

Exercise 12: Population Ecology

Learning Goals

1. Know terminology associated with population biology.
2. Explain how population biologists carry out research on rare and endangered animals.
3. Utilize the mark-recapture method to estimate the size of a population.
4. Use demographics to analyze the current status of a population and use the information to inform management decisions.
5. Explain the ecology of the Northern Spotted Owl and associated environmental concerns.

Evolution Connections

Population Biology for Conservation

In addition to performing a census of population size, ecologists are also interested in a population's effective size, which is a measure of how many and which individuals in a population are actually reproducing. Effective population size is important because it tells us how much genetic diversity is in a population, which dictates how well that population can adapt to environmental challenges (such as introduced pathogens or changing climate).

The Speke's gazelle (*Gazella spekei*) is an endangered gazelle found in the horn of Africa. Due to recent habitat loss and hunting, natural populations of the Speke's gazelle (Figure, courtesy of the St. Louis Zoo) declined to very low numbers and a captive breeding program was initiated with four wild-caught animals (Templeton & Read 1984). The breeding program was successful, and over the course of ten years, there were 19 gazelles born in the St Louis zoo. However, researchers discovered through a genetic analysis of effective population size that almost all of these gazelles were highly inbred because only one male had contributed offspring to the captive population. In fact, inbreeding is unavoidable in very small, isolated populations because eventually, all individuals become related. Thus, this population had a very low effective population size, fewer than 19. With the low level of genetic diversity in the population, the gazelles would be vulnerable to disease, predation, and environmental stress such as drought. Collectively, these consequences are known as inbreeding depression, and present a serious problem in the conservation of endangered species.

To prevent inbreeding depression in Speke's gazelles, scientists increased the effective population size of the herd by introducing unrelated individuals to the breeding program. Today, although they are still endangered in the wild, thousands of individuals exist in captive herds that can help with future reintroduction efforts used in the recovery of this species.

By Loren Sackett



Introduction

Human perturbation of habitats has led to a potentially prominent threat to modern ecosystems by the invasion of species. Non-native invasive species that are introduced into a new habitat are typically used to demonstrate this threat because species within ecosystems are adapted to that ecosystem based on millions of years of interactions. When a new species is introduced, if conditions are right, the species has an enormous potential to proliferate within the new ecosystem. But what about **native invasions** due to habitat alterations, such as those caused by climate change or local human activities? Can alterations in habitat caused by people favor one native species over another? This is a question that can be addressed by population biologists and will be the topic of lab this week.

Prior to recent human activities, the Pacific Northwest (Northern California, Oregon and Washington) was dominated by what is known as late successional or old growth forests. Old growth forests are characterized by trees greater than 200 years of age, that have a high number of snag or broken tops, that shed needles and create a relatively sparse understory. Many animals have been adapted to thrive in old growth forests such as northern flying squirrels. Northern Spotted Owls, in particular, have many adaptations for old growth forests. One such adaptation is related to nest building, they prefer to nest high up in the snags of large old-growth trees and they build their nests accordingly. Periodically in the past, fires and other natural disturbances would wipe out vast areas of old growth forest and create early successional patches within the old growth forest that would favor animals with different adaptations such as Barred Owls. Over the last 200 years, human disturbance through logging has greatly changed the vast expanses of old growth forests and has changed much of the forest habitat in the Pacific Northwest to new growth forests (< 200 years). In the 1980's population biologists noticed populations of Northern Spotted Owls were declin-

ing rapidly and in 1990, the Northern Spotted Owl was designated as threatened under the endangered species act. Since 1990 a recovery plan has been enacted and an attempt to preserve critical Northern Spotted Owl habitat was carried out. In lab today, you will act like a population biologist and gather information on a representative current Northern Spotted Owl population. Before you begin your study, you will need background information.

