Estimating Population Size: Mark Recapture

SC Academic Standards: 4.L.5A; 5.L4A; 6.L.4B; 7.EC.5A,B; H.B.6A,C.

NGSS DCI: 5-ESS3.C; MS-LS2A,C,D; MS-ESS3.C; HS-LS2.A,C.

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.4; S.1A.5; S.1A.6; S.1A.7

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Stability and Change; and Systems Models.

Focus Question(s): Why is being able to estimate a population's size accurately important? What are some of the issues / assumptions surrounding accuracy of population estimates? How accurate is the Lincoln-Peterson mark-recapture method for estimating population sizes?

Conceptual Understanding: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. Limiting factors include the availability of biotic and abiotic resources and challenges such as predation, competition, and disease.

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively stable over long periods of time. Fluctuations in conditions can challenge the functioning of ecosystems in terms of resource and habitat availability

Each plant or animal has a unique pattern of growth and development called a life cycle. Some characteristics (traits) that organisms have are inherited and some result from interactions with the environment.

In all ecosystems, organisms and populations of organisms depend on their environmental interactions with other living things (biotic factors) and with physical (abiotic) factors (such as light, temperature, water, or soil quality). Disruptions to any component of an ecosystem can lead to shifts in its diversity and abundance of populations.

Background: A number of basic measurements are used in **describing populations and communities**. Among these are population density, abundance of particular species, distribution of species, population size, and population age structures. Ecologists call a total count of all individuals in a population a **census**, but it is seldom possible to count every individual within a wild population. At best, ecologists can look at a small portion of the whole population and make inferences about the whole. Environmental Scientists use data like these as **baseline** for comparison to data taken after an environmental impact.

The study of animals involves considerably more problems than the study of plants. Animals are generally harder to see, harder to catch, and more subject to mortality. **Sampling techniques** for estimating population size include line and belt transects, trawls, and nets, which may be good for some types of organisms but not all. Insects can be collected with dip nets and aerial nets; aquatic organisms are usually caught with dip nets, bottom nets and plankton tows; soil organisms are caught by putting a soil sample in a Tullgren or Berlese Funnel; and small mobile animals are often captured with traps or drag nets (or by jumping, running, grabbing, spearing and snatching on the part of the ecologist). Marking captured individuals and returning them to the ecosystem is necessary in order to get population data such as age, longevity, growth rates, dispersal and home range.

Marking techniques may include use of paints or dyes, strap tags of metal which can be wrapped around the animals leg (birds), or attached to a dorsal fin (fish), or pit tags that are inserted into the body cavity (snakes, fish) and detected using a radio-transmitter. Some animals are marked by clipping a toe (frogs, salamanders, lizards, small mammals) which involves the removal of the distal part of one or more toes. Snakes can be marked by removing certain patches of scales. More secretive animals can be marked using radioactive tracers placed in their food source (this works well in tracking animals that have radically different phases in their lifestyles; for example: an adult butterfly can be fed radioactive material. This material is incorporated into the egg which then turns into a radioactive larvae and then adult.)

A population estimate of a highly mobile species is usually done by a **Mark / Recapture** technique. One such technique is called the **Lincoln - Peterson method.** This involves capturing as many individuals from a population as you are able to, marking them in some way and then releasing them. After a period of time, you once again capture individuals from the population and compare then number of recaptures (the ones bearing the "mark") with the total number captured.

Population estimates make several **assumptions** and provide an accurate estimate ***if*** the assumptions are correct:

1. All individuals in the population have an equal and independent chance of being captured

2. No change in the ratio of marked to unmarked animals (i.e. no significant additions or deletions from the population between capturing events - either by births, deaths or immigration / emigration)

3. The marking technique must not increase the chance of either death, survival or recapture

4. Marked individuals distribute themselves randomly with the unmarked individuals (so there is the same opportunity for recapture)

No technique for population size estimation is foolproof and many are **biased** (either underestimating or overestimating population sizes) so we generally calculate a confidence limit as well as a population size estimate. This limit is a measure of our confidence in the accuracy of the estimate. Generally, the larger the sampling effort (or sample size), the more accurate the population estimate.

