Reminders!
- Hydrate at least 24 hours before your lab!
- Bring 1 LITER OF WATER!
- Wear clothes that can get dirty, are loose (so you don’t over-heat; no skinny jeans!); long pants and sleeves would be best to prevent cuts by tall grass and thorny trees
- Wear closed toed shoes (no slippers and no heels!)
- Hat & Sunscreen; and/or raingear
- Read Appendix B before coming to lab

Key Concepts
- Sample vs. Population
- Distribution, Density, Cover, Dispersion, Frequency
- Quadrats, Transects
- Field community ecology sampling techniques

Student Learning Outcomes
After Lab 4 students will be able to:
1. describe biological populations using terms such as density, cover, dispersion and frequency.
2. survey biological populations in the natural environment using ecological field sampling methods using quadrats and transects.

Book Chapters
Campbell: Chp. 53, esp. 53.1

This week, you will learn how to characterize populations in preparation of your research project on Wa’ahila Ridge. You will start thinking about your own questions, hypotheses, and predictions that include field data that you will collect. Data will be collected as a class during labs 6 and 8 according to your manual and TA’s instructions. You will use that data throughout the semester to answer questions about the community on Wa’ahila Ridge, test your hypotheses, present your data as a short oral presentation, and produce a formal report in the form of a scientific publication at the end of the semester.

The study site for your research project is Wa’ahila Ridge. In 1997, Wa’ahila Ridge was listed as one of the Top 11 most endangered places in the US – National Trust for Historic Preservation [https://savingplaces.org/11most-past-listings] to thwart installation plans of power lines along the ridge. Construction of the power lines were delayed until members of the Board of Land and Natural Resources denied the permit in 2002 (https://www.outdoorcircle.org/uploads/2/6/1/4/26147365/curt_sanburn_when_protections_fail_an_ugly_honolulu_emerges_-_civil_beat_news.pdf; http://www.lifeoftheland.org/2014/12/the-struggle-to-protect-waahila-ridge.html; http://malamaomanoa.org/historic-preservation-manoa/span-and-opposition-to-hecos-138kv-line-on-waahila-ridge/). The preservation of Wa’ahila ridge was secured after years of document technicalities and opposition from the community.

In 2007 and 2015, fires broke out along Wa’ahila Ridge, causing many sections of the ridge to be burned down to dry soil. As such, plots that experienced these fires have provided us with successional data, as plants and other species have begun to repopulate the burnt areas.

Wa’ahila Ridge Fire - date not given, but perhaps 2007. (Reddit)
Wa’ahile Ridge Fire – 2015 (Ryan Marshall)

For today’s lab, you will practice how to collect vegetation community data using transects and quadrats. Let your TA know ahead of time if you won’t be able to hike for health reasons.

I. CHARACTERIZATION OF POPULATIONS

A population can be characterized based on four main properties: its distribution, density, percent cover, and dispersion.

**Distribution**

The distribution of a population describes where the population is located. The distribution is usually described as a specific area within which the population of interest is found. For example, Oahu’s Wallaby population (an Australian marsupial) is distributed within Kalihi valley.

**Density**

The density of a population refers to the number of individuals per unit area, volume (as in some aquatic populations) or boundaries of a population. Suppose you were planning a scuba diving trip to see sharks. The tour guide you hire guarantees that the density of sharks in his special dive location is 100. How many sharks will you see? You should explain to your tour guide that “100” is not a density and the number cannot be interpreted without an area or volume attached to it. If the density is 100 per 10,000 square meters (m²) of water, you aren’t going to see many sharks. On the other hand, if it was 100 sharks per 1000 m³, then you better request a dive cage!

**Relative density** is the proportion of all organisms in an area that belong to a particular species of interest.

\[ D_r = \frac{D(\text{Sp. X})}{\sum D(\text{All Sp.})} \]

where \( D_r \) is relative density and \( D \) is density. For example, suppose the lawn outside Edmondson Hall is comprised of three plant species (A, B, C). The density of each species is 3/m², 50/m², and 15/m², respectively. The relative density of species C is calculated as follows:

\[ D_r = \frac{15}{3 + 50 + 15} = 0.22 \]

Note that relative density has no units because square meters in the numerator and denominator cancel each other out.

