

My peer review ID number is: \_\_\_\_\_

#### Acknowledgements

This laboratory manual is compiled and edited by Greg Anderson with significant input from Sharon Kinsman, Will Ambrose, and Ryan Bavis of the Bates College Department of Biology, and Seri Rudolph, the Science Writing Specialist of the Writing at Bates Program, Bates College. We are indebted to various visiting faculty and the students in this course for critical feedback that has greatly improved the content and presentation of this laboratory over the years. Last revised Fall 2011 by GA.

## To the Ecology Student

The faculty and staff of Bio 270 have worked hard to create a meaningful laboratory experience for you and to produce this laboratory manual. Each laboratory description includes an overview of the topic of investigation, procedures for collecting data and analyzing results, and questions to guide your investigation and stimulate your thinking. **It is critical that you carefully read the entire lab protocol prior to coming to lab, and refer to it frequently as you go through each study. If you need clarification of any of the day's activities, have your questions ready when you come to lab.** Not reading the lab beforehand, or trying to read it during introductory comments by staff, is unfair to both your student colleagues and to the teaching staff. We will assume you have read the lab before the laboratory period and have come prepared to carry out the tasks at hand. If it appears that a significant number of people have not adequately prepared for lab, we will be compelled to begin the laboratory period with a quiz that tests your familiarity with the lab. We do not want to spend valuable time with such an exercise, so please read and prepare for each lab.

Thanks in advance for your cooperation!

The Bio 270 teaching staff

## **Plagiarism and Student Misconduct**

It is expected that all students Bio 270 will adhere to the Bates College Code of Student Conduct (1987) (<http://www.bates.edu/x35306.xml>). If evidence of plagiarism or academic misconduct is found, you will be subject to disciplinary action by the college, and you may fail this course. If you have ANY question about appropriate use or referencing of others' materials please consult:

1. your student handbook,
2. the Bates website (<http://abacus.bates.edu/pubs/Plagiarism/plagiarism.html#0>), or,
3. your instructor.

To learn more about avoiding plagiarism, see the CBB Plagiarism website  
<https://ats.bates.edu/cbb/>

The CBB website has a very excellent self-quiz that we strongly encourage you to try out.

<https://ats.bates.edu/cbb/quiz/index.html>

The Web: Information and misinformation abound on the Web. The Web can be a valuable resource, but it can also be misleading. If you have a question about the validity of a website or information derived from a website, please see one of us.

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Instructional Staff

| <u>Name</u>          | <u>Office</u> | <u>Phone</u> | <u>e-mail</u> | <u>lab day</u> |
|----------------------|---------------|--------------|---------------|----------------|
| Ryan Bavis (Lecture) | 415 Carnegie  | 8269         | rbavis        | Mon, Tues      |
| Greg Anderson (AI)   | 530 Carnegie  | 6110         | ganderso      | Mon, Tues      |

## Biology 270 Laboratory Schedule – Winter 2012

| WEEK/DATE        | LAB ACTIVITY/ DUE DATES   | PAGE            |
|------------------|---|-----------------|
| I - Jan 9, 10    | <b>Lab:</b> Introduction to Ecology Lab;<br>Acid Rain: plant seeds; Pine Lab Intro and field practice by Merrill  | 1-12;<br>13-24  |
| II - Jan 16, 17  | <b>NO LAB THIS WEEK – MLK Day observances</b><br>DUE: By Tues, Jan 17 <sup>th</sup> – Pine lab article citation & PDF file to Greg<br>DUE: Wed, Jan 18 <sup>th</sup> – Stats homework I @ lecture   | 11              |
| III - Jan 23, 24 | <b>Lab:</b> Pine Lab FIELD TRIP to Range Pond State Park –<br>Load vans at quad side of Carnegie at 1 pm; Probable return time 4:30-4:45 pm.<br>DUE: Wed, Jan 25 <sup>th</sup> – Stats homework 2&3 @ lecture   | 13-24;<br>25-38 |
| IV- Jan 30, 31   | <b>Lab:</b> Pine Lab data analysis I<br>DUE: Pine Lab draft of <u>Title, Intro, Methods, in lab.</u>  | 39-52           |
| V - Feb 6, 7     | <b>Lab:</b> Pine Lab data analysis II & Discussion<br>DUE: Mon, Feb 6 <sup>th</sup> – Stats homework 4 @ lecture<br><b>Wed –Feb 8<sup>th</sup> - HELP SESSION Pine data analysis in lab 7 – 10 pm.</b><br>DUE: F- Feb 10 <sup>th</sup> - <u>Complete Pine lab draft for Peer Review, in lecture.</u>  | 39-52           |
| VI - Feb 13, 14  | <b>Lab:</b> Acid Rain Lab data collection<br>DUE: Wed Feb 15 <sup>th</sup> - Completed PR of Pine lab paper <u>in lecture</u><br>DUE: Fri Feb 17 <sup>th</sup> - Acid rain lab article citation & e-PDF copy to Greg  | 53-64           |
| VII -Feb 20,21   | Break Week  | ---             |
| VIII–Feb 27, 28  | <b>Lab:</b> Acid Rain Lab Data Analysis I<br><b>&gt;&gt;&gt;DUE: Mon Feb 27<sup>th</sup> Final Draft of Pine Lab&lt;&lt;&lt;</b>  | 60-65           |
| IX - Mar 5, 6    | <b>Lab:</b> Acid Rain Lab data analysis II; discussion of results<br>DUE: Mon, March 5 <sup>th</sup> - <u>IN LECTURE</u> – Draft of Acid Rain lab Title, Introduction & Methods for comment.<br><b>W – March 7<sup>th</sup> HELP SESSION in lab 7 – 10 pm Acid rain data analysis</b><br>DUE: Fri Mar 9 <sup>th</sup> <u>Complete Acid rain drafts for Peer Review, in lecture.</u> | 60-74           |
| X – Mar 12, 13   | <b>Lab:</b> Rocky Intertidal Community Lab: Intro; species identification; Simulations<br>DUE: M – Mar 12 <sup>th</sup> - Completed PR of AR lab, <u>in lecture.</u>  | 75-88           |
| XI – Mar 19, 20  | <b>Lab:</b> Rocky Intertidal Community Lab: <b>FIELD TRIP to Giant Stairs, Bailey’s Island.</b><br>Load vans at quad side of Carnegie at 1 pm; return 5-6 pm<br><b>&gt;&gt;&gt;DUE: Mon Mar 19<sup>th</sup> Final Draft of Acid Rain Lab&lt;&lt;&lt;</b><br><u>(No revisions on instructor comments due to time constraints)</u>  | 89-90           |
| XII -Mar 26, 27  | <b>Lab:</b> Rocky Intertidal Community Lab: Data Collection II & Analysis;<br>DUE: Fri Mar 30 <sup>th</sup> <b>Final revisions of pine lab</b>  | 91-98           |
| XIII– April 2, 3 | <b>Lab:</b> RI Lab discussion<br>DUE: In lab – Rocky Intertidal discussion questions and figures  | 99-101          |
|                  | <b>FINAL EXAM –Wed April 11, 2012 8-10 am</b>   |                 |

