How Many Are There?

Overview

Description

In this activity, students will explore several techniques for estimating a population's size. Students will first practice census techniques using seeds to model a sample population. Then students will census a real population of trees. Some simple statistical procedures will be introduced to analyze reliability of the census techniques.

Final Product: Students will prepare written reports of their investigations, describing numerical results, results of statistical analyses, and evaluations of factors that would affect which technique a biologist would choose to census a natural population for research.

Course

Biology

Task Level

Grades 9–12

Cross-Disciplinary Standards Assessed

1. Key Cognitive Skills
   A.1. Engage in scholarly inquiry and dialogue.
   B.2. Construct well-reasoned arguments to explain phenomena, validate conjectures, or support positions.
   B.3. Gather evidence to support arguments, findings, or lines of reasoning.
   C.2. Develop and apply multiple strategies to solve problems.
   C.3. Collect evidence and data systematically and directly relate it to solving a problem.
   D.1. Self monitor learning needs and seek assistance when needed.
   D.2. Use study habits necessary to manage academic pursuits and requirements
   D.4. Persevere to complete and master tasks.
   E.2. Work collaboratively.

Science Standards Assessed
I. Nature of Science
   B.1. Design and conduct scientific investigations in which hypotheses are formulated and tested.

II. Foundation Skills: Scientific Applications of Mathematics
   A.4. Use proportional reasoning to solve problems.
   B.1. Carry out formal operations using standard algebraic symbols and formulae.
   B.2. Represent natural events, processes, and relationships with algebraic expressions and algorithms.
   E.1. Understand descriptive statistics.

III. Foundation Skills: Scientific Applications of Communication
   B.2. Set up apparatuses, carry out procedures, and collect specified data from a given set of appropriate instructions.

V. Cross-Disciplinary Themes
   C.1. Recognize patterns of change.

VI. Biology
   C.2. Recognize variations in population sizes, including extinction, and describe mechanisms and conditions that produce these variations.

Objectives

Students will:

- Perform lab investigations of two different techniques used by biologists to estimate population sizes.
- Become familiar with simple statistical calculations (sample standard deviation and standard error) and use these techniques to evaluate the collected data.
- Compare results and statistical analyses of two census techniques, and draw conclusions regarding appropriate techniques to use in real census investigations.
- Use at least one of the techniques learned in the lab investigation to census a real field population of organisms.
- Prepare written reports that include the following information: the data collected during the investigations, the results of statistical analyses, and a discussion of the factors affecting which technique a biologist would choose to census a natural population for research.

Preparation

- Obtain the materials that will be used in this activity. Each group needs:
• A square cake pan or similar container with a grid pattern marked on the bottom. Print a grid pattern on paper to fit the size of the cake pan being used and lay or glue the paper in the bottom of the pan. The exact size of each grid square is not important, so long as all the squares are the same size.

• One pair of standard six-sided gaming dice.

• A small screw-capped container of seeds. Plastic specimen jars work well for this. Each container should have the SAME pre-weighed amount of seeds (16 grams is suggested).

• Small amount (75–125) of seeds stained with methylene blue.

• Calculators (recommended, but not required).

• A flat, level surface for the cake pans to rest on.

• A small test tube or bottle.

• Prepare student copies of the Seed Census and Dispersion Patterns handout.

• Locate a map of a local area with a large population of trees. Divide the map into quadrats, and prepare student copies of the map.

Prior Knowledge

Students will need little prior knowledge to carry out this exercise. Familiarity with simple algebraic procedures, such as representing quantities by symbols and rearranging equations, will be necessary. A previous introduction to simple statistics will aid student understanding of standard deviation and standard error.

