Simulation of a Population Study: Mark-Recapture Technique

Introduction:

In both population ecology, which focuses on individual species, and in community ecology, which focuses on groups of species, a central question is often "*How many are there?"* In addition to many research applications, there are also practical applications for being able to answer this question. If you needed to plan a harvest that would not eliminate a population of some organism, such as a particular fish from a lake or deer from a forest, you would need to have a reasonably accurate estimate of the original size of the population. Similarly, if you needed to determine the impact of some predator population on the population of its prey, you would need to know the sizes of both populations. Some decisions about the responsible use of pesticides are based on the population of the pest in question reaching some threshold prior to action. If you were making such a management decision, you would need a way to estimate the size of the pest population.

It is not usually feasible to determine the size of a population of organisms by a direct count of every individual. For this reason, it is very valuable to have techniques that will provide an accurate estimation of population size based on only a **sample** of the entire population.

In this lab exercise, you will simulate one such population estimation method called the **mark-recapture technique** that is often used by wildlife biologists and ecologists in the field. Scientists employ many variations of the mark-recapture technique. You will carryout both a simple mark-recapture and a repeated mark-recapture.

In **Part I**, you will carryout a simple **mark-recapture**. The first step is to capture a random sample of the organism being studied. These captured individuals are 1) counted, 2) marked (in some manner appropriate to the organism), and 3) released back into the environment from which they were captured. The next step is to capture a second sample, after some period of time during

which the released individuals would have re-mixed with the population. The total number of individuals in this second collection would be counted and you would also determine the number of individuals in this second collection that bore the marks you placed on individuals prior to releasing the initial sample. Using a simple ratio based on these numbers, you can determine a quick population estimate (see Equation 1 and Equation 2).

There are limits to the accuracy of estimates based on small samples. In **Part II**, you will carryout a **repeated mark-recapture** in which you will investigate the use of multiple samples (collections) to obtain a more accurate estimation of population size. The first step of this technique is to capture a random sample of the organism being studied. These captured individuals are 1) counted, 2) marked (in some manner appropriate to the organism), and 3) released back into the environment from which they were captured. Then, on a number of subsequent dates, additional collections are made. On each subsequent date (i), a sample (C_i) will be captured. The number of marked re-captures (R_i) will be recorded and the remaining individuals will be marked and returned to the population. Thus, the total number of marked individuals (M_i) increases through time. From the data obtained, a population estimate (N) can be calculated, using Equation 3.

Equation 1:

$$\frac{N}{M} = \frac{n}{m}$$

Equation 2:

$$N = \frac{Mn}{m}$$

To calculate a population estimate, solve for N.

Where

- **N**= Population estimate
- **M**= Number of individuals captured in first sample (and marked)
- **n**= Total number of individuals captured in second sample
- **m**= Number of individuals captured in second sample (n) and marked

Equation 3

$$N = \frac{M_i C_i}{R_i} = \frac{M_2 C_2 + M_3 C_3 + M_4 C_4}{R_2 + R_3 + R_4}$$

Materials

- Beans (2 colors that are roughly the same shape and size):
  - Light-colored beans, enough for 4-6 handfuls per group
  - Dark-colored beans, enough for 1-2 handfuls per group
- Small paper bags

Procedure

Part I: Simple Mark-Recapture

1. Work in groups by lab table.
2. Put 4-6 handfuls of light-colored beans into a sack. Do not count them. Now make a **guess** as to how many light-colored beans you just placed in the sack and record this guess in Table 1.
3. Now take a handful of light-colored beans back out of your sack. This represents your first capture of a group of organisms (**M**). Count these beans and record the number as your value for **M** in Table 1. **DO NOT** return these beans to your sack.
4. You will now mark the organisms (beans) you just captured. To mark these beans merely replace them with dark-colored beans. (For example, if you "captured" 25 light-colored beans, set them aside and count out 25 dark-colored beans to serve as your marked beans).
5. Now you will release the marked individuals back into the population (sack). Place the dark-colored beans you counted out in step 4 above into the sack. The light-colored beans that you replaced with dark-colored beans should be returned to the original light-colored bean container.
6. Shake the sack. Without looking, grab a handful of beans from the sack. This represents your second capture of a group of organisms (n). Count the total number of beans you grabbed in this handful (regardless of color) and record your answer as the value for **n** in Table 1.
7. Examine the same handful of beans you gathered in step 6 above. Count the number of those beans that were "marked" (dark-colored). Record this number as your value for **m** in Table 1. When you are finished counting, return this entire sample to your sack (both the light-colored and dark-colored beans).
8. Use Equation 2 from above to calculate your population estimate (**N**). Record your answer as the value for **N** in Table 1.
9. Now count the actual total number of beans (both light-colored and dark-colored) in your sack. Record your count in Table 1.
10. Separate the light-colored beans from the dark-colored beans and return them to their original containers.

