IBL Institute
Inquiry Based Learning Educational Consultants

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We hope the lesson plans add value incorporating inquiry into your classroom and they become part of your teaching arsenal.

We would appreciate feedback. We would also appreciate a $20 contribution which helps us maintain the website so we can continue distributing these lesson plans to other educators.

Mail your feedback and contribution to:
IBL Institute
Attention: John Hoffman
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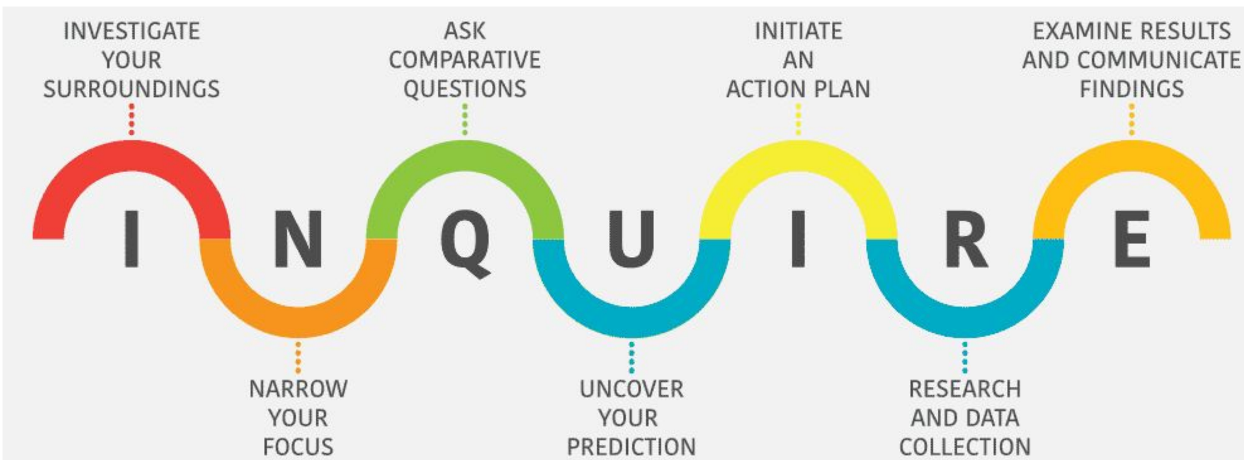
Estimating Biological Populations

An inquiry-based lesson plan designed to promote critical thinking by integrating content with traditional and inquiry-based learning.



All Hands-On Learning is NOT Inquiry-Based Learning
Inquiry-based learning is process-oriented and does not focus on a single correct answer, but rather emphasizes the process of gathering information and forming a conclusion. Traditional hands-on learning tends to be product-oriented and has students follow a pre-planned procedure to come to a single, specified answer.

Key Terms

Process skills (PS)

Skills that students will engage in while thinking critically. These include observing, questioning, predicting, planning, investigating, interpreting, and communicating. These skills are found in each step of the inquiry process.

Investigating Surroundings

Observing the overall surroundings. What do I see? What is understood about the topic? What still needs to be understood?

Narrowing Focus

Observing student needs and interests, as well as academic content. Find the balance between natural curiosity and standards-based concepts. What area can be concentrated on to best promote growth and learning?

Questioning

Forming questions about what is not fully understood. Comparative questions can be investigated. They need to be able to lead to an action plan. What can be found out?

Uncover Prediction

Logically thinking to form a prediction about what could happen. What do I expect to happen based on my experiences and knowledge?

Initiate Plan

Figure out the action plan. Design an experiment that will answer the comparative question. What can I do to answer this question? How can I find this out?

Research and Collect Data

Investigating the elements of the experiment. Researching and collecting data that applies to the action plan.

Examine Results

Interpreting the data collected. What does this data mean? What else do I want to find out?

Communicating

Communicating the information that was found to someone else. The way the data is presented. What will the audience want to know? What will the audience be able to understand about this?

Table of Contents

Overview

This is an inquiry-based learning lesson in which students learn about the Petersen-Lincoln estimator formula. Students will be engaged in a hands-on activity and perform an experiment to answer a comparative question regarding the fish population of two different bodies of water. Finally, the project will link IBL with the application of the formula by biologists and ecologists and the factors they must take into account when implementing it. More questions will emerge to continue scientific investigations and further the learning process.

Practical Application

This experiment allows students to understand a simple, yet effective, sampling technique that is used in the fields of ecology and biology for estimating populations. Each student will have practice with the scientific process, including interpreting and documenting data.

