Population Estimates: Bringing Math and Science Together - Teacher Guide

Setting the Stage

In this activity students will learn how to estimate population size using two techniques, density extrapolation and the mark-recapture method. Each of these methods is used by ecologists, demographers, and others to gain an understanding of population size when it is impossible to count every individual. This activity may be used prior to a field study to provide students with practice in estimating. It may also be used in a lesson or unit on ecosystems.

Flock of birds landing at Elkhorn Slough. Photo credit: dondj2

Lesson Overview

- *Part 1 – Engage (5 minutes) What is population and why is it important?*
  Students define the term "population" and discuss reasons why knowing population size is important.

- *Part 2 – Explore (15 minutes) Average Population Density*
  Students estimate a population size using the population density method.

- *Part 3 – Explore and elaborate (40 minutes) The Mark-Recapture Method*
  Students estimate a population size using the mark-recapture method.

Instructional Overview	
Grade Level	Middle School
Instructional Time	60 minutes *(total time needed)*
NGSS Standards Alignment	Building proficiency towards to the following Disciplinary Core Ideas: MS-LS2.A: Interdependent Relationships in Ecosystems MS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience Science and Engineering Practices: Analyzing and Interpreting Data
Driving Question	● How can we count every individual in a large population or in a population that moves around?
Learning Goals	● Students will apply two techniques, density extrapolation and mark and recapture, to estimate the size of populations. ● Students will identify the assumptions made when estimating the size of a population.
Materials	❏ Dry beans (Great Northern White beans work very well) ❏ Sharpie (1 per group for marking captured beans) ❏ Plastic spoons or other bean-sampling device (1 per group) ❏ Plastic container for holding the beans with enough space for them to be mixed thoroughly ❏ 1 handout per student
Material Preparation	❏ Measure out about ¼ cup of beans per group ❏ Recreate the handout for this lesson and provide access (print or digitally share it) ❏ Practice the mark-recapture portion of this lesson if you are unfamiliar with the technique
Vocabulary	Population: All the organisms that constitute a specific group or occur in a specified habitat Error: Difference between a computed or measured values and a true or theoretically correct value Population density: A measurement of population per unit area or volume Assumption: Accepted existence of a fact or set of facts based on other facts or knowledge

Part 1 (Engage) What is population and why is it important? (5 minutes)

First, ask the class to answer the questions:

1. What is a population? Give an example.

2. Why is knowing population size important?

List two examples where estimating population size for different types of organisms is important:

> By estimating population size for different organisms, scientists can learn many things. For example, fisheries managers can decide how many of a certain fish species can be harvested without damaging the population. They can also learn if a population is threatened by extinction. If population estimates over many years exist, different management strategies can be adopted to protect species if they are in need of protection.

Mention that in this lesson they will practice two different ways a population ecologist determines population sizes.

Part 2 (Explore) Average Population Density (15 minutes)

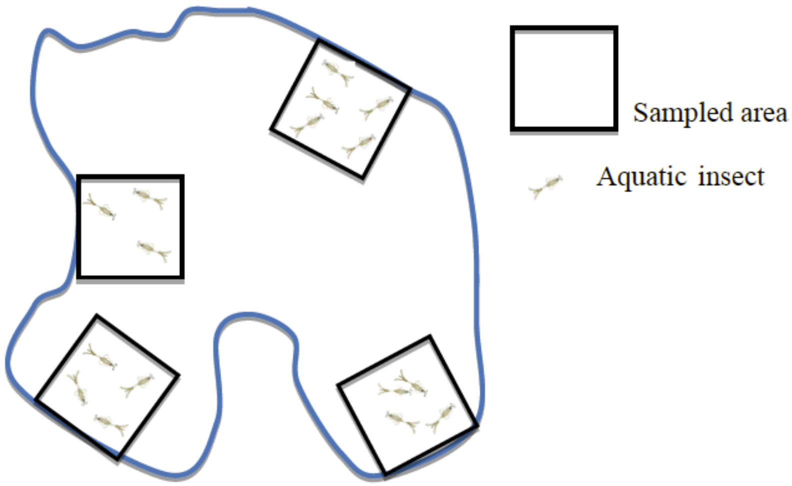
Ask the students to think about if they ever had to guess the number of jellybeans in a jar in school or at a fair. How did they do it?

