Follow that Bird!  A Science and Technology Unit on Tracking Birds

Smithsonian Conservation Biology Institute
Migratory Bird Center
WELCOME TO FOLLOW THAT BIRD! A SCIENCE AND TECHNOLOGY UNIT ON TRACKING BIRDS.

The goal of this inquiry-based unit is to teach core middle-school science concepts through student exploration of the tools used by Smithsonian scientists to track birds, the data they are collecting, and how new information is used for conservation. This project is one component of the larger Experience Migration exhibit coming to the Smithsonian’s National Zoo in 2021 and represents a collaborative effort between the Smithsonian Migratory Bird Center of the Smithsonian’s National Zoo and Conservation Biology Institute and Friends of the National Zoo.
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ACKNOWLEDGMENTS

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Finally, a sincere thank you to the classrooms that piloted the lessons and provided valuable feedback; and to you, the teachers, for participating in this unit. We sincerely hope you and your students have a wild time with it!
INTRODUCTION
INTRODUCTION: NGSS DISCIPLINARY CORE IDEAS

Follow that Bird! is comprised of five lessons that focus on Middle School Life Sciences: MS-LS2-1, MS-LS2-4, and MS-LS-5. The chart below designates which lessons cover each of these core ideas.

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**MS-LS2 Ecosystems: Interactions, Energy, and Dynamics**

**MS-LS2-1** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

**MS-LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

**MS-LS2-5** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Photo by Tim Romano, Smithsonian’s National Zoo
ENCOURAGING BIRD OBSERVATIONS
OPTIONAL SUPPLEMENTAL OBSERVATION ACTIVITY

OVERVIEW
This activity will encourage students to begin connecting with nature, specifically birds, and observing animal behavior, a key component to any scientific study. Begin this activity before or at any point during the lessons and get students in the habit of making observations at the beginning of each class. Continue observations throughout the *Follow that Bird!* unit, the school year or a pre-determined amount of time.

SCIENCE AND ENGINEERING PRACTICES:
- Asking questions
- Planning and carrying out investigations
- Using mathematics and computational thinking
- Analyzing and interpreting data
- Obtaining, evaluating and communicating information

CROSSCUTTING CONCEPTS:
- Patterns

Photo by Tim Romano, Smithsonian’s National Zoo
INTRODUCTION: ENCOURAGING BIRD OBSERVATIONS

Step 1:
ESTABLISH AN OBSERVATION AREA
Create a bird observation area utilizing a variety of feeders. You can purchase pre-made bird feeders, or create your own using recycled materials such as plastic bottles or juice cartons.

Step 2:
DEVELOP A RESEARCH QUESTION(S)
Have students design a scientific experiment using the feeder type and/or food types as variables. Sample research questions students might ask:
- Is there a relationship between the type of seed put out in a feeder and the species of birds observed at that feeder?
- Do the kinds of birds visiting a particular feeder change with the seasons?
- Do feeders attract birds more or less at different times of the year?
- Have the birds visiting feeders in our schoolyard changed over time (long-term study)?
- Does the land/habitat surrounding a feeder affect the birds that visit?
- Does changing land use affect the species of birds that visit a feeder (long-term study)?

Step 3:
SET UP BIRD FEEDERS
1. Refer to the bird feeder tips on pages 9 and 10 for more information on types of feeders, types of foods, maintaining feeders and general feeder facts.
2. Set up your bird feeders and schedule time for students to observe them.
   - Place feeders so that they are visible from a window so indoor viewing is possible when there is inclement weather.
   - To avoid having birds crash into the window, feeders should be placed either within 3 feet of the window or more than 30 feet away (in which case it would be handy to have binoculars for viewing the birds). If birds still collide with windows, it’s likely because the birds are being fooled by the reflection of the outdoors in the glass. You can break up the reflection and make the windows more visible to the birds by putting stickers or tape on them. Hanging old CDs, pie plates or other objects outside the window may also deter birds from flying towards the windows.

Step 4:
RECORD OBSERVATIONS
1. Have students keep track of birds they see at the feeders. Vary observation times so that students can investigate whether visitors change throughout the day - or perhaps even throughout the seasons (another opportunity to hypothesize). If you have multiple feeders containing different types of food, make sure students record which birds visit which feeders, as certain types of birds prefer particular food preferences (yet another variable to investigate!).
2. After several weeks, analyze your data looking for patterns in birds observed at your feeders.

Photo by Pamela Jenkins, Smithsonian’s National Zoo
INTRODUCTION: ENCOURAGING BIRD OBSERVATIONS

TIPS FOR FEEDING BIRDS IN YOUR SCHOOLYARD

TYPES OF FEEDERS

The following types of feeders are likely to be the best options for a schoolyard setting:

- **Tube feeder.** A hollow cylinder with multiple feeding ports and perches, used by a variety of seed-eating birds.

- **Window feeder.** A seed feeder that attaches to a window with suction cups. Should have an overhang above the seed trough to protect seeds from rain.

- **Nectar feeder.** Used for serving a sugar water solution for hummingbirds and less commonly for orioles (see below for recipe).