## Philosophy and Approach of Ecology Laboratory

The lecture, lab and field investigations in Bio 270 will expose you to three levels of biological organization: the **individual level** (acid rain study), the **population level** (White pine population study), and the **community level** (rocky intertidal community study). Each study introduces new levels of ecological complexity and avenues of inquiry to stimulate your critical thinking and to provide a frame of reference for the lecture information. The studies have been designed to incrementally introduce new concepts and techniques that build on and reinforce information and skills learned in Bio 101 and Bio 242. Ecology is a quantitative discipline, and thus we will use a variety of quantitative tools to investigate and analyze the problems posed.

As in the other biology core courses, we place special emphasis on the *processes* of scientific inquiry, analysis, and communication. Effective communication in a scientific discipline requires working knowledge of the conventions of scientific writing and the language used in the discipline. In addition to writing, you will have opportunities to present information in informal discussions. Critical thinking, analytical, quantitative reasoning, and writing skills are best developed through practice with challenging material; thus, lecture and lab provide many opportunities to evaluate and interpret ecological data. The instructional staff functions to assist and guide your learning - use them and the other course resources to your best advantage.

### Field Trip Considerations:

**Clothing/Refreshments:** Two of our studies (White Pine Population and Rocky Intertidal Community) may require fieldwork under adverse winter conditions. It is vital that you dress properly for outdoor work in conditions that are very cold, windy, and wet. For the pine lab, at a minimum, you should have on: **boot socks, insulated waterproof boots (felt-lined are best), gaiters or nylon shell pants, thermal long underwear, warm sweater(s), parka, warm hat, scarf, and finger-type gloves. Snowshoes may be a good thing to have, too, if we get significant snowfall by the day of the trip (you can reserve these through BOC).** The intertidal lab may require similar warm and protective clothing. We have a number of gaiters available for use; these will be distributed first come first served at time of loading. Hot drinks and high energy snack foods will be provided on all field trips.

**Departure/Return Times:** Departure for the field trips is 1:05 pm at the quad side of Carnegie. Work in the snow is necessarily slower than on bare ground, so it is important that we leave the college on time for the pine field trip. We will try to get back ASAP, but it is very likely that we will return later than the normal end of lab. Travel time to the coast for the rocky intertidal trip is close to an hour, so plan on getting back to Bates later than usual, probably between 5:30 and 6 pm. If you will part or all of a sports practice, please make arrangements with your coaches beforehand. *Thank you* in advance for your cooperation on these matters. Let's hope for bright, sunny, warm weather in the field!

## Group Work and Writing in Ecology: READ CAREFULLY

Bio 270 uses the PI system as practiced in Bio 242 for two of the labs (acid rain, pines). Laboratory reports will be written collaboratively in groups of **two** people with anonymous peer reviews. Each student will be assigned an ID number (same # you had in Bio 242, when possible) to help preserve anonymity during the process. Because we devote several weeks to each study, and because the level and complexity of the data analysis increase, laboratory reports will be due several weeks after the actual data acquisition. **PI lab due dates are listed in the Lab Schedule and on the Bio 270 web site.**

1. **Working groups will consist of 2 people – all lab work, including writing, will be done in collaboration.** As in Bio 242, each person will be assigned a **random ID number** (we'll use codes assigned to you in 242) – you will use this number in place of authors' names on the draft of the paper given out for Peer Review. Your names *will be* included on FINAL versions handed in for evaluation.
2. **PI Labs (100 points): All papers should use 12 pt, double-spaced text with 1 inch margins.** There is no length limit per se, BUT you should keep the paper as brief as possible while being complete. The word here is **focus, clarity, brevity**, and attention to the **critical information**. Reference to at least 10-15 primary literature articles is the minimum we can imagine to establish the context for the study, and to discuss your findings; more often papers come in with 15-20 sources. The paper itself is scored 80 points for content and 20 pt for your response to the anonymous peer review.
3. **ANONYMOUS PEER REVIEW (30 pt):** Two complete drafts (i.e., all the parts are included) of your well-revised paper are due, ready for peer review in lecture on the assigned due date. NO EXTENSIONS will be given EXCEPT as the staff deem it necessary on a class-wide basis. Each person in the class will conduct an anonymous peer review of an assigned paper. The reviewer will be identified only by his/her code number, and will not know whose paper they are reviewing. You will use the standard PR form found on the Resources website plus comments made directly on the draft. **Peer reviews must be completed by the specified due date. Plan your time accordingly (figure 2-3 hours).**
4. **REVISION POLICY:** You may revise your Pine lab paper after instructor evaluation for up to half the points lost (not including use of peer review) up to a maximum score of 95. To achieve full revision credit you must do a substantial and credible job of revising the paper – merely correcting flagged typos and grammatical errors is not considered substantial. You must complete the brief **Revision Response Form** (URL below) and include it with your materials when you hand in your revised paper.