> Possible Response: Obtain a value for the number in a measured area [a density measurement] and then multiply that by the entire area.

In small groups, ask students to do the following:

3. Come up with a population estimate of aquatic insects for the lake below based on the knowledge that only ¼ of the lake was sampled. So each sampled area represents 1/16 of the total area.

    - Write one example of a system that you think this technique would work well in.
    - Write one example of a system that you think this technique would not work well in.



Discuss their responses while allowing for multiple ideas as well as a discussion about the inherent error that arises while estimating.

> Typically, scientists do not have enough time or money to sample an entire population in an ecosystem. Instead, they come up with an average population density for that ecosystem by counting the organisms in several small areas to come up with an average population density. Then they multiply the average population density by the entire area of that ecosystem. This results in a population estimate for the entire ecosystem.

Average population density is calculated using the following equation:

Number of organisms counted / Area sampled = Average population density

Then, to estimate the population of the entire ecosystem, not just the area sampled, the following equation can be used:

Average population density X Total area of the ecosystem = Ecosystem Population

Develop a few examples to model how this equation works. Make sure the units are correct!

Part 3 (Explore) The Mark-Recapture Method (40 minutes)

Sometimes, individuals in a population move as a group (think of a school of fish) or are not distributed evenly in an ecosystem. Under these conditions, using average density to come up with a population estimate may not work unless we take a lot of samples. In these cases scientists can use a different method to estimate the population. This method is called the mark-recapture method. In this method a small portion of the population is captured and marked and then released back into the population. Then, a small portion of the population is captured and by using the ratio of marked to unmarked organisms, the population size can be estimated.

Pass out the spoons, bean containers, and permanent markers. Students work in groups to complete the activity and record their data in the tables below.

Sample Time 1:

- Remove two spoonfuls of beans from the container.
- Using a permanent marker, mark each bean with a noticeable mark.
- Count the number of beans in each spoonful.
- Place all the marked beans back in the bowl.
- Record your data in the table below.

	Spoonful 1	Spoonful 2	Total
Number of beans captured			

Sample Time 2:

- Mix the beans in the bowl so the marked beans are evenly distributed throughout the container.
- Remove two spoonfuls of beans from the bowl.
- Count the number of beans in each spoonful.
- Count how many beans have a mark in each spoonful.
- Return all of the beans to the bowl.

	Spoonful 1	Spoonful 2	Total
Number of beans captured (marked and unmarked)			
Number of marked beans			

Work through the calculation for estimating population together.

$$\text{Population estimate} = \frac{\text{Total beans captured in Time 1} \times \text{Total beans captured in Time 2}}{\text{Total marked beans from Time 2}}$$

Then have each group count out the true value of their population.

Fill in their numbers on a class data table.

	Group 1	Group 2	Group 3	Group 4	Average
Total captured T1					
Total captured T2					
Total recaptured (marked) T2					
Population estimate					
True population					
Difference between true and estimated population					

Ask the students to discuss why each group got different estimations for the population and where this error may have come from.

To wrap-up this activity, ask students to come up with problems that might limit the use of mark- recapture method. Discussion prompts for limitations:

- Will I get a good bear population estimate if I sample bears in Glacier National Park in February and then again in July?

- If I put a sticker on the back of a snake, will I be able to use mark recapture next year to learn about snake populations?

- If I catch a fish, mark it (and then do 10 minutes of other measurements on it, causing the fish to be very stressed), have I created a good mark and recapture study? Why?

- If I use a net with a large mesh size to capture small trout in a lake, have I created a good mark and recapture study?

Mention to students when estimating population sizes, assumptions are made. Ask them if they can think of any assumptions for either method they explored in this lesson.

Assumptions for the mark-recapture formula:

- The population is “closed”, so the number of individuals is constant (i.e., none of the organisms can leave or arrive in the population during the time between samples).

- All animals have the same chance of getting captured.

- Marking individuals does not affect their catchability.

- Animals do not lose marks between the two sampling periods.