

2. Place the pans into the oven at 60°C for 48 hours. Mark the pans with a sharpie before putting them in the oven, or note how the pans were arranged in the oven. You

will need to know which weight corresponds to which pan after the soils have been dried.

3. Once the soil samples are dry, reweigh each pan and soil sample together. Subtract the weight of the pan from both the wet and the dry soil weight measurements. To obtain the soil moisture, divide the difference between the wet and dry soil weights by the weight of the wet soil and multiply by 100 (Equation 1). Record these values in table 3.

$$SoilMoisture = \left(\frac{(WetWeight - DryWeight)}{WetWeight} \right) \times 100 \qquad \text{(Eqn. 1)}$$

Table 3. Soil moisture data.

Station ID	Pan (g)	Wet Soil (g)	Dry soil (g)	% soil moisture
M 1				
M 2				
M 3				
M 4				
M 5				
O 1				
O 2				
O 3				
O 4				
O 5				

M = mineral horizon; O = organic horizon; wet and dry soil weights include the weight of the pan.

Data Analysis

1. Make three column graphs, one for each of the following three soil characteristics: soil moisture, soil pH, and organic horizon thickness. The x-axis should be the station ID and the y-axis should reflect the value of soil moisture, soil pH, or organic horizon thickness for a particular station (see Figure 5 for an example figure). Include organic and mineral layer for both soil moisture and soil pH on one graph.

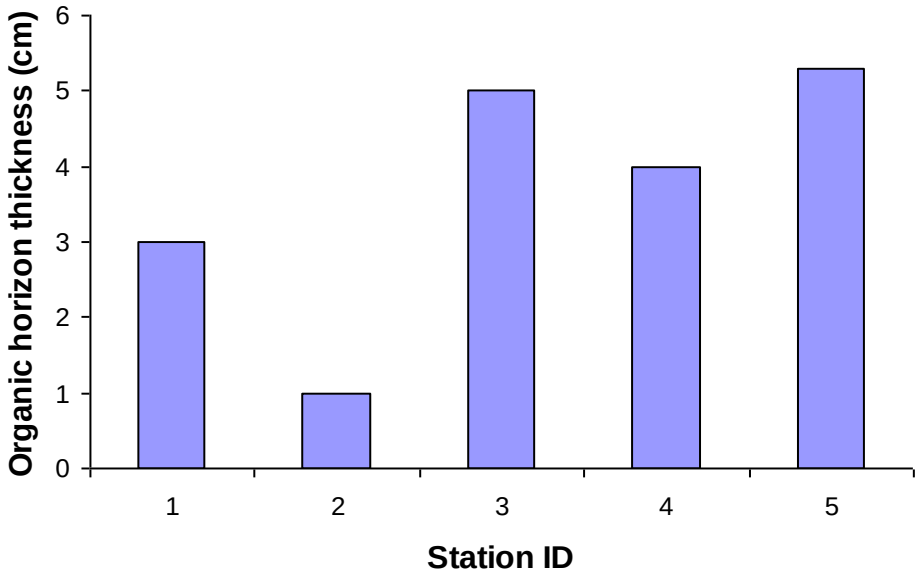


Figure 5. Organic horizon thickness at each station. 1 = south facing upper; 5 = north facing upper.

2. The variables we measured in lab are not truly independent of one another. In other words, there may be a relationship between two or more of the variables. For example, as organic matter increases, one may see a parallel increase in soil moisture due to the high soil moisture content of organic matter. To determine whether there is a relationship between the different variables, create x-y scatter plots for the following combinations of variables:
    i. soil moisture (x) vs. soil pH (y)
    ii. organic horizon thickness (x) vs. soil moisture (y)
    iii. organic horizon thickness (x) vs. soil pH (y)

3. Fit a linear trend line to each of the scatter plots. Be sure to include the three graphs, one for each pair of variables listed above, in the results section of your lab write up (see below). Make sure that all of these graphs display the linear trendline equation and R^2 value from the regression analysis. When comparing the organic thickness, only use the organic layer for soil moisture and soil pH. When comparing soil moisture and soil pH, compare specific layers to each other and on one graph.

4. Use the data analysis tools in Excel to perform a regression analysis on each of the 3 pairs of variables listed above (*i.e.*, soil moisture vs. soil pH, *etc*.). Report the R^2 value, linear equation, p-value, and hypothesis with an alpha value of .05.

Discussion Guides

- How would you expect soil moisture, soil pH, soil texture, and organic horizon thickness to vary along the transect at O-Hill? **Why**? Do your results match your expectations? **How**?

- Look at the graph of importance values that you created for the first part of this lab. Explain how at least **one** of the soil properties you measured might affect the spatial distribution of at least **one** of the tree species on O-Hill for which you made a graph of importance values.

- What sort of relationship (positive or negative, weak or strong) to you expect to see between the following sets of variables? **Why**? Do the results of the linear regression analysis match your expectations? **How**? (Use your regression results to answer this)
    i. soil moisture vs. soil pH
    ii. organic horizon thickness vs. soil moisture
    iii. organic horizon thickness vs. soil pH

- Considering the information that you have at your disposal regarding species distributions and resource, direct, and indirect gradients along the transect, what do you think are the main controls on species distribution at O-Hill?

Write up Procedure

For this lab, the assignment is to write a full lab write up that combines the data gathered in this exercise with the data on species distributions and importance values that you obtained in the first part of this lab.

For the **introduction**, try to find papers that consider the environmental variables that drive changes in species abundance and community composition, especially changes in tree species abundance and forest community composition. When describing the results of these papers, you should be sure to provide information on what the authors did (*e.g.*, what environmental variables or gradients they surveyed) and what their conclusions were (*e.g.*, what drove changes in species abundance or community composition?). Make sure that the information that you provide is relevant to the concepts explored in this lab. Be sure to give information that sets up your hypotheses regarding differences among the different stations on O-Hill, both in terms of tree species distribution (discussion question 1 in the handout for the first part of this lab) and soil properties (discussion question 1 in this handout). You should present your objectives and hypotheses for parts 1 and 2 of this lab in the last paragraph of the introduction.

Keep the **methods** short and be sure to include any statistics and equations that you used (*e.g.*, equations for relative frequency, relative dominance, importance value, slope, and soil moisture).

In the **results** section, be sure to provide the following figures:

1) A graph of the Relative Frequency for each tree species found along the transects. Make a 100% Stacked Column Graph by following the directions on the Excel worksheet.
2) A graph of the Relative Dominance for each tree species found along the transects. Make a 100% Stacked Column Graph by following the directions on the Excel worksheet.
3) Select **five** of the tree species that you identified along the transect on O-Hill based on how interesting you found their results. For these species, construct a bar graph that shows the Importance Value for all the species at each of the 5 stations in the transect by following the directions on the excel worksheet
4) Three column graphs, each of which shows values for one of the following three soil properties at all 5 stations on O-Hill: soil moisture, soil pH, and organic layer thickness (see Figure 5 in this handout for an example)
5) One table that presents the soil texture classes for the soil at each of the 5 stations on O-Hill
6) 3 scatter plots that show the R^2 values and linear trendline equations for the relationships between the following variables:
    a) soil moisture vs. soil pH
    b) organic horizon thickness vs. soil moisture
    c) organic horizon thickness vs. soil pH.
7) One table that presents the results of the regression analysis of each of the 4 pairs of variables listed above (*e.g.*, soil moisture vs. soil pH, *etc*.). Be sure to include values for the slope and line intercept for the linear equation generated in each regression analysis, as well as the R^2 value and p-value for each analysis (alpha value = .05).

