TEACHER GUIDE

Ecology Disrupted: Using real scientific data about daily life to link environmental issues to ecological processes in secondary school science classrooms

How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?

Major highways that connect Los Angeles and Las Vegas run through bighorn sheep habitat. These highways allow travel between Los Angeles and Las Vegas in just four hours, but what do they mean for the sheep?

Students will use media, source materials, and real scientific data to investigate the question "How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?"

- **Essential Question:** How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?
- **Key Topics:** Habitat, Populations, Inbreeding, DNA, Measuring and Map Analysis, Genetic Diversity
- **Level:** 7th-12th grade. Modify according to grade level needs.
- **Pacing:** Four lessons over six class periods
- **Student Handout:** Investigation Booklet PDF | Word

Note

This resource was produced with two overarching goals - to connect students to the scientific process in the real world and to connect students with the role of ecology in daily life**.** We engage students in science through videos about scientists and their research and by asking students to manipulate published data that are the basis of the media the students watch. We engage students in ecology by studying the environmental issues that result when human daily life disrupts ongoing ecological interactions.

Lessons and Materials

Lesson 1: Setting the Stage and the Scientific Process in Action (45 min. period)

Students learn about Dr. Clinton Epps and his research study on isolation and inbreeding in bighorn sheep. The bighorn sheep population, natural and human-made barriers, and the connection between daily life and wildlife populations are introduced.

Materials:

- (Video) Highways Block Bighorn Sheep
- (Slideshow) Setting the Stage PowerPoint | PDF
- (Video) Scientist Profile: Dr. Clinton Epps
- Popsicle Sticks or M&Ms for inbreeding demonstration (optional)

Lesson 2: Exploring: The role of isolated populations in inbreeding (45 min. period)

Students use short case studies to understand the detrimental effects of inbreeding on human and animal populations.

Materials:

- (Slide Show) Inbreeding Case Study PowerPoint | PDF

Lesson 3: Investigating, Representing, and Making Meaning from Data (two 45 min. periods)

Students learn how DNA is collected in the field, use maps and rulers to analyze the genetic data collected by Dr. Clinton Epps, and then make claims based on the data. Includes an optional activity for more advanced students on understanding F_{ST} values.

Materials:

- (Slideshow) Analyzing the DNA Datasets PowerPoint | PDF
- (Map) Map with Highways drawn PDF
- (Slideshow) Representing Data on a Map PowerPoint | PDF
- (Image) Map of Student Data PDF

Lesson 4: Ecology Disrupted: Changes in habitat can unexpectedly disrupt populations (two 45 min. periods)

Students extend what they have learned about the unexpected consequences of human daily life on habitat and bighorn sheep populations to habitats and populations of other animal species.

Materials:

- (Video) Science Bulletin: Roads Influence Animal Genes
- (Video) Science Bulletin: New Blood Gives New Life to Florida Panthers
- (Video) Science Bulletin: Loggers Imperil Monarch Butterflies
- (Video) Science Bulletin: Plastic Trash Threatens Remote Seabirds
- (Video) Science Bulletin: Species and Sprawl: A Road Runs Through It

What We Are Hoping For: Our Learning Goals

Students will develop a deeper understanding of the following big ideas:

1) **Ecological and Biological Concepts in the Context of Human Impact**
   a. Habitat
      i. Habitat is the full area and physical environment where an organism lives.
      ii. Habitat fragmentation, when an ecosystem is broken into pieces, can threaten the survival of some species.
   b. Populations:
      i. A population is a group of individuals of one species living in the same area that interbreed.
      ii. Small populations may result in inbreeding, which can often cause health problems.
   c. Inbreeding:
      i. Inbreeding is when close relatives mate and reproduce.
      ii. Inbreeding can cause health problems or death in individuals by making it more likely for defective traits to occur.
   d. DNA is a tool scientists use to understand genetic exchange amongst interbreeding populations:
      i. Populations that interbreed (exchange genes) will be more genetically similar than populations that do not breed.
      ii. Scientists can study the similarities/differences in DNA to measure how frequently interbreeding/gene exchange occurs and whether populations are isolated from one another.

2) **Human Impact in the Context of Daily Life**
   a. The daily lives of people impact the ecology of their surroundings.
   b. Highways and other human activities can cause habitat fragmentation and threaten species survival.
   c. Highways, built to help people move around, can isolate populations from one another leading to inbred populations that are less able to survive.

3) **Nature of Science**
   a. Science is based on evidence, which take many forms and is referred to as data. Inference and conclusions are based upon data.
   b. Scientists are people who ask questions about the natural world and gather and interpret data to address those questions.
   c. Communication is central to science so that others can verify data and build upon research.
   d. Scientific research can help people learn about how daily life interacts with the natural world.
   e. Science is a human endeavor.

4) **Data Representation**
   a. Scientists use different tools to represent data.
   b. These tools help scientists compare and interpret data.
   c. Measuring distance on a map can help interpret meaning from data.
   d. Some representations are better than others based upon the type of data collected and the needs of analysis.

Links to Standards

Next Generation Science Standards
Next Generation Science Standards- Middle School (Grades 6-8)
Next Generation Science Standards- High School (Grades 9-12)

Common Core Standards

Common Core - Middle School (Grades 6-8)
Common Core - High School (Grades 9-10)
Common Core - High School (Grades 11-12)

Lesson 1: Setting the Stage & the Scientific Process in Action

Daily Checklist

At the end of the lesson students will have:

1. _____ Been introduced to the case study goals and Dr. Clinton Epps, the scientist who conducted the research
2. _____ Watched the *Science Bulletin: Highways Block Bighorn Sheep*
3. _____ Watched the Setting the Stage Slideshow that includes:
    - Habitat and mating habits of bighorn sheep.
    - Maps of the bighorn sheep range,
    - Why highways between LA and Las Vegas are vital to Nevada's economy,
    - Potential impacts of highways on wildlife (roadkill, pollution).
4. _____ Discussed natural and human-made barriers
5. _____ Discussed the effect of isolation on mate choice
6. _____ Watched the profile of the Dr. Clinton Epps and discussed the motivations for his research
7. _____ Discussed the DNA collection in the video to understand how DNA patterns can reveal levels of breeding
8. _____ Completed an activity that models how DNA can be used to detect isolated bighorn sheep populations
9. _____ Completed the *Lesson 1: Setting the Stage* and *Scientific Process in Action* section of the Investigation Booklet

Materials:

- (Video) Highways Block Bighorn Sheep
- (Slideshow) Setting the Stage PowerPoint | PDF
- (Video) Scientist Profile: Dr. Clinton Epps
- Popsicle Sticks or M&Ms for inbreeding demonstration (optional)
- **Student Handout:** Investigation Booklet PDF | Word

1) Introduce students to the case study goals and Clinton Epps, the scientist who conducted the research

Introduction to the Investigation

This case study examines the work that Clinton Epps, now a professor at Oregon State University, conducted while he was a graduate student. This work took him to the deserts of California and Nevada to study desert bighorn sheep. As part of his work, he wondered how major highways that were built to connect Los Angeles and Las Vegas might affect the bighorn sheep populations. These highways mean that people can travel between Los Angeles and Las Vegas in just four hours, but what do they mean for the sheep?

This case study will delve into his published peer-reviewed work. Case study goals:

- Learn about real scientists and their stories—what motivates them, how and why they ask questions, and what type of data or evidence they collect to address their questions.
- Connect regular daily life activities to ecology
- Connect disruptions in ecological function to environmental issues

2) Show students the *Science Bulletin, Highways Block Bighorn Sheep* to introduce students to the case study.

Introduction

This *Science Bulletin, Highways Block Bighorn Sheep* that we are about to watch is based on the scientific research of Clinton Epps. He was interested in understanding if highways built to connect Los Angeles and Las Vegas might affect bighorn sheep populations. We will be exploring the work reported in this video over the next week.

Suggested Questions for Thought

Ask students to write any questions they have about the video while they are watching it. (Collect these questions and after class, write the questions on a piece of chart paper that can easily be seen throughout the unit. Check off answered questions as you go along.

3) Use the prepared *Setting the Stage* slideshow to provide more information on the bighorn sheep habitat and breeding habits and the human motivation for building large highways in the area. The section below provides more details on the material in the slideshow.

- Use the maps to start a discussion on bighorn sheep and their habitat.
- Show pictures of bighorn sheep and describe important elements of their biology. Like:
    i. They live in small mountaintop populations of often less than 50 individuals.
    ii. Males travel through valleys from one high rocky mountaintop to another to find females to mate.
    iii. Teacher Tip: Make sure that students know that populations are individuals of the same species that live in the SAME geographic location.
- Use the series of maps of bighorn sheep habitat to discuss the 27 mountaintop populations of bighorn sheep. Help students interpret the patterns on the map.

Discussion Suggestion

Key Idea: Bighorn sheep live in small mountaintop populations in the desert, and they breed with nearby bighorn sheep populations.

Slide of map of bighorn sheep habitat with vegetation

What are we looking at?
Answer: A close up-view of the bighorn sheep habitat

How would you describe their habitat, the terrain? Use the colors and patterns on the map to help you?
Answer: You can see some green vegetation (along the coast, but that is not the bighorn sheep range), but mostly it looks like a brown desert. The terrain looks very mountainous.

Slide of map of bighorn sheep habitat with vegetation and bighorn sheep range overlaid in brown

Where do bighorn sheep live?
Answer: They live on the mountaintops. You can tell because their range is shown in brown and overlays the mountains.

Slide of map of bighorn sheep habitat with vegetation, bighorn sheep range (brown), and human population centers (black) and highways (yellow)

What are we looking at now? What do the different colors represent?
Answer: The colors represent where people live (black) and show the major highways (yellow) that run through the sheep habitat. Refer to key in the next slide.

Different slide of map of bighorn sheep range that contains the same information in a different representation (This representation is the map that the students will be using in the rest of the unit)

This is the same map as shown previously, only a slightly different representation. Let's go over the key.
Show the next slide with a map that contains a key.