Lesson Plan

Grade Level: 6-8; Environmental Science

Class:

Teacher:

Time Required/Duration: One class period/ around 45 minutes

Objectives

1. Incorporate the process of inquiry-based learning into a traditional direct instruction classroom setting.
2. Students will be able to identify if a population is open or closed.
3. Students will be able to recognize when the Petersen-Lincoln estimator is applicable and when it is not.
4. Work together in groups to use the Petersen-Lincoln formula to estimate a closed population.
5. Students will be able to collect, tabulate and present scientific data.
6. Students will be able to uncover additional questions.
7. Students will be able to think critically about the data found and consider why data may have varied from the actual number.

Educational Standards

Scientific Inquiry, Practices and Applications

–All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.

–During the years of grades 5 through 8, all students must have developed the ability to: Identify questions that can be answered through scientific investigations; Design and conduct a scientific investigation; Use appropriate mathematics, tools and techniques to gather data and information; Analyze and interpret data; Develop descriptions, models, explanations and predictions; Think critically and logically to connect evidence and explanations; Recognize and analyze alternative explanations and predictions; and Communicate scientific procedures and explanations.

Math Standards

CCSS.MATH.CONTENT.6.SP.B.5
CCSS.MATH.CONTENT.6.EE.A.2
CCSS.MATH.CONTENT.6.EE.C.9
CCSS.MATH.CONTENT.7.EE.B.4
CCSS.MATH.CONTENT.7.SP.A.2
CCSS.MATH.CONTENT.HSS.MD.B.7

Science Standards

7.LS.2: In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors.

ENV.ER.3: Water and water pollution

Materials

Needed:
1. Pencils or pens

IBL Institute Provided at No Charge (Shipping and handling fees will apply):[1]
1. Marbles in two colors
2. Bowls
3. Measuring cups

To order the IBL Institute provided supplies, please contact Jessica Begonia at 419-223-1362. Supplies will be scheduled for delivery two days before the experiment starts.

Vocabulary

(See Appendix 4 for Vocabulary Defined)

Closed Population
Open Population
Discrete
Mark-Recapture
Petersen-Lincoln Estimator

[1] For each item, there will be enough for each group to have their own materials. Be sure to include the amount of groups you will have when ordering the materials.

Instructional Plan

The teacher will:

1. Split students into groups of 4-5. Give each group a container of marbles marked "Pond A: Woods" and a container of marbles marked "Pond B: Field."
2. Introduce the dilemma[2]: "A farmer owns two ponds of equal surface area, depth, and volume. One is right next to his largest field of crops, and the other lies deep within the woods on his property. He stocked them with the same amount of fish many years ago and fished them both equally. Over time, he spent less time on fishing and more on farming, and he currently has no idea how many fish are in each pond. His son wants to market one of the ponds as a local fishing spot, but neither the farmer nor the son knows which pond would be best (that is to say, which pond has more fish). The question is: Which pond has more fish, the pond in the woods or the pond next to his field?" **(INVESTIGATE SURROUNDINGS)**
3. Give students time to examine the containers, think to themselves, and talk with a partner about which pond might have more fish and why. Get students to consider what factors might have an effect on the fish populations of the different ponds. No answers should be given right now. At this stage, the point is to generate interest in the prompt and stimulate critical thinking. Have students share their ideas with the class. **(NARROW FOCUS)**
4. Give students a little more time to consider how they can figure out how many fish are in the pond without counting all of them. Again, have students share their ideas with the class.
5. Discuss the background science with your students.
6. Demonstrate the experiment in front of the class.
7. Have students write their predictions individually to the following questions:
    a. Which pond has more fish? Why do you think this?
    b. How many fish does each pond have?
    c. How close will the estimation be to the actual population?
    d. And/or others you come up with as a class.
    (ASK COMPARATIVE QUESTIONS)
    (UNCOVER PREDICTION)
8. Provide each group with data sheets, a sampling container, and replacement marbles.

[2] It is recommended to post this on the board for the class to read and refer back to. This can be found alone in Appendix One.

Instructional Overview

1. Introduce the students to the materials provided, discuss the logistics, and dynamics of the hands-on learning and make assignments.
2. Give students the background science and go over it.
3. Place the students in groups[3] [4] and place each group's materials (sampling container, replacement marbles, and data sheets and shown in Appendix 2) on their table.
4. Have students begin the experiment procedure outlined on page 14. The students will take the samples and record their data. Then, students will plug their data into the formula and find their estimations. **(RESEARCHING AND COLLECTING DATA)**
5. Pass out the worksheet (Appendix 3) to each group to complete together.
6. Pair groups with each other and have them discuss their data and worksheet.
7. Have a group discussion over the lesson and their thoughts on it.
8. Give students the student feedback form (Appendix 4).
9. Have students complete the exit slip before finishing the class period.