Part II

1. Work in groups by lab table.
2. Put 4-6 handfuls of light-colored beans into a sack. Do not count them. Now make a **guess** as to how many light-colored beans you just placed in the sack and record this guess in Table 2.
3. Now take a handful of light-colored beans back out of your sack. This represents your first capture of a group of organisms (C_1). Count these beans and record the number as your value for C_1 for trapping time 1 in Table 2. **DO NOT** return these beans to your sack.
4. You will now mark the organisms (beans) you just captured. To mark these beans merely replace them with dark-colored beans. (For example, if you "captured" 25 light-colored beans, set them aside and count out 25 dark-colored beans to serve as your marked beans). The number of beans you marked now become the number of marked individuals in the population for your next sample. Record this number of marked beans as the value for M_2 for trapping time 2 in Table 2 (it will be the same number as for C_1). Note that M_1 for trapping time 1 is 0 because there were no marked individuals originally.
5. Now you will release the marked individuals back into the population (sack). Place the dark-colored beans you counted out in step 4 above into the sack. The light-colored beans that you replaced with dark-colored beans are set aside and never returned to the sack again.
6. Shake the sack. Without looking, grab a handful of beans from the sack. This represents your second capture of a group of organisms. Count the total number of beans you grabbed in this handful (regardless of color) and record your answer as your value for C_2 in Table 2. Also examine this handful and determine the number of marked (dark-colored) beans and record this umber as your value for R_2 in Table 2. Note that R_1 for trapping time 1 is 0 because there were no captured individuals originally.
7. Still working with the handful of beans collected in step 6 above, you will now mark the unmarked (light-colored) beans in the sample by replacing them with dark-colored beans (you are marking previously unmarked beans). Add the number of individuals you just

marked to the **M_2 number** and record the resulting sum as the value for **M_3** for trapping time 3 in Table 2. The represents the total number of marked individuals now in the population. Return all the beans from this second collection (which are now all marked, and therefor dark-colored) to the sack.

8. Shake the sack. Without looking, grab a handful of beans from the sack. This represents your third capture of a group of organisms. Count the total number of beans you grabbed in this handful (regardless of color) and record your answer as your value for **C_3** in Table 2. Also examine this handful and determine the number of marked (dark-colored) beans and record this umber as your value for **R_3** in Table 2.
9. Still working with the handful of beans collected in step 8 above, you will now mark the unmarked (light-colored) beans in the sample by replacing them with dark-colored beans (you are marking previously unmarked beans). Add the number of individuals you just marked to the **M_3** and record the resulting sum as the value for **M_4** for trapping time 4 in Table 2. The represents the total number of marked individuals now in the population. Return all the beans from this third collection (which are now all marked, and therefor dark-colored) to the sack.
10. Shake the sack. Without looking, grab a handful of beans from the sack. This represents your fourth capture of a group of organisms. Count the total number of beans you grabbed in this handful (regardless of color) and record your answer as your value for **C_4** in Table 2. Also examine this handful and determine the number of marked (dark-colored) beans and record this umber as your value for **R_4** in Table 2.
11. Calculate the population estimate (**N**) using Equation 3 and record your answer in Table 2.
11. Now count the actual total number of beans (both light-colored and dark-colored) in your sack. Record your count in Table 2.
12. Separate the light-colored beans from the dark-colored beans and return them to their original containers.

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Simulated Population Study: Mark-Recapture LAB WRITE-UP:

Submit pages 7-8

Student Name: _____ **Lab Date:** _____

Lab Instructor: _____ **Section #:** _____

Results (Data)

Table 1. Population guess and count, and calculated population estimate based on numbers of captured, marked, and recaptured individuals using a simple mark-recapture technique.

Guess of population size =	
M =	
n =	
m =	
N =	
Count of population size =	

Table 2. Population guess and count, and calculated population estimate based on numbers of captured, marked, and recaptured individuals using a repeated mark-recapture technique.

Trapping Time	# Marked Individuals in Population (M_i)	# Captured (C_i)	# Recaptured (R_i)
1	M_1 = 0	C_1 =	R_1 = 0
2	M_2 =	C_2 =	R_2 =
3	M_3 =	C_3 =	R_3 =
4	M_4 =	C_4 =	R_4 =
Guess of population size=			
N=			
Count of population size=			

Conclusions (Questions): *For full credit, these questions should be answered thoroughly, in complete sentences, in legible handwriting.*

1. For the simple mark-recapture in Part I, how did your initial guess of the population size compare to the actual population number determined by a direct count?

2. For the simple mark-recapture in Part I, how did your initial guess of the population size compare to the calculated population estimate (N)?

3. For the repeated mark-recapture in Part II, how did your initial guess of the population size compare to the actual population number determined by a direct count?

4. For the repeated mark-recapture in Part II, how did your initial guess of the population size compare to the calculated population estimate (N)?

5. Did the simple mark-recapture or the repeated mark-recapture provide the most accurate estimate of population size (N)