ANALYSIS OF POPULATION DISPERSION:
PLANT GALLS AND GALL MAKERS

INTRODUCTION

In previous laboratory exercises, we used plant density (overstory and understory) as a measure of habitat similarity (see Exercise 2). Density, however, provides an incomplete assessment of how individuals are distributed within a habitat. Two different populations may have similar density values but different spatial patterns. In nature, there are three distribution patterns: random, regular (or uniform), and clumped. Distribution patterns (or dispersion) can provide valuable insight into interactions between individuals of a species and their biotic and abiotic environment. In this exercise, we will investigate the dispersion pattern of plant-eating insects on goldenrod (*Salidago canadensis*). We will not observe the insects directly. Instead, we will look for ***galls***, regions of abnormal plant growth surrounding an intruder.

OBJECTIVES

In today's lab you will:

- become familiar with the various distribution patterns of organisms and understand the ecological significance of these patterns.
- learn sampling and statistical techniques to determine dispersion patterns.
- learn how to use the Poisson distribution to determine the randomness of dispersion.
- determine whether insect galls are distributed randomly or non-randomly on goldenrod.

KEYWORDS:

Be able to define the following terms:

dispersion	galls	Poisson distribution
random	Chi-squared	frequency distribution
uniform (regular)	expected	specialist
contagious (clumped)	observed	

BACKGROUND

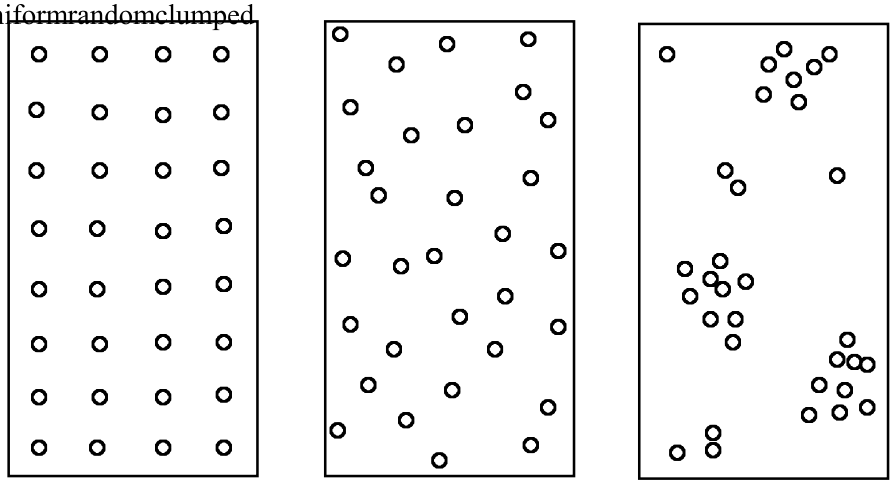
Organisms can be distributed randomly or non-randomly throughout their habitat. If dispersion is ***random***, population members must be distributed independently of all other population members. Individuals exhibit no patterns of attraction or avoidance to any component of their environment (Smith 1980). Total absence of interaction is rare. Therefore, random dispersion is unusual in nature. A truly random distribution may occur in more mature communities.

Non-random distribution patterns are of two types: ***regular*** (also called uniform, overdispersed, or repulsed) and **clumped** (also called patchy, underdispersed, or contagious)(Figure 5.1). In regular dispersion, all individuals are evenly spaced as if they were avoiding one another. Territoriality among animals or allelopathy among plants in a uniform environment can lead to regular dispersion. Clumping suggests extensive interaction among individuals and/or other components of the environment. Organisms congregate because of resource availability, gregarious behavior, or reproductive need. Examples include herds of large mammals, social insects, plants with immobile seeds (e.g., walnuts), migrating waterfowl, and schools of fish. A clumped distribution is the most common type of population dispersion.

Please note: *Dispersion* should not be confused with *dispersal*, which is the movement of organisms or propagules from one place to another.

Figure 7.1

uniformrandomclumped



PLANT GALLS

Plants produce galls in response to invasion by insects, mites, nematodes, bacteria, and fungi. A gall is a conspicuous tissue growth that can be formed on any plant part, including roots, stems, fruits and leaves. The plant is often harmed by the presence of galls, whereas the gall-maker derives protection and food from the gall. The interaction between plant and gall-maker can be best classified as parasitic (-,+).

Gall-forming insects and mites are particularly abundant. There are well over 1000 species in North America. Most gall-makers are ***specialists*** and can form galls on only one plant species or a few closely related species. Moreover, most invade only one particular part of the ***host plant***.

We know little about the mechanisms by galls are formed. It is quite likely that biochemical secretions from the gall-maker stimulate host cells to grow and divide in an abnormal fashion. Gall formation is similar to the unrestricted growth of cancerous tissue in animals.

The distribution of galls can tell us something about how gall-makers choose their host plants. A clumped distribution of galls suggests that the gall-maker prefers certain plants (or areas). Certain plants may provide better food or protection. A uniform distribution, however, suggests that the mites are avoiding one another when searching for a host plant. After observing the distribution of galls, you could generate a number of testable hypotheses regarding the food choices of gall-makers.