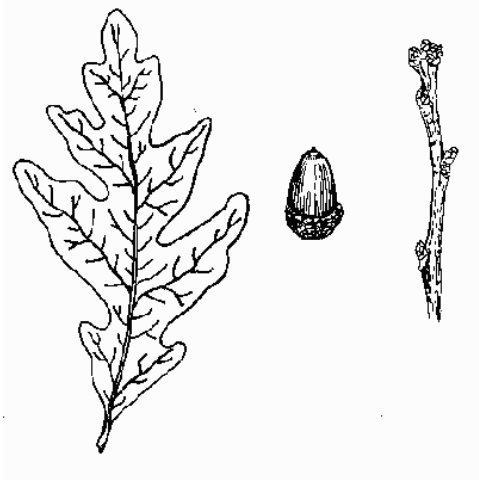
Please remember to WRITE a results section as well which refers to, and briefly describes (but does NOT interpret), each of the figures.

In the **discussion**, be sure to say how your results matched your expectations/hypotheses regarding differences among the 5 stations on O-Hill (*i.e.*, discussion question 1 in this handout and handout for the first part of this lab). You should use the discussion questions to aid in your writing of your discussion; however, you do not need to answer each question specifically. If you do use the discussion questions to help you write the section, do not just answer these questions and they should not be done in the order they are asked. Maybe sure to include all areas of error or any bias, as well as any changes or further research you might suggest.

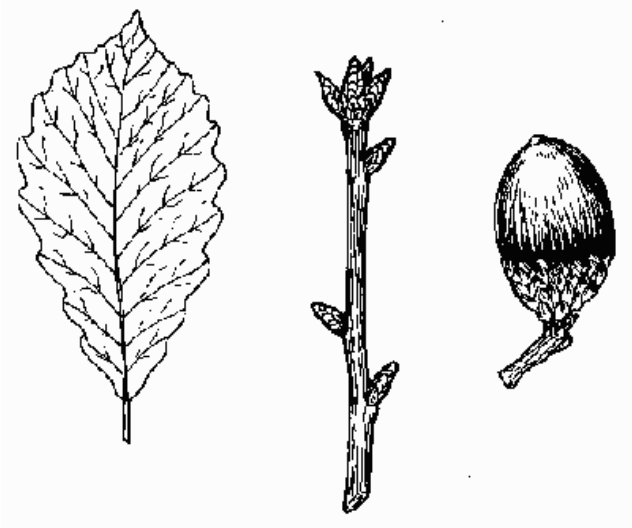
Be sure to reference the first lab on Scientific Writing on what goes into writing a scientific paper and what you should be including in it.

