Estimating Fish Abundance - Mark Recapture Method

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Grade level: 7th – 9th (see basic questions) or 10th – 12th (see advanced questions)

Class size: 15 – 30

Group size: 3-5

Setting: computer lab (or students bring laptops)

Time needed: 50 minutes

Equipment needed: Computers with Microsoft Office©, calculator, Swedish Fish® or Goldfish® Crackers (100 for group 1 and 3; 150 for Group 2), (Alternatively, lesson can be conducted with dry kidney beans, or scrap paper), scissors and/or a marker.

Objectives

Composite Learning Objective: Students will learn the basic procedure by which fisheries managers calculate an estimated population size (N) in a closed system.

Knowledge Outcomes:

- Students will learn the basic assumptions of mark-recapture population estimation, specifically the assumptions of a population estimate calculated using the Lincoln-Peterson method.
- Students will learn how sampling effort can affect estimated population sizes.

Skills Outcomes:

- Students can calculate population size using the Lincoln-Peterson Method. Additionally, students can calculate a 95% confidence interval.
- Students can apply the Lincoln-Peterson Method to actual data from the Black River Streamside Rearing Facility and determine an estimate of the adult male Lake Sturgeon population in Black Lake in 2018.

Disposition Outcomes:

- Students will have a better grasp of how fisheries managers calculate the estimated population size of a threatened fish species.
- Students will view how managers calculate the harvest quota using actual data, gaining an appreciation for how data collection can inform conservation and management efforts.

Background

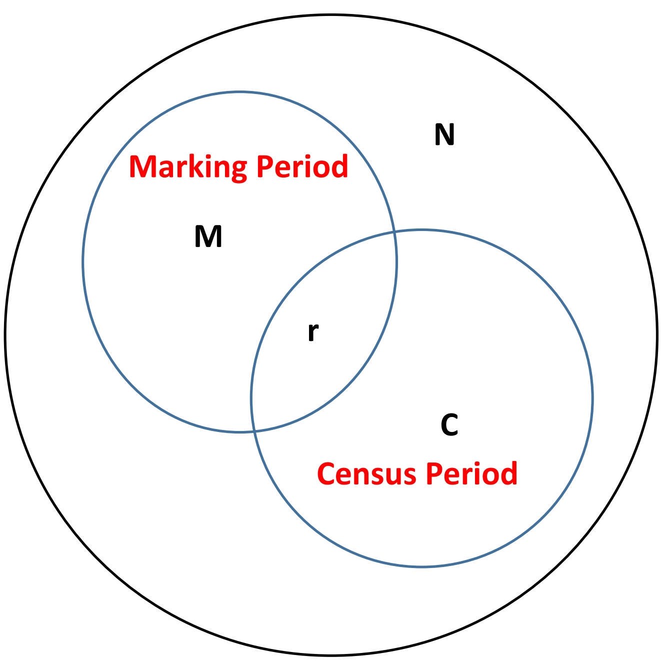
Lake Sturgeon are a highly mobile species that seasonally migrate from the Great Lakes to river habitats to spawn. As a result, Lake Sturgeon population numbers can be difficult to effectively estimate in most systems. As a result of overfishing, habitat loss, and pollution, many Lake Sturgeon populations were reduced or, in some cases, eliminated from their historical range by the early 1900's. Lake Sturgeon are classified as **Endangered**, **Threatened**, or of **Special Concern** in 19 of the 20 states of its current range, and protected in the Canadian waters of the Great Lakes. In some systems, harvest seasons exist, though restrictions on the number of fishes harvested by size, sex or percentage of the population are set.

Lake Sturgeon reach **reproductive maturity** much later than other fishes common to the Great Lakes region. A male Lake Sturgeon reaches maturity around age 15, while a female Lake Sturgeon may not reach maturity until age 25. As they age on a time scale similar to humans, Lake Sturgeon present a unique challenge to managers looking to restore historical populations and manage existing fisheries.

To manage annual **harvest** and stocking goals, fisheries managers require estimates of **population size**. Managers can use "**Mark-Recapture**" techniques to estimate population size without handling every individual in a population. Calculating a population estimate requires two sampling visits. During the first visit (the "**marking period**"), the sample crew will collect as many individuals as possible in a standardized time period. Each individual captured will be given an identifying mark. Lake sturgeon are generally marked with a **PIT (passive integrated transponder) tag,** which can identify each individual captured. After marking, all fish are released back into the system and given time to redistribute. During the second visit (the **"census period"**), the sample crew will, again, capture as many individuals as possible in a standardized time period. Unlike the first sample period, the crew will be looking for **"recaptures,"** or those fish which were marked during the first collection period.

Using the data collected during the two sample periods, we can calculate an estimate of the total population. The ratio of the number of individuals marked to the estimate of the population size is relative to the ratio of recaptured individuals to the total number captured during the census period. By cross-multiplying, we can solve this equation for "N," or our estimate of the population size.