Background on Bighorn Sheep:

- There used to be at least 500,000 bighorn sheep in the U.S.
- Now there are less than 200,000 sheep and fewer than 20,000 desert bighorn sheep with some subgroups considered to be endangered.
- The biggest threats to the sheep are thought to be from livestock. Overgrazing and diseases spread from domestic sheep to the wild bighorns have caused major population declines.
- Recent habitat fragmentation caused by urbanization is a new threat to bighorn survival.
- Each population is restricted to its mountaintop and separated from others by the desert below.
- It is thought that mountaintop populations sometimes go extinct, only to be re-established by sheep from other mountains.
- Movement of sheep between mountaintops is critical for the long-term survival of the sheep.

Discussion Suggestion

Key Idea: Highways are important to the tourist economy of Las Vegas.

Use the map of major roads and highways of the same region to introduce why highways are important to the Nevada economy.

a. About half of Las Vegas tourists arrive by car, most from California.
b. Tourism supports ~300,000 jobs
c. Tourists contribute billions of dollars to the Nevada economy, which helps to fund schools, museums, and city services.

Use the picture of the Bighorn sheep and highway to connect the highways to the study.

Discussion Suggestion

Key Idea: There are many potential ways that highways can impact the bighorn sheep or other wildlife.

Scientists became curious about whether the highways that are so important to the Vegas economy were impacting the sheep.

How might highways impact living things that live near you? What are the consequences?
Answers: Cars run over animals on the roads; an increase in driving leads to increased emissions and air pollution; pollutants runoff roads into waterways; cars are loud and can scare away wildlife

Students may suggest that roadkill harms animals. However, efforts to control roadkill also harm animals. Point out the fence on the next image, which is also a factor in harming the sheep.

Discussion Suggestion

Key Idea: Humans try to limit roadkill by putting up fences.

What do you notice about this picture?
Answer: Humans have put up a fence between the highways and the terrain.

Why were the fences installed?
Answer: To protect people and cars from the harm of colliding with animals at high speeds.

4) After the slideshow, connect the highways to natural and other human-made barriers

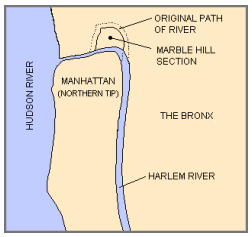
Discussion Ideas:

Key Idea: Boundaries can be natural or human-made.

What are some boundaries with which you are familiar? Are they natural? Are they human-made? Or both?

Sample Answers: (The following examples are taken from some northeastern and mid-Atlantic states.)

- Natural Boundaries:
  - National
    - Lake Ontario separates Buffalo from Toronto.
  - State
    - New York State from New Jersey by the Hudson River.
    - New Jersey from Pennsylvania by the Delaware River.
  - New York City - Water is a natural barrier that defines the different boroughs of New York City.
    - Staten Island is separated from all the other boroughs by the New York New Jersey Harbor Estuary,
    - Brooklyn from Queens by the Newtown Creek,
    - Manhattan from Queens and Brooklyn by the East River,
    - Manhattan from the Bronx by the Harlem River.
    - The case of Marble Hill: It defies the boundary made by water. Marble Hill is a neighborhood in the borough of Manhattan that sits on the other side of the Harlem River connected to the Bronx. What happened? At one point the Harlem River flowed north of Marble Hill, but people rerouted the river, cutting off Marble Hill from the rest of the borough, but linking it to the Bronx (see figure below left).



- Human-Made Boundaries
  - Some of the U.S. border with Mexico or Canada
  - The rectangular boundaries of the Western states as compared to the jagged borders of the original 13 colonies.
  - The Mason-Dixon Line is a line that beginning in 1820 began to be seen as marking the cultural boundary between northern and southern states. States north of the line were considered northern and states south of the line were considered southern (see figure above right).

For NYC: What are some boundaries in your neighborhood? What marks the borders of where you walk? Is there a big road, a highway, train tracks, a park, a large open space, a big building, water, or something else that limits your movement in your neighborhood?

Answer: Answers will vary depending upon their neighborhood. For example, big cross streets like Houston St, 14th St, 34th St. etc. can act as barriers to movement. Hills can also act as borders. Big highways like the Cross Bronx or the BQE are also barriers. Parks often separate neighborhoods too.

Extension

Key Idea: Just like habitats, neighborhoods can be separated from each other by imperceptible boundaries.

Instructions: Get into a group with 3 other students that live in your neighborhood. Discuss the different boundaries of your neighborhood, and then present your ideas to the class. Maps are a great way to represent your ideas to the class. [You can draw the boundaries of your neighborhood.]

Teacher Tip:

The terms "wrong side of the tracks" and "other side of the tracks" are based in how neighborhoods are separated from each other by human-made structures.

5) Discuss the effect of isolation on mate choice.

Discussion Suggestions:
Key idea: Artificial boundaries can decrease mate choice and isolation.

If you and your neighbors never crossed out of the boundary of your neighborhood and people in nearby neighborhoods did the same, how would that affect the people in your neighborhood?
Answers: It would limit food, romantic, and entertainment choices. People would be isolated.

Why is population isolation a negative? How would you feel about only being allowed to hang out with the people in this class? How about for other living things?
Answers: Limited mate choice—bad for people and other living things! Limited mate choice can lead to having to pick undesirable mates.

Key Idea: Highways act as barriers preventing the movement of bighorn sheep, leading to limited mate choice

Isolated populations can lead to limited mate choice. How might highways do the same for bighorn sheep?
Answers: Highways act as barriers to sheep movement between mountaintops. Sheep have limited mate choice because they cannot cross highways to find new mates.

6) Watch the Scientist Profile: Dr. Clinton Epps to learn more about his research and see the bighorn sheep in their natural habitat and connect the profile to Dr. Epps' motivation for the research and remind students that this case study is based on published scientific data.

Discussion Suggestions

How could Clinton Epps make such an impact on science even though he was only a student at the time?
Answer: He had a creative impulse and he did the hard work necessary to pull it off. He also had a group of collaborators to work with as well as guiding him.

What motivated Dr. Epps to do fieldwork outside of his lab and office?
Answer: Dr. Epps needs to feel connected to his research, which he finds difficult to do when he is at a desk. He likes to visualize his research, so he often goes to field sites so that he can really understand the places that he studies.

How common do you think it is for scientists to work outside?
Answers: Depending upon the subject, scientists often work outside. Ecologists, Earth scientists, botanists, entomologists, primatologists, all work outside.

8) Discuss DNA collection in the video to understand how DNA patterns can reveal levels of breeding.

Discussion Suggestions

Key Idea: DNA from individuals in a population can be collected from animal droppings

Why does Dr. Epps collect and smell sheep droppings?
Answers: Freshness. The fresher the droppings, the easier it is to extract DNA.

How is Dr. Epps using DNA to investigate the effect of highways on bighorn sheep?
Answers: By looking at the genetic material of the different populations of bighorn sheep to see whether they are breeding.

Key Idea: Populations that are isolated from one another will share less DNA than populations that interbreed.

How would you expect the genes of mountaintop sheep populations that are separated by highways to compare to the genes of mountaintop sheep populations that have no highway separating them?
Answer: Bighorn sheep populations separated by highways will share fewer genes than bighorn sheep populations without highways separating them.

9) Complete the following demonstration to show students how DNA can be used to determine whether populations breed with one another. This same concept is also explored in the investigation booklet.

Demonstration: How can DNA be used to determine if populations are isolated from one another (i.e., whether they breed with one another)?

Prepare

Set up four populations of colored popsicle sticks or M&Ms. Each population will have a different color composition. Each color represents a different allele or a different version of the same gene.

Population A contains:
1) 15 blue sticks
2) 12 green sticks
3) 12 plain sticks

Population B contains:
1) 10 blue sticks
2) 15 green sticks
3) 10 plain sticks

Population C contains:
1) 5 blue sticks
2) 15 green sticks
3) 19 plain sticks

Population D contains:
1) 1 blue stick
2) 2 green sticks
3) 26 plain sticks

Which populations breed the most frequently with one another?
Answers: Population **A** breeds most frequently with **B** and **C**.

Which population appears to be the most isolated? Why?
Answers: Population **D** appears to be the most isolated because it has very few blue and green sticks (or versions of that gene). If individuals from population D bred more frequently with the other populations than the number of blue and green sticks would increase.

10) Summary/Assessment: Ask students to complete the *Lesson 1: Setting the Stage and the Scientific Process in Action* section of the Investigation Booklet

Investigation Booklet Lesson 1 Answers

1. What is the research question for this unit?
How might being able to drive from Los Angeles to Las Vegas in just four hours put bighorn sheep at risk?

2. What geographic area defines each bighorn sheep population?
Each bighorn sheep population is defined by the mountaintop on which it lives.

3. How have people changed bighorn sheep habitat and what is the economic motivation for making these changes?
People have built large highways that cut off different mountaintop populations from each other. Highways make travel much easier and quicker for people and have increased Las Vegas' tourism revenue.

4. How do highways affect mating between different sheep populations?
Sheep from different mountaintop populations will not breed with sheep from mountaintop populations separated from them by a highway.

5. Clinton Epps made this statement in the video:
I have to be able to see the landscape to visualize the important questions. I have to experience the landscape to really be able to think well about what I want to study, how I want to study— I can't do that studying at a desk.
Why do you think he feels this way?
Clinton Epps can't really understand what is happening in wild populations without experiencing it for himself. Without the familiarity, he feels like he can miss something crucial.

6. From the allele frequency diagram below determine which two populations, A, B, or C breed most frequently with one another and explain your answer.
Populations A and B breed most frequently because they have a similar frequency of alleles. Pop C is more isolated because although it has the same alleles, its allele frequencies are very different. For instance, Pop C has many squares, whereas Pop A and Pop B, each have only one square. Pop C also has fewer triangles and circles.

7. Use Xs and Os to draw two populations that show **high** levels of breeding.
Answers will vary but should show populations that have similar numbers of the same type of popsicle sticks (or should show both populations with a similar number of Xs and Os, which represent different alleles).