Population Growth and Demography

The rate of growth of a population is determined by four factors: **births**, **deaths**, **immigrations** (animals entering the population from another population), and **emigrations** (animals leaving the population). In many cases, and for cases in this exercise, immigration and emigration account for little change compared with that of births and deaths. Therefore, we will concentrate on influences of births and deaths on the size and growth of populations.

Birth rates and death rates may depend upon the age structure within the population. For instance, grizzly bears can live more than 20 years, they typically do not start reproducing until an age of 5, and their mortality rate is high for the first 4 years of life, decreases in middle-aged bears, and increases after an age of 15 (Knight and Eberhardt 1985). Therefore, the rate of growth of a population of grizzly bears would depend on the relative frequencies of young individuals, middle-aged individuals, and old individuals in the population. The study of age-specific and other statistical factors influencing the size of a population is called **demography**. Population demographics are determined through research, and organized into **life tables**. Two types of life tables are **cohort life tables** and **static life tables**. A **cohort** is a group of individuals born at the same time or during the same season. A cohort life table is developed by marking a cohort at

Exercise 12: Population Ecology

birth, following them throughout their lives and estimating age-specific **fecundity** (reproduction) and survival rates. A cohort life table is developed through a longitudinal study and may take many years. For instance, to develop a cohort life table for grizzly bears it may take longer than 20 years of research. In contrast, a static life table is developed by aging and marking a randomized sample from the entire population all at the same time, then following them for a short period of time to determine age-specific fecundity and survival rates. Age-specific fecundity of male animals is often difficult to determine especially when the mating system is not monogamous. Therefore in the life table, you will examine age-specific fecundity and mortality of females only. The following symbols are important to know for evaluating life tables.

x = age class. An age class is a group of individuals in the population that are a certain age (0, 1, 2, 3, ... years old), or group of ages (0-4, 4-8, 8-12 ... years old). Age classes are usually determined by the ability of a researcher to distinguish the age of the organism, the size of the population, and the generation time of the organism.

s_x = survival in age class. The probability an individual survives from the beginning of an age class to the end of the age class and is calculated by the equation:

$$\frac{\text{\# alive in age class}}{\text{\# alive in age class} + \text{\# dead in age class}}$$

l_x = survival to age class x . The probability that an individual survives from the beginning of its life to age class x . The survival to age class x can be determined by multiplying values of s_x for all age classes $\leq x$. For example, if you wanted to determine l_3 , you would multiply s_1 , s_2 , and s_3 .

b_x = age-specific fecundity. The number of female offspring produced by a female during age class x . Under situations where you cannot determine the sex of the offspring you can assume that the sex ratio of males to females is equal. You can determine the age-specific fecundity rates from the equation:

$$b_x = \frac{\text{\# of offspring in age class}}{\text{\# of females in age class}} \times 0.5$$

R_o = net reproductive rate. The number of female progeny produced by a female during her lifetime. The net reproductive rate can be determined by summing the products of l_x and b_x in each age class ($l_1b_1 + l_2b_2 + l_3b_3 \dots$). This value indicates whether each individual can replace itself in its lifetime. If $R_o = 1$ the individual replaces itself exactly. If $R_o < 1$ then the individual does not replace itself, and thus, the population is decreasing. If $R_o > 1$ then the individual over-replaces itself, and thus, the population is increasing. If R_o is 0.5 then the individual is only replacing 1/2 of itself over its life. Note that R_o is an average value for all individuals in the population.

Mark-Recapture Method of Estimating Population Size

One method of estimating total population size from a sample is the mark-recapture method. The mark-recapture method involves capturing a certain subset of the total population, marking them in some way that they can be recognized in the future, releasing them back into the population, then capturing another subset of the population. For this lab you will use a modified mark-recapture method and use a sight resight method. From knowing the total number of individuals marked, and the number of recaptures during the second capturing bout, an estimate of the total population size (N) can be made from the following equation.

$$N = \frac{(\text{total \# in pop. with a band}) (\text{\# of living owls seen})}{\text{\# owls seen with a band}}$$

The total # in the population with a band is shown in Table 12.2. In order for the mark-recapture method to be valid, the probability of capturing any individual in the population must equal the probability of capturing any other individual. When using traps, animals cannot become trap-shy or trap-happy. When using a mark-resight method, the resighting trips must be randomized rather than on the same pathways over and over.

