Estimating Population Size: Mark & Recapture

Objectives:

1. Learn a common method to estimate population size in ecology
2. Learn how sampling effort affects reliability of estimates

1. Introduction

A fundamental quantity in population ecology is the size of the population. That is, how many individuals are in the population? This may sound rather simple and straightforward, but in practice it is not because it is difficult to individually count and identify every individual. This is because not all individuals are easily observed and distinguished as well as some parts of the species distribution may be remote. We will put into practice mark-recapture methods of population estimations, which are a common used in ecology.

The mark-recapture method involves initially capturing and marking some individuals in the population, releasing them, and then resampling the population. The proportion of resampled individual who have marks provide a means by which to calculate the overall size of the population.

The simplest mark-recapture estimate of population size is the Petersen method, initially developed for marine fish. It is based on the principle that if a proportion of the population was marked, returned to the original population, and after complete mixing, a second sample was taken, the proportion of marked individuals in the second sample would be the same as was initially marked.

That is,

$$\frac{k}{n} = \frac{K}{N}$$

where N is the total population size (unknown), K is the number of individuals that were collected and marked in the first sample, k is the number of individuals in the 2nd (recapture) sample that had marks, and n is the total number of individuals in the 2nd (recapture) sample. N is the the quantity we want to estimate. If we know k, n, and K, then we can calculate the total population size as:

$$N = \frac{Kn}{k}$$

For example, suppose you took 200 mice out of a forest having an unknown number of mice, put leg bands on them, return them to the forest and let them mix thoroughly.

If you then take 250 mice from the forest and find 50 of them to have leg bands, then $K = 200$, $n = 250$, $k = 50$, and the unknown total number of mice (N) is:

$$N = K*n/k = (200)(250)/50 = 1000 \text{ mice}$$

Assumptions

The accuracy and precision of the Peterson mark-recapture estimate is based on a number of assumptions:

Assumption 1: During the time between releasing animals from the first capture (and marking) and the second sample, there is no change to the proportion of marked animals.

Assumption 2: The probability that each individual is captured is equal and does not change between the initial capture and the subsequent recapture.

Assumption 3: Marked individuals do not lose their marks.

2. Methods

You will use the Peterson mark-recapture method to estimate the number of black beans in four cups of black beans. You will do the experiment three times, once for each sampling effort, and then share your data with the rest of the lab. Your report will involve analyzing the lab dataset.

Materials

You will need the following items that are a part of most kitchens and are also inexpensive and readily available at most grocery stores:

- Approximately 1 kg of dried black beans (black)
- Approximately 500 g of dried navy beans (white)
  - Note: if you cannot find dried black or navy beans, then dried pinto beans will work as a substitute
  - Note: do not used canned beans! It will not work.
- Mixing bowl or medium sized pot that can hold four cups (approximately 1 L) of dried black beans
- One measuring cup or set of measuring spoons that can measure
  - 1 cup (240 ml)
  - ½ cup (120 ml)

Here is a picture of what these items look like:



Experiment

We will use the Peterson mark-recapture estimation method to estimate the number of dried black beans in 4 cups of beans in a bowl. We will examine three levels of sampling effort (1/8, 1/4 and 1/2 of the population). Make sure to record your numbers as we proceed. You will need to upload your estimates to a lab dataset in order to complete the assignment.

Experiment 1 (a small sample). We will use an initial sample as well as re-sample that are both approximately 1/8 of the total population.

1. **Set the total population size.** Measure four cups of black beans into the mixing bowl or pot. We will try to estimate how many beans are in the bowl using the Peterson mark-recapture method.

2. **Mix the population.** With your hand or a spoon or similar device, mix the black beans by stirring the beans for approximately 30 seconds.

3. **Collect an initial sample from the population.** Collect your initial sample from the population of beans by using the measuring cup to remove a ½ cup of beans from the mixing bowl. Put that sample of black beans aside in a separate bowl or container. These beans are your initial sample of the population. Count them and record the number - this is our estimate of *K*, the number of individuals that were captured in the initial sample and marked.

4. **Create marked individuals.** In a separate container, add *K* navy (white) beans. These will represent our marked individuals –imagine that the black beans you just removed in the previous step have now been marked and are represented by these white beans.

5. **Release the marked individuals and allow them to disperse in their habitat.** Add the *K* navy (white beans) to the mixing bowl. With your hand or a spoon or similar device, mix the black beans by stirring the beans for approximately 1 minute.

6. **Resample the population.** Collect your resample from the population of beans by using the measuring cup to remove a ½ cup of beans from the mixing

bowl.

7. **Examine the resampled population.** Count the total number of white and black beans in your resample of the population. The total number of beans (white plus black) is the resample size *n.* The total number of white beans in your sample is the number of marked individuals in the resample, *k*. Record your numbers for *n* and *k*.

The above steps 1-7 and your estimates for *K*, *n*, and *k* are the quantities needed to calculate the Peterson estimate for the total number of beans in the bowl, *N*. Keep track of your estimates for *K*, *n*, and *k*, as you will need to upload those data to a class dataset.

Intermission 1

Remove the white beans from the mixing bowl. Return the black beans that were initially removed in the first sample to the mixing bowl.

Experiment 2 (an intermediate sample)

Repeat steps 1-7 in the experiment but use a sample size of ¼ of the population. That is, use a sample size of 1 cup for the initial sample as well as the resample. Record your numbers for *K*, *n*, and *k*.

Intermission 2

Remove the white beans from the mixing bowl. Return the black beans that were initially removed in the first sample to the mixing bowl.

Experient 3 (a large sample)

Repeat steps 1-7 in experiment 1 but use a sample size of 1/2 of the population. That is, use a sample size of 2 cups for the initial sample and the resample. Record your numbers for *K*, *n*, and *k*.

Lab Assignment (70 points total, 8% of final grade)

Answer the following questions. Use the lab datafile for calculations, as appropriate. Explain your reasoning.

1. (20 points) Upload your data from experiments 1-3 into the shared lab data file provided by your TA. Each individual should upload their numbers for *K*, *n*, and *k* for each of the three experiments for this file.

2. (10 Points) Explain five assumptions about a population that are needed to be met for Assumption 1 to be true.

3. (6 Points) Explain three assumptions about the population that must be true for Assumption 2 to be true.

4. (6 Points) Describe three ways that animals could lose their marks.

5. (8 Points) Describe two species, their life histories, and fieldwork context for which the above assumptions are met for a Peterson mark-recapture population estimate. (1 page single spaced 12 pt font maximum).

6. (3 Points) What is your estimate for the total population size of beans in each of the three experiments. Show your work.

7. (6 Points) What is the mean estimate of the population size of beans in each of the three experiments. Use the lab dataset.

8. (6 Points) What is the standard error of the mean for the population size of beans in each of the three experiments. Use the lab dataset.

9. (5 Points) Given your results for questions 7-8, which experiment gave the most reliable estimates of population size? Why?