- **Suet feeder.** A specially made cage for holding suet (hardened beef fat) which attracts woodpeckers and other insect-eating birds. Instead of a suet cage, you can offer suet in a net bag, such as the kind onions are often sold in.

- Have students make seed feeders using recycled materials such as plastic bottles or juice cartons--an online search will turn up lots of simple designs.

TYPES OF FOODS

Seeds

- Black oil sunflower seeds are the preferred feeder food for a wide variety of seed-eating birds, including chickadees, titmice, nuthatches, and cardinals. You can purchase these seeds with the shells removed, which cuts down on the amount of debris collecting on the ground below the feeder. The larger black striped sunflower seeds are slightly less popular.

- Be careful when buying bird seed mixes because the cheaper brands tend to contain a high proportion of “filler” seeds that are rejected by most birds and end up being tossed to the ground. This can cause a mess and attract rodents. Filler seeds that are unpopular with most birds include milo, red millet, and wheat.

Suet

- Suet cakes made from beef fat are a good choice for attracting woodpeckers and other insect-eating birds. This high-calorie food is best offered in winter because it can quickly spoil in warmer temperatures, unless you purchase specially processed “heat-resistant” suet cakes.

Sugar Water

- Hummingbirds, and less commonly orioles, are attracted to sugar water feeders, also known as “nectar” feeders. Mix ¼ cup sugar to 1 cup boiling water, and allow to cool. Do not use honey or other sweeteners other than sugar, and do not use red dye.
MAINTAINING FEEDERS TO KEEP BIRDS HEALTHY

To avoid mold contamination and the spread of disease amongst the birds that come to your feeders:

- Clean seed feeders and suet cages once every 2 weeks. Soak empty feeder in warm, soapy water or a dilute bleach or vinegar solution (1 part bleach or vinegar to 9 parts water). Use a bottlebrush to get out any caked debris. Rinse well and dry thoroughly before refilling.
- Clean sugar water feeders every 3 to 5 days with warm water and a brush to prevent fermentation or mold.
- Store seeds in a cool, dry location.
- Clean up area beneath seed feeders by raking and disposing of shells and wasted seeds.
- If possible, relocate your feeders periodically to keep wastes from accumulating.

OTHER HELPFUL FEEDER FACTS

- With few exceptions, birds that come to seed feeders are not migratory. Although insects make up most of their diet during the breeding season (insects provide added protein necessary when raising young), seeds are a staple of their diet at other times of the year. Because seeds are available in the wild throughout the year, there is no reason for these birds to migrate.
- Most migratory birds require insects throughout the year and do not eat seeds. They therefore must migrate to warmer places during the winter where they will be able to find the food they need.
- Seed and suet feeders will attract more birds during the winter months because naturally occurring foods are in shorter supply at that time of year, and because birds are not eating as many insects as they do during the summer months.
- Feeders usually account for a relatively small portion of any bird’s diet. The only time feeders may play a critical role is during severe winter weather when birds’ naturally occurring foods are covered by ice or snow. In this instance, having access to a seed or suet feeder may be a lifesaver.
- In most parts of the United States and Canada, nectar feeders are used from early spring to late summer because that is when hummingbirds are present. Exceptions are the West Coast and southwestern corner of the United States where Anna’s hummingbirds are year-round residents. However, reports of hummingbirds lingering through the winter in the Gulf Coast states are becoming relatively common. An online search should tell you when hummingbirds typically arrive and depart in your area, and whether there have been any local reports of hummingbirds in the winter. It is a myth that keeping up a feeder in the fall will prevent hummingbirds from migrating.

For more information on feeding birds and having your students collect data on birds at feeders, visit: [https://feederwatch.org/learn/feeding-birds/](https://feederwatch.org/learn/feeding-birds/).
LESSON 1:
A Year in the Life of a Migratory Bird
LESSON 1:  
A YEAR IN THE LIFE OF A MIGRATORY BIRD

OVERVIEW
Lesson One will provide foundational knowledge regarding the annual cycle of migratory birds (wintering, migration, and breeding) through the use of maps and tracking data.

| ENGAGE | Which animals migrate? | Students identify animals that migrate. Teacher then focuses on birds and students brainstorm how we know where birds go when they migrate. | 10 minutes |
| EXPLORE | What is a bird’s annual cycle? | Students receive information about a bird and record what the bird is doing during each season. Students are introduced to the annual cycle diagram. | 50 minutes |
| EXPLORE | What does live tracking data teach us? | Students use a table generated from live tracking data to map the annual cycle of the black-crowned night-heron. | 30 minutes |
| ENGAGE | Where’s that bird? | Students are given latitude and longitude coordinates and try to find objects on the school grounds. | 50 minutes |
| EXPLAIN | What are the habitats of black-crowned night-herons? | Students use a map of the world to explain the different ecosystems the birds utilize in their annual cycle. | 50 minutes |
| ELABORATE | What is happening to the long-billed curlew? | Students use the long-billed curlew to see how populations of migratory birds are impacted by changing land use within their range. | 50 minutes |
| EVALUATE | Exit Ticket | Students explain the annual cycle of migratory birds. | 10 minutes |

DISCIPLINARY CORE IDEAS
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

OVERARCHING UNDERSTANDING
Migratory birds move large distances throughout their annual cycle. Tracking allows us to understand how these species interact with their environment.