Vocabulary

• Census
• Mark-recapture
• Mean
• Population
• Random number
• Standard deviation
• Standard error

Time Frame

This assignment generally requires 20–25 minutes of class time for introducing the project and giving instructions on procedures. Once students begin collecting data, 30–40 more minutes of class time will be needed to collect the quadrat-sampling data and do the initial calculations. The second part of the exercise (mark-recapture
sampling) will probably require an additional 20–25 minutes. If the third part of the assignment (estimating number of trees in an outdoor location) is done, this will require an hour or more, depending on travel time to the location. Doing the statistical analysis part of the exercise will require another 15–20 minutes to introduce and explain the mathematical procedures and 20–30 minutes for the students to carry out the computations.
Instructional Plan

Getting Started

CCRS Performance Expectations

Cross-Disciplinary Standards:

I. Key Cognitive Skills
   C.2. Develop and apply multiple strategies to solve a problem.
   C.3. Collect evidence and data systematically and directly relate to solving a problem.
   D.2. Use study habits necessary to manage academic pursuits and requirements.

II. Foundational Skills
   C.5. Synthesize and organize information effectively.
   D.3. Present analyzed data and communicate findings in a variety of formats.

Science Standards:

I. Nature of Science
   B.1. Design and conduct scientific investigations in which hypotheses are formulated and tested.

IV. Foundation Skills: Scientific Applications of Mathematics
   A.4. Use proportional reasoning to solve problems.
   B.1. Carry out formal operations using standard algebraic symbols and formulae.
   B.2. Represent natural events, processes, and relationships with algebraic expressions and algorithms.
   E.1. Understand descriptive statistics.

V. Foundation Skills: Scientific Applications of Communication
   B.2. Set up apparatuses, carry out procedures, and collect specified data from a given set or appropriate instructions.

VII. Cross-Disciplinary Themes
   C.1. Recognize patterns of change.

VIII. Biology
   C.2. Recognize variations in population sizes, including extinction, and describe mechanisms and conditions that produce these variations.

Learning Objectives
Students will:

- Perform lab investigations of two different techniques used by biologists to estimate population sizes.
- Become familiar with simple statistical calculations (sample standard deviation and standard error) and use these techniques to evaluate the collected data.

**Procedure**

1. Have students work in pairs or groups of three.

2. Provide the groups with the required materials:
   a. A square cake pan or similar container with a grid pattern marked on the bottom.
   b. One pair of standard dice.
   c. A small screw-capped container of seeds.
   d. Calculators.
   e. A flat, level surface for the cake pans to rest on.

3. Instruct students to release the organisms into the counting area. As they do so, they should hold the jar no more than 10–11 inches above the pan.

4. Be sure that each group understands that they are to census the same population five times, using the random-sampling technique. Each complete census requires that they count five quadrats. The students will count 25 quadrats, in batches of five. Between each estimate, all the seeds must be removed from the counting pan, returned to the container, and then released back into the pan and counted again.

5. When the census of each group's population has been taken five times, the group will then calculate the mean (average) of the estimates and will use the five estimates to calculate the standard deviation around the mean. Students will then use the calculated standard deviation to calculate the standard error.

6. Have each student pair or group post their results on a chalkboard or some other location in which the entire class can examine the results.

7. Have students construct a bar graph in their handout or on a separate sheet of paper displaying all these data. Then they should answer the questions on the handout about the class data.

**Investigating**

**CCRS Performance Expectations**

Cross-Disciplinary Standards:
I. Key Cognitive Skills
   A.1. Engage in scholarly inquiry and dialogue.
   B.2. Construct well-reasoned arguments to explain phenomena, validate conjectures, or support positions.
   B.3. Gather evidence to support arguments, findings, or lines of reasoning.
   C.2. Develop and apply multiple strategies to solve a problem.
   C.3. Collect evidence and data systematically and directly relate to solving a problem.
   D.1. Self-monitor learning needs and seek assistance when needed.
   D.2. Use study habits necessary to manage academic pursuits and requirements.
   D.4. Persevere to complete and master tasks.
   E.2. Work collaboratively.

Science Standards:
I. Nature of Science
   B.1. Design and conduct scientific investigations in which hypotheses are formulated and tested.