Tree Identification Pictures

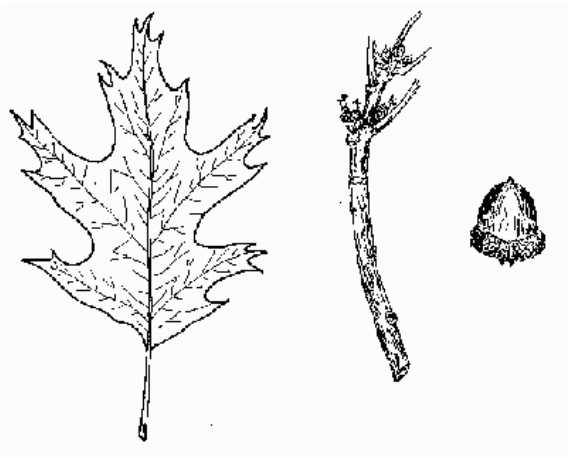
- White Oak: *Quercus alba*



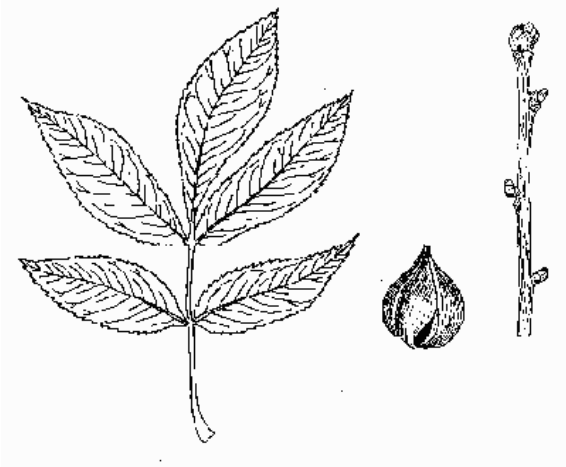
- Chestnut Oaks: Quercus prinus



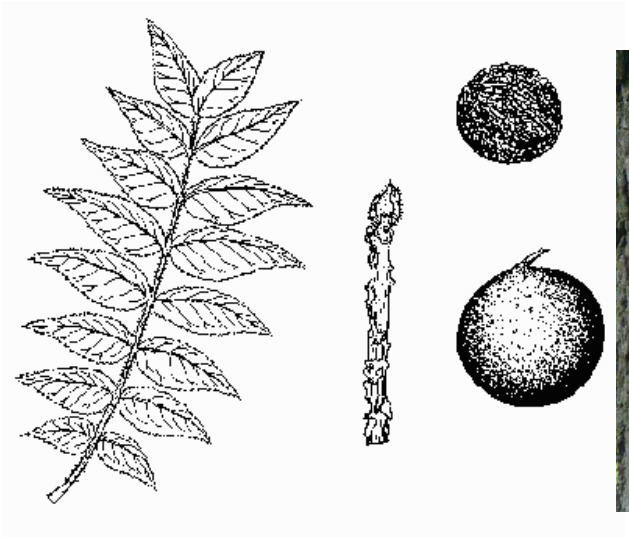
- Northern Red Oak: Quercus rubra



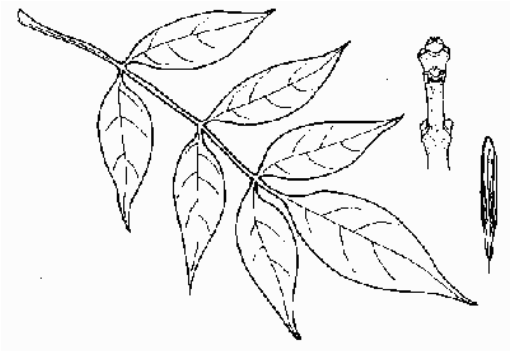
- Pignut Hickory: Carya glabra



- Black Walnut: Juglans nigra

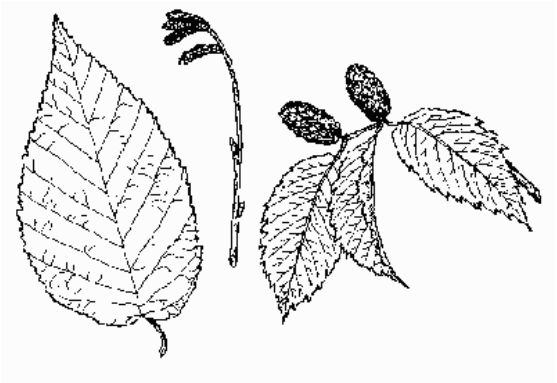


- White Ash: Fraxinus americana



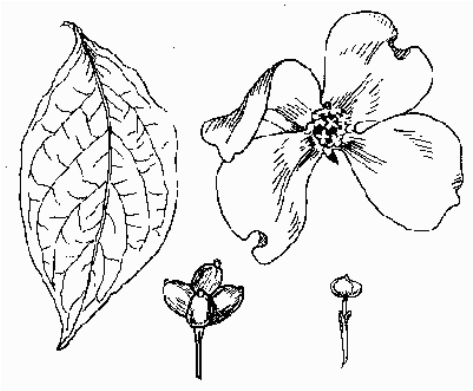
- Tulip Poplar: Liriodendron tulipifera

- Yellow Birch: Betula alleghaniensis

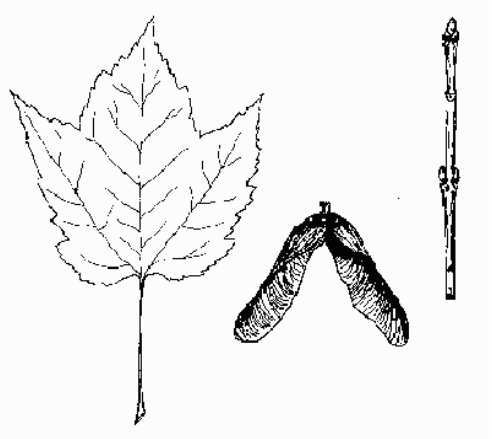


- Mountain Laurel: Kalmia latifolia

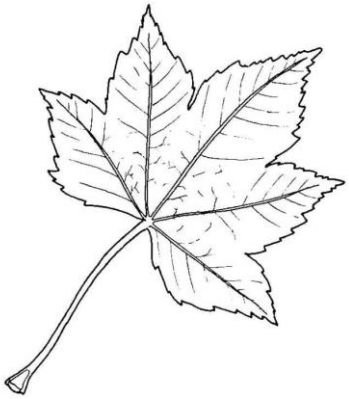
- Dogwood: Cornus florida

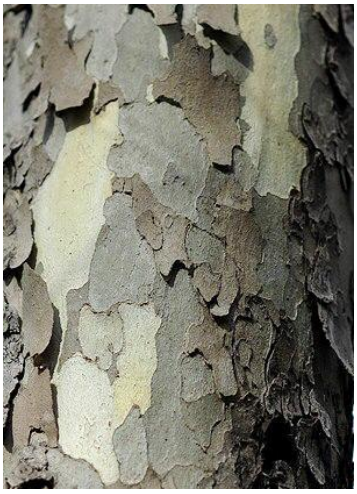


- Red Maple: Acer rubrum



- Sycamore Platanus occidentalis





Thermo Orion 210 A+ pH meter Instructions

1. Make sure pH meter is plugged in or has batteries that are charged (see mfrs. instructions for details.)

2. Turn on meter by pressing power button.

3. If desired, conduct self-test – unplug electrode and put attached "shorting cap" on, turn meter off, then on, then quickly press "yes" key. When code 7 appears, "0" also will be displayed, then (within 10 seconds) press each key, including the power key, one at a time. A numeric digit will be displayed when each key is pressed. After the keypad test, the meter will shut off. If any problems are found, the meter will display the operator assistance code until acknowledged by pressing the "yes" key. Consult the "Trouble shooting" section of the mfrs. instructions for further assistance.

4. Press the "mode" button until "Setup" appears to check the setup. Hit yes to accept the 7.00 setting, yes after "5E7" appears, and yes after "570" appears in order to accept this setting. (for info about what the codes mean, see mfrs. instructions) .

5. Press "mode" button until you get the "Calibrate" setting. Press the "no" button to choose the pH calibration options: 7 – 4, 7, or 7 – 10. Greater ranges can be set manually (see mfrs instructions).

6. In the calibrate mode, wait for "Ready" and the temperature-corrected value to be displayed, then press yes to enter this value into memory (note: I waited for quite awhile and "ready" was never displayed. Perhaps this is a discrepancy in the mfrs. manual with the UVA meter.)

7. A 2 – buffer calibration is recommended at the beginning of each lab to make sure the electrode is working properly and to store the slope in memory. Use 4 & 7 buffers or 7 & 10 buffers, depending on whether the samples are expected to be acidic or basic. Soils around O-Hill may be slightly acidic, so using the 4 and 7 buffers is advised.

8. Plug the electrode into the far left terminal on the top of the meter, remove the rubber cap and rinse the electrodes with de-ionized water.

9. Autocalibration instructions are continued on the next page.

"I frequently tramped eight or ten miles through the deepest snow to keep an appointment with a beech-tree, or a yellow birch, or an old acquaintance among the pines."

- *Henry David Thoreau*

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Stream Ecology

Introduction

The management of freshwater resources has become an issue of increasing concern in the last century. Freshwater is essential for purposes of human consumption, livestock and agricultural production, and various industrial activities, including the generation of power. Freshwater, which is contained in rivers, creeks, lakes, and freshwater marshes, accounts for only 0.008% of the water on earth (Hornberger et al. 1998). Human civilizations have long utilized these waterways for food, energy, and transport. For this reason, **anthropogenic** (*i.e.*, human-related) practices have had substantial impact on these aquatic systems. With increases in the size of the human population, and in the use of technology, these effects have become pronounced. In well-developed nations, problems such as acidification from industrial emissions, contamination with organic toxins and metals, and **eutrophication**, or an increase in nutrients above desirable levels, have been linked to the degradation of many of these stream systems. In developing nations, it has been estimated that as much as 80% of disease and 33% of deaths can be associated with contaminated water supplies (Hornberger et al. 1998).

Lotic ecology deals with *flowing* freshwater systems, especially streams. Streams include creeks (up to tens of feet wide) and rivers. The varied anthropogenic uses of freshwater highlight the importance of understanding stream ecology. A stream's biotic components are closely linked to both geomorphological attributes and the physical-chemical parameters of the system. The biotic community may be influenced by these abiotic components and may, in turn, modify them, especially the physical-chemical parameters. Some of the more important abiotic mechanisms driving these feedback loops include: width, depth, rate of flow, color, turbidity, pH, temperature, substrate type, and the concentration of dissolved gasses (Rohde et al. 1994). In this lab, we will assess abiotic and biotic characteristics, and examine their relationship, in two different streams in central Virginia.