Black-crowned night-heron
Photo by Stan Bysshe, Smithsonian’s National Zoo
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

ESSENTIAL QUESTIONS
1. What is an annual cycle of a bird?
2. What can tracking data tell us about the annual cycle of migrating birds?
3. How can habitat impact migratory birds?

RELATED MISCONCEPTIONS
• Students may think all birds migrate in the winter.
• Students may not understand the importance of looking at the full annual cycle of migratory birds in order to manage bird populations.

KNOWLEDGE
Students will know...
• The annual cycle of migratory birds.
• That Smithsonian scientists track birds in real time and over long periods of time.
• That birds face many hazards while migrating.

SKILLS
Students will be able to...
• Illustrate the annual cycle of migratory birds.
• Look at the full annual cycle of a bird to make informed decisions about managing bird populations.
• Determine how land use might affect migratory bird populations.
• Interpret live tracking data.

PRIOR STUDENT KNOWLEDGE:
• Students should have a basic knowledge of what migration is and know that some birds migrate.
• Students should have a general understanding that migratory birds move to warmer climates during colder months.

SCIENCE AND ENGINEERING PRACTICES:
• Asking questions
• Using mathematics and computational thinking
• Analyzing and interpreting data
• Obtaining, evaluating and communicating information

CROSSCUTTING CONCEPTS:
• Systems and system models
• Cause and effect
• Patterns

SAFETY CONSIDERATIONS:
• When taking students outdoors in Activity 4, look for areas that may have poison ivy, or other potentially hazardous materials. Do not place objects in areas that have a water depth of more than three inches, or are difficult for students to access.

TERMS:
annual cycle ● habitat ● migration

Refer to the Glossary in the Appendix.
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

TEACHER BACKGROUND INFORMATION

Refer to the Follow that Bird! website for information about annual cycles and the long-billed curlew. Information about annual cycles is located under “The Full Annual Cycle of Migratory Birds” in the menu and information about the long-billed curlew is located under “Species Profiles.”

In addition, the following website: https://nationalzoo.si.edu/migratory-birds/news/texas-shorebird-expedition-blog has some excellent background information and videos on tagging and monitoring migratory birds (including curlews) that you may want to consider showing your students.

On this page, there is also an interesting blog where Smithsonian Migratory Bird Center scientists Amy Scarpignato, Autumn-Lynn Harrison, and Pete Marra document a season of tracking birds.

MATERIALS:

Activity 1: ENGAGE
• Whiteboard, chalkboard or large paper to record student ideas

Activity 2: EXPLORE 1
• Internet access for each group of two to three students
• Activity Sheet 1: Seasonal Cycle
• Reference Sheet: Annual Cycle Diagram

Activity 3: EXPLORE 2
• Internet access for each group of two to three students
• Journals
• Activity Sheet 2: Mapping the Black-crowned Night-Heron
• Green, purple, red, and blue colored pencils or crayons

Activity 4: ENGAGE
• 10-12 stuffed animal birds or pictures of birds (preferably in color)
• Map of the school property
• Field journal
• Google maps (optional)
• GPS units (optional)
• Binoculars (optional)

Activity 5: EXPLAIN
• Internet access for each group of two to three students
• Activity Sheet 1: Seasonal Cycle (same handout from Activity 2: Explore 1)
• Optional - Reference Sheet: Black-bellied Plover Map

Activity 6: ELABORATE
• Internet access for each group of two to three students
• Map of North and South America
• Green, purple, red, and blue colored pencils or crayons

Activity 7: EVALUATE
• Annual Cycle Exit Ticket
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

ACTIVITY 1
ENGAGE - Which animals migrate?

1. Activate students’ prior knowledge. Have students brainstorm examples of animals they know migrate.
   - Ask: *What are some animals that you know migrate?* Record students’ answers on the board so everyone can see. If there aren’t any birds listed, prompt students by pointing out the groups of animals listed (mammals, fish, etc.) but then asking them what is missing.
   - Then ask: *How do we know where they go?* Record student’s answers on the board so everyone can see.

2. Introduce the topic of tracking birds.
   - Circle the birds listed on the board and tell students they are going to focus on birds for the rest of this unit (approximately two weeks).
   - With birds in mind, ask students if there is anything more they want to add to the second question, “how do we know where they go.” Record any new responses.

ACTIVITY 2
EXPLORE 1 - What is a bird’s annual cycle?

1. Read the bird profiles.
   - Break students up into groups of three or four.
   - Assign each group a bird: Pacific loon, brown pelican, or black-bellied plover.
   - Instruct students to read about their assigned bird on the *Follow that Bird!* website. All descriptions are located under “Species Profiles”. Students should avoid clicking on the other links at this point.
   - In their small groups, have students summarize the reading in two to three sentences.

2. Fill in the Seasonal Cycle activity sheet.
   - Hand out Activity Sheet 1: Seasonal Cycle to each student.
   - Using their bird profile, have students fill in each quadrant according to what the bird is doing during the specified time of year. They should work as a group but every student should fill out the activity sheet.

3. Discuss findings as a large group.
   - Have each group report on their findings.
   - Allow the opportunity for all groups to report out.