II. Foundation Skills: Scientific Applications of Mathematics
   A.4. Use proportional reasoning to solve problems.
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   B.2. Set up apparatuses, carry out procedures, and collect specified data from a given set of appropriate instructions.

V. Cross-Disciplinary Themes
   C.1. Recognize patterns of change.

VI. Biology
   C.2. Recognize variations in population sizes, including extinction, and describe mechanisms and conditions that produce these variations.

Learning Objectives
Students will:

- Perform lab investigations of two different techniques used by biologists to estimate population sizes.
- Become familiar with simple statistical calculations (sample standard deviation and standard error) and use these techniques to evaluate the collected data.
- Compare results and statistical analyses of two census techniques, and draw conclusions regarding appropriate techniques to use in real census investigations.

Procedure

1. Students will now use a different technique to census the same population they previously examined. The new technique is called "mark-recapture."

2. Each group of students will need:
   a. A sample population of organisms (use the same jar of seeds as before).
   b. A small group of marked organisms (students will use approximately 100 seeds stained with methylene blue).
   c. A trap for the organisms, such as a small test tube.

3. Have the students pour the small group of marked organisms (the stained seeds) onto a white sheet of paper or into a shallow dish and make an accurate count of those marked seeds. The pan with the marked grids will be useful as a container for counting; ignore the grid marks for now. Students will count each of the marked seeds and then record the number in the chart on the Seed Census handout.

4. When students have counted the marked individuals, have them gather up all the stained seeds and dump them into the jar with the unmarked seeds that were counted in the first part of the exercise.

5. Instruct students to screw the lid on the jar and shake vigorously for a few seconds until the marked individuals are mixed thoroughly and uniformly with the original population.

6. Students should now remove the lid, invert the small test tube into the jar, and press the open mouth of the tube down through the seeds until it is firmly against the bottom of the jar. Some seeds will be trapped inside the test tube.

7. Keeping the tube pressed firmly against the bottom of the jar so that the seeds inside cannot escape, instruct the students to tip the jar into the pan so that all trapped seeds will fall into the bottom of the test tube. Be sure that they hold the test tube upright so the trapped seeds can’t escape. Now they can carefully pour all the trapped seeds onto a separate sheet of white paper.
8. Students will now count the seeds that were trapped. First, have them count the total number of seeds (marked and unmarked), and then count only the marked seeds. Instruct students to enter each count onto the chart on the handout.

9. Students will then use the following formula to calculate the total population

\[
\frac{\text{Total Population} (P)}{\text{Original Number Marked} (a)} = \frac{\text{Total in Sample} (n)}{\text{Total Marked in Sample} (r)}
\]

This can be rearranged to the form:

\[
P = \frac{(a)(n)}{(r)}
\]

10. After calculating, students should post their new population estimate on the chalkboard beside the original estimate. Have students examine the two estimates. Ask: Do the two estimates agree? Do the estimates agree with those of the other groups?

11. Students must now carefully remove all marked seeds from the sample—both the ones that were in the test tube and the others that were dumped into the pan. Have them return all marked seeds to the stock jar on the central supply table. They should put all the unmarked seeds back into the small plastic jar where they were when the exercise began. It is very important that students pick out and remove all marked seeds, so this original population will be ready for use by another group.

**Drawing Conclusions**

**CCRS Performance Expectations**

Cross-Disciplinary Standards:

1. Key Cognitive Skills
   
   A.1. Engage in scholarly inquiry and dialogue.
   
   B.2. Construct well-reasoned arguments to explain phenomena, validate conjectures, or support positions.
   
   C.3. Collect evidence and data systematically and directly relate to solving a problem.
   
   D.1. Self-monitor learning needs and seek assistance when needed.
   
   D.2. Use study habits necessary to manage academic pursuits and requirements.
   
   
   D.4. Persevere to complete and master tasks.
   
   E.1. Work independently.
E.2. Work collaboratively.