ANALYSIS

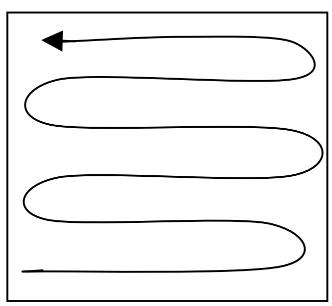
One can distinguish between random and non-random dispersion by using two statistical concepts: the ***Poisson distribution*** (named for its creator Simone Poisson) and the ***Chi-squared test***. We will use the Poisson distribution as an ***expected*** random distribution to which we will compare our actual (***observed***) distribution using the Chi-squared test. To create a Poisson distribution, you need only know the mean number of individuals per plot. The Chi-squared test determines the magnitude of the difference between the observed and expected distributions. If the magnitude of difference is large enough, the observed distribution is non-random. By visually inspecting a non-random observed distribution, one can determine if the population is uniform or clumped.

DIRECTIONS

<u>DATA COLLECTION</u>: Deerfield Park or Veit's Woods.

Work in groups of 5-6 students. Each group will collect data from a single patch of goldenrod.

1. Demarcate the goldenrod patch with a 5 x 10 m (15 x 30 ft.) grid using two tape measures placed perpendicular to one another. Adjust the grid dimensions to fit the shape of your patch (ex: 3 x 15 m). Record proximity of patch to road, trees, etc.
2. Beginning on one side of the grid, drop the quadrate (hula-hoop) along the first meter (0-3 ft.). Check to see that there are *at least* 5 goldenrod stems within the quadrate. Record the number of galls found within the quadrate on your data sheet. Also record distance from the edge of patch (1, 2, 3 m etc.). If there are fewer than 5 goldenrod stems, move to the next meter mark and repeat the procedure. Do not overlap quadrates!
3. Proceed along the length of the meter tape sampling every second meter. Once you have completed one row, move one meter into the patch and return along the second row. Continue sampling until your group has data for 25 or more quadrates. For greater efficiency, divide your group in half so that each half can begin on a separate side of the goldenrod patch.



<u>CALCULATIONS</u>: See Table 5.1.

1. Create the observed distribution for number of galls per quadrate using class data from *all goldenrod patches*. How many quadrates have 0 galls, 1 gall, 2 galls, etc. Combine categories that have fewer than 5 observations -- typically those with a

large number of galls (7 galls, 8 galls, etc.). Label the newly created category (example: “>6 galls”).

2. Calculate the total number of galls in each quadrate category by multiplying the number of galls per quadrate by the number of quadrates with that value. Sum the products and divide by the total number of quadrates to get the mean number of galls per quadrate ($\bar{x}$).
3. Calculate the expected relative frequency for each gall category (*f*) using the Poisson expression: $f = \frac{e^{-\bar{x}} \cdot \bar{x}^{m}}{m!}$ where e is the base of natural logarithms and m is the number of galls per quadrate. Remember: **!** indicates factorial, ex: 3! = 3x2x1. The value for 0! and 1! is one.
4. Generate the expected distribution by multiplying the expected relative frequency (*f*) by the total number of quadrates sampled by the class.

<u>SIGNIFICANCE TESTING</u>: To determine the magnitude of difference between the observed and the expected values, we will use a chi-squared test.

1. Subtract expected values from observed for each category (O-E), then square the difference: (O-E)^2. Divide the squared difference by the expected value for that category: $(O\text{-}E)^2/E$. See Table 5.1.
2. Sum the values in the last column ($(O\text{-}E)^2/E$) to obtain a chi-squared value.
3. Compare the chi-squared value with a table value using the 95% probability and the correct degrees of freedom. The degrees of freedom is one less than the number of categories. If the chi-squared value is greater than the table value, your observed distribution is non-random. * If you do not have a table, use EXCEL. Highlight a free cell. Choose “insert function” and select “CHIDIST”. Type the chi-squared value and degrees of freedom between the parentheses. The resulting number is a p-value. If the p-value is less than 0.05, the observed distribution is non-random.
4. Compare the observed and expected values by plotting the two frequency distributions on the same graph (use EXCEL). If the galls are distributed randomly, the observed values will equal the expected values. If the galls are distributed uniformly, most quadrates will have only 1 gall. If the galls are clumped, many quadrates will have 0 galls and many will have >1 gall.

DISCUSSION QUESTIONS

1. What biological processes might have caused the dispersion pattern you saw?

2. If some plants were more heavily attacked than others, what could account for this?

3. Is there a correlation between the number of galls and distance from edge of plot? If so, what does this tell you?

4. Is the mean number of galls per quadrate higher in some patches than in others? Why might this be?

TABLE 7.1

Comparison of observed frequencies of quadrates containing various numbers of individuals and frequencies expected on the basis of a Poisson distribution.

Number galls per Quadrate	Observed Number of Quadrates (O)	Total number of galls	Poisson Relative Frequency (*f*)	Expected Number of quadrates (E)	(O - E)	$(O - E)^2 / E$
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
>9						
Total			1.0000			
Mean	-----		-----			

DATA COLLECTION SHEET

Section____________________ Date____________________

Names____

Site:

Distance from road, trees, etc.______________ Number of trees_____

Quadrate	# galls	Distance from edge	Quadrate	# galls	Distance from edge
1			14		
2			15		
3			16		
4			17		
5			18		
6			19		
7			20		
8			21		
9			22		
10			23		
11			24		
12			25		
13			26		

Total __________

Mean __________