River Continuum Concept

The **River Continuum Concept** (Vannote et al. 1980; Minshall et al. 1985) suggests that there is:

> An orderly progression of predictably intergrading, dependent regions containing organisms whose ecological roles reflect changes in river basin geomorphology, current speed, gradient, sediment and organic matter composition, and allochthonous versus autochthonous production. (Helfman et al. 1997).

According to this hypothesis, as one moves from the headwaters to the mouth of large rivers, there are predictable patterns of change in the abiotic environment that shape the local biotic communities. Streams are categorized by **stream order** within this hypothesis. The headwaters are first order (low stream order). When two first order streams join, they form a second order. Two second order streams join to form a third

order and so on. However, a first order stream and a third order stream do not form a fourth order; streams must be of the same order to create the next order (Figure 1). The largest rivers (highest stream order) like the Mississippi and the Amazon are tenth and eleventh order streams. In this lab, we will be investigating the difference between Steger Creek, which is a 2nd order stream, and the Rivanna River, a 5th order stream.

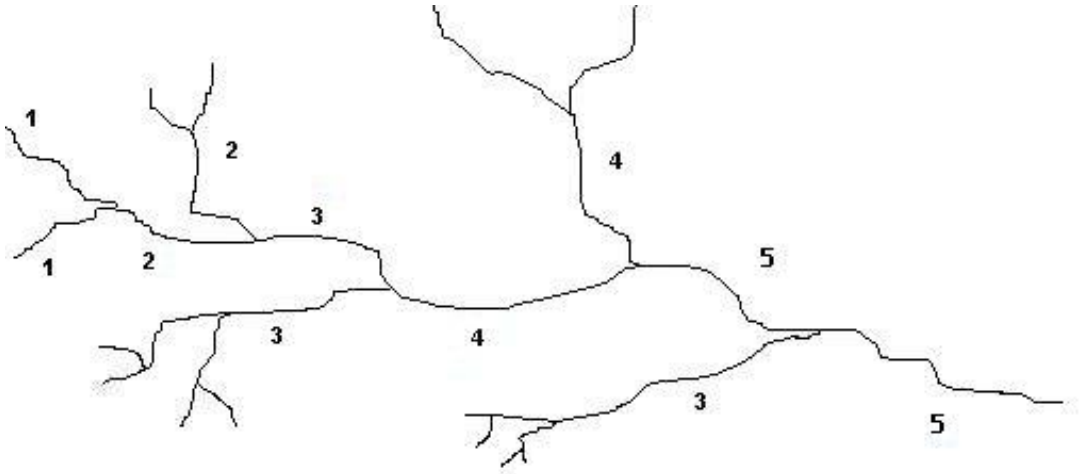

Figure 1. A fabricated diagram of a 5th order stream, like the Rivanna River, and its tributaries. Numbers represent stream orders. Please note that not all tributaries are shown or numbered.

In keeping with the River Continuum Concept, there are changes in abiotic parameters from the headwaters to the stream's mouth (see Table 1 for a summary). First order streams are typically located in high **gradient** areas, such that there is a larger drop in elevation over a given length of stream, and therefore tend to have steep slopes and swiftly flowing water. These streams are often shallow, have rocky substrate, and, since they are typically at higher altitudes, the water is often colder than it is in higher order streams. First and second order streams are typically narrow, with little meander, and many are shaded by forest canopies, which also contributes to the lower temperature of the water. Due to their smaller size, these streams are "**flashy**," such that they are very responsive to local precipitation patterns. During periods of heavy rain, lower order streams receive a pulse of nutrients in the form of direct inputs from the catchment and as a result of weathering of the substrate. These headwaters may be **ephemeral**, meaning that streams are present when there is spring run-off, and may dry up entirely during the summer. Organisms living in these harsher **reaches**, or defined lengths of stream, need to be highly mobile or well adapted to endure these conditions. For example, fish are often streamlined and active (like trout), or small and bottom dwelling (like darters and sculpin). Such harsh conditions typically result in *lower* biodiversity.

In lower order streams, the high current flow (which removes nutrients and stresses sessile organisms), lower temperatures, and shading reduce the number of successful **autotrophs**. Autotrophs are "self-feeding" organisms that obtain their energy from the sun, and typically form the base of the local food web. These lower order streams are therefore **allochthonous**, such that they are dependent on nutrient inputs from *outside* the

stream. In these reaches, the ratio of community production to respiration (P/R) is less than 1, and primary consumers, which typically feed on autotrophs, become the base of the food chain. These primary consumers are dependent on inputs from leaf litter, falling insects, and nutrients that are washed into the stream.

Table 1. Differences in abiotic and biotic parameters between low (1st and 2nd) and high (up to 8th) order streams according to the River Continuum Concept.

Stream order	Low	High
Canopy cover/shade	Higher	Lower
Dissolved nutrients	Flashy	More stable
Dissolved oxygen	Higher	Lower
Energy source	Allochthonous	Autochthonous
Fish diversity	Low	Higher
Gradient	High	Low
Habitat heterogeneity	Low	High
Macroinvertebrate diversity	High	Lower
Primary productivity	Low	Higher
Shape	Straighter	Meandering
Stream depth	Shallow	Deeper
Stream width	Narrow	Wide
Substrate	Rocky	Cobble/Gravel/Sand/Mud
Turbidity	Lower	Higher
Water temperature	Colder	Warmer
Water velocity	Faster	Slower

In higher order streams (moving from 3rd to 8th), the concentrations of dissolved nutrients, water temperature, and light levels (due to lessened canopy shading) are more constant in time (less flashy). Most of these streams are considered **intermediate** or **depositional**. Intermediate stream reaches are characterized by a moderate gradient, warm water, and moderately fast, deeper water with cobble, gravel, or sand substrate. Minnows, sunfish, darters, and madtom catfish are common in such reaches. Depositional stream reaches have a low gradient, and slow water that is typically warm and turbid. Sediments are muddy, aquatic plants are common, and there are typically a large variety of fish, including many deep-bodied fish and fish that are adapted for feeding from the bottom. Fish found in depositional stream reaches include bass, bullhead catfish, carp, herring, minnows, suckers, and sunfish (Moyle and Cech 1996).

Higher order streams tend to have greater habitat heterogeneity and volume, which allows for *greater* biodiversity. Conditions are favorable for both autotrophic and **heterotrophic** organisms as light and detritus are readily available. Heterotrophs are "other-feeding," such that they obtain energy by feeding on other organisms. In higher order streams, P/R is typically greater than 1. As a result, these reaches are **autochthonous**, which means that they are autotrophic or self-supporting. However, above 8th order streams, the pattern switches back to allochthonous. This is because these higher order streams are light limited; they have increased **turbidity,** from suspended solids and organic materials, that causes primary productivity to drop, especially in deeper reaches.