[http://abacus.bates.edu/~ganderso/biology/resources/PI\\_Revision\\_Response.pdf](http://abacus.bates.edu/~ganderso/biology/resources/PI_Revision_Response.pdf)

**Revised Pine papers are due no later than 4 pm on Friday March 30, 2012.**

PI Website info: <http://abacus.bates.edu/~ganderso/biology/resources/pi.html>

## Instructions for Using Google Docs™

Many of you have likely used Google Docs in previous courses or in high school to share your work with an instructor or collaborators. For our purposes, Google Docs is an excellent platform to support collaborative writing when you, the authors, have difficulty getting together to talk about the writing or to check in on progress. Using Google Docs, you will create a single draft of your work that all of you can access individually, or simultaneously, to edit. When editing simultaneously, there is a chat window to facilitate communication. The overarching advantage is that (1) you will all see all parts of the paper develop from the first word, even if you have split up the writing by sections, and therefore you will always have a good sense of the whole structure and content, and (2) you can continue collaborating on the writing even over breaks. (Yay)

### How to get started:

1. Open your browser and go to **docs.google.com**. One group member should create a new account.
2. When you get to the home page, look to the left side and click on **Create New** and then choose **New Collection**. A collection is like a folder. Give your collection the name "**Bio270 Lab**"
3. To start a document, either create a Word doc, save it, and then use the **Upload; files** tool to bring it into Google Docs, or click on **Create New; Document**. The Google Doc editing is a bit slow,
4. Next, you will give your other group mates access to the Collection and file by clicking on **Sharing settings** (over there on the right side of the screen) and then entering the email address of each member followed by **Share**. They will be sent an email alerting them that they have been added.
5. Each added member then will follow the emailed link to create their own Google Docs login password. Once logged in, you will see the **Bio270 Lab** collection in your window.
6. When you then open the document, the window on the right side will appear to indicate who (email address) is currently viewing it. Click on that person's email address and that will open a communication panel on the right side. Any edits that you do will appear in real time for everyone who may have the document open.
7. **SAVING:** While you are working on the document, the program will automatically save every few minutes after a change has been made. The most recent saving time is shown in the upper right of the window. Under **File**, the save option will say **Save now** if there have been changes since the last indicated save time. Similarly, there will be a floppy disk save icon on the upper left.
8. To export your paper from Google Docs, use **File; Download; Word**. Don't be surprised if you have to do some final formatting in Word before printing the final copy.
9. To Close a file, simply close the browser tab.
10. **SAVE A BACK UP COPY!!** Prudence suggests that you periodically export/save a backup of the paper as a Word doc on your Paris account or computer. We love Google (we think...) but you don't want to be caught short.

**PRISM:** We recommend that you do not add graphs made in Prism to your final document until after you have exported it to Word and completed your final formatting. At that time you can copy/paste the figures/graphs into the document from Prism and you should get perfect printing.



**Bio 270 Website:** The Bio 270 website includes a lot of information needed for doing the labs, including important photographs, problems, etc. Check it out early and get familiar with where to find needed information.

<http://abacus.bates.edu/~ganderso/biology/bio270/ecology.html>



**E-mail List:** Our course email list is called **wbio270a**. This list is maintained by the Registrar's office and it includes all students enrolled in this course and the staff. The list is updated daily to track enrollment changes. **All course announcements will be posted to this list beginning in week two** after the enrollment period has settled down. We also encourage you to use the list to post questions of interest to the whole class. **We use this list to communicate with the class as a matter of routine, so it is necessary that you read messages sent out.** At times we may distribute data sets via email attachment. If you do not know how to download attachments, or, if you need assistance learning to use the email system, please see the folks at the Information Services Help Desk (x8222) in Ladd Library.

**To mail a message** to the list: Address the message to [wbio270a@lists.bates.edu](mailto:wbio270a@lists.bates.edu)

**Please DO NOT use the list to send mail to specific persons**—use the specific addresses of the people you are trying to reach. Addresses for each instructor are given in the course syllabus.



**Resource Materials Web Site:** This site contains invaluable support materials for this course. These materials include a scientific writing style guide, basic statistics information, directions for obtaining Prism statistics and graphing software, use of various equipment used in our labs, and miscellaneous other information which will aid you in the core courses.

URL = <http://www.bates.edu/~ganderso/biology/resources/>

You will find it useful in lab and when writing your lab reports to have this site open in your web browser for quick access to the information it contains.



**CBB Plagiarism Resource Website:** This site contains lots of good information and resources to help you avoid the hazards of plagiarism – intentional or accidental. If you are unsure whether or not something you may write might constitute plagiarism of another's work, please check this site for answers, or talk to an instructor. Plagiarism is a confusing issue for everyone, and we want you to be protected from making an avoidable mistake.

URL = <https://ats.bates.edu/cbb/>

## Research Article Submission and List

The acid rain and pine labs require you to read primary research literature to provide an adequate context and background, and to support your interpretation of the results. To assist you in finding adequate literature, we will compile, and post, relevant citations of articles that you will turn in. To facilitate this process, each student will be asked to search out and submit:

1. Via email to Greg (*ganderso*): the **full, bibliographic citation** (see example below) for an article relevant to each of the PI labs using the *author(s). year. title, journal title, vol (no): pages* format. See the “**How to Write Guide**” for the correct information if you are not yet sure. Citations in the wrong form will be sent back to you for correction. **Note: Do not worry about indentation when sending it by email – the sequence of info and abbreviation is most important for our purposes – simply type the citation into the body of the email message.**

### SAMPLE CITATION (journal article):

Adams, C. M. and T. C. Hutchinson. 1987. Comparative Abilities of Leaf Surfaces to Neutralize Acidic Raindrops. II. The Influence of Leaf Wettability, Leaf Age, and Rain Duration on Changes in Droplet pH and Chemistry on Leaf Surfaces. *New Phytologist*, 106(3): 437-456.

2. **A PDF version of the article including all figures and table in legible form, and the complete literature cited section.** Always choose PDF format if printing from on-line journals. You should send e-copy as an attachment. Hardcopy will be acceptable if a PDF version is not available. Greg will triage and post an alphabetical listing of the articles on the Bio 270 webpage ASAP (locate the list by clicking **Research Articles**).

<http://abacus.bates.edu/~ganderso/biology/bio270/270resv.html>

**Primary Literature Search Considerations:** Use the excellent library resources to your advantage. The Science/Reference Librarian, Laverne Winn, is especially helpful and is very happy to assist you in your search for literature. The resources we have available change periodically, so do visit the reference librarians to get the latest info for searching.

