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Measuring community structure of a forest using the wandering quarter method

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Abstract: A plant community can be sampled using a “wandering quarter” survey, a plotless survey method that requires no set-up and minimal equipment. Participants zig-zag from tree to tree, always heading in the same general compass direction. Data collected can be used to calculate several common measures of plant community structure, including species richness, species diversity, relative basal area, stems per hectare, relative dominance, and importance value. Hypotheses about the effect of various abiotic parameters, such as altitude, or aspects, or the effect of various forest management techniques, can be tested by comparing the parameters of community structure.

Keywords: community structure, wandering quarter, plant ecology, sampling

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Introduction

This field study teaches methods and concepts related to plant ecology at the community level. Methods of quantifying several community parameters are included. The exercise can be adapted for use at various levels. I have used it for one 3-hour lab where the objectives consisted of learning to use a dichotomous key and learning one method of quantifying plant community structure. Others have used adaptations of this exercise in a senior level Ecology course, where the lab consisted of an all-day field trip to collect data from sites at two different altitudes, and was followed by two weeks of analysis, incorporating most of the objectives listed below.

The lab could be adapted to fill some or all of these objectives:

- Learn to identify trees using a dichotomous key.
- Learn a method of sampling plant communities, i.e., the wandering quarter method. This method does not require one to set up a plot, thus minimizing set up time in the field and maximizing time for data collection.
- Learn one method of quantifying horizontal structure by calculating Importance Values based on relative size and relative density of trees sampled.
- Learn two methods of quantifying biodiversity.
- Practice measuring, collecting data, graphing, calculating, and hypothesis testing.

Materials

(per group of 4 unless otherwise noted)

- A dichotomous key to trees in the region (1 per person allows everybody to key)
- 1 Measuring tape -- 50 or 100 meter flexible tapes
- 1 Directional Compass
- Handouts and data sheets per each individual
- 1 Clipboard
- Calculators (1 per person makes the calculations less tedious)

Optional materials:

- Binoculars (may be useful for looking at leaves high up in a tree, if there are none close to the ground for use in keying)
- Computer with spreadsheet program for calculations

Student Outline

Measuring Community Structure

Biological regions, like ecosystems and biomes, are often named for the dominant forms of plant life; hence the terms: grasslands, rain forests, scrub forests, deciduous forests. These names not only describe dominant plant forms; they also reflect abiotic factors such as climate, latitude and altitude (Kricher, 1988). The terms 'desert', 'tundra', 'savannah', and 'taiga' are also terms associated with a particular association of plants.

A **community** is a group of populations of different species occupying a specific area. One can speak of the animal community of a lake, the insect community in a vegetable garden, or the plant community of a city park. Several physical properties of communities can be described, including species diversity, horizontal and vertical structure, and dominance (Krebs, 1985).

However, the aforementioned names of communities are quite broad. Biologist can describe communities more specifically by naming particular plants in the community. Plant communities are often too heterogeneous to be described by a single dominant species or by listing all the species present. For example, over 500 species of trees occur in the eastern deciduous forest of North America (Kricher, 1988). Thus communities are often described by the species or genera that are determined to be the most dominant in the community. The dominant species can be quantified by calculating a statistic known as 'importance value' (Smith and Smith, 2001). Once importance values are determined, a particular community can be described in terms of its most important species. For example, within the deciduous forest of the eastern United States are oak-hickory communities and maple-beech communities (Kricher, 1988).

Importance values can be calculated after the size and number of individual trees of the various species is measured. (Formulas for these calculations are found on a separate sheet). The trees with the highest importance values will be those that exist in the greatest number or are of the greatest size -- these are the trees that may have the greatest effect on the community.

What is the value of knowing the physical structure of a plant community? It can tell us something about the biological structure of the community, i.e., something about interactions between species and how the community functions in gathering energy and cycling nutrients. The structure of the plant community can tell us something about what animals are present, so is of use in wildlife management. For instance, an oak-hickory forest produces lots of nuts. Animals that feed on nuts, like wild turkeys, blue jays, and squirrels will likely be present (Kricher, 1988). Studies of plant communities over the course of many years have allowed biologists to understand ecological succession, i.e., the replacement of species by other species over time.