This is represented visually as:



$$\frac{M}{N} \approx \frac{r}{C}$$

$$N * \frac{r}{C} \approx M$$

$$N \approx M * \frac{C}{r}$$

$$N \approx \frac{MC}{r}$$

N = Estimated population size

M = Number of individuals captured and marked during the Marking Period

C = Total number captured, including recaptures, during the census period.

r = Number of recaptures

Definitions

- **Endangered –** A species of animal or plant that is seriously at risk of extinction.
- **Threatened -** Any species which are vulnerable to endangerment in the near future.
- **Special Concern** - Though not endangered or threatened, the species or has unique or highly specific habitat requirements or deserves careful monitoring of its status.
- **Reproductive maturity** - The capability of an organism to reproduce.
- **Harvest –** To take or kill for food, sport, or population control.
- **Population size** is the actual number of individuals in a population.
- **Estimated Population size (N) -** is the estimated number of individuals in a population.
- **Mark-Recapture** – A technique by which an estimated population size (N) is calculated by multiplying the number of marked individuals during the "marking period" by the number of individuals captured during the "census period", then dividing the product by the number of individuals "recaptured" during the "census period."
- **Marking period (M)** – The first sampling period of a Mark-Recapture survey. During this period, all individuals captured are marked, and released.
- **PIT (passive integrated transponder) tag -** a small radio transponder that contains a specific code, which allows individual fish to be assigned a unique 10 or 15-digit alphanumeric identification number.
- **Census period (C)** – The second sampling period of a Mark-Recapture survey. During this period, all individuals are checked for marks from the first period. The number of recaptures is documented as well as the number of first time captures.
- **Recaptures (r)** – Individuals captured during the "Census Period" which were captured and marked during the "Marking Period."
- **Immigration –** New individuals migrate into the system.
- **Emigration –** Individuals migrate out of the system.
- **Potamodromous** – A fish that migrates to reproduce within fresh water only
- **Iteroparous –** An organism that can undergo many reproductive events throughout its lifetime.

Students will use a simple "Lincoln-Peterson" design, which operates with the following assumptions:

1. All individuals in the population have an equal chance of being caught.
2. Marking does not alter an individual's behavior making them more likely to leave the area, more susceptible to predation, or influence their likelihood of being recaptured.
3. There is no movement of new individuals into the population during the sampling period as this changes the ratio of marked vs. unmarked individuals in the population. This results in an increased likelihood of capturing unmarked individuals, increasing your population estimate. **(Immigration).**
4. Fish leaving the population does not occur during the sampling period as this changes the ratio of marked vs. unmarked individuals in the population. This results in a decreased likelihood of

capturing both marked and unmarked individuals, which can alter your population estimate **(Emigration).**

5. No new fish (births) can enter the population, nor can fish die.

Part 1. Mark Recapture Activity (7^{th} – 12^{th} grade)

In part 1, we will be estimating the population size of Swedish Fish® or Goldfish® Crackers so that you can examine the effect of violating assumptions on the final population estimate. Group one will mark a number of "fishes" to simulate a marking effort. Group two will add unmarked individuals (immigration/birth) after the marking period. Group 3 will remove individuals at random (emigration/death) after the marking period. If the teacher would prefer work in smaller groups, groups one through three can be replicated, as needed.

Part A – Testing Assumptions

1. Provide each group with 100 Swedish Fish® or Goldfish® Crackers.
2. At random select 10 individual fish and mark them. If using Swedish Fish® or Goldfish® Crackers, perform a "fin-clip" by removing a small portion of a fin.
3. Reintegrate population allowing for random redistribution of marked and unmarked individuals.
4. Students in Group 1 can move on to step 6. Students in Group 2 should add an additional 50, unmarked fish to their population. Group 3 should remove 50 fish from their population at random. Take care to remove this fish without noting whether the fish is marked.
5. After fish have been redistributed, randomly sample 10 fish, recording the number of recaptured fish from the marking period (ie: fin clipped fish). These fish are the "marked cohort."
6. Perform the following calculation:

$$N = \frac{MC}{r}$$

where:

N = Estimated population Size
M = The number marked during the "marking period" (10)
C = Those captured during the "census period" (C = 10)
r = Those captured during the "census period" which were marked during the "marking period"

7. Compare group results, identifying how violating the assumptions of the Lincoln-Peterson method changes the estimated population size (N).

Part B – Modifying Effort

1. Split students into two groups – “low effort” and “high effort.”
2. Provide each group with 100 Swedish Fish® or Goldfish® Crackers.
3. Low effort group – At random, select 10 individual fish and mark them. High effort group – At random, select 25 individual fish and mark them.
4. Reintegrate population allowing for random redistribution of marked and unmarked individuals.
5. Make sure you don’t eat any fish! As seen in Part 1, this can affect your population estimate.
6. Low effort group – At random, select 10 individual fish recording the number which were recaptured from the marking period. High effort group – At random, select 25 individual fish recording the number which were recaptured from the marking period.
7. Perform the following calculation:

$$N = \frac{MC}{r}; \text{ where:}$$

N = Estimated population Size
M = The number marked during the “marking period” (10)
C = Those captured during the “census period” (C = 10)
r = Those captured during the “census period” which were marked during the “marking period”

8. Compare group results, identifying how violating the assumptions of the Lincoln-Peterson method changes the estimated population size (N).

