LAB-3
PLANT POPULATION PATTERNS

The size of a population in relation to a definite unit area is its density. However, populations do not occupy all the space within a unit because it is not all suitable habitat. Goldenrods inhabiting old fields grow in scattered groups or clumps because of soil conditions and competition from other old field plants. They also grow in clumps because they spread by rhizomes. The number of trees in a hectare is not very informative if that hectare contains open water or a rock cliff. Density measured in terms of the amount of area available as living space is ecological density. Ecological densities are rarely estimated because it is difficult to determine what portion of a habitat represents livable space. Determining just what area is available to one particular kind of organism and just how suitable it is represents one of the most important problems in population biology.

From a practical viewpoint, density is one of the more important parameters of populations. It tells ecologists about potential patterns in energy flow, resource availability and utilization, physiological stress, dispersal and productivity of a population. Crude density, though, only provides a minimal amount of information about a population. It provides no information about the evenness of the distribution of individuals.

Dispersion of individuals is a better measure of how individuals might be utilizing resources or how effective seed dispersal is. Plant populations exhibit a characteristic spatial dispersion pattern. Individuals within a population can be distributed either 1) randomly, 2) aggregated (clumped, contagious), or 3) uniformly (regular, overdispersed, or evenly-spaced).

![Random, Clumped, Uniform dispersion patterns](image)

These are both non-random patterns

An aggregated pattern suggests that the underlying biotic or abiotic environment is divided up into favorable and unfavorable patches, and that individuals in the populations are "attracted" to or survive best in the favorable patches. For plants, a clumped distribution often reflects the nature of reproduction. Non-mobile seeds, such as those of oak or walnut, are clumped near the parent plant, or where they have been placed by an animal. Mobile seeds, such as those from maple or birch, are more widely distributed, but even these will demonstrate a concentration...
around the parent plant (Recall the Kettle curve). A uniform dispersion suggests that some repulsive force prevents individuals from occurring (or surviving) very close to each other. This may be due to competition for crown space (light) or root competition for below ground resources (water, nutrients). Some plants, such as *Ailanthus altissima*, produce root exudates that are toxic to other plants (allelopathy), while some desert species produce substances that are autotoxic (toxic to individuals of the same species). This produces a uniform distribution in an environment where resources are limiting. A random distribution is considered the least common since it theoretically occurs where the environment is uniform. In addition, the location of any individual is not influenced by the location of another individual of the same species. A random distribution is not evidence for a lack of interacting factors. Larger forces, such as fire, climate (hurricanes, flooding) or large scale herbivory may predominate over subtler forces of substrate quality or dispersal.

Plant population pattern can be quantified and statistically tested in several ways. One method involves documenting the density of trees of a population in many quadrats and comparing the distribution of densities to the distribution expected if the population were randomly distributed. This method can be laborious. We will use an easier, plotless method in which a single or multiple quadrats are laid out and the distances between individuals of the population are measured (Clark, P.J. and F.C. Evans. 1954. Distance to nearest neighbor as a measure of spatial relationship in populations. *Ecology* 35: 445-453.). The mean distance within the population is then compared to the expected mean distance if dispersion were random.

In this lab, we will investigate the dispersion patterns of tulip poplar (also known as yellow poplar (*Liriodendron tulipifera*) growing in two different aged stands. The young stand is at Rocky Ridge County Park. It has been growing for 10 years after a microburst (see [http://faculty.ycp.edu/~kkleiner/envbio/envbiolabs/lab4RockyRidge.pdf](http://faculty.ycp.edu/~kkleiner/envbio/envbiolabs/lab4RockyRidge.pdf)) blew down much of the overstory. The old stand is at Nixon County Park, York PA. This stand ‘may have’ been the scene of a fire many years ago. (I have a second hand report of this, but the primary source could not recall the incident.) I have cored two of the trees on the other side of the stream for our study site for this lab. The two trees are each about 66 years old.

**SAMPLING PROCEDURE**

As a class we will lay out quadrats as specified by me. (Record the size of your plot on your data sheet). I will divide you into 3-person teams. I will provide orange flagging so that you can mark the corners of your quadrat and one or two trees along the side.