Post-Assessment

1. After the experiment is over and the data has been recorded, give students the worksheet (Appendix 3) to fill out as a group. Encourage discussion during this time, with each group member contributing their understanding about the lesson.
2. Keep students in their original groups, pairing them with another group[5] to discuss. They should bring the worksheet and datasheet to use as a reference. **(EXAMINE RESULTS AND COMMUNICATE FINDINGS)**
3. Students will share the information on their worksheets with the other group. They will compare their data and discuss similarities and differences between their work.
4. On the back of the worksheet, make notes of any important ideas discussed.
    a. These can be similarities, differences, or interesting findings from the discussion.

Exit Slip[6]

1. Before ending the period, have students get out a half sheet of paper.
2. Tell them to write down any other questions that could be answered using this sampling method.
3. Collect their answers before moving on or dismissing them. .

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[3] Groups of no more than five would work best, but alter to the needs of the classroom. Just be sure that each group will have another group to be able to discuss their findings.

[4] Designated group roles are beneficial to some classrooms. Suggested roles are Sampler (gets the samples and replaces the marbles), Recorder (records data), Manager/ Monitor (makes sure all work is accurate and on task), and communicator (communicates data and findings to group members and the other group)

[5] If possible, try to pair groups together that had differences in their work (estmations, procedures, etc.) as this will create more opportunity for discussion and critical thinking.

[6] If the class uses an online communication app (a discussion board, etc.), this can be done using that platform.

Background Science[7]

When performing research on a certain species of animal within a certain area, it is useful for biologists and ecologists to know how many of that species live in that area.[8] These scientists need an accurate method for estimating populations. The Petersen-Lincoln estimator is a relatively simple formula that lets scientists do just that:

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

N = *population (we cannot directly measure this number with the Petersen – Lincoln estimator)*
$\hat{N}$ = *estimation of population*
K = *number of species captured in second sample*
n = *number of species captured in first sample*
k = *number of species recaptured*

Using the Petersen-Lincoln estimator involves a technique called mark-recapture. Performing a mark-recapture study requires taking a sample of a species and then marking each individual in the sample. Marking includes techniques like fin-clipping, ear-tagging, giving the individuals collars, etc. Each animal is released, and then another sample is taken at a later time. Once recorded, this data can be entered into the formula, and the result that the Petersen-Lincoln estimator gives should be an accurate estimation of the population of that species within the given area. However, a few conditions need to be met in order for the formula to produce an accurate result:

- The animals are not harmed by the marking technique.
- The animals captured in the first sample become completely mixed back in with the rest of the population after the initial capture.
- The probability to capture a marked animal is the same as the probability of capturing any member of the population.
- The sampling is performed at discrete time intervals.
- The population is closed. This means that the population remains constant over the period of the study.
    - In an open population, changes occur due to birth, death, migration, etc.
    - If the period of study is small enough (as in this experiment), a population that is normally open can be sampled as a closed population.

There are some things to consider in a mark-recapture study, including:

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[7] Source: Henderson, P.A. Practical Methods in Ecology. "Mark-Recapture Methods for Population Size Estimation." pp. 48-59.
Source: Henderson, P.A. Practical Methods in Ecology. "Comparing the Magnitude of Populations – Trapping and Other Relative Abundance Methods." pp. 76-94

[8] To use this method on wild populations, either for research or demonstration, one must obtain a permit from their state's Department of Natural Resources.

- the accuracy required
- the possible population size
- the difficulty of capturing the chosen species

Why does the Petersen-Lincoln estimator work? Well, it is based on the assumption that each individual in the species being studied has an equal chance of being selected. Say we capture 10 individuals in the first sample, mark, and release them. If a quarter of the second sample are marked, then we would assume that the total number of marked individuals (10, the first sample) is a quarter of the population. We can do this because each individual had an equal chance of being selected. Therefore, we would estimate the total population at 40, because 10 is one quarter of 40.

About Inquiry-Based Learning As It Applies To This Lesson Plan

This is a project that works best when students work in small groups (4-5). Inquiry is collaborative in nature. The process takes advantage of students' strengths to contribute to the project. Some are great communicators, some are problem-solvers, and some have well-developed technical skills. In the workplace, we also work in groups. We work as part of a team. The inquiry process develops skills necessary to solve complex problems in the world.

