



NSDAR Educational Resources Committee

“AP Environmental Science; Statistics; Using the Point-quarter Method to Sample Trees in a Forested Area”

Lesson Plan

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Grade Level: 11-12th Grade

1. Identify the standards to be addressed:

CCSS.MATH.CONTENT.6.SP.A.1

Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. For example, "How old am I?" is not a statistical question, but "How old are the students in my school?" is a statistical question because one anticipates variability in students' ages.

CCSS.MATH.CONTENT.7.SP.C.8

Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.

CCSS.MATH.CONTENT.7.SP.C.8.A

Understand that, just as with simple events, the probability of a compound event is the fraction of outcomes in the sample space for which the compound event occurs.

CCSS.MATH.CONTENT.7.SP.C.8.B

Represent sample spaces for compound events using methods such as organized lists, tables and tree diagrams. For an event described in everyday language (e.g., "rolling double sixes"), identify the outcomes in the sample space which compose the event.

CCSS.MATH.CONTENT.7.SP.A.1

Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

CCSS.MATH.CONTENT.7.SP.A.2

Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction might be.

2. Statement of the objective and lesson outcomes:

The student will be able to describe and apply basic approaches to sampling organisms.

The student will be able to describe and apply sampling to a tree community, thus, applying the point-quarter sampling method.

The student will be able to utilize a Table of Random Numbers to select random sample points.

The student will be able to calculate and interpret Importance Values to a forested area.

3. Materials, resources, and technology to be used by teacher/students:

Lab Materials

A 10-foot (or 3 meter) tape measure will be needed per student/lab group. Some of the distances that the student measures in this lab are likely to be longer than 10 feet but a 10-foot measure can be used to measure these if the student does not have a longer tape measure. Each student lab group will also need a tree guide for tree identification, a notebook, calculator and flagging to mark “points”.

4. Introduction of the topic:

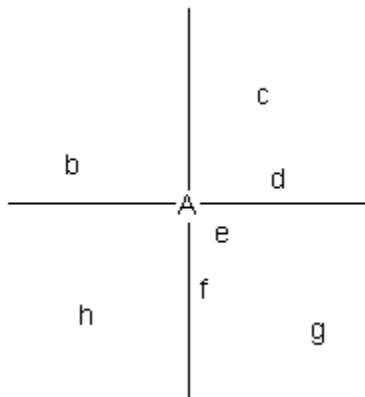
In Class Lab Prep/Explanation

Sampling: There is often a need to estimate the number of individuals present in a population or community for ecological and environmental studies. If there are a few, large individuals, a census can be performed directly by counting each individual. If there are many individuals, the community is large, or the individuals are small, it may be impractical to count all the individuals. In these cases it is easier to take representative samples of the community and then estimate density the population size based on the samples.

Example: For example, suppose that you wanted to know how many native American Holly trees are in a large forested area. It would be impossible to count every tree in say a 2.4 million hectare (6,000,000 acre) park. Instead, randomly-located samples can be taken. Suppose that 100 one-hectare samples were taken at random locations in the park and in each of these samples, the number of Holly trees was counted. The average number of hollies per one-hectare sample was 500. From this we can estimate the number of hollies in the entire park by multiplying $500 \times 2,400,000$.

Plotless Sampling: Plot sampling as described in this example may be difficult for sampling trees, particularly if a large area is to be sampled. It may be easiest to sample trees using a plotless technique. Plotless techniques are best used with stationary organisms because they involve measuring distances to organisms.