4. Introduce the Annual Cycle.
   - Show students the Annual Cycle diagram. Ask: *Do you notice any similarities between this diagram and your Seasonal Cycle sheet?*
   - Instruct students to do the following:
     - Cross out “Seasonal Cycle,” and replace it with “Annual Cycle.”
     - Cross out the months above each quadrant, and replace them with Breeding, Migrating South, Overwintering, and Migrating North.
   - Students will need this sheet for a future activity. Either collect sheets and redistribute later or instruct students to keep this for future use.
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

ACTIVITY 3

EXPLORE 2 – What does live tracking data teach us?

Prior Knowledge: Students should have a general knowledge of latitude and longitude.

1. Remind students of the migration discussion.
   - Ask: Where do the birds go? Allow for a few responses from students.
   - Then say: Today we are going to look at one bird in particular: the black-crowned night-heron. Scientists from the Smithsonian Migratory Bird Center have been tracking individuals of this bird species. We will look at their data and map out where these birds go throughout the entire year.

2. Find out about the black-crowned night-heron.
   - Break students up into groups of two to three and have them go to a computer.
   - Have them visit the Follow that Bird! website to find out background information about the black-crowned night-heron. They should record the following information in their journals:
     - How big is it?
     - Where can it be found?
     - What does it eat?
     - Where does it breed?
     - Are populations currently stable?
     - Draw a sketch of the bird (optional)

3. Introduce students to live tracking data.
   - Hand out Activity Sheet 2: Mapping the Black-crowned Night-Heron.
   - Direct students to the Follow that Bird! website.
   - Give students a “tour” of the interface. Point out the following:
     - Students can access the tracking table and map by clicking on the appropriate links in the Menu.
     - The tracking map shows where the birds have been, and the tracking table provides the latitude and longitude of their locations.
     - In the upper left corner of the map, the + and – symbols will allow students to zoom in and out.
     - The drop-down menus on both the tracking map and table pages will allow students to refine their search to look at specific data.

Migratory Birds Tracking Table

Screen capture of the menu on the Follow that Bird! website.
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

4. Start with the tracking map.
   - Below the map, have students choose the black-crowned night-heron from the drop-down menu under “Bird species.”
   - As a group, let students choose either Parker or Smith to follow and select the name from the drop-down menu under “Identity of bird.” Those are names given to two individual birds that have been tagged.
   - Tell students to mentally note where the bird has been.

5. Examine the data from the tracking table.
   - Have students choose the black-crowned night-heron from the drop-down menu under “bird species” and the same “Identity of bird” (Parker or Smith). The table shows a chronological order of where the individual bird was at a given time.
   - Hand out Activity Sheet 2: Mapping the Black-crowned Night-Heron and have students map these locations according to the annual cycle of the bird (Parker or Smith) they have chosen. Students should work directly from the data tables on the Follow that Bird! website.

6. To assess for understanding, collect student sheets and check for completion.

ACTIVITY 4

ENGAGE - Where’s that bird?

1. Prepare the activity.
   - The morning of the activity, place 10 to 12 stuffed animal birds or pictures of birds around the school yard. Place them on tree limbs, hidden in the grass, perched on a soccer goal, or other places you might find a bird.
   - Optional:
     • Place the birds in locations around the school property and get their latitude/longitude by using a GPS unit or app. You can also use the following free websites:
       • https://www.gps-coordinates.org/
       • https://www.maps.ie/coordinates.html
       • Google Earth
     • Create a map of the locations of the birds using Google Maps.
     • Create a handout with pictures of the birds you placed in the field.

2. Prepare students to track the birds.
   - Break students up into groups of three or four.
   - Explain that they will be bird scientists trying to find 10 birds (or however many you placed in the field).
   - Show students the map of the school property and orient them to the different landmarks.
   - Show them pictures of the birds they are looking for. Tell them to leave the birds where they are (do not collect them).
   - Let them know the boundaries of their search.
   - Go over proper behavior for outdoor learning and give them a time limit for finding the birds.
   - Optional:
     • If you are using GPS units or other mapping technology, explain how to use it.
     • Explain how to use the latitude/longitude map and give students the lat/long locations of the birds.
LESSON 1: A YEAR IN THE LIFE OF A MIGRATORY BIRD

- Hand out binoculars and other equipment you choose to use for this activity.

3. Have students find the birds.
   - Give groups 20 to 30 minutes to find the birds.
   - Have students record where they found each bird (in a tree, on a building, on the ground, etc.). They should note how easy or difficult it was to find each bird.

4. Wrap up the activity with a group discussion.
   - When students are back in the classroom, use the following discussion questions to get students thinking about the ease or difficulty of finding birds in the field:
     - Which birds were easy to find? Which were difficult?
     - What kind of problems do you think scientists would run into finding birds they’ve tracked?
     - What could they do to make it easier to find the birds?

ACTIVITY 5

EXPLAIN - What are the habitats of black-crowned night-herons?

Prior Knowledge: Students should know: migratory birds have an annual cycle and that throughout their annual cycle, migratory birds live in different places.

