Lincoln Index Bean Lab

Estimating Populations of Animals

*Problem: How can the population size of a mobile organism be measured?*

Introduction

**Background:**

The best way to measure the size of a population is to count all the individuals in that population. When determining the population sizes of trees or other relatively immobile organisms, this method is practical. If the organism is mobile, however, such as a fish, counting every individual would be difficult. Some individuals might be counted twice or not at all, since the experimenter would not know which fish had been counted and which had not. In determining populations of a variety of species, one method biologists use is tagging. Sometimes the ‘tags’ are stickers, ear clips, or notches made in the fins of fish. The purpose of these tags is to track migration patterns, health, and range as well as to help determine population numbers of species in an area. Determination of population occurs by capturing and tagging a sample of animals. Biologists then release the animals and allow them to naturally “redistribute themselves.” By then taking random samples and determining the percent tagged, biologists are able to hypothesize the population of the species in that area. This method – used to estimate the size of a mobile organism – is called the *Lincoln Index.*

**Goals:**

In this investigation, you will **model** a population of mobile organism, capture and make a sample of the population, and then capture a second sample. You will then **estimate** the size of the model population using the Lincoln Index. The accuracy of the Lincoln Index will be inferred by counting the model population.

**Concepts:**

To use the Lincoln Index, scientists capture a sample of the population they want to measure. They mark these individuals and release them. After waiting several days, the scientists return and capture another sample. Some of the individuals in the second sample will carry the mark from the first sample.

The scientists then use the following formula to estimate the size of the population:

Where **N** is the total size of the population

 **n1** is the size of the first sample

 **n2** is the size of the second sample

 **m** is the number of marked individuals recaptured in the second sample

The Lincoln Index makes several assumptions that must be met if the estimate is to be accurate. These assumptions are:

* The population of organisms must be closed, with no immigration or emigration.
* The time between samples must be very small compared to the life span of the organism being sampled.
* The marked organisms must mix completely with the rest of the population during the time between the two samples.



**Materials:**

* Paper bags
* Dry beans
* Colored markers

**Procedure:**

Experiment #1:

1. The paper bag represents the habitat of your model population. Add 1 to 2 small handfuls of dry beans to the habitat. The beans represent your organisms in your habitat. **NOTE: Do not count the exact number of beans until the end of both experiments.**
2. Remove a small handful of beans from the model habitat. This handful will be your first sample. The sample should be at least 20 beans but less than half of the total population.
3. Using a colored marker, mark all organisms in this first population. Mark them well enough to be easily identified if recaptured. Count the beans and record this number as n1 for Trials #1-6 in both Experiments #1 and #2 on the data table provided.
4. Place the beans from your first sample (n1) back into the habitat. Mix them well by shaking the bag.
5. Without looking, one member of your lab group should remove another handful of beans. The sample size should be about the same as the original. Count the total number of beans in the second capture. This is your n2 value for Trial #1 in Experiment #1. Notice that some of the beans will have the marking from the first capture. Count these organisms and record this number as m for Trial #1. If m is zero, do this step over again.
6. Return the organisms to their habitat and mix them well.
7. Repeat steps 5 and 6 five more times giving you a total of six trials for Experiment #1.
8. Using the Lincoln Index, calculate N for Trials 1-6 for Experiment #1.
9. Show all work on a separate page and to turn into the teacher.

Experiment #2:

*How does immigration and emigration affect the population size estimates calculated with the Lincoln Index? To test this situation:*

1. Remove 10 beans from the bag. Do not look at the beans; any 10 should be removed.
2. Come up to the front desk and count 25 new unmarked beans and add this to your habitat. This removal (emigration) and addition (immigration) represents change in the population size.
3. Without looking, one member of your lab group should remove another handful of beans. The sample size should be about the same as the original. Count the total number of beans in the second capture. This is your n2 value for Trial #1 in Experiment #2. Notice that some of the beans will have the marking from the first capture of Experiment #1. Count these organisms and record this number as m for Trial #1 in Experiment #2. If m is zero, do this step over again.
4. Return the organisms to their habitat and mix them well.
5. Repeat steps 3 and 4 five more times giving you a total of six trials for Experiment #2.
6. Using the Lincoln Index, calculate N for Trials 1-6 for Experiment #1.
7. Show all work on a separate page and to turn into the teacher.
8. **DO NOT THROW AWAY YOUR BEANS YET!**