II. Foundational Skills

B.1. Write clearly and coherently using standard writing conventions.
C.5. Synthesize and organize information effectively.
D.3. Present analyzed data and communicate findings in a variety of formats.

Science Standards:

I. Nature of Science

B.1. Design and conduct scientific investigations in which hypotheses are formulated and tested.

II. Foundation Skills: Scientific Applications of Mathematics

A.4. Use proportional reasoning to solve problems.
B.1. Carry out formal operations using standard algebraic symbols and formulae.
B.2. Represent natural events, processes, and relationships with algebraic expressions and algorithms.
E.1. Understand descriptive statistics.

III. Foundation Skills: Scientific Applications of Communication

B.2. Set up apparatuses, carry out procedures, and collect specified data from a given set of appropriate instructions.

IV. Cross-Disciplinary Themes

C.1. Recognize patterns of change.

IV. Biology

C.2. Recognize variations in population sizes, including extinction, and describe mechanisms and conditions that produce these variations.

Learning Objectives

Students will:

- Use at least one of the techniques learned in the lab investigation to census a real field population of organisms.
- Prepare written reports that include the following information: the data collected during the investigations, the results of statistical analyses, and a discussion of the factors affecting which technique a biologist would choose to census a natural population for research.

Procedure

1. For the third part of the exercise, the class will need a map of some local area such as the school campus if it is large enough, the surrounding
neighborhood, a nearby park, or some semi-natural area. Draw lines on the map to divide it into grid quadrats, and label each quadrat so each student group can roll their dice to determine which area they sample.

2. Each pair of students rolls the dice to determine which quadrat they will census. Each group will need a copy of the gridded map of the area where the census will be taken. Once each group knows the location of their quadrat, they must go there and count the trees in that quadrat. They should take along their copy of the map so they can accurately determine the boundaries of the quadrat they are to census. For this exercise, a tree will be defined as any plant with a stem with at least a 10-cm diameter when measured 20 cm above the ground. Each group should also take along a tape measure to check these sizes and heights.

3. While each group is at their quadrat, they should also look closely at the dispersion pattern of the trees. They should try to decide whether the trees are random, regular, or clumped in their dispersions.

4. Finally, students use the Dispersion Patterns handout to identify the dispersion of the tree population they censuses. Students will then prepare written reports of their investigations, describing the collected data, the results of statistical analyses, and factors that would affect which technique a biologist would choose to census a natural population for research. Have students turn in their completed handouts and final reports.
**Scaffolding/Instructional Support**

The goal of scaffolding is to remove support gradually to encourage student success, independence, and self-management. The following suggestions are examples of scaffolding that can be used by instructors to meet diverse student needs while students are completing this assignment:

- If an old-fashioned overhead projector is available, print the grid pattern on a transparency. Make a set of cardboard fences or walls to surround the grid pattern. Place the transparent grid on the projector, surround it with the walls, turn on the projector, and pour a sample of seeds onto the grid. Students will be able to see what their seeds will look like when they pour the seeds into their pans. Roll a pair of dice, read the numbers and locate the corresponding square (called the quadrat) on the grid. Use a sharp pencil or similar pointer and point to each seed in the chosen quadrat in turn as you count the seeds in the quadrat. Record the number in a data table (use another transparency with the standard data table format printed on it, or sketch the data table on the chalkboard).

- Make it clear that five quadrats are to be sampled, so the dice must be rolled five times, with the selected quadrat counted immediately after rolling the dice, before rolling again.

- When five quadrats have been counted and the first data table is filled, students should immediately complete the calculations to make their first estimate of the total population in their seed jar. When this first set of observations and calculations is complete, each group must CAREFULLY pour ALL their seeds back into their container. At this stage, the grid pan should be completely empty of seeds.

- The instructor should walk around the room while these counting and calculation procedures are underway, watching for horseplay, spilled pans, and other signs of confusion or misdirection.