1. Discuss the black-crowned night-heron as a class.
   - Ask: When we looked at information about the black-crowned night-heron, what was its southern-most range? What was its northern-most range? Allow students to respond.
   - Ask: You probably have never been to Cuba or Nicaragua, and maybe you’ve never been to Washington, D.C., but do you think the habitat is the same in both places? Would the birds occupy the same types of habitat in both places? Have a discussion about this and define “habitat”, if needed.
   - Tell students: Today we are going to look at different types of habitats throughout North and South America. You will use your activity sheets (Activity Sheet 1) from the first annual cycle diagram you filled out and add to it.

2. Look at different habitats throughout North and South America.
   - Break students up into small groups.
   - Have students navigate to the Follow that Bird! website to examine various habitats.
   - Ask: Does your migratory bird occupy more than one habitat?
   - Ask: If yes, how do you think that bird survives in these different places?
     - Is it eating different foods?
     - Does it occupy different spaces? For example, maybe it lives on the beach when overwintering, but occupies forests during migration.

EXPLAIN Assessment

Have students complete a Venn Diagram comparing and contrasting different habitats.
Activity 6

ELABORATE - What's happening to the long-billed curlew?

Prior Knowledge: Students should know: migratory birds occupy various habitats during their annual cycle.

1. Read for understanding about the long-billed curlew.
   - In small groups, have students read about the long-billed curlew by visiting the Follow that Bird! website and selecting long-billed curlew under “Species Profiles”. Have students note the following:
     - What does it look like?
     - What is its habitat during its annual cycle?
     - What are its current threats?
   - Next, have students examine data for the long-billed curlew. Students can access the data by selecting “Migratory Birds Tracking Table” from the menu.
   - Have them map out the annual cycle data like they did for the black-crowned night-heron, using appropriate colors to indicate Breeding, Overwintering, Migrating North, and Migrating South activities for the birds.

2. Look at an image depicting cropland expansion in the USA.
   - Scroll to the bottom of the long-billed curlew description page and look at the image showing tracking data in their habitat.
   - Say: We will use the image to see if it can help us understand what is happening to the long-billed curlew.
   - Ask students:
     - What is happening to long-billed curlew habitat?
     - Given what we know about the long-billed curlew, how might this affect their populations?
     - Why are bird scientists concerned about long-billed curlew habitat?

Activity 7

EVALUATE - Exit Ticket

1. Create an annual cycle.
   - Hand out the Exit Ticket.
   - Have students create their own annual cycle of the long-billed curlew. They should use the appropriate colors to represent breeding, migrating south, overwintering, and migrating north.
   - Give students 10 minutes to complete the activity.

Extending the Lesson

1. Act out the annual cycle.
   - Use different-colored rope to make an outline and represent the US (including Alaska), Central America and Canada.
   - Using the Annual Cycle sheets for the long-billed curlew and black-crowned night-heron, have students “migrate” along the same routes, recording what the birds are doing in each part of the cycle.
2. Watch the career connection video (page 20).
3. Discuss what students can do to protect birds (page 20).
LIKE SCAVENGER HUNTS AND SAVING SPECIES?
Meet Calandra Stanley, a PhD Candidate at the Smithsonian Migratory Bird Center. She is studying a small species called the wood thrush whose population has been dropping for years. In this career connection video, learn about Calandra’s scavenger hunt-like quests to track and locate the birds so she can reverse their decline.

HOW CAN YOU HELP?
Taking Action to Protect Birds!

As you’ve learned in this lesson, migratory birds live in and visit many different habitats throughout the year. You can help by making your yard, neighborhood, and/or schoolyard bird-friendly for migratory and resident birds! Here are some tips...

• Create habitats for wildlife: plant native trees, bushes and flowers to provide food and shelter.
• Provide a water source year round.
• Avoid chemical pesticides and fertilizers.
• If you put up bird feeders or bird baths, clean them regularly.
• Don’t throw trash on the ground.
Seasonal Cycle
for the (circle one):
Black-bellied Plover   Brown Pelican   Pacific Loon

Directions: Using your migratory bird profile, fill in bird activities during each of the months indicated. It is OK if the months do not exactly match up with the bird’s activities.
Mapping the Black-crowned Night-Heron

Directions: Using the tracking table on the Follow that Bird! website, map the annual cycle of the black-crowned night-heron you chose (Parker or Smith). Place dots on the map using the appropriate colors:

- Red - overwintering
- Blue - migrating north
- Green - breeding
- Purple - migrating south

Finally, connect all the dots with the appropriate color.
Annual Cycle Diagram
Black-bellied Plover Map

Black-bellied Plover

*Pluvialis squatarola*

**Legend:**
- **Resident**
- **Breeding**
- **Winter**
- **Migrant**

Image source: https://dcbirds.si.edu/bird/black-bellied-plover
Annual Cycle Exit Ticket

Directions: Fill in the annual cycle chart below. You don’t need to pick a specific bird (although you may); rather, make sure you describe each part of the annual cycle and what the migrating birds are doing.
Black-crowned Night-heron

Photo by Stan Bysshe, Smithsonian's National Zoo
LESSON 2:
Tracking the Annual Cycle of Migratory Birds
LESSON 2:
TRACKING THE ANNUAL CYCLE OF MIGRATORY BIRDS