Part 2. Mark Recapture – Black River Streamside Rearing Facility Data (10th – 12th grade).

In part 2, we will take the concepts learned in part 1, and apply them to actual data collected by the field crew at the Black River Streamside Rearing Facility in 2017 and 2018. For this activity, you will use the BlackRiverMales20172018.xlsx spreadsheet.

Left: 23 mm Radio Frequency Identification Tag (RFID). Right: Technician Zack Witzel implanting an RFID tag into an adult Lake Sturgeon.

Lake sturgeon are **potamodromous** (live in lakes, migrate upstream to spawn) and **iteroparous**, meaning they spawn multiple times during adulthood. We can take advantage of that strategy to estimate the population size of males migrating upstream during two consecutive years. The Black River Streamside Rearing Facility uses Radio Frequency Identification (RFID) tags to collect data on adult fish moving in and out of the Upper Black River, MI (Figures 1 and 2) during the spawning season. Like a PIT tag, a RFID tag is a small radio transponder that contains a specific code, which allows individual fish to be assigned a unique alphanumeric identification number. However, a RFID tag is much larger (12 mm PIT vs 32 mm RFID), with a much larger detection range. When a tagged fish passes a detection antenna, the unique tag ID is detected and stored in a database with the date and time the tag was detected. From this data, Black River Streamside Rearing Facility staff can evaluate behavioral data for each fish migrating the river in a given year. Specifically, we can determine if a specific male is captured during 2017 (the "marking period") or in 2018 (the "census period"). For this lesson, we will assume the Black River and Black Lake are a single, closed system.

1. In the "2017 Male Captures" tab, you will find data on the male Lake sturgeon detected in 2017.
    a. "RFID Tag" is the unique ID of each male which entered the river in 2017.
    b. "Capture Date" is the first date the fish was detected in the spawning grounds in 2017.
2. Using the "2017 Male Captures" Tab, determine the number of males detected in the spawning grounds in 2017. These males represent the fish captured in the "Marking Period" (M).
3. Using the "2018 Male Captures" tab determine the number of males detected in the spawning grounds in 2018. These males represent the total captured in the "Census Period" (C).
4. Finally, in column H in the "2018 Male Captures" tab, we marked whether a fish was captured both in the marking period and the census period. A fish with the label "Yes" represents a capture in both years. These fish are your "Recaptures" (r).
5. Using the skills learned in Part 1. Estimate the population size (N) of male Lake sturgeon in the Upper Black River, MI in 2018.

Lesson Questions

Basic Questions (7^{th} – 12^{th})

1. How did the resulting population estimate from the Groups differ in Part A when assumptions were violated? Why would Groups 2 and 3 answers differ from Group 1?

2. How did the resulting population estimates differ between the low effort and high effort groups?

3. What can we conclude about the amount of effort we put in to sampling a population?

Advanced questions (10^{th}-12^{th})

4. Fisheries managers use Mark-Recapture population estimates to calculate the number of fish that can be harvested on a system. The Black Lake system allows a seasonal annual harvest of 1.2% as described in the Black Lake Management Plan. Based on your calculation of the male population size in Black Lake, what would a hypothetical harvest number be?

5. A major assumption of a mark recapture model is that you have an equal likelihood of catching fish during the marking and recapture periods. Lake sturgeon females do not return to the river to spawn annually, but rather spawn every 3-4 years. How might this affect calculated population size if female data were included?

6. The actual calculated population size of Black Lake Male Lake sturgeon in 2018 was 637. How does your calculated population size compare?

7. Bonus question: A 95% confidence interval is an estimate of where the calculated sample mean (or in this case, estimated population size, N) would fall if we took repeated samples. The 95% confidence level loosely quantifies the level of confidence with which one can expect to find the true population size in the calculated interval. In short, the 95% confidence interval quantifies uncertainty in our calculation of the population, as we cannot be 100% confident in the population size unless we sample every single individual fish in a system. The wider the interval, the greater the uncertainty in our sample collection. We can decrease uncertainty by increasing sample effort.

   Utilizing a "normal approximation," one can calculate the 95% confidence interval of Lincoln-Peterson mark-recapture estimate as follows. For this population, calculate the 95% confidence interval. Does the true population size (calculated in question 6) fall in this interval? Use the equations below.

Upper Limit:

$$\frac{M}{\frac{r}{C} - 1.96 * \left(\frac{1}{2C} + \sqrt{\left(1 - \frac{r}{M}\right) * \frac{\frac{r}{C} * \left(1 - \frac{r}{C}\right)}{C - 1}} \right)}$$

Lower Limit:

$$\frac{M}{\frac{r}{C} + 1.96 * \left(\frac{1}{2C} + \sqrt{\left(1 - \frac{r}{M}\right) * \frac{\frac{r}{C} * \left(1 - \frac{r}{C}\right)}{C - 1}} \right)}$$