Parameters of Interest

Aquatic productivity and dissolved oxygen

Photosynthesis is the process by which light is converted into chemical energy by green plants, algae, and some bacteria. The rate at which photosynthesis occurs is known as primary productivity. Respiration occurs concurrently, and, during a given period of measurement, uses up some of the organic material produced by photosynthesis. Both plants and animals respire, and stresses, such as increased temperature, will increase the rate of respiration.

$$n\,(CO_2) + n(H_2O) \xrightarrow{light\ \textit{Pigment/Receptor}} n(O_2) + (CH_2O)_n$$

The methods used to measure primary productivity vary with the habitat and organism studied. In aquatic habitats, the most common method involves an assessment of gas exchange; more specifically, of the accumulation of oxygen, which is one of the products of photosynthesis. The concentration of dissolved oxygen (DO) in water can easily be measured using a DO meter.

The concentration of oxygen in water may be affected by a number of abiotic factors, which need to be accounted for in the determination of primary production. First, gasses are more soluble in cold water than they are in warm water. Increasing pressure also increases the amount of gas dissolved. Salinity or ion concentrations can also affect DO; seawater holds about 20% less gas than freshwater. Oxygen typically enters the water column either by diffusion from the atmosphere, or as a byproduct of photosynthesis in the water column. Diffusion may be enhanced by **turbulence**, or physical mixing, resulting from surface water flowing over rocks, as well as from wave and wind action.

Many metabolic processes require oxygen, and are thus termed **aerobic**. However, in high concentrations, oxygen may actually act as a toxin. One might expect cool, sunny, turbulent habitats to have higher oxygen availability. Oxygen would become limiting under warmer, shaded, stagnant water conditions where respiration is higher and photosynthesis is lower. In natural aquatic systems, DO stress occurs most often at the water-substrate interface on dark calm nights in the middle of the summer, or dry season, when water flow is at a minimum. Pollutants that either drastically increase plant life, such as fertilizers, or that contribute organic matter (*e.g.*, sewage), thereby causing

increased oxygen demand by aerobic decomposers, will increase DO stress and may even cause **anoxia** (conditions of zero measurable oxygen).

Fish* and macroinvertebrate diversity

Riffles, or areas of shallow fast-moving water, are the most productive freshwater stream habitats as they produce large populations of macroinvertebrates, which are a food source for benthic, or bottom feeding, fish. However, colder, flashier, fast moving shallow waters impose greater stress on fish. The fish adapted to these regions are typically small and streamlined. They are either benthically oriented, and seek shelter from the current behind wood and rocks, or very active, like trout, and constantly swimming against the currents.

As steam order increases, pools and runs develop. These pools and runs have room for larger adults and deeper bodied fish. The pools receive insects and detritus flushed from the riffles, and typically have increased numbers of fish. According to research by Isaac Schlosser (1987), increasing stream order is directly related to an increase in the number of species, or **species richness,** and species diversity. In addition, deeper waters are better able to buffer fluxes in temperature and chemical changes, thus providing better shelter for fish populations. The increased presence of primary producers in higher order streams adds both structural heterogeneity, and a broader base to the trophic pyramid (Moyle and Cech 1996). With these conditions, fish are better able to specialize in terms of what they eat. As a result, specially adapted feeders, like planktivores (*e.g.*, shad), become more prominent in higher order streams. Body morphology (shape and position of body parts like fins, mouth, etc.) can provide great insight into the habitat needs of fish. As habitat complexity increases, we would expect to see an increase in the diversity of these body morphologies. Certain fish species are more likely to be found in deeper waters. Centrarchidae (sunfish and bass) are deep bodied and would be battered in high flow streams. However, in slower still waters, they are efficient predators and many are **piscivores**, such that they eat other species of fish (Jenkins and Burkhead 1993). It should be noted that a fish's habitat preferences are likely to change throughout its lifecycle. Many fish migrate upstream to shallower waters to breed. This act helps segregate larval and juvenile fish from the adult populations and deeper water areas where piscivory is more likely.

Benthic **macroinvertebrates** (like crustaceans, mollusks, and insect larvae) are easily quantified and are typically easier and less expensive to collect than fish. Diverse species of macroinvertebrates occupy stream microhabitats. Many of these species are limited in their mobility. Stream flow and substrate have an effect on the presence/absence of macroinvertebrates. Riffle areas, where stream water flows quickly over rocks, support more diverse populations than pools. The turbulence in the riffles helps keep water oxygenated and clear of silt, which can entomb and suffocate many sessile or slow moving organisms. Riffles also have greater food and habitat availability, and provide refuges where rocks, wood, sand, algae, and trapped organic matter are abundant. Stochastic events, including heavy storms that can wash out eggs, macroinvertebrates, etc., leave open niches that are then quickly recolonized.

*We may be excluding fish observations from this lab.

Based on this framework, one would expect small headwater streams to support a high diversity of macroinvertebrates, yet have only the few fish species that are well adapted to a flashy, stressful environment. Higher order streams are likely to have a greater diversity of fish. In terms of the streams that we will be sampling, Steger Creek has a homogeneous bedrock substrate, few developed pools, and low overall habitat volume. The Rivanna has a high degree of habitat differentiation, with many well-developed pools, a heterogeneous substrate, and various types of potential cover for fish to utilize.

Objectives

The main objective of this exercise is to collect data on a variety of abiotic and biotic parameters to compare the ecology of two streams that are of different stream order, specifically Steger Creek (2^{nd} order) and the Rivanna River (5^{th} order). In particular, we will collect data that can be used to test hypotheses developed based on the River Continuum Concept.

Materials

- Waders
- Seine net
- Dip nets
- Surber samplers
- Clear tanks
- Orion 842 Oxygen Meter
- Bobber
- Measuring tape
- Stop watch
- Meter stick
- Dichotomous keys (for fish and macroinvertebrate ID)
- Datasheets

Exercise: Field Data Collection

Macroinvertebrate sampling

A **Surber Sampler** is a device used to sample benthic animals in streams. The sampler's frame marks off a $1ft^2$ quadrat of the substrate, and has an attached net to collect benthic organisms that are dislodged from the sampled area. **Dip nets** can also be used to sample macroinvertebrates.

1. **Surber or dip net sampling**: To sample benthic organisms using a Surber sampler, place the sampler frame with the attached net facing upstream. Disturb the rocks and sediment that comprise the substrate within the sampler's frame to dislodge the benthic organisms. Dig down several inches if possible. This process is performed for approximately three to five minutes, and then the net is carefully gathered to prevent the loss of any of the collected organisms. A dip net can often be effectively used to capture macroinvertebrates, especially if the current is not strong enough to carry organisms into the net of the Surber sampler. Regardless of whether they are

caught with a Surber sampler or a dip net, the organisms should be put in a clear tank, identified to order, and counted. The sampling procedure, whether performed using a Surber sampler or a dip net, should be replicated 3-5 times within a 10-meter section of the stream channel. Several riffles and at least one pool should be examined. Any macroinvertebrates captured in the dip or seine nets while observing other organisms should also be identified and counted.