Pop A	*Pop B*
X X X O O O X O O O O X X X O O X X O O X	X X O X O O X O O X X X O O X X X O O O O

8. Instead of using shapes, use Xs and Os to draw two populations that show **low** levels of breeding.
Answers will vary but should show populations with very different frequencies for each allele type (i.e., one population will have mostly X type popsicle sticks and one population will have mostly O type popsicle sticks).

Pop A	*Pop B*
X X X X X X X X X X O X X X X X X X X X O	O O O O O O O O O O O O O O X O O O O O O

Lesson 2: Exploring: The role of isolated populations in inbreeding

Small populations and inbreeding

Daily Checklist

At the end of the lesson students will have:

1. _____ Been seated in groups of five students
2. _____ Reviewed how scientists define bighorn sheep populations
3. _____ Investigated and summarized one inbreeding case study
4. _____ Completed the jigsaw activity for the five inbreeding case studies
5. _____ Completed the *Lesson 2: Exploring: The role of isolated populations in inbreeding* section of the Investigation Booklet

Materials:

- Inbreeding case studies in investigation booklet
- Inbreeding case study slideshow PowerPoint | PDF

1) Seat students in groups of five before class begins.

2) Begin today's lesson by reviewing how scientists define bighorn sheep populations.

Discussion Suggestion

Key Idea: Bighorn sheep live in small mountaintop populations.

What is a population?
Answer: Populations are groups of the same species that live and breed together.

How are the bighorn sheep populations different from one another?
Answer: They are different genetically and geographically.

What geographic feature defines them?
Answers: The bighorn sheep populations are determined by the mountaintops on which they live.

3) Assign students to groups of five to investigate and summarize one inbreeding case study. Ask students to complete the graphic organizer for their case study in the Investigation Booklet. The case study is in investigation booklet and in attached slideshow.

4) After the first groups summarize their case study, jigsaw the students into new groups of five with one student representative from each inbreeding case study. Have each student in the new group share the case study that they previously investigated. Ask the students to complete the rest of the graphic organizers in the investigation packet.

a. Domestic dogs
   i. Purebred dogs were inbred for desired characteristics like herding, fetching, and tracking skills
   ii. Health problems resulted like hip, elbow, heart, and eye problems

b. The Florida Panther
   i. Hunting and habitat loss have reduced its numbers to 70 individuals confined to South Florida.
   ii. So few panthers remain that they are now inbred, which has caused health problems like heart defects and abnormal sperm. These defects make it even harder for them to survive.

c. Thoroughbred Horses
   i. Thoroughbred horses were selectively bred (inbred) for speed
   ii. Some Thoroughbreds have skeletal defects, which can lead to broken bones. They also have reproductive problems.

d. The Hapsburg Royal Family of Europe
   i. The Hapsburg family ruled Austria and Spain as well as many other European countries between the 15-18th centuries.
   ii. To keep "pure" bloodlines and seal alliances for increased power, the Hapsburgs inter-married one another frequently. Marriages between first cousins and uncles and nieces were common.
   iii. One result of this inbreeding is the "Hapsburg Jaw" where the lower jaw grows longer than the upper jaw making for an extended chin.

e. Maple Syrup Urine Disease
   i. The Amish communities had very small founding populations, which led to genes for this disorder to be more common in today's population.
   ii. This circumstance results in the high rate of Maple Syrup Urine Disease in today's population. This disease can cause seizures, comas, and death, if left untreated.

Key Concepts:

Populations
- A population is a group of individuals of one species living in the same area that interbreeds
- Small populations may result in inbreeding which can often cause health problems

Inbreeding
- Inbreeding is when close relatives mate.
- Inbreeding can cause health problems or death in individuals by making it more likely for harmful recessive traits to be expressed.

5) **Summary/Assessment:** Students complete the final question in *Lesson 2: Exploring the role of isolated populations in inbreeding* section of the Investigation Booklet.

Investigation Booklet Lesson 2 Answers

	Domestic Dogs	**Florida Panthers**	**Thoroughbred Horses**
Why has inbreeding occurred?	*Dogs have been selectively bred for desired traits like herding, fetching, and tracking skills.*	*Overhunting and habitat loss has led to a population of 70 panthers in South Florida.*	*Horses have been inbred for speed.*
Describe the related health problems.	*Hip, elbow, heart, and eye abnormalities.*	*Heart defects and abnormal sperm.*	*Broken bones and reproductive issues.*

	Hapsburg Family	**Amish People**
Why has inbreeding occurred?	*To keep pure bloodlines and concentrate power, first cousins, uncles, and nieces were commonly married.*	*This group was founded by a very small group of people, which led to the marriage of closely related people.*
Describe the related health problems.	*The Hapsburg Jaw – where the lower jaw grows longer than the upper jaw.*	*Maple syrup disease, which can cause seizures, comas, and death.*

1. Why is it important for individuals from different small populations to be able to breed with one another?
If individuals from small populations are not able to breed with individuals from other populations, the small populations may eventually become inbred, which increases the likelihood that undesirable traits will occur.

Lesson 3: Investigation, Representing, and Making Meaning from Data

Daily Checklist (times indicated below are approximate, two 45-minute lessons)

At the end of the lesson students will have:

1. _____ Optional activity: F_{ST}: How to measure breeding levels between populations (For advanced biology students**; 25 minutes**)

2. _____ With instructions from the slideshow, analyzed the DNA datasets in the investigation booklets to make claims about the impact of highways on bighorn sheep. (**45 minutes – 1 hour**)

Materials:

- Slideshow Analyzing the DNA Datasets PowerPoint | PDF
- Investigation booklet with maps, datasets, and guiding questions for the following populations:
  - Cady Mountain
  - Eagle Buzzard Spring Mountain
  - Hackberry Mountain
  - Indian Spring Mountain
  - Marble Mountain
  - San Gorgonio Mountain

Learning Goals:

How do you?

- Investigate
- Use DNA data
- Represent DNA data

Teacher Tip:

Begin class with students already seated in groups of three or six. For groups of three, each student will be responsible for two datasets. For groups of six, each student will be responsible for one dataset.

1) Optional Activity: F_{ST} Values: How to measure breeding levels between populations.

a. The first activity for this lesson in the investigation booklet, it explains the role of F_{ST} values in uncovering breeding levels between populations.

b. It also includes an exercise transforming mountaintop bighorn sheep population F_{ST} values into connectivity lines that indicate levels of breeding between mountaintop populations. These connectivity lines are used in the rest of the Lesson 3 data analysis.

2) In the slideshow, analyze DNA datasets and overview maps to predict breeding levels between bighorn sheep populations with and without highways. Then students use the genetic data and rulers to represent the data on the six maps provided.

a. Use the prepared slideshow and datasets in the investigation booklet to help students learn how to analyze the datasets—particularly the meaning of the arrows and the mountaintop names.

b. The slideshow reminds students of the collected DNA evidence to understand how highways might affect bighorn sheep breeding (slide 1).

c. Ask the class to make predictions about breeding among bighorn sheep populations (slide 2).

Discussion Suggestion

Key Idea: Highways cause habitat fragmentation, which may lead to inbreeding.

How would a highway running through two sheep populations affect their mating habits? Look at this overview map. What predictions can you make about the mating habits of bighorn sheep populations?
Answer: Populations that are cut off from each other by roads will not show large levels of interbreeding and vice-versa.

How would a highway that runs through two sheep populations affect their mating habits?
Answer: It would cut the male sheep off from the different populations, which would decrease the level of breeding.

d. Use the next set of slides (slides 3-6) to work through how to use the genetic data to understand the role of highways in bighorn sheep mating.

Discussion Suggestion

Key Idea: Geographic distance and highways affect breeding between populations.

This is a zoom in on Cady Mountain. Based only upon geographic distance, with which population would you expect Cady Mountain sheep to show more signs of mating, Granite, Old Dad, or Newberry? Why?
Answer: Newberry because it is closest to Cady Mountain.

If highways block bighorn sheep breeding, which population would you expect Cady Mountain sheep to show the LEAST signs of mating, Granite, Old Dad, or Newberry? Why?
Answer: Newberry Mountain because it is separated from Cady Mountain by a highway, which isolates the populations from each other.

e. The slideshow then contains an overview of instructions for analysis (slide 7). Each investigation booklet has 6 maps with data and instructions. Ask students refer to their own maps as you discuss the instructions.

Step 1: Use a metric ruler to measure the minimum distance in millimeters between mountaintops.

> **Purpose**: To give students a baseline for which populations SHOULD have the highest levels of breeding without the impact of the highway.

Step 2: Draw double-headed arrows between populations to signify the level of breeding between populations. More arrows show more connection, (i.e., more breeding; fewer arrows show less connection, i.e., less breeding.)

> **Purpose:** To see the genetic data in a visual manner. Populations that share (i.e., mate frequently) a lot of genetic information will have more arrows connecting them than populations that do not mate frequently.

Step 3: Compare your results from Step 1 and Step 2 and use them to predict where the highways are located. Draw the highway onto the map.

> **Purpose:** Students will predict that the closest populations share the most genetic information (Step 1). However, the genetic data (Step 2) tell a different story. They show that nearby populations with a highway between them share less genetic information (i.e., mate less frequently) than nearby populations without highways between them.

f. The next slides (slides 8-12) show the three-step instructions overlaid onto the Cady Mountain example.

g. Slide 13 is an overview map of the area without highways. When student groups complete their work, they should transfer their data and highways onto the overview map.

h. The final slide is a map with the highways overlaid, so students can determine if their highway placement predictions match where the highways are in real life.

i. Ask the students what the data indicate about the impact of highways on bighorn sheep

3) **Summary/Assessment:** Ask students to complete the final question in *Lesson 3: How do you investigate and represent data?* section of the Investigation Booklet.

Investigation Booklet Lesson 3 Answers

Optional F_{ST} Value Activity

1. Quickly scan the diagram on the previous page. Which population do you think is the most isolated? Why?

Pop C is the most isolated because even though it shares the same alleles as Populations A and B, it has a much different frequency for those alleles.