OVERVIEW
Lesson Two will introduce students to the technology of tracking. Students will compare and contrast several tracking devices and gain a better idea of how each device is used.

| ENGAGE | What do we know where people are? What do we know where our things are? | Class has a group discussion on tracking technologies students may be familiar with and connects it to tracking technologies for birds. | 5 minutes |
| EXPLORE | What kinds of tracking devices do scientists use to track birds? | Students are assigned groups and gather information about their assigned tracking device. | 30 minutes |
| EXPLAIN | How do the tracking devices compare? | Students form “jigsaw groups” and share information with one another about their assigned tracking devices. | 50 minutes |
| ELABORATE | How do we decide which tracking device to use? | Given a bird and a research question, students determine which tracking device to use. | 15 minutes |
| EVALUATE | Written paragraph | Students write paragraphs describing why they chose a certain tracking device for a given scenario. | N/A |

DISCIPLINARY CORE IDEAS

**MS-LS2-5:** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

OVERARCHING UNDERSTANDING
Scientists use different types of tracking technologies to figure out where birds are throughout their annual cycle.

Scientists attach a tracking device to a black-bellied plover.

Photo by Tim Romano, Smithsonian’s National Zoo
### LESSON 2: TRACKING THE ANNUAL CYCLE OF MIGRATORY BIRDS

<table>
<thead>
<tr>
<th>ESSENTIAL QUESTIONS</th>
<th>RELATED MISCONCEPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can we use technology to track migratory birds?</td>
<td>Students may think technology is so advanced that we could put any kind of device on any bird (not taking into account size of bird, type of data we need, etc.).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KNOWLEDGE</th>
<th>SKILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students will know...</strong></td>
<td><strong>Students will be able to...</strong></td>
</tr>
<tr>
<td>• Some of the types of technology available to scientists for bird tracking.</td>
<td>• Name and describe five different types of tracking devices.</td>
</tr>
<tr>
<td>• What kinds of data different tracking devices can collect.</td>
<td>• Compare and contrast different tracking devices in terms of data collected and advantages/disadvantages of use.</td>
</tr>
<tr>
<td>• How scientists use tracking data to understand and solve problems.</td>
<td>• Given a scientific question or problem, choose an appropriate tracking device to investigate or answer the question or problem.</td>
</tr>
</tbody>
</table>

### PRIOR STUDENT KNOWLEDGE:
**Students should be familiar with the annual cycle of migratory birds.**

### SCIENCE AND ENGINEERING PRACTICES:
- Asking questions
- Using mathematics and computational thinking
- Developing and using models
- Engaging in argument from evidence
- Obtaining, evaluating and communicating information

### CROSSCUTTING CONCEPTS:
- Structure and function
- Patterns

### TERMS:
- bird band
- radio telemetry
- global positioning system (GPS)
- satellite telemetry
- light-level geolocator
- PIT tag

Refer to the Glossary in the Appendix.
There are many different types of devices used to track animals. The type of device scientists choose to use in a given study depends on the animal they are tracking, the scientific question, and the technological limitations of the device itself. In this lesson, students will look at five methods/devices for tracking birds, including bird banding, light-level geolocators, PIT tags, radio telemetry, and satellite telemetry. These are not all of the devices currently available to researchers but will provide students with a sampling of the variety of technologies used. Refer to the tracking descriptions on the Follow that Bird! website for more information. Students will use these descriptions in this lesson.

MATERIALS:

Activity 1: ENGAGE
- None

Activity 2: EXPLORE
- Internet access for each group of two to three students
- Journals or Activity Sheet 1: Tracking Device Questions

Activity 3: EXPLAIN
- None

Activity 4: ELABORATE
- Scenario Cards
- Scoring Rubric

Activity 5: EVALUATE
- None
**Activity 1**

ENGAGE - How do we know where people are?

As a whole group, discuss how we know where people are at any given point.

- Ask: How do we know where a person is at any given moment? If you had to pinpoint a person’s location, could you do it? How? Allow several students to answer.
- Ask: What if we needed to track an inanimate object - say, someone stole your computer, or cell phone, or perhaps a car - how could we do that? If students do not mention GPS technology, prompt or introduce them to it.
- Discuss how GPS is used in cell phones, and in tracking technology on computers and cars (such as LoJack).
- Ask: How can we use the same technology to determine where birds are at any given time during their annual cycle? Take a few answers from students, then explain that they will examine several different methods of tracking migratory birds.
- Tell students: By the end of the lesson, you will be able to determine which tracking method is best to use, depending on what information is needed or desired by the scientist.

**Activity 2**

EXPLORE - What kinds of tracking devices do scientists use to track birds?

Divide students into Expert Groups.