- It may be useful to coordinate with the math instructors prior to doing the exercise. Student understanding will be enhanced if they have received at least a brief introduction to simple statistics before calculating the standard deviation and standard error of their population estimates.
Solutions

The solutions provided in this section are intended to clarify the problem for instructors. These solutions may not represent all possible strategies for approaching the problem or all possible solutions. It should be used for reference only.

The reasoning behind the mark-recapture method for estimating population size is as follows: You know how many marked individuals are in the study area (in this case, the jar), because you counted them before releasing them. Let's suppose you released 100 marked individuals. You have carried out one sampling, and recaptured some number of the marked ones, along with some number of unmarked individuals. Let's say you captured a total of 107 individuals (seeds in this example) and 10 of those were marked. You know there were originally 100 marked individuals. If you capture 10 of them at each typical sampling effort, how many times must you carry out the sampling to catch all of them? Obviously, you must carry out 10 samplings (100 marked individuals to be captured; 10 caught each time). But at each sampling, you capture both marked and unmarked seeds. In fact, to get the 10 marked individuals, you had to capture 107 total seeds. So by the time you have carried out 10 samplings and thus recaptured all that were originally marked, you will have captured 1070 individuals (10 times 107). To recapture all the originally marked individuals, you will need to capture the entire population. So the total population must amount to about 1070 individuals.

With regard to choosing which technique to use in taking census of a real population: The mark-recapture method can only be used to census active, motile organisms. It cannot be used to census sessile organisms such as trees. The reason for this is that in the mark-recapture method, the marked individuals must circulate freely throughout the population, leaving the spot where they were released, and mixing uniformly among the entire population under study. Furthermore, sufficient time must be allowed for this mixing to take place before the recapture step is carried out. On the other hand, the investigator cannot wait for a long time for the mixing to occur, because of the danger that some marked individuals will wander away from the study area, be caught by predators, die of natural causes, go into hibernation, or encounter some other problem that interferes with the recapture. Therefore, judgment and creativity are needed in planning a census investigation.
How Many Are There?

Introduction

There are many questions a biologist might ask about a population, but the simplest is, "What is its size?" A population's size is determined by how many organisms are present in a given population. To answer this question, we must census, or count, the population. It might appear that this would be simple—that we could merely go to the correct location and quickly count all the oak trees or pillbugs or whatever organism we are studying in a given area. In fact, the actual situation is much more difficult.

Biologists studying small organisms are often faced with very large populations, perhaps numbering several million individuals in an area no larger than a classroom. Another problem is that organisms, especially animals, do not stand still, so the population is constantly running around while the biologist is trying to count. Even oak trees, though they are large and stationary, may be difficult to census if the population is spread over a large area. Imagine the difficulty of trying to count individually every oak tree in Texas or even in the whole southern United States.

Therefore, biologists must use other census methods. There are several ways a biologist may measure the size of a population. The particular technique chosen will depend on the type of organism, the type of terrain, the amount of time available, etc. Commonly, biologists take a sample of the population and use this sample to estimate the total size of the population. The following exercises will give you some practice in sampling and estimating. The instructions are given on the next page.

The Problem

What techniques can a biologist use to estimate the number of individual organisms in a population? How reliable are these techniques? Are some techniques better suited for particular situations than others?
Directions

Getting Started

1. Hold the container of seeds about 10 inches above the pan. Close your eyes, and then dump the seeds in the pan. The seeds represent organisms in a population.

2. Give the "organisms" a few seconds to locate their proper habitat (let them stop rolling).

3. Roll the dice and read the numbers that come up. Do not add the numbers together, but treat them as a 2-digit address. Locate in the bottom of the pan, the grid square marked with those numbers. Count the organisms within that grid square. Each grid square is called a "quadrat". For organisms that lie on the boundaries of a quadrat, use the following rule: organisms on the top and right boundaries are counted as being in the grid square; organisms overlapping the bottom and left boundaries are considered outside of the grid, and are not counted. Record your count on the Seed Census handout.