Data Table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **n1****# of marked beans in sample** | **n2****Size of second (recaptured) sample** | **m****Number of marked beans recaptured in second sample** | **N****Population Estimate** |
| **Experiment #1** |
| Trial 1 |  |  |  |  |
| Trial 2 |  |  |  |  |
| Trial 3 |  |  |  |  |
| Trial 4 |  |  |  |  |
| Trial 5 |  |  |  |  |
| Trial 6 |  |  |  |  |
| **Experiment #2** |
| Trial 1 |  |  |  |  |
| Trial 2 |  |  |  |  |
| Trial 3 |  |  |  |  |
| Trial 4 |  |  |  |  |
| Trial 5 |  |  |  |  |
| Trial 6 |  |  |  |  |

**Note: If m is zero, put everything back in the bag and try again.**

**Analysis Questions:**

1. Use your data to estimate the average size of the mobile population in the model habitat for experiments #1 and #2.

Average estimated population size:

 Experiment #1:

 Experiment #2:

1. Count the number of beans in your bag. This number is your actual population size for Experiment #2. To get the actual number of beans used in Experiment #1 you must subtract 15 (because you took away 10 and added 25 to Experiment #2).

Experiment #1: Actual # of organisms (beans) in habitat:

Experiment #2: Actual # of organisms (beans) in habitat:

1. You will be asked to calculate the percent error for experiments #1 & #2. Before you do, what is your prediction regarding which experiment will be more accurate (will have a lower percent error)? Why?
2. Compare the average population estimates calculated with the Lincoln Index to the actual size of the population. Calculate the percent error for the two experiments by using the formula below. If you get a negative number, take the absolute value and make it positive.



**Actual**: actual population; **Experimental**: estimates calculated with the Lincoln Index

Experiment #1: Percent Error:

 Experiment #2: Percent Error:

1. Which experiment was more accurate?
	1. Was your prediction in question #3 correct? If not, why?
2. Did your results differ greatly from the actual number of individuals in the model habitat? Discuss at least 3 factors that might affect the accuracy of your estimates.
3. Is there an inference you can draw about the size of the samples/populations and the accuracy of the Lincoln Index?
4. In Experiment #2, how did immigration and emigration affect your population size estimates?
5. Calculate the population density for the beans in Experiment #1 in organisms / cm2. The bottom of the bag should be considered your organism’s habitat.
6. How can a data collector determine whether the population being studied is growing or declining?
7. Are the assumptions required for the Lincoln Index method valid for your observations? Why or why not? Why are these assumptions necessary?
8. To get an accurate estimate, why is it important that the beans “caught” during the first sampling are returned to the habitat unharmed?
9. When estimating an organism’s population size, why is it important that the time between first and second samples be a short time compared to the organism’s life span?
10. Based on what you observed in this exercise, do you think that the mark-recapture method is a good way to estimate population? Explain your answer.
11. From an environmental scientist’s perspective, discuss at least three reasons that it is important to be able to determine a population size. Provide examples of three organisms that could be examined using the Lincoln Index.
12. Imagine two ponds, one large and one small. You catch, tag, and release 20 goldfish from each pond. The next day, you catch 20 goldfish from each pond and count 8 recaptures from the small pond and 2 from the large pond.
	1. Estimate the population of goldfish in the small pond.
	2. Estimate the population of goldfish in the large pond.
	3. Why would a large pond tend to have fewer recaptures than a small pond?
13. Which of the following examples do you think reflects the largest population? Which reflects the smallest? **Explain** **your answer.**
	1. large first sample, large second sample, large recapture
	2. large first sample, large second sample, small recapture
	3. small first sample, large second sample, large recapture
	4. small first sample, small second sample, large recapture
14. The United States conducts a national census of its people every ten years. Numbers collected from this census are used to determine many things in each state. Could a sampling technique like this be used to calculate the population of the US? Would this type of population sampling cost more or less in the long run? Is this technique even ethical for human population estimation?

Practice Problems

1. In a woodland, the undergrowth was sampled for snails and 430 were found and marked. They were then released and the population similarly sampled after a two-week period. This second sampling produced 410 snails, 100 of which were marked. What is the estimated snail population?
2. Woodlice are terrestrial crustaceans that live under logs and stones in damp soil. To assess the population of woodlice in an area, students collected as many of the animals as they could find, and marked each with a drop of fluorescent paint. A total of 303 were marked. 24 hours later, woodlice were collected again in the same place. This time 297 were found, of which 99 were marked from the first time. What is the estimated population of woodlice in this area?
3. While studying field voles, an ecologist caught 500 and ringed a foot of each before releasing them. Every day for the next two weeks he examined the waste material found in the nests of their predators. He collected a total of 300 field vole skulls and 15 rings. How many field voles were probably in the area examined?
4. A population of meadow voles in an area of woodland was sampled using small mammal traps over a period of four days. On each occasion any unmarked individuals were marked and all the voles from the capture were then released. The following table represents the data obtained on each of the four days.