- Divide students into five groups. Tell students: These are your Expert Groups, where each group will become an expert on a tracking device.
- Assign each Expert Group one of five tracking devices: bands, light-level geolocators, radio telemetry, satellite telemetry, or PIT tags.
- Have each Expert Group read about their tracking device by visiting the Follow that Bird! website.* Descriptions of each tracking device are located under the “Tracking devices” drop-down in the navigation bar.
- After reading about their device, have groups record answers to the following questions about their device in their journals or on Activity Sheet 1: Tracking Device Questions:
  - How does this technology work?
  - What kind of data can be recorded?
  - How is it attached to the bird? Draw a schematic.
  - How much does it weigh?
  - What does it cost?
  - How is the data acquired by the scientist/observer?
  - What are the advantages/disadvantages of using this type of device?
- Tell students: All members of the Expert Group should agree on the answers to these questions, as you are each going to be presenting the information to your Jigsaw Groups in the next portion of the lesson, so consistency and accuracy are important.

*Alternatively, teachers can print the information for students to use in their Expert Groups.
LESSON 2: TRACKING THE ANNUAL CYCLE OF MIGRATORY BIRDS

ACTIVITY 3
EXPLAIN (Student-Centered) – How do the tracking devices compare?

1. Break up Expert Groups into “Jigsaw Groups” and have students share what they learned.
   - Place students into Jigsaw Groups such that each group contains one banding expert, one light-level geolocator expert, one radio telemetry expert, one satellite telemetry expert, and one PIT tag expert.
   - In their Jigsaw Groups, have students take turns sharing the information they gathered about their tracking devices in their Expert Groups until all students have shared, and each student has information about all five tracking devices.

2. Show a brief video about tracking the black-crowned night-heron.
   - As an example of how tracking devices can help scientists answer questions about migratory bird behavior, show a short video (4:07 minutes) about black-crowned night-herons at the Smithsonian’s National Zoo: [Wild Inside the National Zoo: The Great Night Heron Mystery](#).

ACTIVITY 4
ELABORATE - How do we decide which tracking device to use?

1. Have students choose a tracking device based on a given scenario.
   - Randomly assign one of the Scenario Cards to each student.
   - Given the bird information and the question the scientist wants to answer on the Scenario Cards, ask students to determine which tracking device would be best to use.
   - Have students write a brief paragraph explaining why they chose that particular device. Share the Scoring Rubric with students before they begin.

2. Discuss as a group in a “cognitive closure,” aligned with objective(s).
   - Once the student answers from Activity 4: Elaborate have been collected, ask students to share the scenario they were presented with and which tracking device they chose.
   - Have them justify their answers to the class.

ACTIVITY 5
EVALUATE - Student Write-ups

Grade students’ paragraphs.
- Use the provided Scoring Rubric to score each student’s written justification for his/her chosen tracking device presented in Activity 4: ELABORATE.
- Adapt the rubric as needed to fit your class.

EXTENDING THE LESSON

1. Complete the following lesson on determining latitude and longitude, given sunrise and sunset.
   - Research American redstart, black-capped chickadee, red knot and wood thrush migration patterns.
   - Give students the sunrise and sunset information for a given area within one of these species ranges.
   - Have students determine latitude and longitude based on the sunrise/sunset information and explain what part of the annual cycle the bird is in. Refer to [NOAA’s Solar Calculator](http://sunrise-sunset.org) or sunrise and sunset at any given location.

2. Watch the career connection video (page 33).
3. Discuss what students can do to protect birds (page 33).
CAREER CONNECTION

SPOTLIGHT ON: AUTUMN-LYNN HARRISON, RESEARCH ECOLOGIST

LOVE NATURE? WANT TO TRAVEL THE GLOBE?
Maybe you have what it takes to be a Research Ecologist like Autumn-Lynn Harrison at the Smithsonian Migratory Bird Center. Her job has taken her to the Serengeti, beaches in Patagonia, Arctic Alaska and even a diamond mine in South Africa. In this career connection video, you will learn how scientists like Autumn-Lynn use the tracking devices you learned about to help save animals across the globe.

HOW CAN YOU HELP?
Taking Action to Protect Birds!

As you’ve learned in this lesson, there are many different ways to track animals. The simplest way is to observe them! You can help by learning more about birds and becoming a bird watcher. Learn more about birds and how to stay involved by visiting the Smithsonian Migratory Bird Center website (https://nationalzoo.si.edu/migratory-birds/public-outreach).
Tasking Device Questions

1. How does this technology work?

2. What kind of data can be recorded?

3. How is it attached to the bird? 
   
   Draw a schematic.

4. How much does it weigh?

5. What does it cost?

6. How is the data acquired by the scientist/observer?

7. What are the advantages/disadvantages of using this type of device?
American Redstart

The American redstart is a brightly colored songbird that, despite its very small size, migrates great distances every year. Studies of the redstart by the Smithsonian’s Pete Marra have shown that the quality of habitat on wintering grounds in Jamaica affects how successful they are on their breeding grounds. Researchers from the Smithsonian and the Cornell Lab of Ornithology now want to determine where wintering redstarts in Jamaica spend their summers.

Which tracking device should they choose? Why?

Black-capped Chickadee

Many aspects of the daily lives of even common backyard birds remain a mystery. Scientists at Cornell University’s Lab of Ornithology are trying to determine the relationship between weather and bird behavior. They will be conducting a study on how often birds feed at bird feeders in response to changes in weather. To do so, they will tag black-capped chickadees and count the number of times individuals use a bird feeder per day over a period of two years.