1. **On-line journals:** Many peer reviewed scientific journals now publish complete articles on the web. These can be printed locally, which is extremely convenient. Whenever possible, print the PDF format since it will give you the cleanest copy and will include all figures and tables.
2. **Literature Cited in Papers You Read:** Once you have located a decent article, check its Literature Cited for other papers that may be interesting and relevant to your study. See the reference librarians for other suggestions for efficiently searching for papers by particular authors.
3. **Inter-library Loan (ILL):** Ladd Library’s journal collection is good but not extensive due to the expense of subscriptions. Therefore, if you find great articles in one of the important journals we do not have in house, you can take advantage of the inter-library loan service. It may take some time to get an article by ILL, so plan ahead.



**Week 1****Population Structure, Growth, and Recruitment Patterns in a Stand of Eastern White Pine (*Pinus strobus*) in Range Pond State Park, Poland, Maine, Following a Selective Harvest in 2006**

**Study Objective:** The goals of this study are to document changes in the population structure, growth, and recruitment of white pines following a selective harvest in Range Pond State Park in relation to the goals of the RPSP forest management plan. We will examine the effects of the harvest on regeneration and growth of the white pines as this is of great interest and concern to the park authorities and the State of Maine Department of Conservation, Bureau of Parks and Lands.



Supplementary Reading: (access via Bio 270 Homepage)

[http://abacus.bates.edu/~ganderso/biology/bio270/Ecological\\_Considerations\\_pinelab\\_sup1.pdf](http://abacus.bates.edu/~ganderso/biology/bio270/Ecological_Considerations_pinelab_sup1.pdf)

[http://abacus.bates.edu/~ganderso/biology/bio270/Pine\\_lab\\_questions\\_sup2.pdf](http://abacus.bates.edu/~ganderso/biology/bio270/Pine_lab_questions_sup2.pdf)

**Skills you will learn and/or reinforce in this lab:**

- biology of tree growth and factors affecting growth
- sampling techniques for determining the size, age, and spacing of trees
- field site description
- statistical analyses including descriptive statistics, t-tests, correlation and regression analyses, chi-square frequency analysis
- graphing techniques including bar graphs, frequency histograms, and scatter plots
- scientific writing/peer review
- collaboration and team work

## Preparation for the Acid Rain Lab

Please carry out the following protocol to plant seeds for the acid rain lab. This experiment will be running in the background as we do the pine lab. For more information, see the acid rain lab.

### Seed Planting (per group of two students)

- Materials:** Seeds from Connecticut Valley Biological Supply (clover CS 2638, radish CS 2507A, and sunflower CS2765); soil is a standard potting soil mix. Pots are 8.5x8.5 cm square (3.5 in<sup>2</sup>).
- Fill 9 pots with soil, then tamp down with another pot to loosely compact the soil to fill about  $\frac{3}{4}$  full.
  - In each sunflower pot,** plant five intact sunflower seeds (no cracks in the seed coat) pointy end down with four seeds arrayed in a square and the 5<sup>th</sup> planted in the center (Fig. 1) and then cover with a layer of soil to the hip of the pot. The goal is to provide each seedling equal space in the pot. LABEL each pot with an "S" if not already so marked.
  - Radish and Clover:** In each pot, plant 12 seeds in a 3 x 4 square array (Fig. 1), gently pushing them slightly into the soil (about a seed diameter) using forceps. LABEL each pot with an "R" or a "C," respectively, if not already so marked.
- Cover each pot with a shallow layer (1 cm) of soil and gently tamp down again. About 0.5 cm of the rim of the pot should still be exposed above the soil level.
- When all pots have been planted, place them in the labeled trays provided on the cart in lab so that they can be transported to the greenhouse.
- Watering of the plants to initiate germination and seedling growth will begin 30 days prior to the completion of the experiment (10 days for seedling establishment; 20 days for treatments).

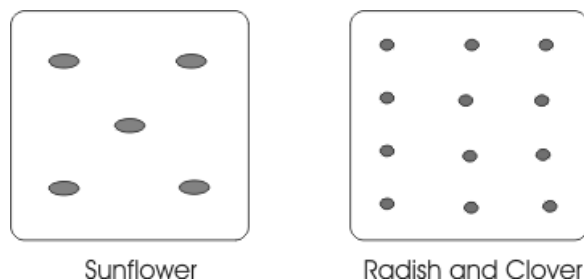


Figure 1. Suggested seed planting arrays to assure equal spacing. Forceps can be used to move individual seeds around to achieve equal spacing.

## Introduction

The White pine (*Pinus strobus*) (Fig. 2) is an important component of the northern forests including New England's. The prevalence of white pines in New England forests has increased over the last century due to, in large measure, historical changes in the landscape related to removal, during the early settlement, of hardwood-pine forests for timber and agriculture and the subsequent abandonment of agricultural fields. A species capable of rapid colonization of open space, white pine originally (pre-New World colonization) was probably found in small stands associated with disturbances such as forest fires or gaps created by canopy deaths or blow downs. Following colonization of New England, a long period of deforestation occurred as pastures and crop fields were carved out of the forests. However, subsequent abandonment of much of the agricultural area allowed the forest to regenerate, albeit in a somewhat different pattern. The regenerated forest we know in southern Maine today is a mixture of hardwood and softwood species often dominated, at least initially, by white pine. Hardwoods common in these forests include birch, beech, maples, oaks, and ash. Virtually all forest stands in this area of Northern New England are recent, young forests on abandoned agricultural land.



Figure 2. White pine, mature.

In this study we continue an ongoing Bio 270 investigation of a population of eastern white pine growing in a young, early successional, mixed hardwood-pine forest along Plains Road on the northeastern border of Range Pond State Park in Poland, Maine (Fig. 3). Based on analysis of aerial photographs of the area, we determined that the forest in this area had been last harvested sometime in the 1950's. The park was established in 1970, and since that time (and probably since the last harvest) there had been no forest management interventions on the site until the spring of 2006. In an effort to generate revenues to help fund state park operations, and to improve forest and habitat quality, the Bureau of Lands Management and the park system undertook a demonstration forest management project that resulted in a selective harvest of white pines and other species in the area we have been studying. The relevant portions of the management plan for Range Pond State Park are provided for you in Appendix 1. The 2006 harvest presents an opportunity to study the effect of the selective harvest on the pine population in terms of subsequent growth of the mature stand and to evaluate the impact on recruitment and growth of seedlings.