4. Roll the dice again, read the numbers, and locate the corresponding grid square in the pan. Repeat the counting procedure as outlined in step 3. Do the same for the 3rd, 4th, and 5th random numbers, for a total of five counts. Record your counts in the appropriate place in the data table each time. While this counting is underway, do not shake the pan.

5. After completing the five counts, compute the mean (or average) number of organisms per grid square, and multiply by the number of squares in the pan to estimate the total number of organisms in the study area.

6. Carefully tilt the pan and pour all the seeds back into their original container without spilling any.

7. Now begin again with the 1st step, and pour the seeds into the pan once more. Continue the procedure, step-by-step, following steps 2 through 6, as you did before. As you count each randomly-chosen grid square, record the count in the appropriate space in the data table on the handout. Repeat until you have five separate population counts.

8. You should now have five separately-measured estimates of your population. Your numbers probably did not turn out the same each time. Should we regard these estimates as essentially the same, or are they significantly different? To answer such a question, we can use some well-known statistical procedures. First we calculate a value called the "Sample Standard Deviation" (abbreviated "s" or "SD") Here are the steps to carry out the calculation:
a. Compute the mean for the data set.
b. Compute the deviations by subtracting the mean from each value.
c. Square each individual deviation.
d. Add up the squared deviations.
e. Divide by one less than the sample size
f. Take the square root

This arithmetic is simple, but there are several steps in the calculation. Here is an example:

Suppose you took a census of a small population five times and got these results:

- population count #1 = 4
- population count #2 = 5
- population count #3 = 5
- population count #4 = 7
- population count #5 = 9

The total number of data points you have is represented by the letter \( n \). In this case, \( n = 5 \) (sample size = 5). The mean of the five data points is 6.

\[
\frac{4+5+5+7+9}{5} = 6
\]

To calculate the standard deviation, we take the absolute difference between each data point and the mean, and then square the result:

- \( (4 - 6)^2 = (-2)^2 = 4 \)
- \( (5 - 6)^2 = (-1)^2 = 1 \)
- \( (5 - 6)^2 = (-1)^2 = 1 \)
- \( (7 - 6)^2 = (1)^2 = 1 \)
- \( (9 - 6)^2 = (3)^2 = 9 \)

Next we add up these numbers, divide the total by \( n - 1 \), and then take the square root of the resulting number:

\[
\sqrt{\frac{4+1+1+1+9}{4}} = \sqrt{4} = 2
\]
Now complete the calculations to determine Standard Deviation and Standard Error, using the data you obtained from your own population estimates. Since you censused the population 5 times, your sample size (n) is 5.

Population estimate from Count I
Population estimate from Count II
Population estimate from Count III
Population estimate from Count IV
Population estimate from Count V
Mean of population estimates I - V

Calculate Standard Deviation by following steps b - f from page S-3.

b. compute deviations (subtract mean from each value).

c. square each individual deviation.

d. add up squared deviations.
e. divide by n-1 .
f. take the square root. this value is the Standard Deviation (SD) for your set of population estimates.

Now calculate the Standard Error (SE) for your estimate (see pages S-5 & S-6).

SE = \frac{SD}{\sqrt{n}}
This standard deviation indicates the distribution of samples around the mean. If we think of a "normally-distributed" population (also called the bell-shaped curve of distribution), we want to know how wide the spread of the "bell" is. For example, does it look like the curve on the right or on the left?:

![Curves](image)

The curve on the left represents a population with a small or narrow standard deviation. The curve on the right represents a population with a large or broad standard deviation.

Now suppose we want to compare two sets of data. Suppose that when we calculate the mean of each data set, the means are not exactly the same. Should we conclude that the sets are really different, or is the apparent difference only due to random events in our data collection? To answer this question, we do one more calculation and find the standard error ("SE"). Here is how we do that calculation:

**Standard Error** = Standard Deviation ÷ \sqrt{n} where "n" is the sample size.

or \[ SE = \frac{SD}{\sqrt{n}} \]

In this example, we previously calculated SD = 2. Our sample size was 5.

