Lab 8 — Community Ecology: Measuring Plant Species Diversity

Please Read and Bring With You to Lab

Location:

We will meet at the parking area for the **north** side of **Piestewa Peak Mountain Preserve**, at the end of 40th St. To reach this site from campus, head east on Thunderbird Rd. until it becomes E. Cactus Rd. Turn south (right) on 40th St., passing Shea Blvd. until the road dead-ends at the parking lot. Allow about 25-30 min travel time from campus.

What you should bring:

Sun protection: hat, long-sleeved shirt, and/or sunscreen
Good closed-toed walking shoes or hiking boots!
Notebook & pencil or pen.
Water!
This handout and print-out of random numbers (from Statistical Analysis *Excel* file)

What you will be provided:

Clipboard; measuring tape & meter stick; field guide to plants

Objectives:

- To learn basic plant population sampling techniques in a natural environment.
- To learn the common and scientific names of several of the common perennial plant species of the Sonoran Desert.
- To understand the components of alpha diversity (species richness and equitability), how they are combined in diversity indices, and how they can be used to compare biological diversity between communities.

Preparation:

Students should read the laboratory exercise handout and Chapter 16 ("Species Abundance and Diversity") in Molles or equivalent text.

Introduction

Species diversity is a characteristic unique to the community level of organization. The concept of diversity, however, can be applied at three different levels of organization. *Alpha diversity*, the most widely used and important concept of diversity, refers to the diversity of species within a given habitat. *Beta diversity*, in contrast, describes the degree of change in species from one habitat to another. *Gamma diversity*, finally, relates to the total regional species diversity that results from the number of habitats present, the diversity of species within each, and the degree of turnover of species between habitats (i.e, how similar or different are the species compositions of the habitats). In this exercise we shall confine our attention to alpha diversity.

Species diversity, as most ecologists use the concept, combines two distinct aspects of the species composition of communities: *number of species* and *equitability* of their abundance. These aspects of diversity can be described separately, by indices of species

richness or of equitability of abundance, or they may be considered together, by indices of *heterogeneity*. Many indices of richness, equitability, and heterogeneity have been proposed. These indices vary widely in their mathematical basis, and often behave quite differently as sample size increases. None of the commonly used indices is independent of sample size, so that most comparisons of diversity indices require samples of equal size.

Community Comparison: Washes versus flats

In this week's lab we will compare the plant diversity of two different desert communities. One obvious pair of communities that can be compared are 'desert riparian' areas (washes) and desert upland (flat) areas. We will restrict our study to woody perennial plants—trees, shrubs and cacti—since these are abundant, present year-round, and easy to identify.

(Many students choose to study some aspect of plant diversity for their independent project. For example, comparisons of flat areas and slopes, slopes with different exposure [e.g. north vs. south or east vs. west], different distances from edges or disturbances, or the size or urbanization of different parks.)

Sampling Techniques

In order to study species diversity, one must first tally the species **and** the numbers of individuals for each species in a community. It is usually cost prohibitive to count every organism in an ecosystem, even if one limits the study to one species. What is typically used by community ecologists is a sampling technique. A sampling technique is a method that collects a sample of the population being studied. The sampling technique is considered unbiased if the probability of an organism being sampled is roughly equivalent to its frequency in the environment. Obtaining an unbiased sample is one of the crucial goals in designing a good scientific study.

One technique for sampling plant diversity is the use of a **belt transect**. A transect is a line of specified length, placed in an ecosystem. For a belt transect, the researcher marks the transect, and then records all of the organisms of interest that are located within a predetermined distance of the transect line. For example, a transect of fifty meters in length, where all plants that grow within one meter of either side of the transect line are counted, would sample 100 m^2. The length and width of the belt transect can be designated by the researcher, and are usually set with respect to the natural densities of the plants being studied. For example, a one meter long by 10 cm wide belt transect would be far too small to adequately sample desert woody plants, while a 1 km by 10 m belt transect would be too large to completely count small plants such as grasses.