2. Would the pairwise F_{ST} value for Population C be high or low in relation to the other populations?
The F_{ST} value should be high for Pop C in relation to the other populations.

3. To conclude that highways are a barrier to breeding between sheep populations, what would F_{ST} values be for the following conditions?

A. Populations that are geographically close **without a highway** between them:
Low F_{ST} values.

B. Populations that are geographically close **with a highway** between them:
They would have higher F_{ST} values than the populations without the highway.

4. Write a hypothesis statement for your predictions above.
If highways are a barrier to breeding, F_{ST} values for geographically close populations separated by a highway will be higher than F_{ST} values for geographically close populations without a highway between them.

5. What do the low values indicate (0.001) about breeding and connectivity between populations?
Low F_{ST} values indicate high levels of breeding and high connectivity because individuals can migrate (and mate) between populations.

6. What do the high values indicate (≥0.25) about breeding and connectivity between populations?
High F_{ST} values indicate low levels of breeding and low connectivity because individuals cannot migrate (and mate) between populations.

7. Apply the scale to the bighorn sheep mountaintop populations. Fill in the appropriate number of arrows (↕ **).** A sample response is filled in for Old Dad and Cady Sheep**.**

Breeding Evidence of Cady Sheep		
	Cady Sheep (F_{ST})	**Cady Sheep (↕)**
Old Dad Sheep	0.11	↕↕↕↕
Granite Sheep	0.11	↕↕↕↕
Newberry Sheep	0.26	↕

Breeding Evidence of Eagle-Buzzard Spring Sheep		
	Eagle Buzzard Spring Sheep (F_{ST})	**Eagle Buzzard Spring Sheep (↕)**
Little San Bernardino Sheep	0.11	↕↕↕↕↕↕
Orocopeia Sheep	0.11	↕↕↕
Eagle Lost Plains Sheep	0.26	↕↕↕↕↕↕

Breeding Evidence of Hackberry Sheep		
	Hackberry Sheep (F_{ST})	**Hackberry Sheep (↕)**
Wood Sheep	0.02	↕↕↕↕↕
Piute Range Sheep	0.08	↕↕↕↕
Providence Sheep	0.06	↕↕↕↕

Breeding Evidence of Indian Spring Sheep		
	Indian Spring Sheep (F_{ST})	**Indian Spring Sheep (↕)**
Clark Sheep	0.20	↕↕
Old Dad Sheep	0.10	↕↕↕
Providence Sheep	0.11	↕↕↕

Breeding Evidence of Marble Sheep		
	Marble Sheep (F_{ST})	**Marble Sheep (↕)**
Granite Sheep	0.10	↕↕↕
South Bristol Sheep	0.04	↕↕↕↕↕
Clipper Sheep	0.05	↕↕↕↕

Breeding Evidence of San Gorgonio Sheep		
	San Gorgonio Sheep (F_{ST})	**San Gorgonio Sheep (↕)**
Cushenbury Sheep	0.07	↕↕↕↕
San Gabriel Sheep	0.27	↕
Little San Bernardino Sheep	0.15	↕↕↕

Lesson 3: How Do You Investigate and Represent Data?

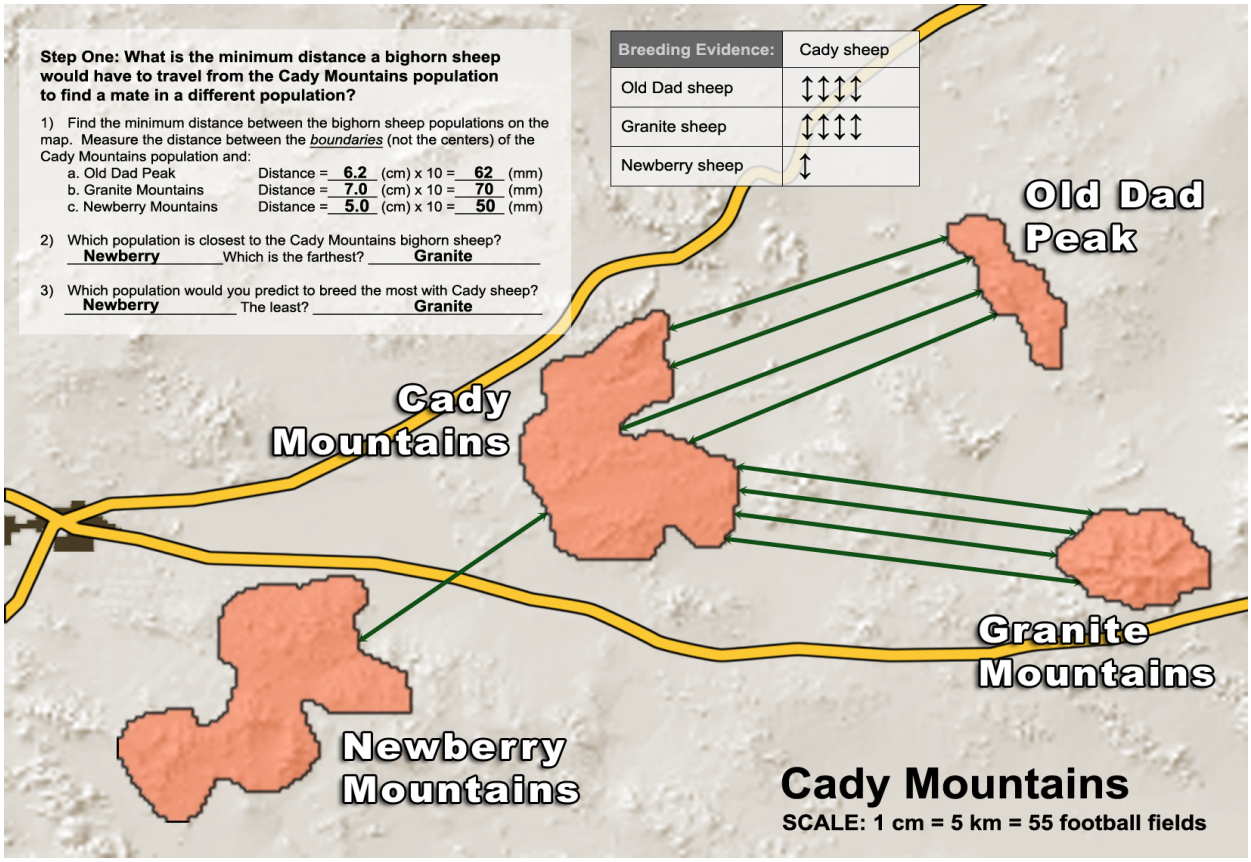
On the following pages you measure and record the geographic distance between populations and draw the number of arrows that show breeding connectivity between populations. Answer questions below to explain how knowing geographic distance and DNA connectivity among populations helps understanding bighorn sheep breeding.

1. What is the purpose of measuring the geographic distance between the bighorn sheep populations?

Measuring geographic distance quantifies the distance sheep from nearby mountains need to travel to mate with sheep from other populations. The assumption is that sheep from nearby mountaintops should frequently mate and therefore show high levels of gene flow.

2. If two bighorn sheep populations breed frequently, would you expect them to share many or few DNA arrows? Many arrows would indicate high genetic connectivity and few arrows would indicate low genetic connectivity. Explain your answer.
Sheep populations that breed frequently are expected to share many DNA arrows, which would indicate high genetic connectivity due to their frequent breeding.

Step 1 and Step 2: *On map*



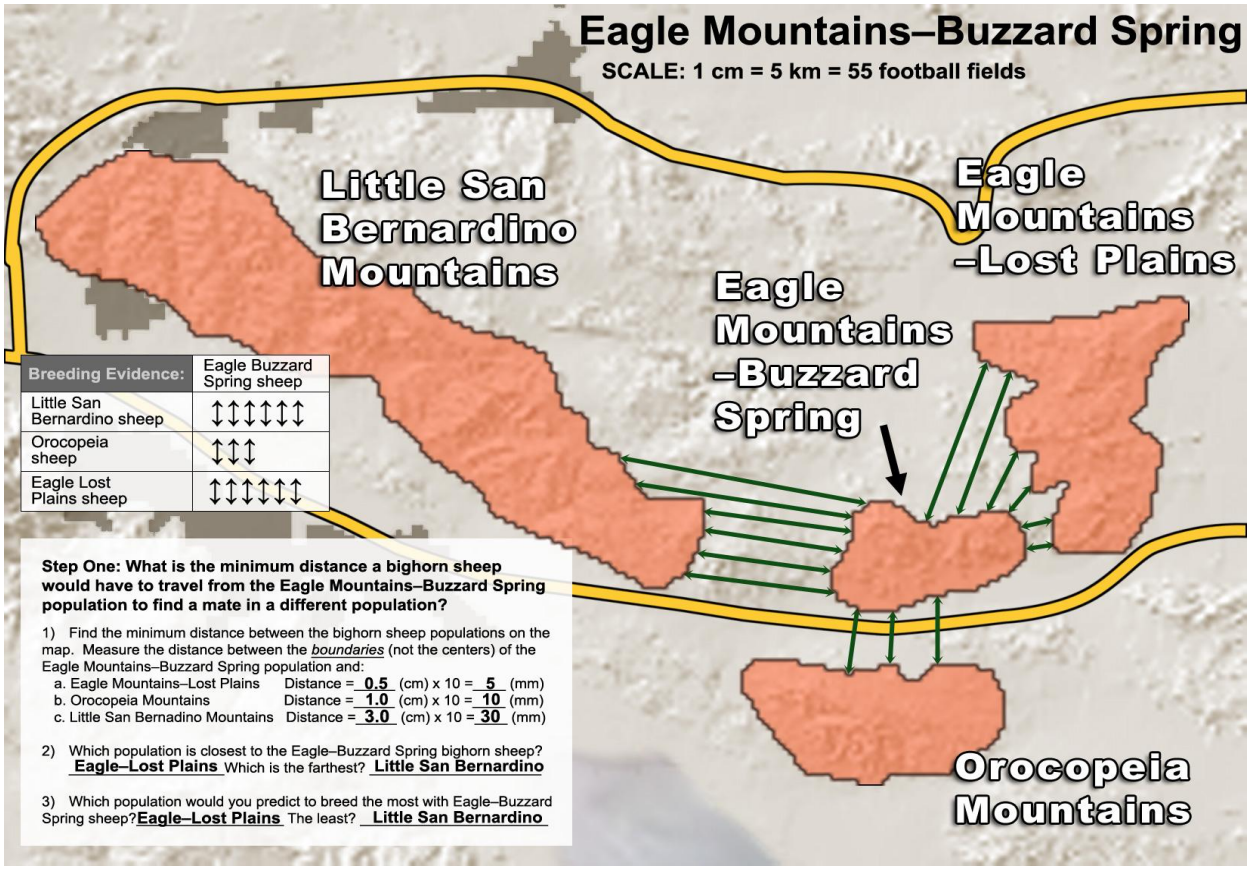
Step 3: Compare your predictions from Step 1 with the data from Step 2:

Q1. Based upon distance, what sheep population would you have expected Cady Mountain sheep to breed with most frequently? *Cady Mountains sheep should breed most frequently with Newberry Mountains sheep.*

Q2. What do the genetic data show? Which population do they breed with most frequently? *They breed most with Old Dad and Granite Mountains sheep.*

Q3. Predict where the highway is located and **draw it onto the map.** *The highway is located between Cady Mountains and Newberry Mountains. Drawn on map.*

Step 1 and Step 2: *On map*



Step 3: Compare your predictions from Step 1 with the data from Step 2:

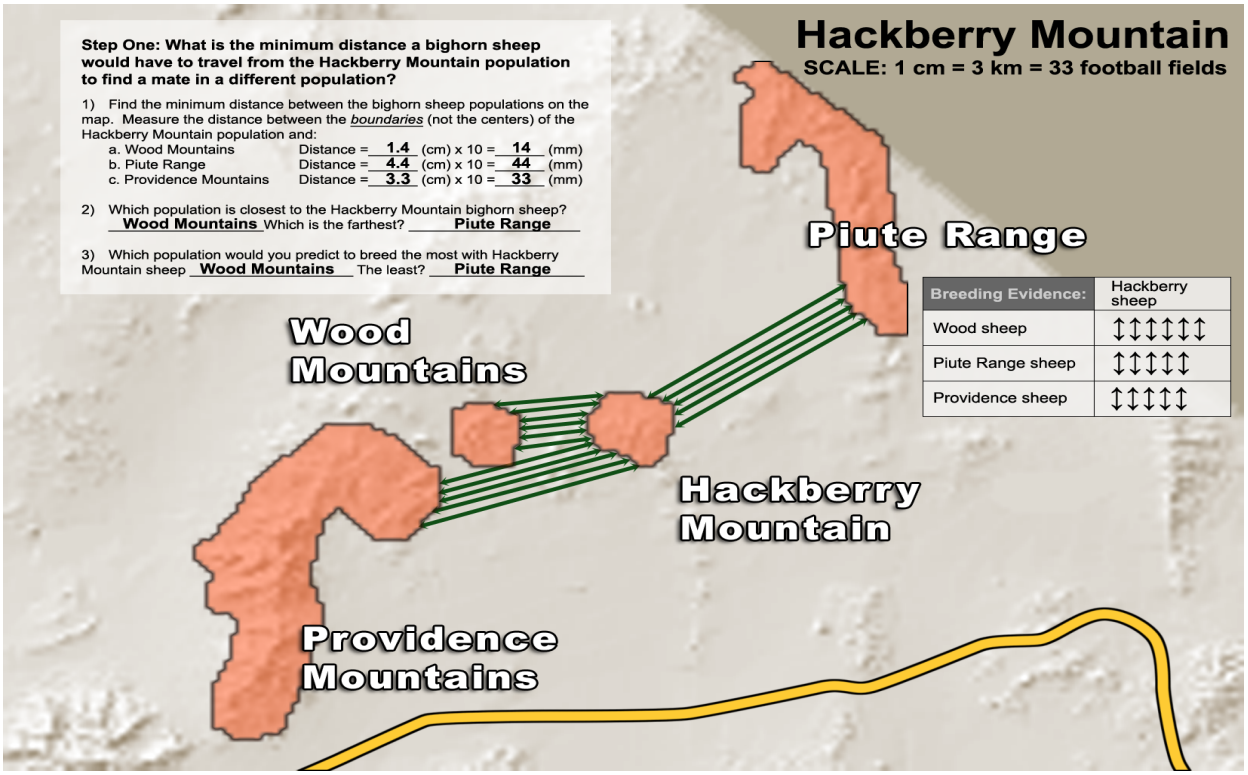
Q1. Based upon distance, what sheep population would you expect Eagle-Buzzard Spring sheep to breed with least often*? Eagle-Buzzard Spring sheep should breed least frequently with Little San Bernardino Mountains sheep.*

Q2. What do the genetic data show? With what sheep population do they show the least signs of breeding? *They breed least with Orocopeia Mountain sheep.*

Q3. Predict where the highway is located and **draw it onto the map.** *The highway is located between Eagle Mountains-Buzzard Spring and Orocopeia Mountains. Drawn on map.*

Ecology Disrupted – How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?

Step 1 and Step 2: *On map*



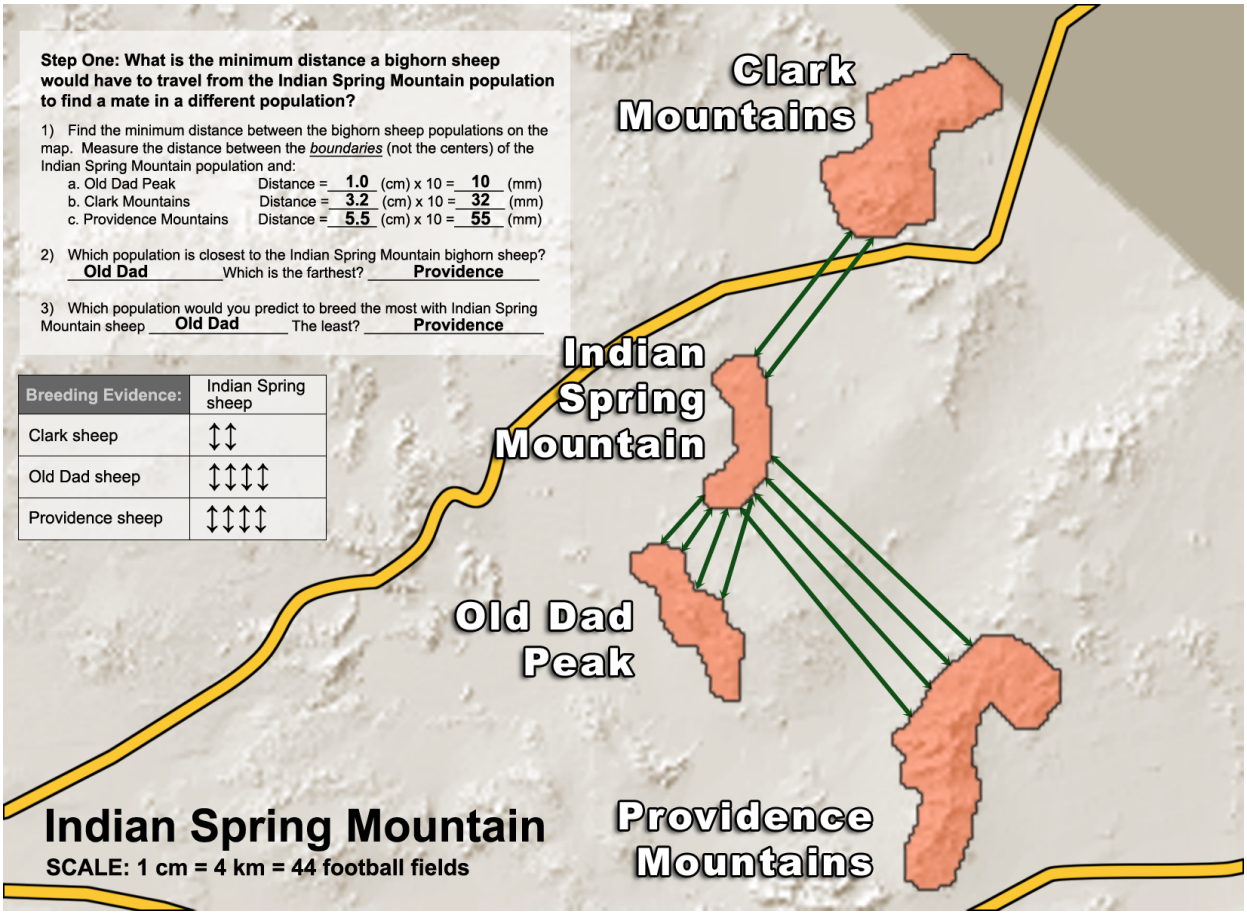
Step 3: Compare your predictions from Step 1 with the data from Step 2:

Q1. Based upon distance, what sheep population would you have expected Hackberry sheep to breed with most frequently? Hackberry Mountain sheep should breed most frequently with *Wood Mountains sheep.*

Q2. What do the genetic data show? Which population do they breed with most frequently? *They breed most with Wood Mountains sheep.*

Q3. Predict where the highway is located and **draw it onto the map.** *A highway does not separate Hackberry Mountains from any of the other mountains shown.*