Observation of vertebrates

Vertebrates may be observed using a standard seine net and dip nets. These methods are inexpensive and work well in environments where vertebrate movement is relatively restricted, and vegetation and structure allow netting. We shall be observing these species rather than catching them.

1. **Seining**: Position the net perpendicular to the direction of water flow with at least one person stabilizing each end of the net. The floats should not be underwater; if they are, they will allow vertebrates to escape over the net. Small rocks should be placed on the bottom of the net to prevent vertebrates from swimming underneath it. Two or three other people should walk up the bank and disturb the area approximately 10 meters upstream of the net by stomping and kicking over rocks. This method works best if the "disturbers" start upstream and move toward the net. When the "disturbers" reach the net, the seine should be quickly lifted by pulling up the bottom and making sure no vertebrates escape under the net. Vertebrates can then be placed in clear tanks that have been set up on the riverbanks and identified using the dichotomous key provided. The total number of species and individual vertebrates identified should be recorded for each site. In addition, careful attention should be paid to the morphology of the vertebrates being observed. There should be obvious differences between the types of vertebrates (*i.e.*, families) collected at each location. After the vertebrates have been identified, counted, and observed, they should be released into the stream.

2. **Dip netting**: Dip nets should be used in pools outside the seining area to ensure that the seining process is not disrupted. Dip nets are used to catch organisms where seining is not possible (*e.g.*, under debris, along banks, etc.) and therefore to observe vertebrates that the seining may miss. Organisms should be observed in the clear tanks for identification as described above, and immediately released to minimize stress.

Estimating stream discharge, dissolved oxygen, and temperature

Many abiotic parameters vary as a result of stream discharge. Discharge is defined as the volume flux of water, or the speed at which a volume of water moves through the stream reach (Hornberger et al. 1998). A rough approximation of stream discharge will be calculated for each stream using the following equation:

$$Q = U \times w \times h \qquad \text{(Eqn. 1)}$$

where :
Q is discharge in meters cubed per second (m^3/s)
U is the average water velocity in meters per second (m/s)
w is the average width in meters (m)

h is the average depth in meters (m)

1. Measure the stream width at approximately 1 m intervals at 4 spots along the sampling area. Calculate the average width (**w**).
2. Measure the depth at 0.5 m intervals across the channel. Average these values to calculate average depth (**h**).
3. Use a bobber or float (a stick or leaf may do) and a stopwatch to time the rate of surface flow over a 10-meter reach in the sampling area. Do this at least 4 times. Divide the length of stream over which the bobber travelled by the recorded time to calculate velocity. Then calculate the average of these water velocities (**U**).
4. Use Equation 1 to calculate the average discharge (**Q**) of each stream.
5. Use the Orion 842 Oxygen Meter to measure dissolved oxygen and water temperature. Take at least 4 measurements within the sampling area.

Data Analysis

1. Calculate the Simpson's Diversity Index (**D**; Equation 2) for macroinvertebrates and vertebrates separately at each study site. In other words, you should calculate a total of 4 values for **D**, 2 for each stream.

$$D = 1 - \sum_{i=1}^{t} (n_i / N)^2 \qquad \text{(Eqn. 2)}$$

where
t = total number of taxa (families for macroinvertebrates; species for vertebrates)
n_i = number of individuals of a given taxon (***i***)
N = total number of individuals of all taxa ($n_1 + n_2 + ... + n_t$)

Please note, our taxon of interest is family for macroinvertebrates, species for vertebrates.

Example calculation:

Taxon rank	1	2	3	4	5	6	7	8	9	10	**Total (*N*)**
# of individuals (n_i)	50	25	12	12	6	4	2	2	1	1	115

$$D = 1 - [(50/115)^2 + (25/115)^2 + \ldots + (1/115)^2]$$

(n_i/N) is an estimate of the proportion of the total community represented by taxon ***i***, and $(n_i/N)^2$ represents the probability of picking two individuals of taxon ***i*** at random from this community. The Simpson's Diversity Index represents the probability of picking two individuals at random that are from different taxa. The index varies from 0 (no diversity; all individuals from one taxon) to [1- (1/***N***)], which is the maximum diversity (all individuals from different taxa). For the example calculation given

above, the maximum diversity = 1 - (1/115) = 0.99. Values of the Simpson's Diversity Index are not strongly affected by rare taxa, but are influenced by common taxa.

2. Plot dominance diversity curves for each stream. Put both curves for the same type of organism (*i.e.*, macroinvertebrates or vertebrates) on one graph for comparison between streams. In other words, you should make a total of two graphs, one for macroinvertebrates and one for vertebrates. Multiply the (n_i/N) values calculated above by 100 to obtain a percentage for each taxon. Sort the taxa from most abundant to least abundant (use the n_i values) and rank the taxa from 1 (most abundant) to ***t*** (least abundant). For the dominance diversity curves, plot the percentages on the y-axis and ranks on the x-axis (see Figure 2 for an example). Also make a table that shows the ranks and associated taxa (*i.e.*, macroinvertebrate families or vertebrate species) for each stream. Make a total of two tables- one for macroinvertebrates and one for vertebrates. Include only the common name and the rank in these tables (i.e., don't include abundance). The richness of the community is a function of the length of the dominance diversity curves. Communities with longer curves have a greater taxa richness. The degree to which one or a few taxa dominate the community is represented by the steepness of the curve. A steep curve indicates a community with high dominance and low evenness.

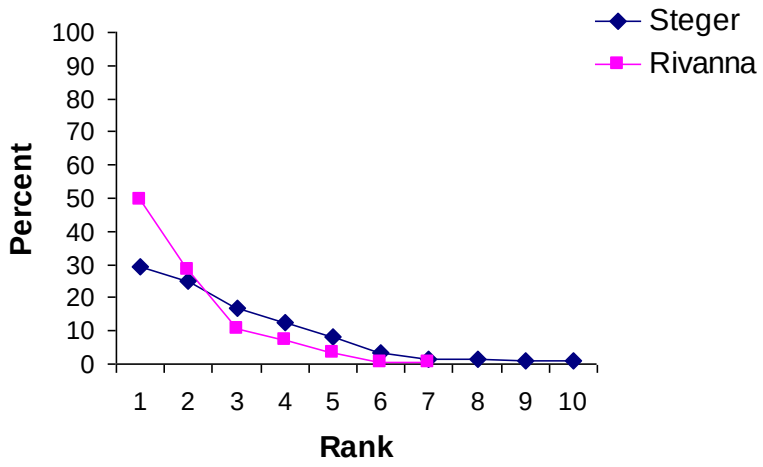

Figure 2. Fabricated example of dominance diversity curves for macroinvertebrates sampled in Steger Creek and the Rivanna River.

3. Use the dataset posted on Collab, which contains data from previous years, data from groups this year, and room to put your sections data to perform a t-test of the following variables, and thus compare them between the two streams: discharge, dissolved oxygen, Simpson's Diversity Index (macroinvertebrates and vertebrates), and temperature. From your data, you should include an average discharge and two Simpson's Diversity Indices for each stream, and each of the dissolved oxygen and temperature measurements as repetitions. Make one summary table that shows the average of all values of each of these four variables for each stream and all the important t-test parameters calculated in the t-test.