The number of transect plots is quite important. Each individual belt transect is considered a single sample. The probability of detecting a difference in community structure, if it exists, increases with increasing sample size.

The placement of the transects is also important. In order to avoid bias, placement within the area of study is often done by some random method. A common method to randomly place transects involves the use of a **baseline**. This technique starts by the

researcher placing a baseline of fixed length (often twice the transect length) in the center of the study area. A random number generator is then used to pick points on the baseline from which transects will be sampled, *perpendicular to the baseline*. For our study, the baseline will be placed along the edge of a wash and run parallel to the wash (thus, it may not be a straight line). The transects will then extend from the baseline into the wash and into the flats. Your *Excel* Statistical Analysis workbook includes a random number generator. You will need to enter the minimum and maximum values (we recommend a minimum of no less than 10 and a maximum of around 30).

(Another technique that you may find useful for your independent project is a **plot sample** or **quadrat**. A quadrat is simply a square that is placed in an ecosystem and all plants inside the square are recorded. Similar to the belt transect, the size of the plot is designated by the researcher with respect to the natural densities of the species being studied. Whether you use a belt transect or a plot sample will depend on the question that you are testing and the size and shape of areas of interest and whether transects are feasible. Circular plots can also be used.

Placement of quadrats must also be done to avoid any bias. If the plot size is small enough, random techniques such as throwing a marker behind oneself and using where it lands as the corner of the plot can be used. With larger plot sizes, a random location can be generated by imposing a grid over a map of the study area. A random number generator is then used to determine in which grid space the plot will be placed. Alternatively, separate random numbers can be used to generate both distance and compass direction to the next plot location.)

Species Richness

Species richness refers simply to the number of species in a given area of habitat or in a sample of given size. A number of mathematical indices of species richness, some tending to be independent of sample size, have been suggested (Pielou 1977). These indices, however, assume specific patterns of frequency of common to rare species, and are not accurate if these assumptions are not met. Rarely can a particular pattern be assumed with confidence, so that most ecologists prefer simply to use the number of observed species itself as the index of species richness.

The number of species can be determined either for a unit area of habitat or for a sample of a certain number of individuals. When number of species is related to area of habitat, the value is best considered to be **species density**. Species density varies widely with the productivity and favorability of the habitat, and is important to consider, for example, in the selection of areas for preservation of biotic diversity. Differences in species density can be tested using the standard t-test that we have used previously.

Shannon-Wiener Index

Interest in diversity indices and concern for the environmental impacts of pollution developed at about the same time, and diversity indices were quickly introduced into analyses of environmental quality. The observation that mature communities of stable environments typically show high species diversity, and those of disturbed or stressed situations are less diverse, led some investigators to use low species diversity as indicators of environmental stress (Godfrey 1978). Indices of heterogeneity and

equitability remain in general use. The most important is the **Shannon-Wiener Index** (Peet 1974, Pielou 1977), and we will apply this in this exercise.

This index is the most widely used index of heterogeneity (i.e., it combines both species richness and species equitability). It describes the average degree of uncertainty of predicting the species of an individual picked at random from the community. This uncertainty increases both as the number of species increases and as the individuals are distributed more and more equitably among the species already present. This index, ***H'*** can be calculated from the proportion of individuals of each species (p_i = number of individuals of species i/total number of individuals) by the expression

$$H' = -\sum p_i \ln p_i$$

The Shannon-Weiner index varies from a value of 0 for communities with only a single species to high values for communities having many species, each with a few individuals. The null hypothesis that two Shannon-Weiner diversity indices come from communities equal in diversity can be tested by a specialized version of the t-test. Alternatively, we can collect multiple samples (transects or quadrats) from each community and calculate means and standard deviations of the Shannon-Weiner diversity indices of each sample and compare the communities using a standard Student's t-test. This is the approach taken on the *Excel* analysis worksheet for this lab.