**Percent Cover**

For an ecologist, the number of individuals of each species in a given area do not always provide an adequate picture of what a community looks like. Let us say a community consists of a mixture of 20 Banyan trees and 10,000 Chinese violets (small herbs). What does this community look like? It depends on the physical size of each of the two species. Differences in physical size make it difficult to visualize and compare the dominance of different species using measures of density or relative density alone.

Ecologists have devised other methods to assess the dominance of different species that are dependent of the abundance or have the highest biomass altogether. For example, percent cover is defined as the percentage of an area covered by a species. This can be estimated visually in the field. Alternatively, cover can be measured from aerial photographs of an area. In the example given above, knowing that the community consists of 85% Banyan tree cover and 20% Chinese violet cover (herbs) allows us to visualize the community more accurately than the data on population densities. It is mostly trees (85%) with a few herbs in between (20%).
Species with the highest percent cover are often called **dominant species**.

**NOTE:** If species grow on top of each other, it is possible for the total cover of a community (all species combined) to exceed 100%. It is also possible for the total cover to be less than 100% if the ground contains bare areas.

As with density, it is possible to calculate **relative percent cover**. Simply use measurements of percent cover instead of density:

\[ \%C_r = \frac{\%C(\text{Sp. } X)}{\sum \%C(\text{All Sp.})} \]

In the example above, the relative percent cover of Chinese violets is calculated as follows:

\[ \%C_r = \frac{20}{85 + 20} = 0.19 \]

The numerator is the cover of the Chinese violets and the denominator is the sum of the cover for all species (Chinese violets + Banyan trees).

**NOTE:** The equation above actually gives us the fraction of cover that is Chinese violets (0.19), which can be multiplied by 100 to get a true percent (19% relative cover).

**Dispersion**

The **dispersion** of a population describes the spacing of individuals within an area. The dispersion of a population varies along a continuum from **clumped** (where the individuals are grouped into patches), **random** (where the location of an individual does not depend on the location of its neighbors), to **uniform** (where the distance between each individual is evenly spaced).

A **clumped** distribution of organisms is often the result of limited or restricted distribution of a resource in the environment (e.g., individuals may tend to congregate in areas with more food, shade, or water). A clumped distribution may also be associated with social behaviors such as mating. For example, several males may gather around a female, or vice versa, competing for an opportunity to mate.

**Random** spacing occurs in the absence of strong interactions among individuals. The position of each individual is independent of the positions of other individuals. This is often the case when resources are not limited. Organisms that exhibit random distribution may be early stage oyster larva within a water column or wind-dispersed plants.

A **uniform** distribution usually results from direct interaction between the individuals in the population. Examples of these interactions may be animals defending territories or soil laced with growth inhibitors released by plants to reduce competition.

Determining the dispersion of a population may seem easy when looking at a map showing the location of each individual (as in Figure 1). For such extreme cases, one can tell the type of population dispersion without mathematical techniques. Unfortunately, it is often very difficult to assess dispersion when you are on the ground in a real world setting (“can’t see the forest for the trees”). Even if you were able to charter a helicopter or airplane, there are usually many species coexisting in any given area, obscuring your view of the population you are interested in. Thus, mathematical techniques are necessary for determining population dispersion.
The dispersion of the individuals within a population can be determined by graphing the proportion of sampled plots containing $X$ individuals, $p(X)$, against the number of individuals in each plot ($X$) and comparing it to the Poisson distribution (Figure 2). A Poisson distribution can be thought of as a mathematical model of randomness. The shape of the Poisson distribution can appear very different for different samples, but all Poisson distributions are skewed towards the $y$-axis (positively skewed, See Lab 1).

A second method for estimating the type of dispersion is based on the coefficient of dispersion ($C_d$): $$C_d = \frac{s^2}{\bar{X}}$$

where $s^2$ is the sample variance and $\bar{X}$ is the mean number of individuals per plot among all the plots sampled. When a population has a Poisson distribution (random), $s^2 = \bar{X}$. Therefore, $\frac{s^2}{\bar{X}} = 1$. When $C_d > 1$ the population is clumped and when the $C_d < 1$ the population is evenly dispersed (uniform).

Table 1. Interpretation of various coefficients of dispersion ($C_d$).