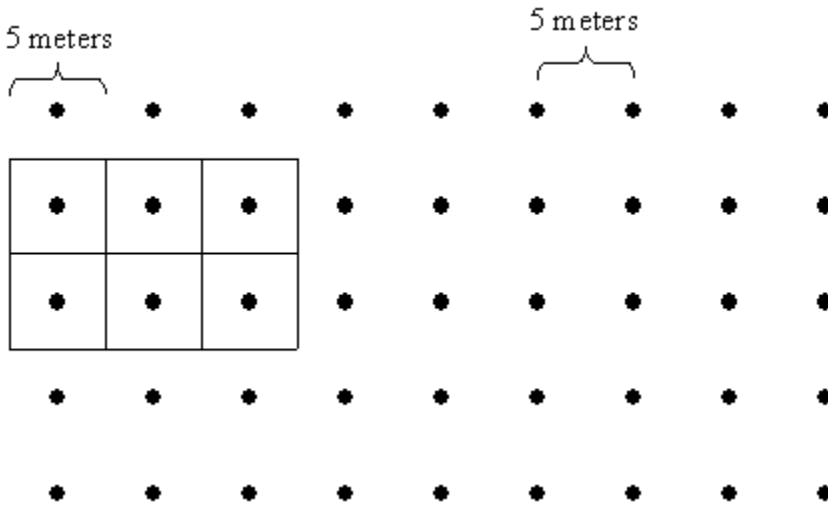
Point-Quarter Sampling: The point-quarter technique is perhaps the most popular of the plotless sampling techniques. Each sample is taken at a random location in the area to be sampled. This is frequently done by choosing random points along a transect but any randomization technique may be used. The area near each random point (sample point) is divided into four imaginary quadrants as indicated below. Within each quadrant, the distance from the random point to center of the nearest individual is measured. There are four quadrants, so you will measure a total of four trees at each sample point. In the diagram below, point A represents a random point (sample point) and the letters b through h represent specific trees. The distance from A to the center of b, d, e, and h would be measured. For each individual (b, d, e, and h), the species name and its basal area or area of coverage are also recorded.



Basal area is the area of a cross section of the stem. For trees, the basal area can be calculated by measuring the circumference or the diameter at 4 ft above the ground (called DBH or diameter at breast height) and converting these measurements to area. For smaller plants, the total area of coverage by the entire plant is frequently used.

Calculations

The diagram of a hypothetical forest below will be used to explain the rationale for density calculations. Each dot in the diagram represents a tree. The distance between each tree is 5 meters.



If you were to draw a square around each tree, the sides of each square would also be 5 meters (see diagram). The area occupied by each tree is therefore $5\text{ m} \times 5\text{ m}$ (or 25 m^2). Hence, you have calculated the number of square meters per tree.

Next, calculate density, which is the number of trees per square meter. Density is therefore the inverse. Density = $1/(\text{distance between trees})^2$.

In nature, organisms are seldom distributed in such a regular pattern. The distance between each tree in a forest, for example varies. The formula for density calculations given above can still be used if we use the average (mean) distance between each tree.

To calculate the density of all species, it is necessary to sum the point-to-organism distances for all species and calculate a mean. The square of this number is equal to the mean area occupied per organism.

$$\text{Mean area per organism} = (\text{mean point-to-plant distance})^2$$

Density is equal to the inverse of the area per organism:

$$\text{Density (all species)} = 1/(\text{mean point-to-plant distance})^2$$

Note that this formula computes the density of **all species combined**. The unit of density is the same unit as the mean point-to-organism. For example, if the point-to-organism distance is in meters and you want density calculated in individuals per square meter, then use the equation given above. If you want to know the number of individuals per 100 sq. meters, then Density = $100/(\text{mean point-to-plant distance})^2$. In our samples, we will measure distance in meters but calculate the number of individuals per hectare. The numerator in the equation becomes 10,000 because there are 10,000 square meters in one hectare.

The equations below show calculations for relative density, dominance, relative dominance frequency, relative frequency, and importance value:

Relative Density = (# individuals in a species)/(Total # of individuals in all species) X 100

Density = (Relative Density of a species)/100 X Density (all species)

The units for density will be the same units that you used for measuring the distance from the sample points to the trees. For example, if you measured these distances in meters, the calculation for density will be trees per square meter. If you measured these distances in feet, density will be given as trees per square feet. Usually these measurements are converted to trees per **hectare**. There are 10,000 square meters in one hectare.