There are several ways to analyze community structure. Methods include setting up a plot of a particular size and counting and measuring all the individual plants within that plot. Methods which don't require setting up a rectangular grid are known as plotless methods; these methods include the line intercept method, the point-quarter method (Smith and Smith, 2001) and the wandering quarter method. For our study we will use the wandering quarter method.

Comparison of Vegetation on Different Aspects of a Hillside

Question:

Given that there are differences in environmental characteristics on different aspects (north facing, south facing, etc) of a hillside, are there any differences in vegetation for different aspects?

H₀: There is no difference in vegetation at different aspects

H₁: There will be a difference in vegetation at different aspects.

Wandering Quarter Method

This method is a modification of the plant-centered quarter method, and like it requires no assumptions as to the pattern of population dispersion. In fact, it provides within itself a means of detecting regular, random or contiguous distributions.

1. Randomly select a starting point in a homogeneous stand of trees. Edge areas should be avoided. At the random starting point select a compass line that leads through the stand of trees
2. Stand at the starting point and sight within a 90° angle; 45° on either side of the compass line. The nearest tree (3 cm in circumference or over) whose center lies within the inclusion angle is the first sample.
3. Determine the species and diameter (in cm) at breast height (dbh) of the tree at which you are starting and record the data.
4. Standing at this tree, sight along the compass line and again find the nearest tree within the 90° inclusion angle (as in 2). Measure and record the distance of the first tree to the second tree and record its species and dbh.
5. Repeat step 4 until you've measured a predetermined number of trees and distances, always staying within the same compass quadrant. You will end up zigzagging through the forest from one tree to the next. If your originally selected compass quadrant was NW to NE, you will zigzag in a northerly direction. i.e., you wander about within a particular quadrant or quarter of the compass, hence the wandering-quarter method.

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Statistics you can calculate with data from a wandering quarter survey

1. Calculate the **relative density** of each species.

$$\text{Relative density} = \frac{\text{Number of individuals of a particular species}}{\text{Total number of trees counted}}$$

Express your answer in the form of a percentage.

2. Calculate the basal area of each tree.

$$\text{Basal area} = \pi (r)^2 \quad \text{for } r \text{ use dbh} / 2.$$

3. Calculate the basal area of each species.

4. Calculate the total basal area for all species.

5. Calculate the **relative dominance**.

$$\text{Relative dominance} = \frac{\text{Basal Area per species}}{\text{Total basal area}}$$

Express your answer in the form of a percentage.

6. Calculate the importance value of each species.

$$\text{Importance value} = \text{relative density} + \text{relative dominance}.$$

7. Calculate the mean distance (d_m) between trees. (Probably best to use meters as the units here, to facilitate the calculations at 9 and 10)

$$d_m = \frac{\text{sum of all distances}}{\text{number of distance measurements}}$$

8. Calculate the Mean Area (MA) of all trees. $MA = (d_m)^2$

9. Calculate the density (D) of all trees (in stems, i.e. tree trunks) per unit area.

$D = A / MA$ where A = unit of area. Hectares are a metric unit for measuring area. A hectare is 10,000 m², which is about 2.47 acres.

So $D = 10,000\text{m}^2 / MA$ which gives density of trees (in stems, i.e., tree trunks) per hectare. This will tell, based on the sample, how many trees there are per hectare, assuming the sample taken is representative of the larger area.

10. Calculate the basal area per hectare. Divide the total basal area (from #4 above) by number of trees measured to get mean basal area per tree. Then multiply mean basal area by density (in stems per hectare from #9) to get basal area per hectare.

This will give an estimate, based on the sample, of how much wood there is per hectare.

11. Using data from all groups at the particular site you surveyed, calculate a mean and standard error (s.e.) for a particular statistic you wish to compare. Compare the mean \pm s.e. with the mean \pm s.e. for the same statistic from the other group to see whether there's a significant difference in the measure from the two sites.

Standard error = standard deviation $\div \sqrt{n}$ where n = the number of items being averaged.