Radio Telemetry

Radio telemetry is important in population biology. Radio telemetry utilizes a transmitter that emits a signal. The transmitter is usually in the form of a small battery-powered object that is placed on the animal. The transmitter may be in the form of a collar (for larger animals), a backpack for birds, it can be surgically implanted into the animal, or it can be glued on the outside of the animal such as on the shell of a turtle. The signal from the transmitter is then picked up by a portable receiver and an antenna carried by the researcher. Transmitters can vary in the frequency of their signal so that the receiver can be adjusted for the given transmitter. Radio Telemetry has many useful applications to population biologists.

- **Visually Locating Animals.** The antenna picks up a directional signal (i.e. the signal is loudest when the antenna is pointing directly at the transmitter). This allows the researcher to use the signal to walk in and visually sight the animal. This is helpful if you are doing a cohort population study, because you can locate the animal, then gather data such as the number of offspring and its mate. It also helps with behavioral studies because you can find the animal in the field for behavioral observations.
- **Mapping Animal Locations.** Telemetry can be used to locate animals from many miles away. To do this, researchers use triangulation. Telemetry produces a directional signal. A biologist can get a signal and determine its direction then move to a second location to get a second signal. By plotting each signal on a

map, the biologist can get an approximate location of the organism. This is very useful for estimating home-range sizes and tracking dispersing animals. Do males disperse farther than females? How far do animals disperse? At what age do animals disperse?

- **Determine Survival Rates and Causes of Mortality.** You can use telemetry to determine mortality. For a little more money, the transmitter can be equipped with mortality sensitivity. When the transmitter does not move for more than a day, the signal doubles in frequency. Then as a researcher you can locate the dead organism and determine the cause of death.
- If you even have more money, you can use transmitters that send their signal to a satellite and you can use GPS to give you a periodic location of the organism without constantly going out in the field to track the organism. (A more time efficient method, but not as fun.) This application is especially useful for migrating animals such as whales.

Some problems with radio telemetry exist. The radio telemetry transmitter is typically very small so it does not negatively impact the organism, thus battery life is limited. Capturing and re-capturing the animals is time intensive and may have an impact on the animal as well, so banding birds or tagging mammals is still often preferable to radio telemetry for many population studies.

Procedure 1

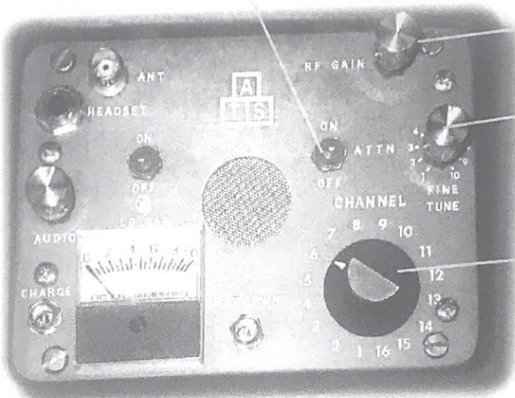
Overview. Since we have 4 classes doing this lab simultaneously, we have two set ups. One set of directions will be for rooms C-147 and C-159 and the other set of directions will be for rooms C-148 and C-151. For each class, there are two transmitters out the north side of the Ramaley Building by Boulder Creek. One transmitter is located with a simulated, 9-year-old female, Northern Spotted Owl. Your assignment is to use telemetry to walk in and visually sight her. Once you have sighted the owl you will determine the number of fledglings she has. The second transmitter is mortality sensitive. Your assignment is to determine whether the simulated animal with the transmitter is alive or dead.