Dominance = (density of a species) X (average basal area for that species)

Relative Dominance = (Dominance)/(Total dominance of all species) X 100

Frequency = number of sample points at which species occurs*

*Clarification: Frequency is not equal to the number of individuals in your samples. There are 4 measurements taken (4 trees measured) at each sample point. Regardless of how many times a species occurs at that point (1, 2, 3, or 4), it's frequency for that point is still 1. For example, if you sampled 5 points (20 trees), there may have been 6 hollies. If these hollies occurred at two sample points, the frequency for hollies is 2. If your samples are obtained from 5 sample points, the maximum value that a species can have for frequency is 5.

Relative Frequency = (Frequency)/(Total frequency of all species) X 100

Importance Value = Relative Density + Relative Dominance + Relative Frequency

Teacher Field Lab Preparation:

The teacher should complete field trip paperwork to obtain school permission as required by your school district. Make sure you have permission to access the wooded lot you have chosen for this lab.

Before going into the woods, make sure your students can identify poison ivy. They should also be aware that animals may be hidden in the forest litter and they should be careful where they walk to avoid injury to them and to themselves.

This method of sampling usually only assesses stems taller than breast height (1.37 m; 4.5 ft). If you are only interested in larger trees, you can choose to limit your inventory to those stems over a specified diameter.

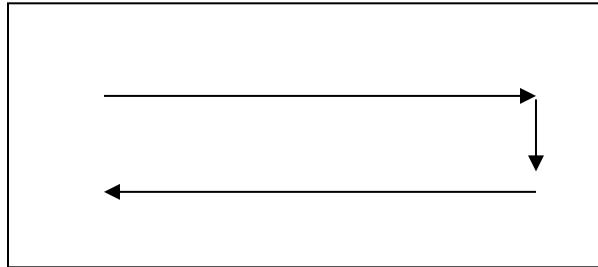
5. Procedure for instruction:

Field Methods

Students will use this technique to sample a wooded lot. Most wooded areas will have several different tree species. Choose a woodlot that has at least 3 tree species. This should not be a problem unless you choose to sample a tree plantation that has only one species. Your samples should include at least 3 species of trees.

1. One method of determining the location of sample points in a field is to first obtain two two-digit random numbers that are less than 50 from a table of random numbers. See the **Instructions for Using a Table of Random Numbers**. These numbers are used to determine the coordinates of a

sample point. For example, if these numbers were 22 and 12, you would pace 22 steps along one border and then turn 90 degrees and pace off another 12 paces into the area to be sampled. In our case, we will simply walk in a straight line through a woodlot. The number of paces will be determined by selecting a two-digit random number that is less than 50. If you reach the end of the woodlot before obtaining 5 sample points, turn 90 degrees and walk along the edge for a few paces and then turn another 90 degrees and walk in a line parallel to the one you just sampled as is indicated in the diagram. The distance between the two lines could be determined by a single random digit.



2. At each sample point, measure the distance to the center of the nearest tree in each quadrant and record this measure along with the name of the species in the Point Quarter Sampling Data Sheet. You should have four trees per sample point. Next, record the circumference in the Point Quarter Sampling Data Sheet. Record all of your measurements in meters to the nearest 0.01 m, e.g., 6.51 m. If your measurements are in inches, you will later need to convert them to meters (# centimeters/ 39.4).
3. Repeat this procedure until data for 7-10 sample points (up to 40 trees) have been recorded. This sample size is adequate but more accurate estimates can be obtained by collecting data from more points. If the lab time period is limited, 7-10 teams could each collect data for one different sample point for each team; then consolidate class data.
4. Develop a table to help organize your data for performing the calculations leading to and including Importance Values. This table can also be used for entering the data into the spreadsheets for calculations and analysis.

Data Collection/Results

1. Complete the Sampling Data Sheet for 7-10 points, or as instructed. (See the separate document, **Sampling Data Sheet**)
2. Develop a table to help organize your data for performing the calculations discussed below.

6. Lesson closure:

Analysis/Conclusion

1. For each tree species identified, calculate Relative Density, Relative Dominance, Relative Frequency, and Importance Value. Display these results in a table.
2. Which species have the highest importance values?
3. In what types of ecological communities would measurement and accuracy be greatest for the point-quarter technique?

- a. Describe a community in which this method would be useless to use in.
4. Describe some of the limitations of Importance Values found in this way.
- a. What assumptions do you have to make?