Example: Let's say we want to compare basal area per are in two different forests. We hypothesize that the two forests will have a different basal area per are; if so, the means of our various surveys from the two forests should be different. After doing four surveys at each plot you end up with the following data:

Basal area (in m² per hectare) of two different forests

	<u>Sherwood Forest</u>	<u>Gump Forest</u>
Survey 1	30	27
Survey 2	31	29
Survey 3	32	31
Survey 4	33	33
Mean	31.5	30
standard error	0.645	1.29

The margin of error around the mean is from one standard error above the mean to one standard error below the mean. Though the means in the above example are different, the margins of error overlap, and we would conclude that the evidence does not show a significant difference in the total basal area of these two forests.

Margin of error bars tell you that if you took more measurements your new mean is likely to be found somewhere within the margin of error. The new mean could fall outside the margin of error, but that is less likely.

If error bars of two means overlap, then it is quite possible that with more sampling, the new means will turn out to be even more similar. So we conclude that the means are not significantly different - not different enough for us to be confident that they would stay different if we took more measurements. We must conclude that the hypothesis of different means was not supported by the data.

If the error bars of the two means do not overlap, then we conclude that they are significantly different. That is, we are reasonably confident that with more sampling, they will continue to be different. But we are not absolutely sure. These first samples may be very unusual and repeated sampling may still eliminate the difference we thought we saw with our initial data. Because of this uncertainty, we would say that the hypothesis was **supported**; we do not say it was proved.

Measuring Biological Diversity

Objectives:

1. Learn two methods of quantifying biological diversity.

Introduction

A **community** is a group of different species (including plants and animals) occupying a specific area. Communities are often described briefly by their dominant vegetation, as with the terms “grasslands,” “deciduous forest,” or “rain forest.” However, communities can be more precisely described and quantified. One property of a community that is quantifiable is its structure. Community structure includes characteristics such as the number of species, and the relative abundance of each species.

The number of species is known as the **Species richness**; it is simply the number of different species of organisms in the sample. Just count the species in your sample to calculate it.

Measuring the relative abundance of species or the ‘**Species heterogeneity**’ is a bit more complex. Species heterogeneity takes into account the relative numbers of individuals of the various species in a community.

‘Hetero’ is from a Greek word meaning ‘different’; ‘homo,’ is from a Greek word meaning ‘same.’ A lawn with only one species of grass in it would be homogeneous. If it had a few dandelions in it, it would be less homogeneous since now it has two different species. A meadow with several species of wildflowers in it would be even less homogeneous and more heterogeneous than the weedy lawn.

For an example, compare the data from the two communities below. The numbers represent the number of individual organisms of each species. So, in community 1 there are 18 of species A, 1 of species B, and 1 of Species C.

	Community 1	Community 2
Species A	18	7
Species B	1	8
Species C	1	5

The **Species richness** is 3 in both Community 1 and 2; it is the same in both communities, but the communities are quite different. By measuring **species heterogeneity** biologists can place a numerical value on the diversity in communities and then use that value when describing or comparing communities.

We will measure species heterogeneity by calculating a number known as Simpson’s index. **Simpson’s index** is a scale ranging from 0 (no heterogeneity and no diversity) to a maximum close to 1 (high heterogeneity or lots of diversity).

This index is a measure of the probability that two organisms picked at random from the community will be different species. If there is only one species in the community, then the probability of picking two different organisms will be 0, and Simpson’s index would be 0. If there are two species in the community, then the chance of obtaining two species in a random pick of two individuals will be higher, i.e. some number above 0 but less than 1.

This is how to calculate Simpson’s index: Let p_i stand for the proportion (a fraction of the number of species to total number of individuals in your sample). The probability of picking two individuals of this species at random is their joint probability, that is: $[(p_i)(p_i)]$, or $(p_i)^2$. If we add up the joint

probabilities for each species, and subtract it from 1, we get Simpson’s index.). [The subscript 'i' means to calculate the proportion for each species.]

$$D = 1 - \sum_{i=1}^s (p_i)^2$$

where D = Simpson’s index

p_i = the proportion of individuals of species 'i' in the community

s = number of species in the community

\sum means sum of all the $(p_i)^2$, one for each species in the community.

Example 1: Using the data from Communities 1 and 2 in the Introduction.