1. Familiarize yourself with the receiver and antenna. Use the photograph associated with your receiver (FM17 or FM100) for guidance. Attach the antenna to the receiver and turn the knob on the receiver to the correct input range for transmitter 1 (rooms C-147 and C-159 use 150.154 MHz, rooms C-148 and C-151 use 150.064 MHz). Make fine adjustments with the "fine tune" knob. Put the strap of the receiver over your shoulder so you are free to move.

Note. The battery life on the FM17 is not long so be sure to turn off the power when you are not using the receiver.

2. Hold the antenna over your head and listen for the beep. Once you get a signal, find the direction of the loudest signal. You may want to adjust the "fine tune knob", the "gain knob", the volume and you may want to turn on the attenuation if you need to. A very low sharp "beep" is best. Sometimes turning the volume way down until you barely hear the beep can help. Once you have a direction for the loudest signal start walking in that direction. Keep going until you find the marked owl up in a tree.
3. Record the number of fledglings she has in the caption of Table 12.3.
4. Readjust the input range to that of transmitter 2 (150.083 MHz for C-147 and C-159, and 150.024 MHz for C-148 and 151). Determine if the simulated animal tagged with transmitter 2 is dead or alive. Transmitter 2 is mortality sensitive, meaning that if the animal has not moved in 24 hours the frequency of the beep speeds up and gives three quick beeps. Record info. in table 12.3.

Attenuation. Start with this off and if you cannot determine direction then try with it on.



Gain. Adjust the sound so you can hear the beep the best.

Fine tune to the transmitter here. Look at Table 11.1 to get the range per channel and then adjust the fine tuner.

Choose the channel that corresponds with the transmitter. Use Table 11.1 for guidance.

Photograph 1. Functions of various knobs and switches on the FM-17 receiver.

Table 12.1. The range (MHz) associated with each channel on the FM-17 receiver. Note that on the receiver there is a "fine tune" dial. Get the exact frequency of the transmitter, choose the correct channel and make final adjustments with the "fine tune" knob.

Channel	Range (MHz)
1	150.004 - 150.016
2	150.014 - 150.026
3	150.024 - 150.036
4	150.034 - 150.046
5	150.044 - 150.056
6	150.054 - 150.066
7	150.064 - 150.076
8	150.074 - 150.086
9	150.084 - 150.096
10	150.094 - 150.106
11	150.104 - 150.116
12	150.114 - 150.126
13	150.124 - 150.136
14	150.134 - 150.146
15	150.144 - 150.156
16	150.154 - 150.166

Procedure 2:

Overview: We have set up a simulated owl population along the south side of Boulder Creek just north of the recreation center. The simulated population consists of laminated photographs of owls varying in sex and age attached to trees. Instead of trapping the owls, you will make observations and record data. Suppose that you are in the middle of a research project and you have already captured and banded many of the owls in the population. Information on the banded owls is in Table 12.2

There are 5 age classes: 0 to 1 years old, 1 to 2 years old, 2 to 8 years old, 8 to 13 years old and 13 to 18 years old. Each group of students will get one identification guide to help you sex and age the owls.

Your assignment is to use observations to estimate the number of owls in the population and the net reproductive rate (R_0) of the population.

1. Divide into groups of three and each group gets one pair of binoculars.
2. In population biology, transects are often used to help remove subjectivity. A transect is typically a straight line that you would walk to make your observations and is derived with your compass. One person in the study group should use the compass to keep everyone on the transect. Once you have established the transect you want to use, walk the transect looking for living owls in trees and dead owls on the ground or in the grasp of a predator. When you see an owl alive or dead you need to:

- classify it into a specific age class;
- record whether it is alive or dead
- determine the sex;
- determine if it is banded;
- if living and female, determine the number of fledgelings.

Note. Some owls are marked with three-colored bands around their lower legs. If you can recognize the color code on the band around the foot, you can look at Table 12.2 to determine its sex and age class. Dead owls can be anywhere including in the mouths or talons of predators.

3. Record your data in Table 12.3.
4. Return to your classroom. Use Table 12.3 to fill out Tables 12.4 and 12.5 in your lab manual.