<table>
<thead>
<tr>
<th>Result</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_d &lt; 1$</td>
<td>Perfectly Uniform</td>
</tr>
<tr>
<td>$C_d = 1$</td>
<td>Random</td>
</tr>
<tr>
<td>$C_d &gt; 1$</td>
<td>Clumped</td>
</tr>
</tbody>
</table>

Obviously it would be very rare for any population to have $C_d = $ exactly 1. How do you know if your result is a significant departure from randomness? You can use a $t$-test to assess a population’s departure from randomness. The null hypothesis ($H_0$) is that the population is randomly dispersed ($C_d = 1$). You use the $t$-test to determine if the null hypothesis can be rejected in favor of the alternative hypothesis ($H_a$) that the population is not randomly distributed. In plain English, if your $t_{stat}$ is significant ($p < 0.05$) then your dispersion is significantly different than random. It is important to note that if $p > 0.05$, then we must fail to reject the null hypothesis that the population is randomly dispersed. To calculate $C_d$ and $t_{stat}$ from your data, an automated Excel template has been created (similar to the Regression/Correlation sheet you have already used in Lab 2). You don’t need to do any math, but you are responsible for interpreting the meaning of the coefficient of dispersion and the $t_{stat}$.

**Frequency**

The frequency of a species is the chance that you will encounter an individual of that species in one of your samples. To estimate frequency, you must take multiple samples of an area. Suppose that you sample an area by using 10 randomly placed quadrats (1 m$^2$ each). If individuals of a particular species are found in 3 of the 10 quadrats, then the frequency of that species is $\frac{3}{10} = 30\%$. The number of individuals in each of
Laboratory 4  
Characterization of Populations

those three quadrats does not affect the population’s frequency.

**Frequency** is affected by the area of each sample, the population density, percent cover, and dispersion. If a population is tightly clumped it will have a lower frequency than if it were evenly dispersed across an area. Density and percent cover affect a population’s frequency because as the number of individuals of a population increases or as the percent cover increases in an area, the chance that a sample quadrat will contain at least one individual will increase. Area of each sample is a factor for the same reason: the larger the area sampled, the higher the chances of finding at least one individual within that area.

When there is more than one species or population in an area, it is possible to calculate relative frequency. Relative frequency is calculated in the same manner as relative density and relative cover.

\[ F_r = \frac{F(Sp. X)}{\sum F(All Sp.)} \]

The importance value (IV) of a species or population in a community is calculated by adding the relative frequency, relative cover, and relative density. As the name implies, the importance value can give an overall estimate of the dominance of a species in a community.

\[ IV = D_r + C_r + F_r \]

**NOTE:** In calculating IV, the 3 components that you sum must all be expressed as fractions. e.g., – if you already converted relative cover to a percent, then you must convert it back to a fraction by dividing by 100 before calculating IV.

**II. SAMPLING POPULATIONS**

The most accurate way to determine population size is to count every individual throughout the entire distribution of the population. This method, called a census, is practical only if the population size is small and the population is restricted to a small area (although as an exception, the U.S. government makes a census of U.S. citizens every 10 years as mandated by the U.S. Constitution; this is an extraordinary feat that costs hundreds of millions of dollars; this obviously can’t be done for most other species). In general, total population counts are only made for rare, intensively studied species, like some of the most endangered plants and animals.

To estimate population sizes or densities for common organisms, ecologists count only a fraction of the individuals in a population. The partial counts are used to obtain an estimate of the total population size or density. Population **sampling methods** are utilized to estimate total population size after counting only a fraction of the total population, saving time, effort, and money.

Some sampling methods work well for some organisms but not for others. The three factors that will affect the appropriateness of a given sampling method are the size, abundance, and mobility of the organisms you would like to sample.

**Sampling Methods for Plants & Sessile Animals**

Sampling populations of plants and other non-motile organisms is simpler than sampling motile animals. Non-motile organisms cannot run away from a curious scientist, making them easier to count. In this class, you will use two methods to estimate populations of plants and non-motile organisms: **quadrats** and **transects**. It is important to note that these methods can also be applied to slow-moving organisms such as snails or sea urchins.

**Quadrats**

A quadrat is a square, as the name implies ("quad" = 4). Quadrat sampling involves delineating a square area and counting or measuring what lies inside the square (quadrat). The size and number of quadrats you use depends on the size of the organisms you are interested in, as well as, the population’s density and dispersion (i.e., clumped or uniform). Quadrats are usually randomly placed within the general area of interest (see Importance of Randomization below). Counts or measurements
from several quadrats are averaged and used to infer information about an entire population. Data commonly recorded from quadrats include: number of individuals, size of individuals, percent cover (area covered by a species), number of different species, and biomass (determined by harvesting and weighing).