The students will benefit from the background science of the Petersen-Lincoln population estimator. Make sure the section on the background science is available to each group. Some in the group may have little interest in the material provided whereas others will want to read it in depth, but the end result will be that everyone in the group will know more about this population estimation technique. It's important for them to know that the population must be closed and that each individual must have an equal chance of being sampled. It is also important that students don't attempt to count every fish (marble) in the pond (container). Connect the relevance of the group working with this formula as it relates to the comparative question. The Petersen-Lincoln estimator is an efficient formula that can be used to estimate populations when the certain conditions for using the formula are met. Biologists and ecologists can use it to monitor the health of an ecosystem and different species within ecosystems. They can monitor increases or decreases in populations over time by using multiple mark-recapture studies, and this information affects decisions on how to best manage certain populations within an ecosystem.

Investigate your surroundings and narrow your focus: Encourage each group to observe containers of marbles. Have them consider how many marbles are in each container and how they might figure that number out without counting. Have them discuss what factors might contribute to the differences in the populations of the two ponds. This is a good time for students to write down questions. We suggest having them write individual questions on individual pieces of paper so the questions can later be sorted. It's not important to sort those now, but this can be revisited once the students are more in tune with the inquiry process.

Ask comparative questions: At the heart of inquiry is the comparative question. Comparative questions are ones that can be investigated. Some questions are very good questions, but they are very difficult to investigate. For example: Why are butterflies attracted to my flower garden? Good question, but difficult to investigate. However, we can take that question and change it to: Are butterflies attracted more to red flowers or white flowers? Do you see where we are going with this? You can now design an experiment to count how many butterflies visited each of the colors and compare the results. More questions will come of this process. Do the findings hold up for different kinds of butterflies? Another experiment can be designed. In the case of the Petersen-Lincoln formula, the comparative question, at least initially, is being provided by you. This makes the lesson plan a guided inquiry. An open inquiry is one in which the students pick the topic, create the questions, create the action plan, etc. The comparative question for this lesson plan is: Are there more fish living in pond A or in pond B? Later, we will revisit the questions the students asked above and have them separate those questions that can be investigated and those that cannot. Often, questions that would be difficult to investigate can be made investigable by turning them into comparative questions.

Uncover your prediction: We are not talking about group-think here. What do you individually think? At this point, each group has containers of blue marbles (representing 2 ponds with a certain amount of fish) and a smaller container of red marbles, and soon they will have an experiment to follow. Each student will have a prediction and they should record that prediction. Which pond has more fish? Why might that be? How many fish does each pond have? How close will the estimation be to the actual population? A prediction is not the same thing as a hypothesis. A hypothesis might be: All swans are white. A prediction would be: I think the next swan I see will be white. A prediction is based upon the individual's experiences, observations, opinions, knowledge, and instincts.

Initiate an action plan: The experiment has been provided. The action plan was designed to help students answer the comparative question. The amount of marbles in each container is known, but it's still not one of those "do the experiment and I will let you know the right answer." There is no wrong estimation. The important aspect of the lesson is to have students thinking and working like scientists and assessing why the numbers they came up with were as close or far away to the actual number as they were. Ask the students to record their data on the data sheet provided. To make future lesson plans or repeats of this one more inquiry-based, simply ask them to make a data sheet and record their findings. Perhaps have half the groups use the data sheet provided and then let the other half come up with their own. Part of inquiry requires you to give up some control to allow your students to figure it out.

Examine results and communicate findings: Each group will present their findings. It is recommended in this lesson that students present to another group instead of to the whole class in order to avoid redundancy, but students may present to the whole class if you so choose. Students should fill out the data sheet that is provided to present their data. Alternatively, they can create their own data sheet and put together any graph, chart, or picture they might want for their presentation. A poster or section of white board is helpful. As a group, they share their findings. Each member usually participates. They share their individual predictions. They share results from each sampling and comment on whether they were close to the actual number of marbles in the container or not. They should also discuss how they could have changed their procedure to make the results more accurate (e.g., doing a better job of mixing the marbles to get a more random sample or taking a larger sample size). How do they answer the comparative question? What did they learn from the experience? Classmates then have an opportunity to ask questions to the presenting group.