The objective is to measure the distance between each pair of nearest neighbor trees. Starting from one corner of your quadrat will help you keep track of which trees you have previously measured. Start with any individual. Measure the distance (in meters) from this "focal" tree to the "nearest neighbor" of the same species. Measure to the center of the tree. Do this for all individuals of this species in your plot. If a nearest neighbor occurs out of the plot, use it as a nearest neighbor but not as a focal tree. If two trees are nearest neighbors for each other, you should record the distance between them twice. You should end up with the number of individuals and a list of distances between neighbors for each of the two species in each quadrat. Put your name on your data sheet. Write legibly and with a black or blue pen.
STATISTICAL TESTS

For each stand (young and old), combine the data for the quadrats. Do the following calculations for all of the combined measurements in each stand.

1. Calculate an observed mean distance, $r_A$, as follows: $r_A = \frac{\sum r}{n}$ (where $r$ is distance in meters between trees and $n$ is the number of distances).

2. Calculate an expected mean distance (the expected distribution is that the population is randomly distributed) as follows: $r_E = 0.5 \sqrt{A/n} + (0.051 + 0.041/n) L/n$

   where $A =$ total area of your plot, $n =$ the number of nearest neighbor distances, $L =$ length of the perimeter of the plot. This is the corrected $r_E$ developed by Donnelly (1978) and reported by Sinclair (1985) in the journal Ecology.

3. Calculate the Dispersion Index, $R$, as the ratio of these values: $R = r_A/r_E$. This index ranges from 0 (maximum aggregation) to 1.0 (random population dispersion) to 2.1491 (maximum uniform pattern).

4. Now that you have your Dispersion Index, you need to determine if the value you calculated is significantly different from an expected random distribution. To test the statistical significance of the deviation of observed from expected mean distances, you must calculate the standard error ($\sigma$) of $r_E$ as follows: $\sigma(r_E) = \sqrt{0.07A + 0.037L \sqrt{A/n}} / n$. This is the corrected $\sigma(r_E)$ developed by Donnelly (1978) and reported by Sinclair (1985) in the journal Ecology.

   Then, calculate the $z$-value as follows: $z = (r_A - r_E)/\sigma(r_E)$. Record $z$ as an absolute value. (This is because $r_E$ will sometimes be larger than $r_A$.) The observed mean distance $r_A$ is significantly different from the expected mean distance $r_E$, if $z > 1.96$. Then $P < .05$. If your $z > 2.58$, then your $P < .01$.

   For example, suppose your Dispersion Index $= 0.96$. Seems pretty close to 1.0 (a random population dispersion). But how can you be sure? Calculate $z$. If $z = 0.75$, this means that your observed mean distance is not significantly different from the expected mean distance of 1.0 (random distribution). (If the observed mean distance $r_A$ is not different than the expected mean distance, $r_E$, then the ratio of $r_A/r_E$ will be 1.0, or random.)
What if your Dispersion Index is 1.1371? That also seems close to 1.0, but is it? The calculated $z = 3.46$. That means that your Dispersion Index is significantly different from 1.0. Therefore, the distribution of your sample is not random. Since your Dispersion Index is greater than 1.0, this suggests that your Index is statistically closer to a uniform distribution. Both of these examples are from the data in Clark & Evans. Read it. It is not that difficult. All of the calculations are in an easy to read table.

LAB REPORT

The data will be posted on my web page after lab.

I want you to write a short lab report. It should include:

1. An Abstract.
2. A short introduction 1 -1.5 pages that introduces the concept of dispersion, reviews the different types of dispersion (cite references!) and then logically leads the reader to your hypothesis. Be sure to include your own observations before you state your hypotheses.
3. Hypotheses as stated below.
4. Methods. Someone else should be able to duplicate this study based on your written methods.
5. Results – A short results section plus a data table. Include the following values: $n$, $r_A$, $r_E$, $\sigma(r_E)$, $R$, $z$, the critical value you’re comparing $z$ with, and $P$.
6. A Discussion of your results, which will address the 4 questions listed below. By answering these questions, you will be better able to explain your data. Be sure to investigate the life-histories of tulip poplar to help you answer the questions. Cite sources of information.