For Community 1:

For Species A, $(p_i)^2$	= $(18/20)^2$	= 0.81	18 of 20 individuals are Species A
For Species B, $(p_i)^2$	= $(1/20)^2$	= 0.025	1 of 20 individuals are Species B
For Species C, $(p_i)^2$	= $(1/20)^2$	= 0.025	1 of 20 individuals are Species C
	\sum	= 0.815	

Simpson's Index is $1 - 0.815$, or 0.185 for Community 1

For Community 2, more briefly:

$$\text{Simpson's Index} = 1 - [(7/20)^2 + (8/20)^2 + (5/20)^2]$$

$$\text{Simpson's Index} = 1 - [0.1225 + 0.16 + 0.0625]$$

$$\text{Simpson's Index} = 1 - [0.345]$$

$$\text{Simpson's Index} = 0.655$$

Problems: Tables to organize the data needed to calculate Simpson's Index are found on the next page of this exercise.

1. Compare the diversity of these two kinds of mixed nuts.

Species	Number in "Mixed Nuts"	Number in "Deluxe Mixed Nuts"
Brazil Nut	1	8
Cashew	8	15
Pecan	1	7
Almond	15	18
Hazel Nut	5	30
Peanut	85	0

Species Richness for Mixed Nuts =

Diversity Index for Mixed nuts =

Species Richness for Deluxe Mixed Nuts =

Diversity Index for Deluxe Mixed Nuts =

Table 1: _____

Species	Number	$p_i = \text{Number} / \text{Total Number}$	p_i^2
Total Number:		Σp_i^2:	

$D = 1 - \Sigma p_i^2 = \underline{\hspace{2cm}}$

Table 2: _____

Species	Number	$p_i = \text{Number} / \text{Total Number}$	p_i^2
Total Number:		Σp_i^2:	

$D = 1 - \Sigma p_i^2 = \underline{\hspace{2cm}}$

Notes for the Instructor

Many of the parameters measured or calculated in this exercise are used in forest management. A frequency diagram of size classes will show whether the forest is an even-aged or an uneven-aged stand (Hilts and Mitchell, 1999). Most uneven-aged stands have larger numbers of small trees and smaller numbers of large trees. Uneven-aged stands are more sustainable; as the largest, oldest trees are harvested or die, there are always younger trees to replace them.

Forests, of course, are often managed for timber. Sustainable techniques include leaving trees behind in the most appropriate numbers and size to encourage the fastest regeneration. Foresters call the trees left behind after an area is cut the “residual stocking.” The recommended “residual stocking” varies by geographic region, species composition, altitude, and many other factors. One example of recommended residual stocking for a northern hardwood forest is a total basal area of 19 square meters per hectare (Hilts and Mitchell, 1999).

Forests are also managed for wildlife and, if this is the case, the number and sizes of trees recommended will vary greatly. For example, managing habitat to sustain Kirtland’s Warbler will require a very different plan than managing for Ruffed Grouse. However, in wildlife management generally there is a desire for mast trees. Mast is the fruit of a tree that is utilized by wildlife. Oaks, hickories, and walnuts are examples of trees that produce hard mast, while dogwood, cherry, and blackgum are examples of trees that produce soft mast.

The wandering quarter method of sampling minimizes set up time. Since it is plotless method, there is no time spent on laying out plots. Once one is at the site, and students have been briefed on the method, they can get started right away on data collection.

Keys can be obtained for the local area, or for a state (e.g. Brown and Kirkman, 1990) or larger geographic region (e.g. Petrides, 1972). Keys to trees are available on the web, e.g., a key to trees of West Virginia is available (Grafton, 1995). A key to trees alone, rather than to the entire regional flora, facilitates identification. Keys to deciduous tree species using winter twigs are available, and would allow this lab to be performed even in winter months.

If students have little experience with dichotomous keys or tree identification, this lab can bog down on the first step. Obviously, if students can not properly identify a tree, many of the statistics will be hard to calculate. A couple of ways to deal with this potential problem are: (1) make sure students are proficient with these identification skills in a prior lab or prior course, (2) Use a key that includes only those tree species present in the particular forest in which the sampling is done. Such a key will generally have fewer species than a regional or state guide, which may simplify the identification process, and (3) have students collect a twig as a voucher specimen from each tree they measure. Faculty could then check the students’ identifications, or students could identify them outside of class when time was not as limited as it might be at a field site.