Student/Teacher Roles for Each Step:

Investigate your surroundings:	The teacher and students are doing this
Narrow your focus:	The teacher and students are doing this
Ask comparative question:	The teacher is doing this

Uncover your prediction:	Each student is doing this
Initiate an action plan:	The teacher is doing this
Research and data collection:	The students are doing this*
Examine results and communicate findings:	The students are doing this

*The teacher or students may generate the data sheet

Experiment: Group Procedures

In this experiment, the marbles represent fish, and the containers that the marbles are in represent ponds. One "test" is made up of all of these steps. Start with the pond by the field.

1. Without looking inside the pond, use one of the small plastic cups to take a sample.
2. Count how many fish were taken in the first sample.
3. Record this number on your data sheet. This number is n, "First Sample."
4. Do **not** place these fish back in the pond! Count out an equal amount of red marbles. Place the red marbles in the pond that you sampled from. These red marbles represent the fish that you "marked" in your first sample.
5. Mix up the marbles.
6. Without looking inside the pond, take another sample.
7. Count how many fish were taken in the second sample (blue marbles **and** red marbles).
8. Record this number on your data sheet. This number is K, "Second Sample."
9. Count how many fish there are in the second sample that were also caught in the first sample (red marbles).
10. Record this number in your data sheet. This number is k, "Marked Fish in Second Sample."
11. Write out the following equation on your data sheet, plugging in all of the correct numbers.

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

    Note: $\hat{N} = \textit{estimation of population}$

12. Solve the equation. Write your answer on your data sheet.

You will do this test 3 more times in total, once more for the same pond, and twice for the other pond. Record all of this data in your data sheet.

Appendix 1: Dilemma

A farmer owns two ponds of equal surface area, depth, and volume. One is right next to his largest field of crops, and the other lies deep within the woods on his property. He stocked them with the same amount of fish many years ago and fished them both equally. Over time, he spent less time on fishing and more on farming, and he currently has no idea how many fish are in each pond. His son wants to market one of the ponds as a local fishing spot, but neither the farmer nor the son know which pond would be best (that is to say, which pond has more fish).

The question is: Which pond has more fish, the pond in the woods or the pond next to his field?

Appendix 2 – Data Sheet

Group members:

Pond by Field	1st Test Number of Fish	2nd Test Number of Fish
First Sample (n)		
Second Sample (K)		
Marked Fish in Second Sample (k)		
Equation $\hat{N} = \frac{K \times n}{k}$		

Pond in Woods	1st Test Number of Fish	2nd Test Number of Fish
First Sample (n)		
Second Sample (K)		
Marked Fish in Second Sample (k)		
Equation $\hat{N} = \frac{K \times n}{k}$		

Appendix 3 – Worksheet

Group members:

	1st Equation	2nd Equation
Pond by Field (real # of fish)		
Pond in Woods (real # of fish)		

1. **How close were your estimations to the actual number of fish?**
    a. **If your estimation wasn't close, why do you think that is? What could you have done differently?**
2. **What factors could affect the amount of fish in each pond?**
3. **If you were a biologist or an ecologist, how might you use this information?**
    a. **If your estimations were off, how might that impact the usefulness of the data?**
4. **Can you think of a different way to find a population estimate?**

Appendix 4 - Vocabulary Defined

Closed Population: The population remains constant over the period of the study.

Open Population: Changes within the population occur due to birth, death, migration, etc.

Discrete: Separate times that are distinct from one another.

Mark-Recapture: the common method for estimating populations through capturing a sample of a species (here, fish), marking and releasing them, then at a later time taking another sample of the species and observing how many were recaptured. It is used with the Petersen-Lincoln estimator to estimate population size.

Petersen-Lincoln Estimator: Formula used with the Mark-recapture method to find an estimation of the population size. The formula is:

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

N = *population (we cannot directly measure this number with the Petersen – Lincoln estimator)*
$\hat{N}$ = *estimation of population*
K = *number of species captured in second sample*
n = *number of species captured in first sample*
k = *number of species recaptured*

Appendix 5 – Student Feedback

1. **What did you learn from this?**

2. **What additional questions come to mind after having done the experiment?**

3. **Was it fun and/or interesting?**

Appendix 6 – Teacher Feedback

1. **What evidence suggests students grasped the major themes of the experiment?**

2. **Do you anticipate other guided or open inquiry projects arising from this project? What questions did the students ask that suggest understanding and interest in the subject?**

3. **To what extent did this project fit into your curriculum and teaching agenda?**

4. **Would you consider doing this again?**

5. **What would improve the experience?**

Please return completed surveys to jessica.begonia@alloway