In this study you will (1) characterize and compare "mature" white pine populations in both harvested and adjacent non-harvested areas for age, size, and spacing, and (2) characterize the seedling/sapling populations in the same areas for age, size, recruitment, and growth patterns to determine the effects of the selective harvest on these populations.

## Characteristics of the White Pine Population Pre-2006 Selective Harvest

In our initial study in 2004, we noted a significant number of dead pines in the stand, roughly estimated by a walking tally at approximately 50-60% of the standing stems and later confirmed to be about 66% overall by quantitative sampling. The vast majority of dead pines were still standing, suggesting that the mortality may have been relatively recent. Subsequent studies were designed to identify patterns of mortality (size and degree of decomposition, proximity to neighbors) and suggested that intraspecific competition (e.g. for light, space, nutrients) was not likely a major factor in the mortality. Instead, we noted that poor soil quality (a sandy loam with poor water retention) combined with a period of frequent droughty years in the region caused a condition called **white pine decline** to develop which non-selectively kills the trees. Such a pattern of mortality has been documented in similar stands of pines throughout much of southern Maine.



A.

Figure 3. A) Pre-harvest view of the study site along Plains Road (left side), and B) location of study site (star) near Lower Range Pond in Range Pond State Park, Poland, Maine.



B.

See also: *Aerial photos of the park area 1949 to present for changes to landscape over time.*

[http://abacus.bates.edu/~ganderso/biology/bio270/RP\\_USGSaerial\\_photos.html](http://abacus.bates.edu/~ganderso/biology/bio270/RP_USGSaerial_photos.html)

The stand was composed primarily of white pine and a small fraction (<10%) of mixed hardwood species (oak, maple, aspen, birch, cherry), few of which were of mature size. The pines were uniformly sized, exhibiting a tall, straight-stemmed, growth form with live branches only on the top third of the trees. Lateral branch development on the lower portions of the stems is weak, which, in combination with an average spacing of all stems of approximately 2.0 m, strongly indicates that the trees were competing for light at the canopy level. Post-mortality spacing of live pines was approximately 2.8 m (mean distance to the two nearest living white pine neighbors.) Age was also quite uniform, averaging approximately 45-50 years, with most of the trees having established between the late 1940's and the mid-60's. A few trees, most notably those in the row of pines that lined the road (Fig. 3a), were of much larger size and were considerably older (70-80 years). Analysis of USGS aerial photos of the stand since 1949, clearly show that the area, then privately held, was selectively harvested between 1949 and 1964, and most likely during the mid-50's, and we believe these larger trees were remnants of the mature

stand that previously occupied the site. Notably missing from the current population were understory trees less than 40 years of age, suggesting a failure of recruitment for several decades. There are areas in the stand where pine seedlings have established since the late 90's; however, these seedlings exhibited **suppressed** primary and secondary growth likely due to shading by the forest canopy. We believe that the high mortality of pines and subsequent loss of foliage from the canopy functionally created canopy light gaps that allowed successful germination of new seedlings, although growth conditions were not optimal.

### BRIEF PRIMER ON WHITE PINE NATURAL HISTORY

(Suggested reading: Lancaster and Leak, 1978 – pdf posted on Supplements page of the Bio 270 website)

**Woody plant growth:** Long-lived plants such as trees exhibit tremendous plasticity in growth form and can respond to changing growth conditions (abiotic and biotic) throughout their lives. In woody plants we recognize two growth axes: **primary growth**, which occurs at the **apical meristems** (branch tips and stem leader) and adds height to the plant and length to branches, and **secondary growth**, which occurs at the **lateral meristems** and adds girth to the stem and branches. In areas of the world such as ours, with distinct winter and summer seasons, each year a new layer of wood is produced – familiar to most of you as growth rings – whose density and cell size are very sensitive to local growing conditions. This fact makes trees of temperate latitudes excellent historical records of climate conditions over time.

**Recruitment strategy:** *Pinus strobus* is a **ruderal** species, that is, it is an early colonizer of disturbed sites; white pine is usually one of the first species to grow on abandoned agricultural land and newly opened **gaps** in the forest. A gap is an area in which a tree, or many trees, may have died, or fallen, or have been cut, leaving a clear area open to the sky. Gaps provide a place for many shade intolerant herbaceous and woody plants to grow. Assuming there is some seed fall every year from the pines, those seeds that fall into gap areas will be most successful in germination and subsequent establishment. You may see patches of older, larger seedlings at the study site that established and grew in such gaps. Because white pine is shade intolerant, it is unusual to see pine dominated stands comprised of more than 2 age cohorts.

**Growth characteristics:** White pine is a long-lived species and may attain ages of 200+ years. Typically, during the first 5-6 years, pine seedlings grow slowly, attaining 30-35 cm total height. In New England, a white pine growing in good light conditions (~50% full sun) requires 8-10 years to reach 1.37 m (4.5 ft) in height; foresters call this point **breast height** and use it as a standard benchmark for growth measurements. Following this period of relatively slow growth, a tree with adequate access to light enters a period of rapid growth (average 30-35 cm height growth per year) and development that lasts until the onset of reproduction at the age of approximately 20-25 years. However, depending on local density of trees, competition for light may drive primary growth to be far greater (over 1 m per year if crowded), resulting in stands of tall straight trees with live foliage restricted to the upper 1/3<sup>rd</sup> of the stem. White pines that grow up under a mature canopy will be heavily **suppressed** exhibiting very slow primary growth (< 5 cm per year) and reduced secondary growth (think Charlie Brown's Christmas tree). White pines growing alone in the open do relatively small increments of primary growth and, instead, channel energy into secondary growth and branch development. They appear to be short and stout, with a globose growth form. Each year, most of that primary growth occurs in the first few weeks of the growing season. Secondary growth (girth, branch growth) occurs throughout the season. The **growth form** of a tree largely depends upon the prevailing local biotic and abiotic conditions, allowing the tree

to respond to changes in its environment. Because white pine growth form is so responsive, we say it exhibits **plasticity**.