- b. What information is lost as you do this calculation?

- c. How do mistakes in the field measurements affect Importance Values?

5. An importance value for Sugar Maple (*Acer saccharum*) is 1.6, calculated from the following values:

$$RF = 0.8 \quad RD = 0.6 \quad RC = 0.2$$

As a forester or forest ecologist working for a large logging company, interpret these values and provide recommendations.

7. **Assessment of student understanding:**

Students shall be assessed on the completion of the sampling data sheet and analysis/conclusion answers.

Teacher answers:

1-2. Answers will vary.

3. In what types of ecological communities would measurement and accuracy be greatest for the point-quarter technique?

- a. Describe a community in which this method would be useless to use in.

Measurement and accuracy will be the greatest in natural areas that random. It would be useless to use in a regularly spaced plantation that consisted of a monoculture like a pine plantation.

4. Describe some of the limitations of Importance Values found in this way.

- a. What assumptions do you have to make?

- b. What information is lost as you do this calculation?

- c. How do mistakes in the field measurements affect Importance Values?

Importance value provides an overall estimate or the influence or importance of a species in a community. This value is weighted toward density, in that the number of trees present exerts a greater effect on the index than does their size. A critical assumption is that we have adequately sampled the area. If the area is homogeneous in terms of diversity it would require fewer transects and plots than if it is heterogeneous in terms of diversity. Four trees per sample plot may not be enough to adequately describe the ecological community.

5. An importance value for Sugar Maple (*Acer saccharum*) is 1.6, calculated from the following values:

$$RF = 0.8 \quad RD = 0.6 \quad RC = 0.2$$

As a forester or forest ecologist working for a large logging company, how do you interpret these values?

The few trees are clumped together but are large and make up a majority of the coverage of the stand. As the red oak is a commercially important lumber species the forester would be interested in the logging of the red oak in this stand.

Instructions for Using the Table of Random Numbers

Close your eyes and then point your finger anywhere in the table below. Open your eyes and begin reading the digits beginning where your finger touches the table. For example, suppose that your finger points to the beginning of the line below and you need five random numbers between 0 and 20.

553617280595580771997955130480651347088612

In this example, you will need to read the digits two at a time until you get two that are between 00 and 20. The first two digits are 55. Because this number is greater than 20, it will be discarded. The second two (36) will also be discarded. The next two digits can be used; your first random number is 17 (underlined above).

Continue reading the digits two at a time, discarding all numbers greater than 20. The next two digits (28) are discarded but the 05 (or 5) is used. This is your second random number. The following will be discarded: 95 and 58. The third random number is 07. The next two random numbers that will be used are 13 and 04.

If you needed a random number between 0 and 1000, you would read the digits four at a time until you obtained a number between 0000 and 1000. You would discard the following: 5536 and 1728. Your number is 0595.

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Table of Random Numbers

0773137438507747205718328480835962711226093562787915351435849662797030
0668374899530550910672951040184222303800536236386975767809161865095583
5241943252709172177912241897259855701752672524318621544507384818342032
2257122055944377750865856074704173408196415608317556498049367554156868
8327451734507593120204735051834890715937898637423904351483590131661737
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9393158338217705557218072959827065427424742349717079782759946696761083
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9127642217502111609370270546559567026402160306940942678318644978725571
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5688848050703777782933095007058395016304010733006272065928066690862437
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8931914368580313248389016049658855407516606231916064858991627368093534
1463312251409328712149470441081083284506852853117557678849825195462688
2322221927750071054580354154790269663706773975541641005780564982249334
7674324082238239382880786493335946434626265975877036299696586531502714

Point Quarter Sampling Data Sheet

Date _____ Group Members _____

Habitat _____

Location _____

Number of points sampled _____

Point Number	Quarter Number	Species	Diameter or circumference (cm)	Area covered (cm ²)	Point-to-plant distance (m)
1	1				
1	2				
1	3				
1	4				

Point Number	Quarter Number	Species	Diameter or circumference (cm)	Area covered (cm ²)	Point-to-plant distance (m)