Biol 356 – Lab 7. Mark-Recapture Population Estimates

For many animals, counting the exact numbers of individuals in a population is impractical. There may simply be too many to count, or individuals may be highly mobile or secretive, resulting in imprecise estimates of population size. However, one way that fairly good population size estimates may be obtained is by marking a sample of the population at one time, and then resampling the population a second time (or more) and counting the number of marked and unmarked individuals.

Lincoln-Peterson Technique (single recapture)

The Lincoln-Peterson technique is very simple, and relies on a single marking event and a single recapture event. This technique assumes that there is no immigration or emigration, and that there is no recruitment (reproduction) between the time of marking and the time of recapture.

Basically, this technique involves collecting a sample from the population, marking this sample, and then releasing the sample back into the population. This creates a ratio of marked to unmarked individuals in the population. After a sufficient amount of time for the marked individuals to mix into the population, a second collection is made and the ratio of marked to unmarked individuals is calculated. This ratio is then used to estimate the total population size. The formula for this calculation is:

$$N = n_1 n_2 / m_2$$

Where:
N = population size estimate
n_1 = total number of marked animals (from sample 1)
n_2 = total number of animals collected in sample 2
m_2 = total number of marked animals collected in sample 2

The approximate variance (s^2) of this estimate is:

$$s^2 = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}$$

The 95% and 99% confidence limits on this estimate can be calculated by using the standard deviation (s) as:

95% confidence limits: $N \pm 1.96(s)$

99% confidence limits: $N \pm 2.58(s)$

Lincoln-Peterson Technique (multiple recaptures)
If several recaptures (k) are made (with replacement each time), then you can make several estimates of N, and average these to get an even better estimate of the actual population size (N_{mean}). In this case, the approximate standard error of N_{mean} can be calculated by:

$$s_{Nmean} = \sqrt{\frac{1}{k(k-1)}\sum (N - N_{mean})^2}$$

Here, the confidence limits are:

95% confidence limits $N_{mean} \pm 1.96(s_{Nmean})$

99% confidence limits $N_{mean} \pm 2.58\ (s_{Nmean})$

These two techniques make several assumptions in order to provide a valid estimate of population size. First, as already noted, this must be a closed population with no immigration, emigration, and no recruitment. Additionally, this method assumes that all individuals are equally catchable and that there is no loss of marks and no differential loss of marked and unmarked individuals during the period between captures. These techniques will provide an estimate of population size at the time that the marked individuals are released. Due to mortality during the period between marking and recapture (assuming equal mortality rates of marked and unmarked individuals), actual population size at recapture may be much smaller, but the ratio between marked and unmarked individuals will not change.

Catch Per Unit Effort
This technique uses the principle of diminishing returns to estimate population size. Basically, individuals are removed from a population with a standard amount of sampling effort. The number of individuals is recorded, but the individuals are not returned to the population (i.e. "destructive" sampling, or sampling without replacement). Thus, after each sample, the population size has decreased. If sampling effort remains constant, then the number of organisms collected each time should decline. After enough samples are collected, linear regression can be used to estimate the initial population size. To do the linear regression, you will record "catch per unit effort", and the "prior cumulative catch" each time you take a sample. For the first sample, "prior cumulative catch" is zero. Then, you do a linear regression (in SPSS) with "prior cumulative catch" as the independent variable (X axis) and "catch per unit effort" as the dependent variable (Y axis). When the intercept (b) and the slope (m) have been determined, an estimate of the population size can be obtained by:

$$N = -b/m$$

Confidence limits on N are determined by using the confidence intervals for the slope and intercept. SPSS will provide upper and lower confidence intervals (95% only) for you if, when you are setting up the regression (in Analyze), you click on the box that says "Statistics" on the regression menu. This will bring up a second box, and you will be able to check a box there that says "confidence intervals". SPSS will give you the upper (m_u, b_u) and lower (m_l, b_l) bounds for the confidence intervals for both the slope and the intercept. You calculate 95% confidence intervals for the estimated population size then as:

$$N_u = -b_u/m_u \quad \text{(upper limit for 95\% confidence level)}$$
$$N_l = -b_l/m_l \quad \text{(lower limit for 95\% confidence level)}$$

Obviously, this technique only works when you are able to remove enough organisms that you begin to see an effect on population size.

Today, you will collect data on simulated populations in the lab, and you will release some marked pillbugs into the greenhouse. Next week, you will collect pillbugs from the greenhouse and use the Lincoln-Peterson method to estimate population size.