So \[ SE = 2 ÷ \sqrt{5} \approx 2 ÷ 2.2 = 0.9 \]

So we report our data like this:

**Estimated population size is 6 ± 0.9 that is, mean ± SE**

By this statement, we mean that the "true" or "real" population size is somewhere between 5.1 and 6.9 (between one standard error below the calculated mean and one standard error above the calculated mean). So, if another group calculated their census data, and reported an estimated population size of 7 ± 1.3, we would conclude that the two estimates are statistically indistinguishable, because there is an overlap between the mean ± SE values for the two estimates. An easy way to display such comparisons is in the form of a bar graph, like this:
The means are represented by the bars and the standard errors are represented by the error lines at the end of the bars.

9. Now calculate the sample standard deviation (SD) and the standard error (SE) for your data set. Notice that the standard error becomes smaller as the sample size increases, because we have more information to estimate the true mean.

10. Post your census data, including the calculated standard error (mean plus/minus standard error), in the appropriate space on the chalkboard at the front of the room. The data are reported as follows: estimated population size is 6 ± 0.9 (which is the mean plus or minus the standard error). By this statement, we mean that the "true" or "real" population size is somewhere between one standard error below the calculated mean and one standard error above the calculated mean. In this case, the population size is somewhere between 5.1 and 6.9.

11. When all groups have posted their data, including the calculated standard error for each mean, construct a bar graph displaying all these data. Do all the data fall within the limits of Mean ± SE?

**Investigating**

1. You may be a little doubtful of your census data, especially if the population estimate differs widely from that of others. You may even doubt the validity of the census method. How could you test the method's validity? One possible way is to use another method to estimate the same population. Then, you could compare the second population estimate to your first one, as well as the counts of other students using the second method. Let's consider the second method. You will need a sample population of organisms (the same jar of seeds used previously), a small group of marked organisms (seeds stained with methylene blue), and a trap for the organisms (a small test tube).

2. Pour the small group of marked organisms (the stained seeds) onto a sheet
of white paper or into a shallow dish, and then count them. Be sure your count is accurate. Be sure you count each seed, and then record the number in the chart on your handout. This is the value (a).

3. When you have counted the marked individuals, release them into the population that you want to census. To do this, gather up all the stained seeds, and then dump them into the jar with the unmarked seeds you counted earlier.

4. Screw the lid on the jar, and then shake vigorously for a few seconds in order to mix the marked seeds thoroughly and uniformly with the original population.

5. Remove the lid, invert the small test tube into the jar, and press the open mouth of the tube down through the seeds until it is firmly against the bottom of the jar. Some seeds will be trapped inside the test tube.

6. Keeping the tube pressed firmly against the bottom of the jar, keeping the seeds from escaping, and then tip the jar into the pan so that all the trapped seeds will fall into the bottom of the test tube. Hold the test tube upright so the trapped seeds can’t escape. Now carefully pour all the trapped seeds onto a separate sheet of white paper.

7. Count the seeds that were trapped, first counting the total number of marked and unmarked seeds, then the marked seeds alone. Enter each count onto the chart on your handout.

8. After recording your data, follow the same formula as outlined previously to calculate the total population size.

9. Post your new population estimate on the chalkboard beside your original estimate. Do the two estimates agree with those of the other groups?

10. Carefully remove all marked seeds from the sample, both the ones that were in the test tube and the others that were dumped into the pan. Return all marked seeds to the stock jar on the central supply table. Put all the unmarked seeds back into the small plastic jar where they were when you began the exercise. It is very important that you pick out and remove all the marked seeds so this original population will be ready for use by another group.

11. Reflect on these questions:

   a. If you repeated this entire procedure (mark-recapture method), do you think you would get about the same number for total population size? What statistical methods could you use to predict the range of values that you might obtain?

   b. What are some factors that might affect your results in this method for
measuring population size in the lab?

c. What additional factors might affect mark-recapture results in a natural population of animals?