**Shade intolerance:** White pines are shade-intolerant and respond strongly and positively to light (Lancaster and Leak, 1978). On abandoned agricultural land, or following forest removal from logging or other disturbance, White pines may seed-in densely. They grow well in open, well-lit conditions, but, because the cohort can be very dense, they shade one another laterally as the cohort increases in height. This shade encourages both rapid primary growth (height) and **self-pruning**; below canopy level, lateral branches die back on the lower 2/3<sup>rd</sup> of the stem due to reduced light availability (except for those on trees growing at the margins of a stand where they receive full sun.) Some individuals in these crowded stands may be strongly suppressed and unable to persist. Along roads and trails you will observe pines with fully developed limbs on the open side, but very weak branch development on the side facing the stand's interior.

**Growth suppression and release:** White pine also can establish (germinate and persist) in shade. If the canopy is closed, these small pines exhibit features of **suppressed growth**: reduced primary growth (a few centimeters per year maximum) and vastly reduced secondary growth (spindly branches, poor needle formation; see Bormann, 1965). If the shading is removed soon enough by thinning the overstory trees, the suppressed trees are **released**, and, after a period of metabolic adjustment, may achieve normal growth rates. The shade is usually due to a dense canopy of an older cohort of other softwood and hardwood tree species comprising the canopy.

**Competition and natural thinning:** In a mixed-species stand, pines might have been the initial colonizers of a previously open site. Then, more shade-tolerant hardwood species such as beech and maple may have established under the pines. Over time, the rapid growing, shade-tolerant hardwoods join the canopy, and also comprise the lower layers because they can tolerate shade. In stands where hardwoods form a significant portion of the canopy, they may eventually out-compete the pines. In pine dominated stands, pines may establish in high densities. As the pine grow and begin to compete for resources, natural thinning occurs which reduces the population density and over time, results in changes to the spatial distribution of the population. Pines stands tend to naturally thin over time and change from an initially clumped spatial distribution, to being more random, and ultimately, in old growth stands, may achieve a more uniform spatial distribution.

**Aging pines:** Paramount to understanding growth rates of any organism is having a basis for estimating time, preferably as individual age (Fig. 4). Woody-stemmed plants mark the passage of time by annually producing a new layer of **xylem** tissue at the lateral meristems. Xylem, as you will recall, is the water transport tissue in plants. What we call **wood** is the accumulated dead, heavily lignified, xylem tissue in a tree or other woody plant. New xylem and **phloem** (the nutrient conducting tissue) are produced annually at the lateral meristem of trees: phloem to the exterior and xylem to the interior. Over the course of the growing season, the mean diameter of new xylem cells decreases dramatically. The net result is the distinctive pattern of rings, or **annuli**, seen in cross sections of tree stems (Fig. 4). The standard technique for aging a tree is to take a core sample from the stem and count the number of annuli from center to the outside edge (Fig. 4). The width of an annulus, or growth ring, is a measure of a tree's *annual increment of secondary growth*. White pines offer a second record of age: each year the apical meristems produce a new whorl (ring) of branches. This occurs not only at the top of the stem, but also at the branch tips. Thus, the age of the stem and individual branches may be estimated by counting the number of branch whorls each presents.

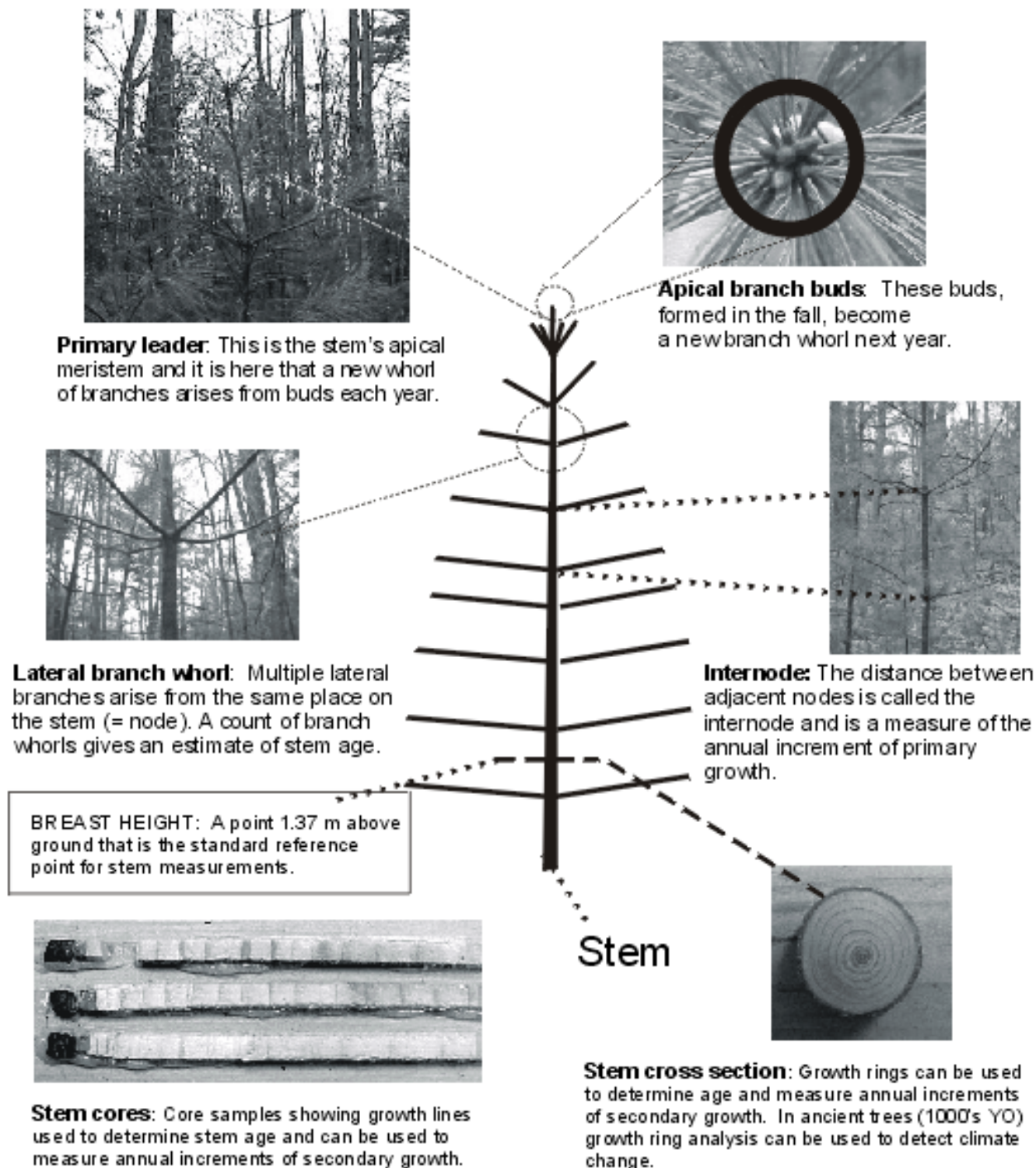


Figure 4. Characteristics of the Eastern White pine useful for study of age and growth.