- All sections should follow the format that is provided in the Lab Report Format for YCP Biology Courses.

Your Hypotheses – This lab report will be a test of the three alternative hypotheses for population dispersion, but you will provide only one hypothesis based upon your observations. This is a little different than the standard null versus alternative hypothesis format you are now accustomed to. (E.g., The behavior of Species A is not affected by substance X –null hypothesis. The behavior of Species A is affected by substance X –alternative hypothesis. You hope to refute your null hypothesis because the reason your doing an experiment is because you have reason to believe substance X will have an effect. If it does not, you most likely do not have an explanation for what influences the behavior of species A. So now your only choice to explain Species A’s behavior is to test a new substance.)

The uniqueness of this lab is that there are only 3 possible outcomes as to how the population is distributed. If your hypothesis is not supported, the dispersion index will indicate which of the other two distributions your data most likely reflects. This means you will always have an explanation for how your population is distributed without any additional experiments.
**Your primary hypothesis should be based on your observations!** The \( z \) statistic above will guide you to your alternate hypothesis. Use this handout and the three references given below (on reserve) to provide (1) an idea of what your Introduction section might look like. These examples will discuss what forces might *generally* cause the various dispersion patterns (and thus why it's interesting to look at dispersion patterns) and (2) well-developed explanations about dispersion patterns from specific studies. These should help you write your own introduction and discussions that explain the anticipated and calculated dispersion pattern of tulip poplar.

For more information on the tulip (yellow) poplar, examine what Burns and Honkala (1990) have written.


**Your Discussion** - Address the following questions as you think about why tulip poplar exhibits the dispersal patterns you found.

1. Were you hypotheses supported? If not, what was the outcome? (Addressing whether your hypothesis was supported should be the first order of business in the discussion. The rest of the discussion is used to explain how/why the data do or do not support your hypothesis and to compare your work with already published work of the same nature.)

2. Using the references provided on this page and the next, how do your results compare to those of others. Can you explain any differences between your results and that of others?

3. Which environmental factors are probably crucial to seed dispersal, seed germination, seedling establishment, and the success of juveniles? Recall from lecture; how did these organisms arrive here? (dispersal) and how come they have stayed? (habitat suitability).

4. Are the distributions of the different aged stands the same? Would you expect this? Do you think that the distribution of trees you have observed and measured could have changed as the trees grew from saplings to larger individuals? How might you explain the similarities or differences?

The grading rubric is as follows:

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Abstract</th>
<th>Introduction</th>
<th>Hyp.</th>
<th>Methods</th>
<th>Table</th>
<th>Results</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Info. Lit.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>100</td>
</tr>
</tbody>
</table>

Rev. 2/13
Note: You should not be citing this lab handout. All citations should be primary or secondary sources.

Available through the library electronic journal collection: (don't forget to refer to these in your lab report, and reference them!)


The following articles (textbook) may be of some use, and are available through the e-journal collection at Schmidt Library (accessible on-line).

Discuss Liriodendron tulipifera.


* cited in Sinclair and referred to in this handout, but a copy is not available.

Discuss Liriodendron tulipifera.


# DATA SHEET FOR PLANT POPULATION PATTERN LAB

**Yellow Poplar**

<table>
<thead>
<tr>
<th>Stand Age</th>
<th>Young</th>
<th>Old</th>
<th>PLOT</th>
</tr>
</thead>
</table>

NEAREST NEIGHBOR DISTANCES (in meters to the nearest 1/10 meter)

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rev. 2/13
# DATA SHEET FOR PLANT POPULATION PATTERN LAB

**Yellow Poplar**

<table>
<thead>
<tr>
<th>Stand Age - Young</th>
<th>Old</th>
<th>PLOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
</tbody>
</table>

NEAREST NEIGHBOR DISTANCES (in meters to the nearest 1/10 meter)