**Drawing Conclusions**

1. Now use your new skills and knowledge to carry out a census of a natural population. Use the instructions and maps provided by your instructor to estimate the population of trees in a selected natural area.

2. Each pair of you will count the trees in one grid square; class data will be pooled to calculate the total tree population of the central campus. As before, a roll of dice will select which grid you will count. When you know which square is yours to count, go there (take along a copy of the map so you won't get lost) and count the trees. For this exercise, we will arbitrarily define a tree as any plant with a stem of at least 10-cm (4 inches) diameter when measured 20-cm (8 inches) above the ground. Be sure to take along a ruler to measure these heights and sizes.

3. While you are at your grid square, look closely at the dispersion pattern of the trees. Review the *Dispersion Pattern* handout. Try to decide whether the trees are random, regular, or clumped.

4. Finally, prepare a written report of your investigations. In your report, include the data you collected, the results of statistical analyses, and an evaluation of factors that would affect which technique a biologist would choose to census a natural population for research.
Seed Census

Part 1

<table>
<thead>
<tr>
<th>Count</th>
<th>Grid Number</th>
<th>Number of Organisms</th>
</tr>
</thead>
<tbody>
<tr>
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- Total organisms counted
- Average organisms per grid (total ÷ 5)
- Total number of grids in pan
- Grand total of organisms (average x total number of grids in pan)
## Count II

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- **Total organisms counted**
- **Average organisms per grid (total ÷ 5)**
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- **Total organisms counted**
- **Average organisms per grid (total ÷ 5)**
- **Total number of grids in pan**
- **Grand total of organisms (average x total number of grids in pan)**
## Count V

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Total organisms counted

Average organisms per grid (total ÷ 5)

Total number of grids in pan

Grand total of organisms (average x total number of grids in pan)
Part Two. Estimating Population Size by the Mark-Recapture Method

Original number of marked seeds

Total number of trapped seeds

Number of trapped marked seeds

Then use the following formula to calculate the total population:

\[
\frac{\text{Total Population (} P \text{)}}{\text{Original Number Marked (} a \text{)}} = \frac{\text{Total in Sample (} n \text{)}}{\text{Total Marked in Sample (} r \text{)}}
\]

This can be rearranged to the form:

\[
P = \frac{(a)(n)}{(r)}
\]

Enter the recorded numbers in the formula below and carry out the calculation.

\[
P = \frac{(\phantom{0})}{(\phantom{0})} = \phantom{0}
\]

To obtain the original population (before the stained seeds were added), it is necessary to subtract the number of stained seeds from the newly-calculated value of \( P \). To avoid having to do this step, field biologists usually capture a few of the original population, mark them, and re-release the marked individuals back into the original population. To save time and allow the marked seeds to be prepared ahead of time, we have used a modified procedure that added a small number of individuals to the original population. So, the final estimate must be corrected for the number that we added. To do this, subtract the value \((a)\) (original number of marked seeds) from the value \((P)\) (calculated population size). The number you get from this subtraction can be compared to the first estimate that you made of population size using the quadrat-sampling method.

\[
P - a = \phantom{0}
\]

Post your new population estimate on the chalkboard beside your original estimate. Do the two estimates agree? Do your estimates agree with those of other groups?
Dispersion Patterns

A. Random

If the presence of one individual has no influence on the presence or absence of another, a random pattern will be shown.

B. Uniform = Regular -- Overdispersed

If the presence of one individual exerts a negative influence on the presence of another, a uniform pattern will be shown. Territoriality or intraspecific aggressive behavior are among the possible causes for a uniform pattern.

C. Clumped = Contagious = Aggregated = Underdispersed

If the presence of one individual exerts a positive influence on the presence of another, a clumped pattern will be shown. The existence of non-homogeneous habitat or reproduction without dispersal as well as social attraction can cause a clumped pattern.
## Grid Pattern

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