**FIELD SAMPLING: LOGISTICS AND TECHNIQUES****A REMINDER ABOUT DRESSING FOR WINTER FIELD CONDITIONS:**

To confirm rumor, this exercise is *nearly* ALWAYS done in knee-deep snow - PLEASE DRESS APPROPRIATELY. Gaiters (we have about 20 pair) and waterproof pants for your legs are especially helpful as are wool socks with wool felt-insulated boots (e.g., SORELS). You must have a PARKA, scarf, and warm hat, and warm gloves. If you have questions about appropriate clothing, please ask an instructor. If you have snowshoes, bring them. Snowshoes can also be checked out from the Bates Outing Club. REMEMBER: You can always take clothing off, but you can't put on what you didn't bring. The vans will be parked close by and will have hot drinks, food, and heat for warming up. We also have lots of disposable hand/foot warmers.

**A. EQUIPMENT**

1. We will provide transportation, field equipment, hand warmers, and nourishment.
2. Your team should bring: Pencils, lab instructions, a calculator, enough warm and dry apparel (plus extras!) to keep you happy in the bitter cold for 3 hours, and binoculars if you have them (since we have only a few pairs).

**B. FIELD PROCEDURES**

Teams of ecologists will work together to carry out the surveys of two 20 x 30 m plots: a harvested area and a nearby non-harvested area that will be a control. We will go over the sampling plan in lab and practice the sampling techniques near Merrill Gym the first day in lab. Teams will be assigned tasks at that time to make data collection as efficient as possible. At the field site, we'll distribute equipment bags to each team, and briefly review the sampling plan and techniques. Instructions for each task are provided below. Waterproof data sheets will be provided in the field bags. Please be certain you understand the data collection procedures before you begin. When your team's tasks are completed, please help others to complete their tasks to minimize our exposure time outside. Each group will also record observations they'll use to write a description of the study site. Because this is a large, collaborative effort, it is vitally important that each ecologist does their utmost to measure and record the data accurately, and legibly, in a manner consistent with that of your colleagues. Be alert for oddball data that make no sense, e.g., a tree of age 14 that measured 275 m in height. More likely it was 2.75 m in height. Use common sense and stay alert. At the end of the day double-check the numbers to make sure that they all make good sense.

**1. SITE DESCRIPTION** (see Appendix 2)

Field ecologists must communicate the location of the field site and what the study site is like physically and biologically. The specific location latitude and longitude can be determined using a GPS unit in the field, or closely approximated using online sources such as Google Earth or MapQuest. To describe the physical and biological features of the site, you will answer a series of prompt questions once we're on the site. Appendix 2 is a sample data sheet for recording some characteristics of the site. Waterproof copies will be provided for the fieldwork. You should add other characteristics that are relevant to the

study objectives. You might also bring a camera to help record the site characteristics photographically for later reference.

## 2. SAMPLING PLAN: COMPARISON OF HARVESTED AND NON-HARVESTED MATURE PINE POPULATIONS

- a. **PLOT SAMPLING:** An efficient method for sampling stationary organisms such as plants is to survey individuals within a defined area we call a **plot**. Plots may be round or rectangular in practice; we will be sampling within fixed, rectangular plots measuring 20 x 30 meters. Prior to your lab day, the staff has gone to the site set the corners of the two plots. The “harvested plot” is randomly located within the same area we have been sampling since 2005. In our initial studies, the plot was situated so as to sample trees that were growing under as near uniform conditions as possible. We purposefully avoided transitional areas (e.g., where dense forest may give way to larger gaps, or areas where the species mix changes) and border areas near the roads because these factors would introduce variability into the data that would make a final interpretation difficult. A second 20 x 30 m plot was located nearby in an adjacent area that was not included in the selective harvest of 2006; this plot will be the “non-harvested control” and will provide a baseline of pre-harvest stand conditions for comparison. We’ll thus compare the population characteristics of the white pines in the two plots to determine how the population structure, growth, and recruitment may have changed since the harvest in 2006.
- b. **DATA COLLECTION – MATURE POPULATION:** We will tag and measure every live white pine tree that is at least 5 cm stem diameter at 1.4 m off the ground, in the entire plot. We will hereafter refer to these trees as “mature trees”. The trees will be individually tagged when you arrive: the tags will show each tree’s *plot*, *ID number* and *species*. White pines should be coded as **WP** on the data sheets. Hardwoods (HW) will be lumped together because there are relatively few of any given species, and most are saplings. Hardwoods will be tagged and included in the sample only if their height is at least half the local canopy height.