Data collection involves identifying trees, measuring their circumference, and the distance between one tree and the next. From this data, several parameters can be quantified including: species richness, species diversity, relative frequency, relative basal area, importance values, basal area per hectare, trees per hectare, mean basal area per species, and number of trees per size class. Many of these plant community parameters are discussed in more detail in basic ecology textbooks, like *Ecology and Field Biology* by Smith and Smith (2001).

Diameter at breast height (dbh) is a traditional parameter of standing timber. A minimum value for dbh should be established before the survey is begun. I’ve used 3 cm as the minimum dbh for inclusion of a tree or shrub in the survey. Many of the understory shrubs and trees are thus included in the survey.

I have sometimes used a minimum dbh of 1 cm; thus very thin-stemmed shrubs like Spicebush (*Lindera benzoin* (L.) Blume) are even included in the survey. Because of the high lipid content of their fruits, spicebush and flowering dogwood (*Cornus florida* L.) are important providers of food for wildlife, so a low minimum dbh is warranted in an ecology class or a wildlife biology class. Even though these plants are relatively small, their value to wildlife is high. A low minimum dbh is also warranted if your survey is to be part of a long term study of a forest. When foresters estimate the value of lumber in a forest, a typical minimum dbh is closer to 10 cm (Hilts and Mitchell, 1999).

The reason dbh is measured is so that basal area, the area of the cross-section of the trunk, can be calculated. Measuring the diameter of a standing tree involves some guesswork, so I generally have the students measure the circumference with a measuring tape, and then calculate the basal area from that. A conversion chart is included in the 'Student Outline' to facilitate those conversions.

The term 'aspect' refers to the compass direction to which the slope of a mountain faces. I have included it on the form because it can be an important environmental parameter in tree growth and distribution.

I include a formula for the calculation of Simpson's Index, an index of species heterogeneity. Various formulations of Simpson's Index exist. See, for instance, Smith and Smith (2001) or Winnett-Murray and Hertel (2001).

I have generally had students work in groups of three or four. It takes two people to efficiently handle the tape measure and measure distance between trees; others can keep the data sheets on the clipboard and record the data. Questions will certainly arise, such as: "This tree looks dead; do we still measure it?" "This trunk splits into two trunks about 1.4 meters off the ground; how do we deal with that?" I tell them to make a decision, and be sure to include their criteria in any report they may write. If the data is going to be combined with data from other groups in the same class, or is part of a study that might continue from year to year, such questions will have to be answered for the class as a whole.

For calculating means and standard errors, we have students use a template provided through the Radford University's Biology Department web page (Kugler, 2004). Description of standard error and the use of margin of error as a statistical test can also be found at the site.

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Several faculty from Radford University contributed to this exercise. Mr. Greg Zagursky gave advice and helped produce some of the lab handouts. Dr. Judy Guinan produced the tables for calculating Simpson's Index. Dr. Eugene Gourley (retired) used the wandering quarter method in his Ecology class and first brought it to my attention. Dr. R. Charles Kugler developed the department's Statistics web page.

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Appendix A: Data Table from Wandering Quarter Survey

Date: _____ Compass direction followed: _____

Location/Aspect: _____

Members of Group: _____

	Species	dbh	distance	basal area
1			xxxxxxx	
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Appendix B: Calculations from Wandering Quarter Data

Relative Density of each species

Species	relative density

Basal area of each species

Species	basal area

Total basal area for all species _____

Relative dominance for each species

Species	relative dominance

Importance value for each species (ranked from highest to lowest)

Species	Importance value
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	

Appendix C: Converting from Circumference (cm) to Basal Area (cm²)