The following measurements can be taken using quadrats:
- Number of each species
- Density of each species
- Relative density of each species
- Percent cover of each species
- Relative cover of each species
- Total community measures

**Line Transects**

Transects may be used either alone or in conjunction with quadrats to make estimates of various characteristics of populations. Line transects work best in simple, low diversity communities. The line transect method involves drawing a line through an area (usually by tying a string between two points) and counting and measuring the organisms that happen to touch the line. As with the quadrat method, the length of the line transect you use depends on the size of the organisms of interest and the population’s density and dispersion. Placement of the line transect is generally random, and the results from several transects are averaged to estimate population parameters.

Data commonly recorded from line transects includes the number of individuals touching the line per length of transect (*Density Index*), the total length of line touching a species per total length of transect (*Cover Index*), and the total number of species along the line. When using transects, you cannot actually measure true density or percent cover because you are not sampling an area; you are sampling a one-dimensional line. Therefore, the density and percent cover indices calculated from a 1m transect will be different from the density and percent cover calculated from a 1m² quadrat. However, you can directly compare the relative species densities ($D_r$) and percent covers ($C_r$) between quadrat data and transect data.

The following measurements can be taken using transects:
- Number of each species
- Density index of each species
- Relative density of each species
- Percent cover index of each species
- Relative cover index of each species
- Total community measures

**Importance of Randomization**

You may obtain biased (inaccurate) population estimates if you choose to count or take samples only in places where the population is unusually dense or unusually sparse. Sampling only in the dense areas will overestimate population size, while sampling in sparse areas will result in an underestimate. It is very common for people to subconsciously choose areas that are not representative of the area as a whole. To avoid this bias, we usually employ randomization to determine where or when to sample the population. Randomization helps to ensure that our samples, when averaged together, are representative of the population as a whole.

An easy way to get randomized points is to use the random function in Excel: =randbetween ($x,y$), where $x$ is the lowest possible coordinate and $y$ the highest. For example, if you would like random coordinates for a quadrat in a plot that is 20x20 m you type into an empty excel spreadsheet =randbetween (1,20). You can use it for two columns on the spreadsheet to get the two coordinates for the quadrat within the plot, drag the columns down to as many quadrat points you need. You do this before you go into the field, note them on your field datasheet, and then decide which corner of the quadrat that coordinate will be at (e.g., right top corner) for all your quadrats.
III. HIKE TO WA’AHILA RIDGE

Today you will experience field work on Wa’ahila Ridge. You will learn how to sample the plant populations on the ridge in order to determine their density, percent cover, and dispersion, so that you are ready to take accurate data next week.

Be Prepared
Wa’ahila Ridge can be extremely hot. Although the temperature rarely reaches 90°F, the sun bearing down on exposed rocky surfaces can sometimes make it feel greater than 100°F! You need to come prepared for climbing in hot, dry conditions. It is recommended to wear a hat, hiking shoes, and lightweight, durable clothing. Wear long pants and a long sleeved shirt to avoid being scratched by tall grasses and thorny trees and bring sunscreen. YOU MUST BRING WATER. Make sure that you eat before hiking or bring a snack with you. Please inform your TA immediately if you feel sick or are injured during our trip. Your TA will be carrying a first aid kit. Coming prepared for hiking will make your experience more enjoyable.

Vegetation on Wa’ahila Ridge
The vegetation on Wa’ahila Ridge is not uniform. In general, you will see that the habitat is composed mainly of grasses interspersed with cactoids, shrubs, and small trees. Some of the shrubs are thorny, so be careful! If you look closely, you will see broad-leaved herbs among the grass. As you travel up the ridge, you will see more woody plants and a transition in grass species. Reaching the top of our study site, the habitat is composed mostly of small trees – a sparse forest.

The majority of plant species you find on Wa’ahila Ridge are aliens (non-native invaders), introduced from many parts of the world. Alien plants now dominate most lowland habitats in the Hawaiian Islands. Most of the alien grasses are from Africa. One of the few natives you may see is pili grass (Heteropogon contortus). Hawaiians traditionally used dried pili grass as a thatching for roofs.