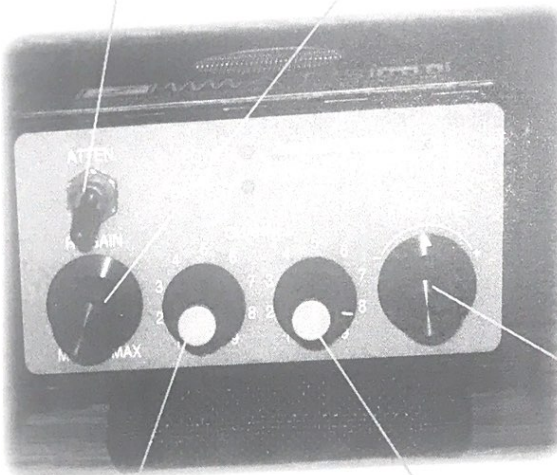
Attenuation on/off switch. Start with this off and if you cannot determine direction then try with it on.

Use the gain knob to adjust the sound so that you can hear the beep the best.

Power
Volume

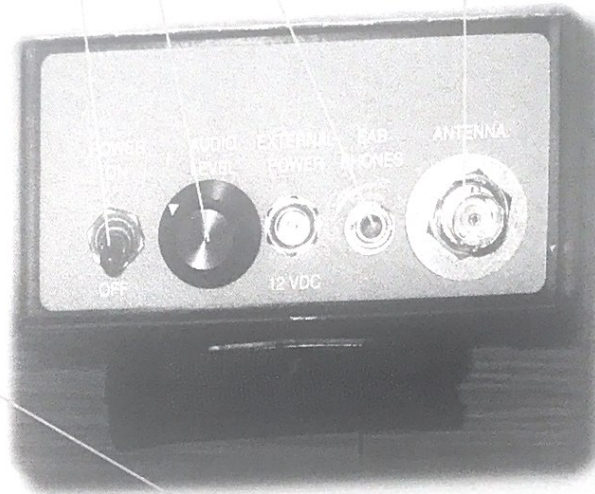
If the surrounding environment is too noisy, headphones are an option.

Location to attach the antenna cable.



Determine the MHz of your transmitter and set this channel dial to the tenths place. For example, for a transmitter at 150.085 this dial should be on 0.

Set this channel to the hundredths place corresponding with the MHz on your transmitter. For example, for a transmitter at 150.085 this dial should be on 8.



Fine tune the "beep" to a high pitched, sharp sound with this dial.

Photograph 2. Functions of various knobs and switches on the FM-100 receiver.

Table 12.2. A table listing banded owls and their demographics. Bands are located on the lower legs of marked owls. Bands are coded from the outside band to the inside band. See the identification guide for an example.

Band Colors			Age Class (years old)	Sex
Outside (top)	Middle	Inside (bottom)		
Blue	Red	Blue	0 - 1	Female
Blue	Orange	Blue	0 - 1	Female
Blue	Green	Blue	0 - 1	Female
Blue	Yellow	Blue	0 - 1	Female
Green	Blue	Green	0 - 1	Male
Green	Red	Green	0 - 1	Male
Green	Yellow	Green	0 - 1	Male
Green	Blue	Red	1 - 2	Female
Red	Green	Red	1 - 2	Female
Red	Yellow	Red	1 - 2	Male
Red	Orange	Red	1 - 2	Male
Red	Orange	Green	1 - 2	Male
Green	Orange	Yellow	2 - 8	Female
Yellow	Red	Yellow	2 - 8	Female
Yellow	Orange	Yellow	2 - 8	Female
Yellow	Green	Yellow	2 - 8	Female
Yellow	Blue	Yellow	2 - 8	Female
Orange	Blue	Orange	2 - 8	Female
Orange	Red	Orange	2 - 8	Male
Orange	Green	Orange	2 - 8	Male
Orange	Yellow	Orange	2 - 8	Male
Orange	Blue	Yellow	2 - 8	Male
Orange	Green	Yellow	2 - 8	Male
Red	Green	Yellow	8 - 13	Female
Red	Blue	Yellow	8 - 13	Female
Red	Yellow	Blue	8 - 13	Female
Green	Yellow	Blue	8 - 13	Male
Green	Blue	Yellow	8 - 13	Male
Green	Blue	Red	8 - 13	Male
Green	Red	Yellow	13 - 18	Female
Red	Green	Blue	13 - 18	Male