Step 1 and Step 2: *On map*

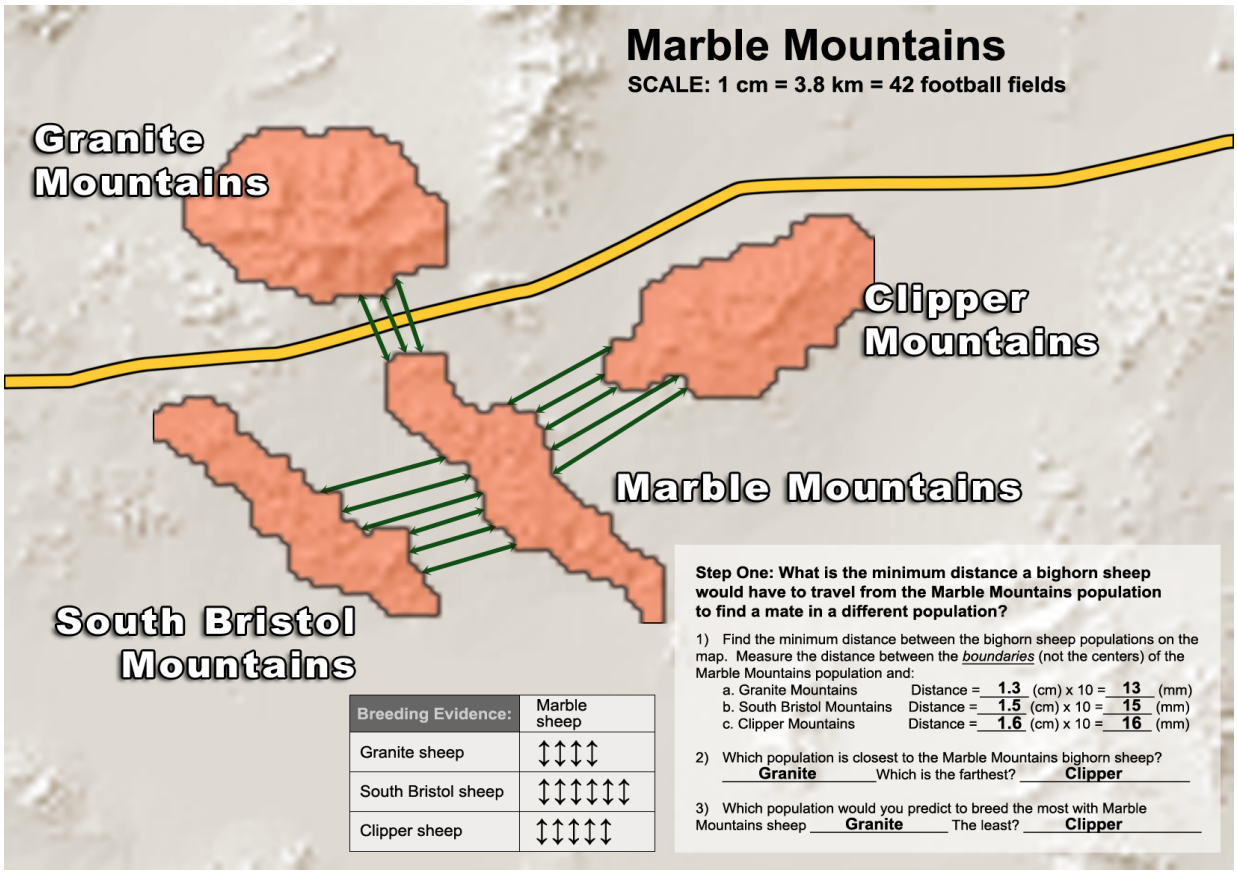


Step 3: Compare your predictions from Step 1 with the data from Step 2:

Q1. The data show that Indian Spring Mountain sheep breed less frequently with Clark Mountain sheep than with Providence sheep. Why do you think this is so? *Indian Spring Mountain sheep breed less frequently with Clark Mountain sheep than Providence Mountain sheep because the Indian Spring and Clark Mountains are separated by a highway, whereas no highway separates Indian Spring Mountain from Providence Mountains.*

Q2. Predict where the highway is located and **draw it onto the map.** *The highway is located between Clark and Indian Spring Mountains. Drawn on map.*

Step 1 and Step 2: *On map*



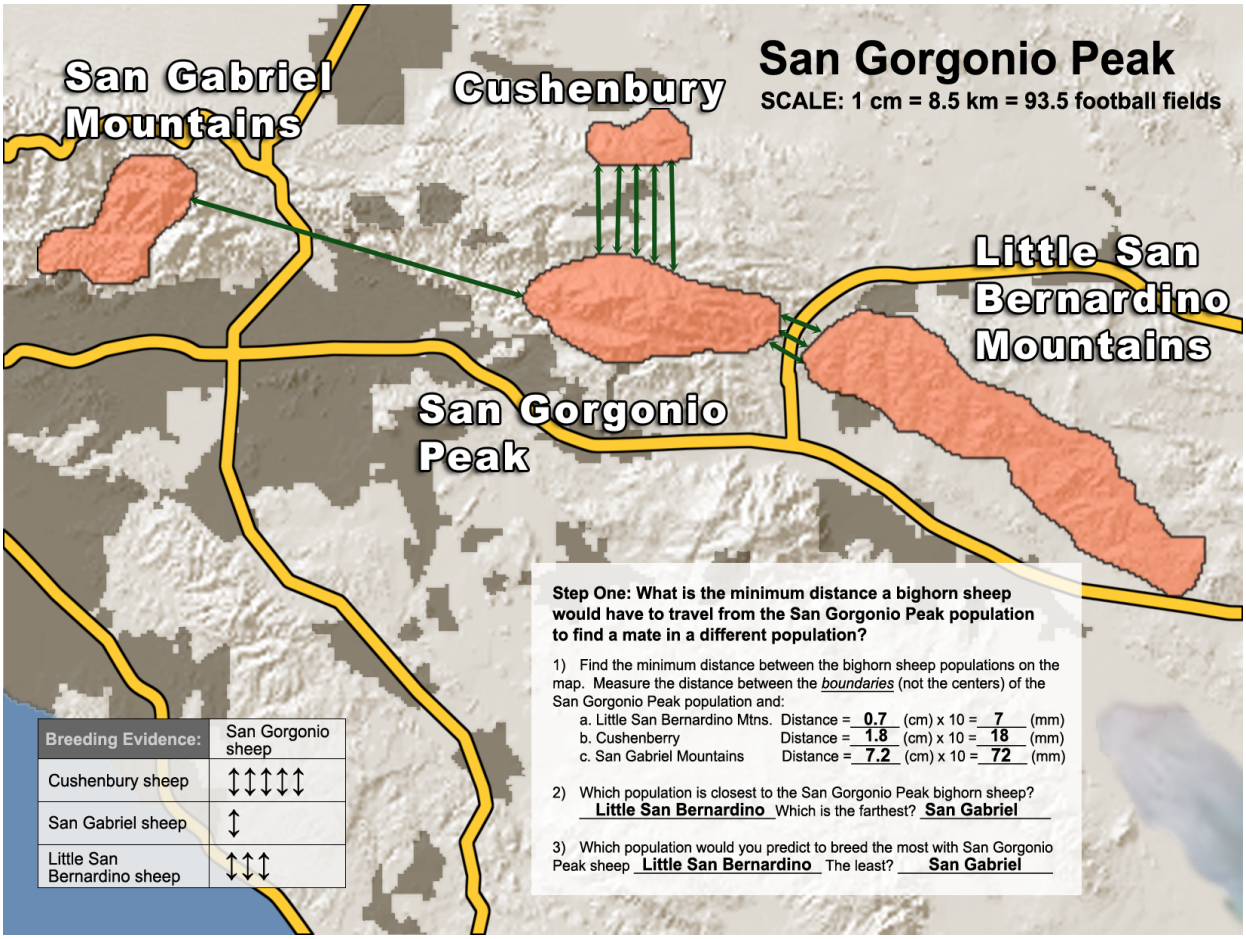
Step 3: Compare your predictions from Step 1 with the data from Step 2:

Q1. Based upon distance, what sheep population would you have expected Marble sheep to breed with most frequently? *Marble Mountain sheep should breed most frequently with Granite Mountains sheep.*

Q2. What do the genetic data show? With which population do they breed with most frequently? *Marble Mountains sheep breed most frequently with South Bristol Mountains sheep.*

Q3. Predict where the highway is located and **draw it onto the map.** *The highway is located between Marble and Granite Mountains. Drawn on map.*

Step 1 and Step 2: *On map*



Step 3: Compare your predictions from Step 1 with the data from Step 2:

Q1. The sheep from San Gorgonio Mountain live very close to the sheep from Little San Bernardino Mountain. Why do the data show that they breed with those sheep less frequently than they do with Cushenbury sheep? *A highway separates San Gorgonio Mountain from Little San Bernardino Mountain, but no highway separates San Gorgonio Mountain from Cushenbury Mountain.*

Q2. Predict where the highway is located and **draw it onto the map.** *The highway is located between San Gorgonio Mountain and Little San Bernardino Mountain. Drawn on map.*

---------- Final Summary Question ----------

1. After reviewing the data, what claim can you make about how roads affect bighorn sheep populations? Explain your evidence.
Roads cut off bighorn sheep populations from each other, isolating them and leading to inbreeding.
Evidence: Bighorn sheep populations that are separated from each other by a highway show less genetic similarity than sheep of equal or greater geographic distance.

Lessons 4: Changes to Habitats Can Unexpectedly Disrupt Populations

Daily Checklist (times indicated below are approximate)

At the end of the lesson students will have:

1. _____ Discussed habitat and populations in the context of daily life and bighorn sheep. **(5 min)**

2. _____ Watched the *Science Bulletins* and completed the graphic organizers for the *Lesson 4: Ecology Disrupted: Changes in habitat can unexpectedly disrupt populations* in the Investigation Booklet. **(50 min)**

3. _____ Discussed findings from the *Science Bulletins.* ***(10 min)***
    - Discussed the consequences of changing habitats on bighorn sheep, the Florida panther, European badger, monarch butterfly, seabirds, and wood turtle populations.
    - Discussed the role of daily life in changing habitats and impacting populations.
    - Discussed possible solutions for each of the environmental issues.
    - Discussed the role of data and scientific investigations.

