Age Structure of Saguaro (*Carnegia gigantea*)
A field laboratory for Ecology 302

**Materials**
- One height-measuring gauge
- One tape measure
- Paper and pencil
- Straight edge ruler

**Background**
Tucson is prime habitat for saguaros, one of the few species of columnar cacti in Arizona. (Most of North America’s 42 species of columnar cacti live in Mexico). In this lab you will learn how ecologists measure the age structure of saguaros and use it to study saguaro population dynamics and natural history.

In 1998, two local ecologists, Betsy Pierson and Ray Turner published a paper about the saguaros of Tumamoc Hill (the peak with a white telescope next to A-Mountain). Tumamoc Hill is a locale of world-importance because plant ecologists have studied its flora for nearly a century. The Pierson & Turner paper (An 85-year study of saguaro (*Carnegia gigantea*) demography, *Ecology* 79:2676-2693) is one of the best examples. It explores the growth rates of saguaros by comparing current measurements with measurements of the same individual cacti taken earlier in the 20th century.

Pierson & Turner discovered how fast saguaros grow by examining the relationship between plant height and age. Their results allow one to estimate the age of each saguaro. If we estimate the age of enough individuals in a population, we can figure out its age structure. If we know its age structure, we can make skilled predictions about its future.

**Measuring saguaro height in the field**

Baby saguaros are often hidden in brush under shrubs and can be very hard to find. So we will measure only saguaros that are one meter high or higher. Plants 1m high are about 30 years old.

Your TA will divide you into four groups of three people. Each group will have an assigned area and measure all the saguaros in it (at least 10). Try to finish in about one hour. Be
sure to stay in your own area so you do not measure any of the same saguaros measured by another group.

You will use a calibrated green plastic triangular gauge. It allows you to position yourself so that the line from your eye to the top of the saguaro is exactly 45° from the horizontal. In this position, \( d_1 \), the distance from you to the plant, plus \( d_2 \), the distance from your eye to the ground, equals the height of the saguaro. (Why?)

**Note:** Keep on the same level as the saguaro. This method does not work if you are downhill or uphill from the saguaro.

One of you will take the gauge and walk gradually away from the saguaro, keeping the saguaro's top in the sighting holes of the gauge. Keep going until the bubble-level reads exactly level. It is level when the bubble is midway between the two marks. You will be able to see the level in a mirror positioned next to the sight.

Another person will walk along with the first one to make sure that the gauge is truly level and that the sighter does not walk into any cacti!

From the place where you get a level sighting, measure the distance between you and the cactus using a meter tape. Also measure the distance from the ground to your eye. Add these two distances together to get the saguaro height.

Record the height and head for the next saguaro. Once you get the hang of it, organize your group for efficiency and speed so that you can measure the plants in your area. To be sure you do not have a biased sample, don’t skip any plants one meter or taller. Try to find and measure them all!

**Analysis**

Once you have measured the saguaros, use Figure 1 in the back of these instructions to convert your heights to estimates of age. Do this graphically with a straight edge. Use the line in Figure 1 that best matches your site (north, south, east, or west facing). Although Figure 1 is based on plants from Tumamoc Hill, your population is similar enough to allow you to use it, too.

Once all four groups have the ages of at least 10 saguaros, your TA will help you pool your data.

With your small working group, plot a histogram of the saguaro ages in the pooled sample. Count the number of plants in each 20-year time interval. Thus you will have bins for 30-50 years, 50-70 years, etc. (If you manage to measure 50 or more plants, you might try using 15 or even 10 year time intervals). Divide the number of individuals in each bin by the number of individuals in the pool. The result is the percentage of individuals in each bin. Plot these percentages on the
graph in Figure 2. This is the age structure.

**Interpretation**

Look at your age distribution keeping the following facts about age structures in mind:

- If the population is neither growing nor declining, and if the birth and death rates are constant, the age structure can be interpreted as a survivorship curve (the proportion of 2 years olds equals the probability of surviving to age 2, etc.). The lines in Figure 2 show the survivorship curve expected if environmental conditions are constant.

- If the rates are constant but the population is growing, the age structure will look like the survivorship curve, but be skewed toward the younger age classes.

- If the rates are constant but the population is declining, the age structure will be skewed toward older age classes relative to a true survivorship curve.

- When birth or death rates vary you can get “bumpy” age distributions: the peaks represent pulses of births with low death rates and the valleys represent weak recruitment or high death rates. True survivorship curves decline monotonically, with the only peak being at age zero. Saguaro have very low death rates after they reach age seven years or so. Therefore, any bumpiness probably reflects variation in recruitment of young past the vulnerable early ages (“birth”).

**Questions to discuss**

1) Does your saguaro population have a smooth or bumpy age structure? How does it compare to the line for constant environmental conditions.

2) At what ages do any peaks or valleys occur (which are higher or lower than the constant environment curve)? Do these peaks and valleys correspond in any way to the weather in the years these plants would have been recruiting? Figure 3 in these instructions shows a drought index (high PDSI is a wet year) and winter temperatures (winter freezes kill or damage saguaros).

3) Can you think of any other reasons for any deviations from the constant environment curve?

4) Can you infer any periods of decline or increase in saguaro abundance.

5) Are the saguaros a stable population? Think about the definitions of stability given in lecture.

6) What aspects of saguaro ecology and natural history might be responsible for the population dynamics of the saguaros?
Figures

Figure 1. Use the top graph to estimate ages from your height measurements. The lower graph shows mortality rates for different size saguaros.
Figure 2 shows the expected age distribution of the saguaro if the environment and recruitment rates are constant (the solid line is for east slopes, the dashed line for the other three slopes). Plot your data (converted to proportions) on this figure to reveal deviations reflecting bigger or smaller cohorts than expected.

Figure 3 shows some climate history for the Tucson area (high PDSI means a wet year).