Plots on Wa’ahila Ridge
An initial observation of the ridge suggests that the climate and vegetation vary across the ridge. Each lab section has been assigned to one 20x20 m plot at differing elevations along the ridge. You will investigate relationships between biotic factors, such as plant and insect species, and abiotic factors, such as temperature, rainfall, and soil depth in the plots. Understanding relationships between organisms and their environments is an important goal of ecology.

Data Collection
Here are the objectives for today’s visit:

1. Start thinking about the vegetation along the ridge and what factors influence its distribution. Start thinking about questions to ask and what hypotheses you could test. Variables that you can use for your questions and hypotheses are provided in the box below. Most of the variables below have datasets that span over a decade (but not all).

<table>
<thead>
<tr>
<th>Biotic</th>
<th>Abiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation:</td>
<td>Elevation</td>
</tr>
<tr>
<td>Species diversity</td>
<td>Soil depth</td>
</tr>
<tr>
<td>% cover (of specific species, group of species (e.g., trees))</td>
<td>Rain</td>
</tr>
<tr>
<td>Height</td>
<td>Temperature</td>
</tr>
<tr>
<td>Animal richness</td>
<td>Light</td>
</tr>
<tr>
<td>Wind</td>
<td></td>
</tr>
</tbody>
</table>

2. Work in groups to collect vegetation data using quadrats and transects. Each section will divide into four groups according to your TA’s instructions. Each group will do two quadrats and one transect (5m) using the same field datasheet we will use next week. Make sure to write legibly to facilitate data entry later on.

3. When you get back from your hike enter your data into one single google doc spreadsheet for your section (ask your TAs for help if you need it).
TA for help). When entering data ensure that you transcribe it correctly. Have a student from your group double check with the handwritten field datasheet that you transcribed it correctly.

- Use scientific names for your species.
- Make sure to enter data for the same species in the same column for all your groups.
- Be sure to use correct units!

4. Calculate the relative densities as well as averages for all species on your section’s data and use the data for your homework assignment.

IV. ASSIGNMENTS (35 pts.)

Project questions (12 pts.)
1. a. Come up with 4 questions that might characterize the vegetation on Wa‘ahila Ridge. Specify the variables you will be using to answer questions considering the actual data collected in Lab 6 and 8 (see box on previous page). (1 pt. each, 4 pts. total)

b. Explain your questions from 1a. What observations led you to your questions and what are your predictions. (2 pts. each, 8 pts. total)

Quadrats and Line Transects (23 pts.)
2. From your section’s quadrat data (not just your group’s):

a. Calculate the average percent cover, relative density, and relative cover values, as well as frequency, relative frequency, and importance value for your class quadrat data (i.e., bottom few rows on your class spreadsheet). (3 pts.)

b. Calculate your 95% confidence interval for your estimate of percent cover for the two most common species. (1 pt.)

How could you narrow your confidence interval and improve the accuracy of your population estimates? Explain and justify your reasoning. (3 sentences max) (2 pts.)

3. From your section’s transect data (not just your group’s):

a. Calculate the average percent cover index, relative density, and relative cover values, as well as frequency, relative frequency, and importance value for your class transect data (i.e., bottom few rows on your class spreadsheet). (3 pts.)

b. Calculate your 95% confidence interval for your estimate of percent cover index for the two most common species. (1 pt.)

c. How does the confidence interval compare between quadrat and transect data? Which one is more accurate? Explain. (3 sentences max) (2 pts.)

(You are not comparing actual percent cover between the quadrat and transect methods to see how plant cover compares, more like which method is more accurate, i.e. has a smaller CI.)

4. As the name implies, "importance value" (IV) gives an overall indication of the prominence of a species in a community.

a. What is the lowest possible IV, and what is the highest possible IV that a species could be assigned? Hint: Recall what the components make up the importance value. (1 pt.)

b. Which species has the higher IV value based on your quadrat sampling? (1 pt.) Does your transect data agree? Explain. (4 sentences max) (1 pt.)

5. Compare and critique the two sampling methods (quadrat vs. transect) in a cohesive paragraph including the following points:

- Which method seemed faster?
• Which method was more accurate? (i.e. does the faster method seem to result in more error in the population estimates?)
• How could you improve the accuracy of your estimates?
• What was the (visually estimated) dispersion of the different species?
• Could dispersion affect the accuracy of your sampling?
• How will you apply what you learned today to ensure that your data used by all students of BIOL 265L for their projects is as accurate as possible? (8 pts.)