Materials:

- Graphic Organizers in Investigation Booklet
- (Video) Science Bulletin: Roads Influence Animal Genes
- (Video) Science Bulletin: New Blood Gives New Life to Florida Panthers
- (Video) Science Bulletin: Loggers Imperil Monarch Butterflies
- (Video) Science Bulletin: Plastic Trash Threatens Remote Seabirds
- (Video) Science Bulletin: Species and Sprawl: A Road Runs Through It

Teacher's Note:

The goal of this part of the activity is to put the bighorn sheep study in the context of ecological terminology and processes and show how daily activities can change habitats, which disrupts the function of local populations resulting in environmental issues. After students understand how human activity disrupts bighorn sheep habitat, they will be asked to develop solutions for the fragmentation of the bighorn sheep habitat and analyze other examples of human disruptions of habitats.

1) Discuss habitats and populations in the context of daily life and Bighorn Sheep

A. Introduce the ecological principles of habitats and populations. The health of a population depends on the health of its habitat.

B. Connect the principles to this case study about bighorn sheep

Discussion Suggestion

Key Idea: Populations live in specific habitats.

What is habitat?
Answer: The environment where a population/organism lives.

What is the habitat for bighorn sheep?
Answer: Mountaintops in the Nevada and California desert.

What is a population?
Answer: A population is a group of the same species that lives in the same area.

How are bighorn sheep populations defined?
Answer: By their mountaintop habitat.

2) Viewing and analyzing other Ecology Disrupted examples to connect to the Ecology Disrupted Learning goals.

Ecology Disrupted Learning Goal:

Human daily life can disrupt ecological function leading to environmental issues.

Students will watch five videos to learn more about how human daily life can affect ecological function:

a. (Video) Science Bulletin: Roads Influence Animal Genes
b. (Video) Science Bulletin: New Blood Gives New Life to Florida Panthers
c. (Video) Science Bulletin: Loggers Imperil Monarch Butterflies
d. (Video) Science Bulletin: Plastic Trash Threatens Remote Seabirds
e. (Video) Science Bulletin: Species and Sprawl: A Road Runs Through It *(8-minute video)*

While watching the videos they will complete a graphic organizer with the following questions:

a. How have people changed the habitat and how has it affected populations?
b. What is the evidence/data?
c. How has daily life contributed to this change and how is it affected?
d. What are possible solutions?

Before the students begin watching the videos, ask them to complete the graphic organizer for *Highways Block Bighorn Sheep* without watching the video. This exercise should familiarize the students with the graphic organizers.

Highways Block Bighorn Sheep

Solutions Background: See *Roads Influence Animal Genes* For More on Road Crossings

Culverts (drain crossings under highways), underpasses, and overpasses specifically made for animals to cross roads unharmed are a strategy to decrease habitat fragmentation. More animals are killed each year in the United States by cars than by any other method. Wyoming has begun to use culverts to protect deer and elk. Florida has built wildlife crossings, which are a combination of culverts and fencing to protect endangered Florida panther populations. Scientists are studying wildlife crossings to determine whether they are helping species survive.

Watch the other videos and pull out the ecological principles. Introductions and background information are included in the following boxes. More detail is also included in the answers to the video graphic organizers in the Investigation Booklet, and here in the teacher guide.

Roads Influence Animal Genes

Introduction:

As you've seen from the bighorn sheep, roads influence animal genes. This video shows actions that people take to reduce the impact of roads on animals.

European Badger Biology: The European badger is a small carnivore in the weasel group. Unlike the American badger, which is mostly carnivorous, the European badger is omnivorous, eating tubers, cereals, along with insects, small mammals, and carrion.

Road Crossings: See Solutions in Highways Block Bighorn Sheep for more details on this subject.

New Blood Gives New Life to Florida Panthers

Introduction:

This video explains how scientists are helping Florida panthers recover from inbreeding. These tactics can be used to help other inbred animals too.

Florida Panther Inbreeding: The panther used to be abundant throughout the southeast United States. Today, due to hunting and habitat loss for homes and agriculture, only 80-100 panthers survive in Southern Florida. So few Florida panthers remain that close relatives breed, making undesirable traits like heart defects and abnormal sperm common. Panthers born with these defects cannot survive in the wild or if they do, they cannot successfully parent a new generation of panthers.

Loggers Imperil Monarch Butterflies

Introduction:

Have you ever seen a monarch butterfly? They are beautiful and orange (if no one volunteers). They live in New York City and the surrounding area from the end of August into the beginning of September. Do you know that these butterflies migrate just like birds? We are going to watch another video like we did for the bighorn sheep when we began this unit. This one will be about the monarch migration. Get ready to fill out your graphic organizers.

Biology: Monarch butterflies have a distinct orange and black pattern, and they are the only butterfly species that migrates north and south like species of birds. They fly all the way from Canada to Mexico.

Migration: Starting in August, monarch butterflies found east of the Rocky Mountains begin migrating to an area in central Mexico. The monarchs that fly south are different biologically than other generations of monarchs because they can live much longer. The life cycle of monarchs is usually 6-8 weeks, but the migrating generation lives for 6-8 months. These monarchs go into a non-reproductive state called diapause, which allows them to make the long journey south and to survive the long winter months in Mexico. After the winter months, multiple generations successively make the journey north to the United States and Canada.

Importance of Overwintering Sites: The sites in central Mexico, 12 high-elevation Oyamel Fir forests, are extremely important because they keep the butterflies at an optimal temperature, a few degrees above freezing. This protects the butterfly. Too cold and butterflies die. Too warm and they use up their fat stores and will die without being able to reproduce and migrate north in the spring.

Impact of Loggers: Loggers in central Mexico have been illegally logging in some of these sites destroying the winter habitat of the eastern monarch butterflies. Without these trees the monarch butterflies will not be protected during winter, and there will likely be a large decrease in monarch butterfly populations because they are unable to reproduce.

Plastic Trash Threatens Remote Seabirds

Introduction:

Have you ever littered? Where does your litter go? Mostly to New York City beaches, but sometimes your litter ends up in the middle of the ocean. If you live out in California, your trash might end up affecting seabirds trying to raise their babies way out at sea. We are going to watch another video. This one will be about plastic trash that threatens seabirds. Get ready to fill out your graphic organizers.

Biology: Laysan Albatross are a species of albatross that live in the North Pacific Ocean. These seabirds nest in huge colonies of 400,000 breeding pairs and are able to travel great distances to forage for food. Their young stay at their nesting sites and their parents feed in the Pacific Ocean, fly back, and regurgitate food for their young.

Eating Habits: Laysan albatross and other seabirds eat a variety of squid, fish, jellyfish, and mollusks.

Pacific Gyre/Western Garbage Patch: The Pacific Gyre or Western Garbage Patch is a large area in the Pacific Ocean that contains immense amounts of human trash. Wind and ocean currents sweep debris from Asia and the western coast of the United States, like California, into one huge area in the Pacific Ocean. Most of the floating trash is non-biodegradable plastic trash.

Affect on Seabirds: Adult seabirds mistake the plastic for food. They regurgitate the plastic to their young, often killing them. This habit has led to a decrease in the size of seabird populations in the North Pacific.

Atlantic Ocean Garbage Patch: The Atlantic Ocean has a smaller garbage patch in the Sargasso Sea, which has plastic trash from the East Coast of the United States including New York City.

Species and Sprawl: A Road Runs Through It (8-minute video)

Introduction:

Have you ever seen turtles in New York City parks? You can find them resting on logs in Central Park and Prospect Park. If you had to describe a turtle, what words would you use? Have you ever heard the story of the Tortoise and the Hare? Yes, turtles are slow and this can be a problem when they are trying to cross a road. We are going to watch a video about the plight of turtles and roads. Get ready to fill out your graphic organizers.

Biology: Wood turtles are a North American species of turtle that prefer wooded areas even though they are semi-aquatic. They grow to be 9 inches long.

History: Wood turtles were extremely common in the 19th century in the lower Connecticut Valley. Exact numbers are not known, but there are many anecdotes that describe people being able to collect over a hundred turtles within a few square miles. These turtles were able to move freely within their habitat.

Impact of Suburban Sprawl: Suburban sprawl is the term used to describe how people are spreading out across the landscape by building new single-family homes, new roads, and malls. The roads, homes, and malls associated with sprawl often disrupt ecosystems and fragment wood turtle populations. Cars and other motor vehicles have decimated the wood turtle, leading to a drastic decline in the number of wood turtles.

Research: Scientists have begun to track the healthiest wood turtles to gauge their habits, to devise ways to protect the remaining wood turtles from the impact of suburban sprawl. The roads cut the wood turtle habitat in two, forcing turtles to cross roads to reach breeding pools or meadows that they need to live. Scientists are tracking habitats that are still intact to protect them.

NYC Connection: New York City has such a high population density that it is in many ways the opposite of suburban sprawl. Everything in the City is close together, and many people use public transportation or walk instead of using cars like in Massachusetts. People living in densely packed cities like NYC help protect even more land from being developed.

3) Convene a final discussion of the *Science Bulletins* bringing the stories together through a discussion of:

How mundane or ordinary aspects of daily life can lead to environmental issues by disrupting ecological function (in this case harming populations by disrupting habitats).

Discussion

Key Idea: The daily lives of people disrupt habitats in many unforeseen ways, but there are solutions.

After watching the videos on environmental issues that result from people changing habitat, give examples of some of the unexpected ways that people disrupt habitats and their consequences?
Answer: People disrupt habitats by:

- Building highways and roads to connect human population centers.
- Cutting down trees for homes and wood products.
- Driving cars, flying, etc.
- Throwing away plastic garbage and littering.
- Constructing malls, roads, and single-family homes spread out across the landscape (suburban sprawl).

What are some possible ways to reduce habitat disruption?
Answer:

- Building animal crossings.
- Replanting trees and protecting important forests.
- Recycling and reducing the use of plastic in ways like turning down plastic shopping bags.
- Smart city planning that limits suburban sprawl and living in dense areas like New York City (this also helps with our carbon footprint because it increases use of public transportation. Also, smaller multi-dwelling housing use lets energy to heat and cool).

4) **Summary/Assessment:** Students complete and discuss the *Final Thoughts* section of the Investigation Booklet.

The *Final Thoughts* section of the Investigation Booklet asks questions on the themes of the unit:

i. How disrupting habitats makes our lives easier
ii. How scientists study about human impact on the natural world.