This lab will demonstrate the Mark / Recapture technique on a population of meal worms (*Tenebrio*). ***Tenebrio*** are beetles that lay eggs which hatch after 7-10 days. The young beetle, or larva, is the grub-like "meal worm" which will pupate after 2-3 weeks and metamorphose into the adult beetle.

Materials: a large container of larval mealworms, paint markers (4-5 of each color, one different color for each group), plastic cups, newspapers to protect desktop from paint, calculators. Mealworm larvae, packs of 100, are found at Carolina Biological for about $12 (or pack of 500 for $30). You will also want some bran meal (about $10 at Carolina), a plastic shoebox to store them in, a couple slices of potato to feed them.

Previous Knowledge: (animal biology): Within the animal kingdom there are over 35 phyla, including phylum Arthropoda, the joint footed animals. These animals all have an exoskeleton, or carapace, that must be shed (molting) in order to grow. Joints in the exoskeleton allow for movement, especially useful in the terrestrial environment without the buoying water to hold them up, and the exoskeleton itself also helps protect the animal from enemies. There are hundreds of thousands of different arthropods, so many that the phylum arthropoda is divided into subphyla like subphylum insecta (which has the true "bugs") and the subphylum crustacea, which included crabs, shrimp, lobsters and the isopods.

Mealworms are actually the larval form of the darkling beetle, *Tenebrio molitor*, so they are not actually worms at all! Real worms, like the earthworm, are in phylum Annelida. Mealworms are in the Phylum Arthropoda, Class Insecta and Order Coleoptera (beetles). Like all holometabolic insects, mealworms go through four life stages: egg, larva, pupa, and adult. Adults live about 80 days. Females lay about 80 small white eggs. After four to 19 days, eggs will begin to hatch. These tiny mealworm eggs are food for their predators, such as reptiles. During the larval stage, mealworms (about an inch long) will undergo repeated molting between bouts of eating various vegetation or dead insects. This takes place 9-20 times (instars) during 12-54 days, as it gets too big for its current exoskeleton. During its last molt, it loses its carapace before curling into its pupal form. The mealworm remains in its pupal stage from three days to around 30 days (dependent on incubation temperature and overwintering). The pupa, about 3/4 inch long, starts off a creamy white color, and changes slowly to brown during its pupation. The beetles and larvae eat decaying leaves, sticks, grasses and occasionally new plant growth. As general detritivores, they also eat dead insects, feces and stored grains.

<u>Procedure:</u> **(Teacher note:** take the total amount of mealworms and divide into as many cups as you have groups – each group gets a cup. The students count all their mealworms, so, adding the totals together we know how many mealworms total that we have (NA). Have students count and mark all mealworms in their cup, then bring all mealworms back to you. You will mix all the mealworms together then divide all mealworms back into cups – so now each group has some mealworms of each color).

1. Count all the mealworms in your cup and record that number as M.

2. Mark all your mealworms with your group's color, using a paint parker. You don't need to pain the entire mealworm, just enough to see it's color. Use newspapers to cover the desk so paint doesn't get all over, and watch out for those mealworms that crawl around trying to find cover. Mealworms are negatively phototactic.

3. Bring all your marked mealworms to your instructor. Your instructor will mix them with the other groups then divide the mealworms back into cups. Take your cup back to your desk.

4. Count all the mealworms in your second cup. This time you need a total number (t) and a number that had your group's mark, or color (R).

5. Calculate a population size estimate using the **Lincoln - Peterson estimator**:

   N_E = Mt / R Where N_E = population size **<u>estimate</u>**
   M = # marked when first caught
   t = total number caught in second sampling
   R = number of recaptures in the second sample (those bearing your color mark)

6. The **Percent Error** can be calculated as follows:
   $$\%E = \left|(N_E - N_A) \div N_A\right| \times 100 =$$

   Where N_E = population estimate (from the Lincoln-Peterson estimator) and N_A = the actual (known) population count. Remember that the I I symbols mean to take **the absolute value** of the number between the bars**.**

Group	M	t	R	N_E	%E
Blue					
Red					
Green					
Purple					
N_A = Total (actual size of population)					

Table 1. Data for mark recapture population estimate of mealworms.