Literature Cited

Knight, Richard, R. and L. L. Eberhardt. 1985. Population dynamics of Yellowstone grizzly bears. *Ecology* 66(2):323-334.

Identification Guide

Age Class 0 - 1

Female

Male



Age class 0 - 1 is easily recognized by the white, fuzzy feathers. Females are usually larger and have longer tail feathers typically with more than 3 bands.

Age Class 1 - 2

Female

Male



Age class 1 - 2 owls are smaller with rounded faces and a lot of white on the face. Males are usually smaller, their tails are shorter but wider and are more rounded at the base.

Age Class 2 - 8

Female

Male



Age class 2 - 8 owls are larger, faces are wider with more distinct patterns on plumage. Females are usually larger and have longer, more-narrow tail feathers typically with more than 3 bands.

Age Class 8 - 13

Female

Male



Age class 8 - 13 owls are a little larger, face is more square, white on face is reduced, spots on breast are less defined. Males are typically smaller with rounded, shorter tails.

Age Class 13 - 18

Female



Male



Age class 13 - 18 owls are slightly larger, face is more square, white on face is reduced, spots on breast are less defined. Females are typically larger with longer less-rounded tails and tail feathers with more than 3 bands.

Banded Owls



Many of the owls have been marked with color-coded bands on their lower legs. Codes are read from outside in. This band is coded as green, red, yellow.

Dead Owls



Dead owls will either be in the talons of a predator such as this Great Horned Owl or they will be on the ground with a few tears to indicate death.



Table 12.3. Record the data you collect in the field. Note: living females should be the only ones with fledglings. Note: Only one group member needs to fill this out. Use these data to fill out Table 12.4. Everyone needs to complete other tables.

[illegible]

Table 12.4. Use this table for information concerning dead individuals and for tallying various demographic parameters of living individuals from Table 12.3. (1 point)

Age Class	Males		Females		
	Alive	Dead	Alive	Dead	Offspring
0 - 1					
1 - 2					
2 - 8					
8 - 13					
13 - 18					

Table 12.5. A life table for Northern Spotted Owls estimated from a simulated population. Since number of offspring by females includes males and females and the sex ratio of females to males is 1:1, the calculation for fecundity rate of females is multiplied by 0.5. Values for l_x should be calculated as the product of values of s_x for age classes $< x$. For example $l_1 = s_1$, $l_2 = s_1 s_2$, $l_3 = s_1 s_2 s_3$. (2 pts)

Age Class (AC)	$\frac{\# \text{ living in AC}}{\# \text{ dead} + \# \text{ alive in AC}}$	$s_1 s_2 \dots s_x$	$\frac{\# \text{ offspring in AC}}{\# \text{ females in AC}} \times 0.5$	$l_x b_x$
	s_x (Females)	l_x	b_x	

$R_o = \text{sum of } l_x b_x \text{ in each age class}$

1. Estimate the # of owls in the population. Show your work. (1 point)

2. The recovery plan for Northern Spotted Owls has been worked on since 1992. From the results of your study, is the recovery plan working for your population. Why or why not? (3 points)

3. One potential problem with the long term recovery of Northern Spotted Owl populations is that of native invasions due to changes in habitat. One potential native invader is the Barred Owl. Your assignment is to go on-line and find at least one peer reviewed journal article that describes original research on the relationship between Northern Spotted Owl populations and Barred Owl populations. Briefly write a synopsis of the study and provide the literature citation. (3 points)