Circ. (cm)	Diam. (cm)	Basal Area (cm ²)		Circ. (cm)	Diam. (cm)	Basal Area (cm ²)		Circ. (cm)	Diam. (cm)	Basal Area (cm ²)
10	3.18	7.96		61	19.42	296.11		112	35.65	998.22
11	3.50	9.63		62	19.74	305.90		113	35.97	1016.12
12	3.82	11.46		63	20.05	315.84		114	36.29	1034.19
13	4.14	13.45		64	20.37	325.95		115	36.61	1052.41
14	4.46	15.60		65	20.69	336.21		116	36.92	1070.79
15	4.77	17.90		66	21.01	346.64		117	37.24	1089.34
16	5.09	20.37		67	21.33	357.22		118	37.56	1108.04
17	5.41	23.00		68	21.65	367.97		119	37.88	1126.90
18	5.73	25.78		69	21.96	378.87		120	38.20	1145.92
19	6.05	28.73		70	22.28	389.93		121	38.52	1165.09
20	6.37	31.83		71	22.60	401.15		122	38.83	1184.43
21	6.68	35.09		72	22.92	412.53		123	39.15	1203.93
22	7.00	38.52		73	23.24	424.07		124	39.47	1223.58
23	7.32	42.10		74	23.55	435.77		125	39.79	1243.40
24	7.64	45.84		75	23.87	447.62		126	40.11	1263.37
25	7.96	49.74		76	24.19	459.64		127	40.43	1283.51
26	8.28	53.79		77	24.51	471.81		128	40.74	1303.80
27	8.59	58.01		78	24.83	484.15		129	41.06	1324.25
28	8.91	62.39		79	25.15	496.64		130	41.38	1344.86
29	9.23	66.92		80	25.46	509.30		131	41.70	1365.63
30	9.55	71.62		81	25.78	522.11		132	42.02	1386.56
31	9.87	76.47		82	26.10	535.08		133	42.34	1407.65
32	10.19	81.49		83	26.42	548.21		134	42.65	1428.89
33	10.50	86.66		84	26.74	561.50		135	42.97	1450.30
34	10.82	91.99		85	27.06	574.95		136	43.29	1471.86
35	11.14	97.48		86	27.37	588.55		137	43.61	1493.59
36	11.46	103.13		87	27.69	602.32		138	43.93	1515.47
37	11.78	108.94		88	28.01	616.25		139	44.25	1537.52
38	12.10	114.91		89	28.33	630.33		140	44.56	1559.72
39	12.41	121.04		90	28.65	644.58		141	44.88	1582.08
40	12.73	127.32		91	28.97	658.98		142	45.20	1604.60
41	13.05	133.77		92	29.28	673.54		143	45.52	1627.28
42	13.37	140.37		93	29.60	688.27		144	45.84	1650.12
43	13.69	147.14		94	29.92	703.15		145	46.15	1673.12
44	14.01	154.06		95	30.24	718.19		146	46.47	1696.27
45	14.32	161.14		96	30.56	733.39		147	46.79	1719.59
46	14.64	168.39		97	30.88	748.74		148	47.11	1743.06
47	14.96	175.79		98	31.19	764.26		149	47.43	1766.70
48	15.28	183.35		99	31.51	779.94		150	47.75	1790.49
49	15.60	191.07		100	31.83	795.77		151	48.06	1814.45

Appendix C (continued): Converting from Circumference (cm) to Basal Area (cm²)

Circ. (cm)	Diam. (cm)	Basal Area (cm ²)		Circ. (cm)	Diam. (cm)	Basal Area (cm ²)		Circ. (cm)	Diam. (cm)	Basal Area (cm ²)
50	15.92	198.94		101	32.15	811.77		152	48.38	1838.56
51	16.23	206.98		102	32.47	827.92		153	48.70	1862.83
52	16.55	215.18		103	32.79	844.24		154	49.02	1887.26
53	16.87	223.53		104	33.10	860.71		155	49.34	1911.85
54	17.19	232.05		105	33.42	877.34		156	49.66	1936.60
55	17.51	240.72		106	33.74	894.13		157	49.97	1961.51
56	17.83	249.55		107	34.06	911.08		158	50.29	1986.57
57	18.14	258.55		108	34.38	928.19		159	50.61	2011.80
58	18.46	267.70		109	34.70	945.46		160	50.93	2037.18
59	18.78	277.01		110	35.01	962.89		161	51.25	2062.73
60	19.10	286.48		111	35.33	980.47		162	51.57	2088.43