Data Analysis:

$N_E = Mt / R$

Where N_E = population size **estimate**
M = # marked when first caught
t = total number caught in second sampling
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Extensions: You can do this in a number of ways, including using beans (http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=7&ved=0CEQQFjAG&url=http%3A%2F%2Fwhsbio.sfinstructionalresources.wikispaces.net%2Ffile%2Fview%2Fbean%2Bpopulation%2Bestimation%2Blab.doc&ei=2gcsVLqHJNf_yQTDw4LQCw&usg=AFQjCNHzWRGRx_D1-5TA7sN2wEHi_3KJXw&bvm=bv.76477589,d.aWw) M&M's (http://www.csiro.au/helix/mathsbyemail/activity/markandrecapture.html), cars passing through an intersection at morning rush hour and evening rush hour, and so forth. I like using mealworms because it is a chance to bring live animals into the classroom - then I can also study their lifecycle, or do the mealworm phototaxis lab, or feed them to the class fish or lizard.

Reflection Questions:

- **Did a group do something wrong if they have a large percent error?** (No – its just the luck of the draw, how many mealworms got apportioned to each cup. In real life, sometimes the estimates are way off).

- **What are wildlife management implications if your estimate isn't close to the actual population size?** (Imagine an endangered species and you underestimate the population size – if you think the population is larger than it is you may not protect it adequately, and without a minimum population size many species go into decline (like wolves, who require a group to raise young, not just one male and one female). Also, in terms of management, say for fishing quotas (tuna, halibut, salmon) or for white tail deer hunting permits: if you overestimate the population size you may give out too many permits and too many will then be hunted and killed, and it will take the population time to recover).

Models and Explanations: In this lab we explored one technique, the Lincoln Peterson mark recapture method, to estimate population size. **A student who demonstrates understanding** of this concept can explain 1) why population size estimates are important, can 2) discuss some factors (assumptions) that must be true in order to get a fairly accurate estimate and 3) discuss implications of estimates that are far off from the actual population size, especially as it might apply to endangered species. Last, a student should be able to calculate a population estimate given M, t and R, and describe a variety of ways that animals might be captured and / or marked.

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<u>**Student Worksheet:**</u>

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Group	**M**	**t**	**R**	**N_E**	**%E**
Blue					
Red					
Green					
Purple					
N_A = Total (actual size of population)					

Table 1. Data for mark recapture of mealworms.

Now, Calculate an estimated population size based on your data (because this is a lab, we know the actual size of the population and so can also do a % error. My population estimate (N_E) is ___________________.

N_E = Mt / R Where N_E = population size **estimate**
M = # marked when first caught
t = total number caught in second sampling
R = number of recaptures in the second sample (those bearing your color mark)

The **Percent Error** can be calculated as follows: $\%E = \left|\left(N_E - N_A\right) \div N_A\right| \times 100 =$

Where N_E = population estimate (from the Lincoln-Peterson estimator) and N_A = the actual (known) population count. Remember that the I I symbols mean to take **the absolute value** of the number between the bars**.**

Reflection Questions:

1. How close was your population estimate to the actual population size?

2. Was it an overestimate or an underestimate?

3. What is the value of being able to estimate the size of a population (for example, the Bluefin Tuna population? White - tail Deer?)?

4. What are three ways an ecologist might sample an animal population? On which animals will these techniques work best?

One way an ecologist might sample a plant population?

Three ways an ecologist might mark a captured animal. On which animals will these techniques work best?

5. Use the following equation to answer this question: N_E=Mt/ R
You are out in Wyoming, catching and marking coyotes. You catch 23 coyotes and mark them. They are released back into the wild. Two weeks later, you catch 15 coyotes. 10 of them have the mark you put on them. What is your population estimate?