Investigation Booklet Lesson 4 Answers

Complete the tables below:

Questions	**Highways Block Bighorn Sheep**	**Roads Influence Animal Genes (European badger)**	**New Blood Gives New Life to Florida Panthers**
1. How have people **changed** the **habitat** in this example?	*Building **highway**s and fences*	*They build roads.*	*They destroyed the habitat. Unclear not stated.*
2. **Why** do people **change** the **habitat**? How does it help us?	*To make **travel quicker** between LA and Las Vegas, which helps the Las Vegas economy.*	*The roads are important for travel.*	*To live our lives, build homes, agriculture (from packet)*
3. How do the habitat changes **impact populations** in this area?	*It isolates bighorn sheep mountaintop populations leading to **inbreeding**, which causes health issues.*	*They reduced European badger numbers.*	*It causes Florida panther inbreeding, which leads to low fertility, physical deformities, heart abnormalities, many parasites.*
4. How do you know that the habitat is being changed and that local populations are affected? Describe the **evidence** or **data**.	*Scientists studied **DNA** evidence from **different populations of bighorn sheep**. They found that populations separated by roads showed less interbreeding than those without highways between them.*	*Badger roadkill. Up to 35% of badgers were roadkill victims in the 1970s.*	*Not discussed, but inbreeding issues found in the Florida panther.*
5. Suggest how to **solve** this problem.	*Build **tunnels** under the fences and highways for the animals to travel. **Elevate** the highway. Construct animal highway **overpasses**. Introduce new bighorn sheep into existing populations to increase genetic diversity.*	*The installation of 600 tunnels allows gene flow and keeps badger genetic diversity stable.*	*Bring panthers from Texas, which has tripled the Florida panther population 15 years later.*

Questions	**Loggers Imperial Monarch Butterflies**	**Plastic Trash Threatens Remote Seabirds**	**Species and Sprawl: A Road Runs Through It**
1. How have people **changed** the **habitat** in this example?	*Loggers are illegally **cutting down trees** that are the winter habitat of monarch butterflies.*	***Plastic** is not bio-degradable, and when thrown away improperly can end up in large areas in the Pacific Ocean. These areas are the habitats of seabirds, which mistake the plastic for food.*	***Suburban sprawl** (the increased development around urban areas) has broken up the wood turtle habitat with roads, malls, single-family homes, etc. This has led to the death of many wood turtles (roadkill).*
2. **Why** do people **change** the **habitat**? How does it help us?	*Loggers respond to the human want/need for **building materials, paper,** & other **wood products**, which leads to illegal logging. These loggers provide for their families by cutting down these trees.*	*People use plastic for everything from food containers to shoes. Plastic **makes our lives much easier**, and it is a large part of our daily lives.*	*To travel from place to place and to live our lives.*
3. How do the habitat changes **impact populations** in this area?	*The monarch butterflies are now **dying** during the winter months because they are no longer protected from the cold by the Oyamel trees.*	*The adult **seabirds feed** the **plastic** to their **offspring,** causing the offspring to **die**.*	*The turtles are killed by **cars** when they try to crossroads to move between different parts of their habitat. Their numbers are at an all-time low.*
4. How do you know that the habitat is being changed and that local populations are affected? Describe the **evidence** or **data**.	***Satellite data** of habitat (trees) show declining number of trees and **survey data** (of monarchs) by scientists show monarch deaths.*	*Scientific research on the Pacific Garbage Patch has shown higher mortality of **seabird young** with **plastic** in their **gullets**. Surveys in the area show high levels of plastic trash.*	***Historic evidence** that wood turtles were **once** very **common**, but now people and scientists rarely find them. Recent surveys show that few turtles remain.*
5. Suggest how to **solve** this problem.	***Protect** more of the Oyamel forests and plant new trees. Police the forests better so that there is less illegal logging. Improve **tourism** so that there is an alternative source of income.*	***Decrease** the amount of **plastic** we produce and use, **recycle**, properly dispose of plastic trash, and clean up the Pacific Garbage Patches.*	*Move **roads away** from **stream/river**beds so that roads do not fragment wood turtle habitat.*

Final Thoughts

1. In this unit, you discussed examples of how we change habitats to make our own daily life better. Think of the examples we discussed (bighorn sheep, Florida panther, European badgers, monarch butterflies, seabirds, and wood turtles) and list **three ways** that **changing habitats improves** our **living** conditions.

Ecology Disrupted – How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?

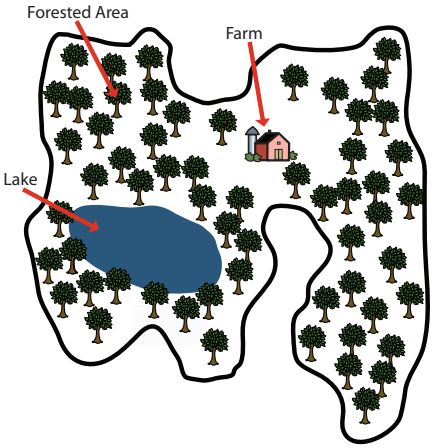
Habitats We Change	**Improves Our Living Conditions**
Example: Add roads to desert landscape	*Facilitates travel*
1. Cut down trees	*Provides subsistence and wood products*
2. Plastic trash	*Plastic shopping bags, plastic toys, plastic containers, ease of disposable goods.*
3.Roads	*Easier travel and bigger homes*

2. State planners plan to build a new highway through a local mountain forest. You are worried that the highway might isolate skunk populations from different sides of the new highway. What data would you collect to determine whether the new highway, once built, is isolating skunk populations from each other?
I would analyze DNA from skunks that live in the area before the highway was built and then do a long-term analysis of DNA from skunks on both sides of the highway after the highway was built. If they share less DNA that would mean that the highway is isolating the skunk populations.

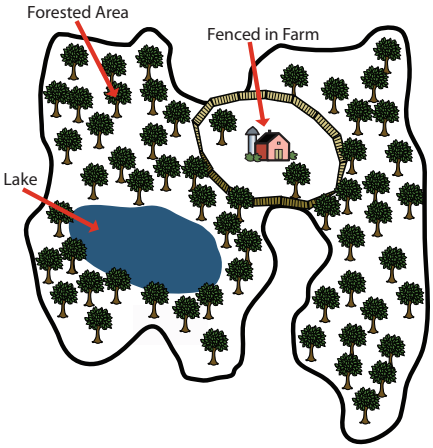
Final Assessments: Below are two potential assessments for this unit.

Ecology Disrupted – How might being able to drive between Los Angeles and Las Vegas in just four hours put bighorn sheep at risk?

Use the illustration and paragraph below to answer the following questions.



Farm in Upstate New York



Farm in Upstate New York with a new fence

Sugar maples, oaks, and yellow birch trees inhabit the mountain forests of upstate New York, which is also home to predators like bobcats. These animals live alone and wander over large areas to search for food and to mate and breed with other bobcats. Recently, a dairy farmer who supplies milk to New York City residents built a fence around his farm to prevent his grazing cows from wandering off. The farmer is happy with these changes because they allowed him to increase milk production.

a) How is the upstate habitat being changed? _____

b) Explain how building a fence on the farm can affect the bobcat population.

_____
_____
_____

c) What data would scientists collect to support the claim that the fence is harming the bobcat population?

_____
_____
_____
_____
_____

d) Describe one other example (other than cutting down trees) where changes people have made to habitats have unexpectedly harmed wildlife populations. Make sure you include in your answer the change to the habitat and how that change harms wildlife populations.

_____
_____
_____
_____
_____

The United States – Mexico Border Fence

a portion of the fence

The U.S. is building a fence along its southern border to prevent undocumented immigrants from entering the U.S. Many organisms like ocelots, Mexican jaguars, black bears, hummingbirds, and endangered Sonoran pronghorn antelope live on both sides of the border.

The armadillo is known for its leathery armor.

Over 20 hummingbird species live in the U.S. and Mexico

Black bear cub

The pronghorn, the fastest North American land animal runs up to 60 mph.

Ocelots found mostly in Central and South America are also found in Texas.

a) How are animals and their habitat affected by the fences?

_____

_____

_____

b) Which animal do you predict will be least affected by the fence? Why?

_____

c) Propose a solution to prevent the fence from harming wildlife habitat.

_____

_____

_____

d) How would you test whether the fence harms wildlife? Think back to the bighorn sheep example.

_____

_____

_____

Responses for Upstate New York Farm

a) **How is the upstate habitat being changed?**
A fence is being built that isolates one part of the habitat.

b) **Explain how building a fence on the farm can affect the bobcat population.**
The fence isolates the bobcat population, so it will have a hard time searching for food and mates.

c) **What data would scientists collect to support the claim that the fence is harming the bobcat population?**
Scientists can collect DNA samples from bobcats from before (or immediately after) the fence is built and then compare the level of breeding in those bobcats with the level of breeding in bobcats from a long time after the fence is built. Lower levels of breeding in the bobcat populations from a long time after the fence is built would show that the fence is preventing the bobcat from mating.

d) **Describe one other example (other than cutting down trees) where changes people have made to habitats have unexpectedly harmed wildlife populations. Make sure you include in your answer the change to the habitat and how that change harms wildlife populations.**
Plastic trash in the Pacific harms baby seabirds.
Roads separate wood turtles from their vernal pools required for breeding and living.

Responses for The United States – Mexico Border Fence

a) How are animals and their habitat affected by the fences?
Their habitat is fragmented which might prevent mating or prevent them from using all the parts of the habitat that they need to survive.

b) Which animal do you predict will be least affected by the fence? Why?
The hummingbirds because they can fly.

c) Propose a solution to prevent the fence from harming wildlife habitat.
Build monitored overpasses or underpasses for wildlife. Don't build the fence.

d) How would you test whether the fence harms wildlife? Think back to the bighorn sheep example.
Census different animals before the fence is built and census them afterwards to see if their populations have declined. Do a genetic analysis of a population before the fence is built and then analyze the population after the fence is built to see if the fence has affected breeding (this would be a long-term study).