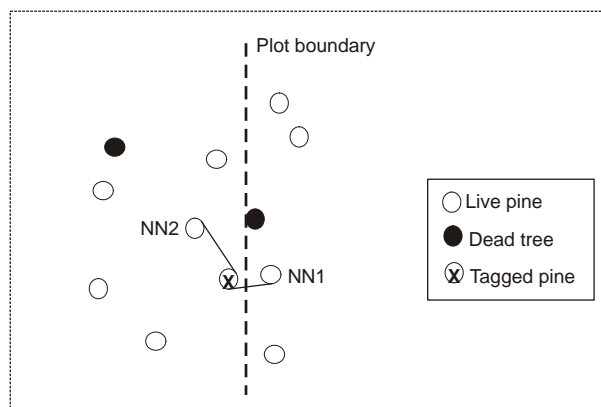
**Measurements:** Each of the measurements below will be practiced on campus prior to the field trip. Data sheets will be provided for each specific task. Completely fill out the top of your data sheet, making sure to note your team’s lab day. For each tagged white pine tree in each of the two plots (including nearest neighbor trees that fall outside the plot boundaries), the teams will:

- **DETERMINE THE AGE (yr):** Age will be determined primarily by branch whorl counts. Pines form a new whorl of branches each year at the apical meristem (and new “branchlets” off the branch meristems). Care must be taken to find branch scars on lower portions of older stems where branches may have been lost. Stem cores may be taken if the age cannot be accurately determined by whorl counts. NOTE: *The age annulus of a tree is “recorded” at the cessation of growth in the fall. For trees in our samples, therefore, growth associated with the present calendar year has not yet occurred. Thus, age by whorl counts or growth rings must use the last calendar year as the reference point for aging.*
- **MEASURE DIAMETER AT BREAST HEIGHT (DBH):** Stem diameter is a function of secondary growth at the perimeter of the stem. To standardize this measurement, we measure the diameter of the stem at breast height = 1.4 m (or 4.5 ft) above the ground. Wrap the DBH

tape around the stem at the level of the tag and measure and **record the diameter to the nearest 0.5 cm**. Do not measure stem diameter of trees less than 5 cm DBH.

- **MEASURE STEM HEIGHT:** Tree height (the result of primary growth) is measured vertically from the base of the trunk to the tip of the topmost stem leader. Since direct measurement is impractical, we will measure tree height by the percent slope triangulation method (see Appendix 3) using a device called an Abney level. If part of the stem has broken off, do not measure the height – simply make a note on the data sheet that it was “topped.” Many of the trees in this stand lost their tops during the Ice Storm of '98 (or possibly in the more recent ice storm of '08!). **Record height to the nearest 0.1 meters.**
- **MEASURE NEAREST NEIGHBOR DISTANCES (NND):** Spacing of trees, measured here as the average distance to a white pine tree's nearest neighboring living white pine trees, provides information about the tree's local “neighborhood” and possible sources of competition for resources (e.g., light, nutrients, water). We will use this measure to assess whether or not the spacing of white pines has changed as a result of the selective harvest. For each tagged pine, measure the distances - stem center to stem center – to the two nearest live, white pines of at least 1.4 m height (Fig. 5). Note that some of these neighbors may fall outside of the plot and should be tagged when encountered so that they can their vitals measured, too. NND will be reported in the data file as the average distance to the two nearest neighbor white pines.

Figure 5. Example measurements of nearest neighbor distances. Note the inclusion of a tree outside the plot for nearest neighbor measurements.



- HARDWOODS:** Hardwoods at least half of the general canopy height will be tagged and should be measured for DBH and height (highest point of the tree's crown). Hardwoods should be coded as **HW** for species.
- WHITE PINE SEEDLINGS AND SAPLINGS:** Sampling of seedlings is difficult in winter due to the snow cover. Therefore, at a minimum, each pair of students will haphazardly sample at least 10-20 seedling pines within the harvested and non-harvested areas. You will collect age, height, and internode length data if possible. IF conditions permit (no snow, or very little), we'll use a quadrat sampling scheme so as to get accurate seedling population density estimates. It is not unusual that we must make a modification of this plan on the fly depending on snow depth.

**Variables to be measured (if possible) on each white pine seedling:**

- **HEIGHT:** Use the folding ruler to measure total height of each seedling to nearest 0.5 cm.
- **AGE BASED ON TOTAL NUMBER OF INTERNODES:** (Fig. 5). Record overall height to the nearest centimeter and age in years.
- **MEASURE THE INTERNODE LENGTHS BACK TO 2006:** Internodes record the individual primary growth history of each tree, with most of this growth completed by early summer of each year. Internode lengths should be measured starting at the top of the stem, and working down in sequence to, and including, the internode produced in 2006. Make sure that the total of all internode lengths is equal to the length of the stem accounted for by the internodes you measured – if not, measure again. In suppressed seedlings (e.g., heavily shaded) primary growth is much reduced and internodes will be short. Following a release by thinning of the canopy, internode growth should increase. If there is snow cover, you will need to clear snow away from the plot (we'll have tools for this).

Once your seedling quadrat has been completed, walk through adjacent areas to observe and record patterns of seedling recruitment in relation to the canopy density/gaps.

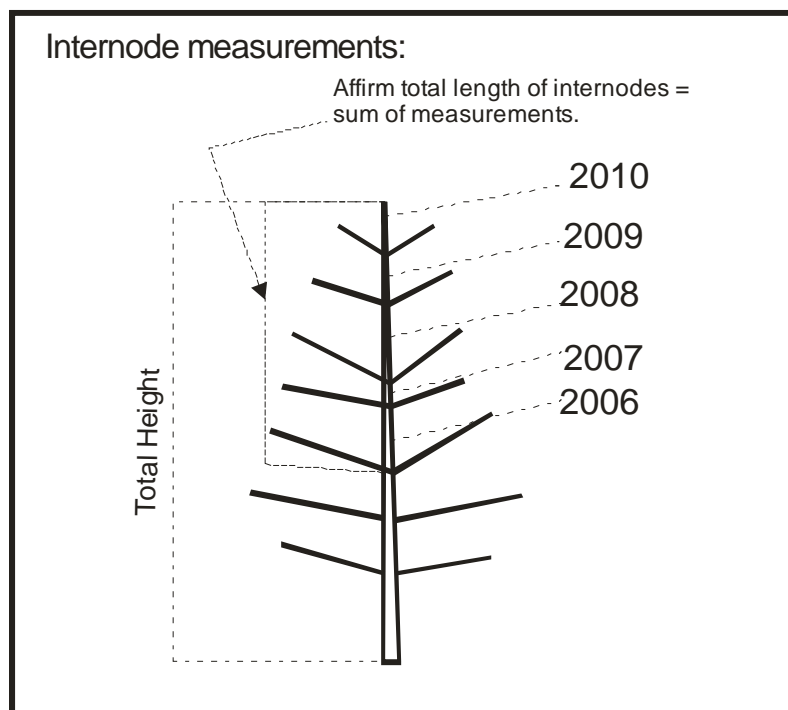


Figure 5. Example of measurements to be made on seedling white pines.