Discussion Guides

- How would you expect the following variables (which we measured in the field) to differ between Steger Creek and the Rivanna River: discharge, dissolved oxygen, macroinvertebrate diversity, vertebrate diversity, and temperature? **Why**? How about these variables, which we did not measure in a quantitative fashion the field: biomass of aquatic plants/algae, canopy cover, substrate, and turbidity? **Why**?

- Do your field data and observations match your expectations? **How**? (Hint: Be sure to consider the results of the t-tests that you performed).

- Would you expect the body morphologies of vertebrates observed in Steger Creek to differ from those observed in the Rivanna River? **Why**? Did your observations in the field match your expectations? **How**?

- Consider the dominance diversity curves that you made for both macroinvertebrates and vertebrates. What do these curves tell you regarding differences between the two streams in the diversity of macroinvertebrates and vertebrates? (Hint: Consider the length and slope of the curves). Did macroinvertebrate and vertebrate diversity follow the same patterns between the two streams? In other words, if macroinvertebrates were more diverse in one stream, were vertebrates more diverse in that same stream? **Explain** your observations.

- What biases may have been created due to our methods of observing organisms (e.g. seine nets and dip nets)? How would you suggest correcting this error in the most cost-efficient and environmentally conscious manner?

- How would you expect the macroinvertebrate and vertebrate communitites in the area that we surveyed at Steger Creek to change over a year? **Why**? How about in the reach of the Rivanna River that we surveyed? **Why**?

- How do you think a large storm would affect collection of macroinvertebrates in Steger Creek? **Why**? Would you expect the same effect in the Rivanna River? **Why**?

Write up Procedure

For this lab, please write a full lab write up.

For the **introduction**, try to find papers that have surveyed stream reaches in different parts of a watershed. When describing the results of these papers, be sure to provide information on what the authors did (*e.g.*, what parameters they surveyed) and what their conclusions were (*e.g.*, how were the stream reaches different from one another?). Make sure that the information that you provide is relevant to the concepts explored in this lab.

Be sure to give information that sets up your hypotheses regarding differences between the two streams surveyed (Steger Creek and the Rivanna River) and present your objectives and hypotheses for this exercise in the last paragraph of the introduction.

Keep the **methods** short and be sure to include any equations that you used (*e.g.*, Simpson's Diversity Index, discharge equation) and mention any statistical analyses that you performed (*i.e.*, t-test) and parameters for these analyses (e.g. alpha value).

In the **results** section, be sure to provide the following figures, most of which are also described above in the Data Analysis section:

1) two graphs, one for macroinvertebrates and one for vertebrates, that show dominance diversity curves for the two streams (see Figure 2 for an example).
2) two tables, one for macroinvertebrates and one for vertebrates, that give the ranks and associated taxa for each stream;
3) a table that presents the averages of the variables for which you measured in the field (*i.e.*, discharge, dissolved oxygen, Simpson's Diversity Index, temperature) for each stream; so you will have two values of discharge, one for each stream, two values of DO, etc
4) **one** summary table containing values of the following entities for each of the 4 t-tests performed: mean value of the variable for each stream (mean will include past and present data), degrees of freedom, t-critical value, t-test statistic, and two-tailed p-value.

In addition to presenting the figures described above, be sure to write a results section that refers to each of the figures and describes your key findings, which you will come back to in the discussion. DO NOT interpret your results in this section. For example, point out any differences between the two streams either in the shape of the dominance diversity curves, or in the variables that were measured in the field (*e.g.*, discharge, dissolved oxygen, temperature), but do not explain these differences.

In the **discussion**, use the discussion guides to interpret your results and be sure to say how these results matched your expectations/hypotheses regarding differences between the two streams (*i.e.*, discussion guide 2).

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Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and G.E. Cushing. (1980). The River Continuum Concept. *Can J. Fish. Aquat. Sci*. 37: 130-137.Stream Order Characteristics:

Stream Order	Stream Width	Gradient (Slope)	Shape	Water Velocity	Dissolved Oxygen	Annual Temperature	Suspended Sediments	Dissolved Nutrients
Low	Narrow	High (steep)	Straighter	Faster (less volume)	Higher	Colder (higher altitude)	Higher (erosional)	Quickly washed away
High (up to 8th)	Wide	Low	Meandering	Slower	Lower	Warmer (broader, more light)	Lower (depositional)	More pools-longer residence

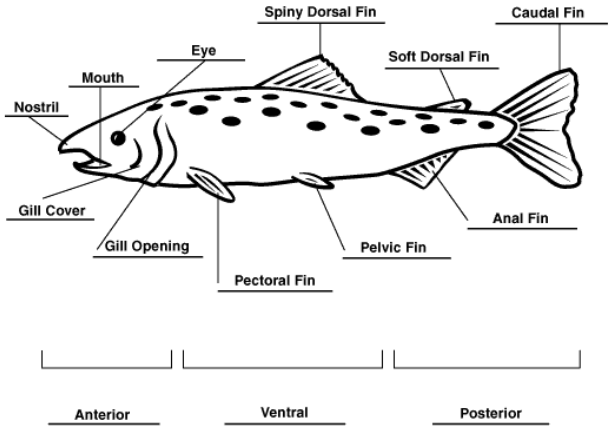
Stream Order	Energy Source	Canopy Cover	Habitat Heterogeneity	Annual Stability	Primary Productivity
Low	Allochthonous	More trees	Low mostly riffles	Flashy	Few primary producers - mostly algae in riffles (very productive) some phytoplankton - quickly washed out
High (up to 8th)	Autochthonous	Wider - less cover	High - pools, runs & riffles	More Stable	Many - Green plants on edges, aquatic plants, algae, phytoplankton, bacteria, etc.

Key to Fishes Page 1 of Key

Key to Fishes of Virginia for EVSC 3201: Ecology Lab

By: Catherine Allisa Vincent

The information in this key has been adapted from Jenkins R.E. and N.M. Burkhead. 1994. Freshwater Fishes of Virginia. Bethesda: American Fisheries Society. 1079 p. and Page L.M. and B.M. Burr. 1991. Peterson Field Guide to Freshwater Fishes of North America North of Mexico. Boston: Houghton Mifflin.