Simulated Populations

First, you will work in groups to estimate population size in some simulated populations. I have provided each group with a container full of brown beans. Each container has a different number of beans in it, and I know the number in each. You also have available a "stock" of white beans. Each group will attempt to determine the number of brown beans in your population in three ways: Lincoln-Peterson single recapture method, Lincoln-Peterson multiple capture method, and Catch Per Unit effort method.

The first thing to do is to draw a sample of your population. Do this by simply reaching in and grabbing a handful of beans. Count the number of beans in your sample and record that number. Now, replace those beans with the same number of white beans (these represent marked individuals). Mix the white beans thoroughly in with the brown beans. Now reach in and remove a second sample. You should probably reach in with your eyes closed (so that you aren't biased toward grabbing either a lot or a few of the white beans). Record the total number of beans in this second sample, as well as the number of white beans in this sample. Use these data to calculate your estimate of population size (and the 95% and 99% confidence limits) by the Lincoln-Peterson single recapture method.

Replace the second sample (do not mark any more individuals), and thoroughly mix the contents again. Collect a third sample (second recapture) and record the number of individuals and the number marked. Replace this sample, mix, and do this a total of 10 times, so that you have 10 estimates of N. Use these data to calculate your estimate of population size (N_{mean} and the 95% and 99% confidence limits) by the Lincoln-Peterson multiple recapture method. (You do not have to calculate confidence limits for each of the 10 samples individually).

Next, we will estimate population size using the catch per unit effort method. Because you replaced your initial sample above with white beans, and then have been replacing your subsequent samples, the population size in your container should still be what it was at the beginning of class (though some of the individuals are "marked"). Using a half of a plastic soda bottle to standardize "effort" (actually, this will standardize surface area) press the bottle down through the beans (do this with your eyes closed), and try to remove only those beans inside the bottle. Count the number of beans removed, and do NOT replace them (ignore whether they are marked or not). Mix the beans around again (basically, smoothing them out to fill the empty space), and take another sample with the bottle. Again, count and record the number, and take another sample, etc. Continue this until you have collected 10 samples. Input these data into SPSS and calculate the appropriate linear regression, estimated population size, and the 95% confidence intervals.

When you are finished, remove the white beans and replace the brown beans. Be sure to keep track of which container you had, because I will let you know how many beans there really were when I hand back your report. Because I want you to be able to include the results of the pillbug marking in your report, it will not be due for two weeks. However, there is no reason that you cannot write all of it that pertains to the simulated populations ahead of time. Here is what I want in your report:

Materials and Methods – 6 points
Describe, in detail, the methods used in this experiment. Include the methods for each of the simulated populations, as well as the methods for the pillbugs. You do not have to include here the formulas for calculating anything (though in a real scientific paper, you would include these), but mention that the various parameters were calculated.

Results – 8 points
I expect a text portion summarizing your results as well as at least one table and three figures. The table should have the population size estimate for each of the three types of analyses, as well as the confidence intervals (95% and 99% for the Lincoln-Peterson analyses, and the 95% for the catch per effort analysis). Additionally, on this table will be the results from the pillbug experiment (it was a Lincoln-Peterson single recapture analysis). The first figure will have these same data plotted as a large dot for the estimate, and bars going up and down from the dot representing the confidence intervals. The Y-axis of this figure will be population size, and the X-axis will be the analysis. Show 95% and 99% intervals separately as two closely spaced dots and bars. (Do not include the pillbug data on this figure.) The second figure should show each of the 10 individual estimates of population size used in the Lincoln-Peterson multiple recapture method. Again, this should be done as a scatterplot, with the Y-axis being population size and the X-axis will be estimate number (1-10). The third figure will show the data for the catch per unit effort analysis, and the regression line. Here you will plot the catch per effort (Y-axis) vs. the prior cumulative catch (X-axis).

Discussion – 6 points. Discuss the difference in the results of the three analyses on the simulated populations. Which are the most accurate? Why do you think this? How do the 95% confidence intervals compare to the 99% confidence intervals? What do these intervals mean? How did the pillbug experiment work out? How can we get a better estimate of the pillbug population in the greenhouse? Do you have any suggestions for improving any of these excercises? Any further hypotheses that you might want to test with the pillbugs? As always, just show me that you understand what your data might mean, and that you have put some critical thought into this report.