Population Dispersion

The data that you will be collecting will also allow you to test for the population dispersion of any of the sampled species (though it will work best with species that were relatively common in your samples). Although not directly relevant to questions of diversity, the dispersion of dominant species may provide clues to overall habitat heterogeneity that can account for species heterogeneity. This may also be a useful measure for some independent projects. Test for dispersion using data from only one habitat (wash or upland) at a time, as combining them my result in a clumped dispersion for species that occur mostly in just one habitat, but may be randomly or uniformly distributed within that habitat.

Populations in which the individuals clump together (such as in a flock or herd) have a **clumped dispersion**. Clumped species should be numerous in a few plots but absent from the majority of plots, resulting in high variation (variance) in the number per plot. In contrast, when individuals space themselves out, such as due to territoriality or competition, they will have a **uniform dispersion**, with about the same number of individuals in each plot. In a **random dispersion**, individuals are distributed randomly with respect to the location of other individuals.

The type of dispersion can be identified with a dispersion index produced by dividing the variance of the number of individuals per plot by the mean number of individuals per plot:

$$I = s^2 / \bar{x}$$

Clumped dispersions will have a dispesion index greater than 1 ($I > 1$), while a uniform dispersion will be indicated by $I < 1$. If a dispersion index is not significantly

different from 1, the dispersion is uniform. To test if the observed variance/mean ratio differs from one, we can use a variation of the t-test. The *t* statistic for your data can be calculated as:

$$t = \frac{\left|\left(s^2 / \bar{x}\right) - 1\right|}{\sqrt{2/(n-1)}}$$

where *n* is the number of transects or plots. You will then need to compare this to the critical value for *t*. If the absolute value of $t > 1.96$, then the population dispersion deviates significantly from a random dispersion at the $\alpha = 0.05$ level.

(An alternative method to determine dispersion is to use a nearest-neighbor analysis. This involves measuring the distance to the nearest neighbor of the same species for every individual in a large plot of known size. The average nearest-neighbor distance can be compared to what is expected based for a random dispersion. This approach would be more practical for determining the dispersion of a large plant such as saguaros. Your instructor can provide additional information on analysis if you wish to use this method for an independent project.)

Procedure

Laboratory for the field portion will meet at the north entrance to Piestewa Peak Park (i.e. the same location as the off-campus vertebrate census lab). Students will work in groups of 3-4 and use the lab period to collect data on the plant densities of native Sonoran Desert vegetation using transects. You will be expected to present your data in summary form and test it statistically. An *Excel* spreadsheet specifically for this lab will be available to help you with the diversity indices.

Assignment:

For this lab you will write up a complete lab report in the form of a scientific paper. You paper should include an abstract, introduction, methods, results, discussion, and literature cited sections. The abstract is a short one-paragraph summary of your entire paper, describing the observed patterns (but generally omitting numerical details). It goes first, after your title, but is best written last. This assignment will be due March 31st.

Citations

Godfrey, P.J. 1978. Diversity as a measure of benthic macroinvertebrate community response to water pollution. *Hydrobiologia* **57**: 111-122.

Peet, R.K. 1974. The measurement of species diversity. *Annual Review of Ecology and Systematics* **5**: 285-307.

Pielou, E.C. 1977. *Mathematical ecology*. 2nd ed. John Wiley & Sons, New York, New York, USA.

DATA SHEET FOR COMMUNITY 1: _____

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12
Blue Paloverde												
Littleleaf Paloverde												
Catclaw Acacia												
Mesquite												
Creosote												
Brittlebush												
Triangle Bursage												
Canyon Ragweed												
Thornbush (*Lycium* sp.)												
Saguaro												
Barrel Cactus												
Teddybear Cholla												
Buckhorn Cholla												
Other: _____												
Other: _____												
Other: _____												
Total Individuals												
Total Species												

DATA SHEET FOR COMMUNITY 2: _____

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12
Blue Paloverde												
Littleleaf Paloverde												
Catclaw Acacia												
Mesquite												
Creosote												
Brittlebush												
Triangle Bursage												
Canyon Ragweed												
Thornbush (*Lycium* sp.)												
Saguaro												
Barrel Cactus												
Teddybear Cholla												
Buckhorn Cholla												
Other: _____												
Other: _____												
Other: _____												
Total Individuals												
Total Species												