1.
   a. Body Elongate; dorsal, caudal, and anal fins continuous…. Anguillidae (Freshwater Eels) ……**Pg. 2**
   b. Body Not Elongate …… 2

2.
   a. Body Scaled…… 3
   b. Body Not Scaled; 8 barbels protruding from mouth area….. Ictaluridae (Catfish) **pg. 2**

3.
   a. Anus behind head but before pelvic fin…… Aphredoderidae (Pirate Perch) **pg. 3**
   b. Anus in front of anal fin…… 4

4.
   a. One dorsal fin…… 5
   b. Two dorsal fins…… 7

5.
   a. Snout Duckbill shaped…… Esocidae (Pikerels) **pg. 3**
   b. Snout Not duckbill shaped…… 6

6.
   a. Dorsal Fin with 9 or less rays…… Cyprinidae (Minnows) **pg. 3**
   b. Dorsal Fin with 10 or more rays…… Castostomidea (Suckers) **pg. 6**

7.
   a. Anal Fin with 2 or more spines (small body size)…… Percidae (Darters) **pg. 6**
   b. Anal Fin with 3 or more spines (larger deeper body size)…… ……Centrarchidae (Sunfish and Bass) **pg. 7**

Anguillidae (Eel)

1. **One Species**: American Eel (*Anguilla rostrata*)

Ictaluridae (Catfish)

1.

a. Caudal Fin Forked…… Channel Catfish (Ictalurus punctatus)

b. Caudal Fin rounded or flat……. 2

2.

a. Soft Dorsal fin free from Caudal fin…….. Yellow Bullhead (Ameiurus natalis)

b. Soft Dorsal fin attached to Caudal fin……. Margined Madtom (Noturus insignis)

Aphredoderidae (Pirate Perch)

1. **One Species**: Pirate Perch (Aphredoderus sayanus)

Esocidae (Pickerels)

1. **One Species**: Chain Pickerel (Esox niger)

Cyprinidae (Minnows)

1.
   a. Lower jaw with hard ridge (yellowish)……. Central Stoneroller (Campostoma anomalum)

   b. Lower jaw with no hard ridge…… 2

2.
   a. Barbel present…… 3
   b. Barbel not present…… 5

3.

a. Barbel before the corner of the mouth…….. Fallfish (Semotilus corporalis)

b. Barbel at the corner of the mouth……. 4

4.

a. Long snout with fleshy area attached to the lip (smaller)…….
……Longnose Dace (Rhinichthys cataractae)

b. No fleshy area attached to the lip (>60mm)……
……Blueheaded Chub (Nocomis leptocephalus)

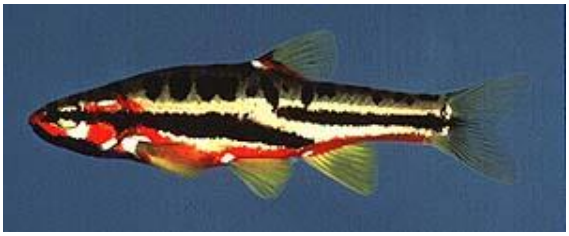
5.

a. Margin of dorsal fin pigmented…… Satinfin Shiner (Cyprinella analostana)

b. No dorsal fin pigmentation…….. 6

6.

a. Distinct mid-body stripe that is broken…. Mountain Redbelly Dace (Phoxinus oreas)



b. No stripe or stripe continuous from head to tail……. 7

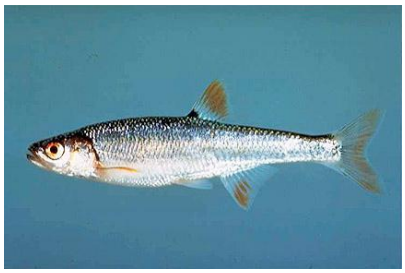
7.

a. Scales along the side of the body more than twice as high as wide……
……Common Shiner (Luxilus cornutus)

b. Scales along the side of the body not twice as high as wide…… 8

8.

a. Brown spot at the base of the dorsal fin towards the head (scales towards the head much smaller than towards the tail)…… Mountain Shiner (Lythrurus ardens)



b. No spot on dorsal fin (scales across the body similar in size)……. 9

9.

a. Large mouth (lateral line not straight)…… Rosyside Dace (Clinostomus funduloides)

b. Small mouth (narrower/elongated body)…… 10

10.

a. Black spot followed by a white spot and then another black spot on dorsal fin (mid-body stripe ending at the eye)…….Swallowtail Shiner (Notropis procne)

b. Cross stitch like pattern of small "=" symbols along the side of the body…….
……Rosyface Shiner (Notropis rubellus)

Catostornidae (Suckers)

1.

a. Caudal fin with 2 pale spots (one above and one below)……. 2
b. Caudal fin lacking spots (Tips of fins black or darker than the rest of the body)……
……. Black Jumprock (Scartomyzon cervinus)

2.

a. Head flat or concave between eyes…… Northern Hogsucker (Hypentelium nigricans)

b. Head convex between eyes…….. Torrent Sucker (Thoburnia rhothoeca)

Percidae (Darters)

1.

a. Dorsal fin toward head shorter than the second (Dorsal, Caudal, and Pectoral fins with series of small dots of pigments)…… Fantail Darter (Etheostoma flabellare)

b. Dorsal fins roughly the same size (no dots on fins)…… 2

2.

a. Football shaped blotches along body (two pale marks on the base of the Caudal fin, one above the other)..... Roanoke Darter (Percina roanoke)

b. Small circular smudge under eye…… Longfin Darter (Etheostoma longimanum)

Centrarchidae (Sunfish and Bass)

1.

a. Anal Spines 5-7 (may have red eye with faint body bars)…….. ……Rock Bass (Ambloplites rupestris)

b. Anal Spines <5……. 2

2.

a. Body relatively elongate…….. 3

b. Body deep and strongly compressed…….. 4

3.

a. Small Mouth Bass (Micropterus dolomieu)

4.

a. 3 distinct dark lines radiating from the eye (upper jaw extending below middle of eye)…….. Warmouth (Lepomis gulosus)

b. Mouth relatively small, if any line around mouth they are not dark. …… 5

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5.

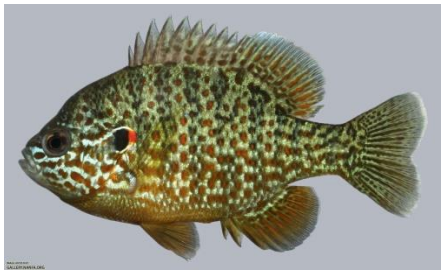
a. Pectoral Fin long and pointed (black or dusky marking on the dorsal fin)…….. ……..Bluegill (Lepomis macrochirus)

b. No dark markings on dorsal fin margin (pectoral fin oriented perpendicular to body)…… 6

6.

a. Redbreast Sunfish (Lepomis auritus)

b. Pumpkinseed (Lepomis gibbosus)



Invertebrate Identification

Detailed Key (Link)
Another Key (Link)

Resources

Research Experience for Undergraduates

Undergraduate Research opportunities in the EVSC Department
NSF Site
- Blandy Experimental Farm
- Mountain Lake Biological Laboratory

Academic

High School vs College

Study Software List

Counseling and Crisis Management:

UVA Counseling and Psychological Services (CAPS): daytime 434.243.5150, after-hours 434-972-7004
Sexual misconduct and reporting, UVa
Shelter for Help in Emergency (SHE)
Sexual Assault Resource Agency (SARA): 24 hr. hotline 434.977.7273
UVA Women's Center: 434.982.2361
Association Deans
Dean on call
Your TA: we're here for you!