Which tracking device should they choose? Why?
Red Knot

Red knots are a fascinating bird that travels incredibly far during its annual cycle. Migrating red knots gather in huge numbers to feed at stopover sites. One of the most important stopover sites is Delaware Bay, USA. Their migration coincides with the spawning of horseshoe crabs -- red knots eat the eggs of the crabs and double their body weight! This gives them the energy to complete their migration. Loss of horseshoe crabs due to human activity has led to a drastic decline in red knot populations in recent years. Smithsonian scientists plan to track individual red knots throughout the year to determine their precise location and survival.

Which tracking device should they choose? Why?

Wood Thrush

Wood thrush are a migratory bird species that is predicted to have declined by over a half (62%) since scientists began recording population records in 1966. Wood thrush live in mature forests in eastern North America during the breeding season and winter in the forests of Mexico and Central America. Loss of their habitats in both regions is expected to be causing their decline. A graduate student at the Smithsonian hopes to help determine what is causing the decline. One of her research questions aims to figure out the amount of habitat that an individual wood thrush uses. She will travel to the forests of Indiana, USA to tag wood thrushes. She will track the movement of birds over a one month period of time.

Which tracking device should they choose? Why?
LESSON 2: SCORING RUBRIC

Scoring Rubric

SCORE: 3

There is evidence in this response that the student has a **FULL AND COMPLETE UNDERSTANDING** of the question or problem, and how the chosen tracking device can help to answer the question or solve the problem.

- The supporting evidence is complete and demonstrates a full integration of scientific concepts, principles, and/or skills.
- The response reflects a complete synthesis of information, such as the data collected by the device, its suitability for the project, and justification for why it was chosen.
- The accurate use of scientific terminology strengthens the response.
- An effective application of the concept to a practical problem or real-world situation reveals a complete understanding of the scientific principles.

SCORE: 2

There is evidence in this response that the student has a **GENERAL UNDERSTANDING** of the question or problem.

- The supporting scientific evidence is generally complete with some integration of scientific concepts, principles, and/or skills.
- The response reflects some synthesis of information, such as data collected by the device, its suitability for the project, and/or justification for why it was chosen.
- The accurate use of scientific terminology is present in the response.
- An application of the concept to a practical problem or real-world situation reveals a general understanding of the scientific principles.

SCORE: 1

There is evidence in this response that the student has **MINIMAL UNDERSTANDING** of the question or problem.

- The supporting scientific evidence is minimal.
- The response provides little or no synthesis of information, such as data collected by the device, its suitability for the project, and/or justification for why it was chosen.
- The accurate use of scientific terminology may not be present in the response.
- An application to the problem, if attempted, is minimal.

SCORE: 0

There is evidence that the student has **NO UNDERSTANDING** of the question or problem.

- The response is completely incorrect or irrelevant.
- Alternatively, there is no response.
Research Ecologist, Autumn-Lynn Harrison releases a black-bellied plover during a trip to Texas for conservation field work.

Photo by Tim Romano, Smithsonian’s National Zoo
LESSON 3:
How can Tracking Data Inform Conservation?
LESSON 3:
HOW CAN TRACKING DATA INFORM CONSERVATION?

OVERVIEW
In Lesson Three, students will learn how tracking data informs conservation decisions made by scientists and that the type of tracking device you use depends on various factors, including bird morphology and annual cycle. Students will solve the mystery of declining Swainson’s hawk populations and learn about biomagnification and its effects on animals.

ENGAGE
How do we use tracking data to help us conserve migratory birds?
Class engages in a group discussion on what is conservation. Students discuss how can tracking data be used to help conserve migratory bird species. Students then read about the annual cycle of the Swainson’s hawk (including sudden population decline).
20 minutes

EXPLORE
What happened to the Swainson’s hawk?
Students continue the story of the Swainson’s hawk. They look at real tracking data and work in small groups to discuss why they think Swainson’s Hawk populations decreased.
30 minutes

ELABORATE
What is biomagnification and what does it look like?
Students learn about biomagnification and how it might affect animals.
30 minutes

EVALUATE
Formative assessment
Students discuss why conserving habitat is critical to conserving bird populations. Individual students will write a paragraph.
10 minutes

DISCIPLINARY CORE IDEAS
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

OVERARCHING UNDERSTANDING
Tracking data informs conservation and the type of tracking device depends on a variety of factors.
### LESSON 3: HOW CAN TRACKING DATA INFORM CONSERVATION?

<table>
<thead>
<tr>
<th>ESSENTIAL QUESTIONS</th>
<th>RELATED MISCONCEPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do scientists use tracking data to make conservation decisions?</td>
<td>• Students may think conserving bird species is all about birth rate.</td>
</tr>
<tr>
<td>2. What are some examples of using tracking data to conserve bird species?</td>
<td>• Students might not consider all of the habitats utilized during the annual cycle.</td>
</tr>
<tr>
<td>3. Why is conserving bird habitat so critical to conserving bird populations?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KNOWLEDGE</th>
<th>SKILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students will know...</strong></td>
<td><strong>Students will be able to...</strong></td>
</tr>
<tr>
<td>• How tracking data can be used to make conservation decisions</td>
<td>• Explain how tracking data was used to understand Swainson’s hawk populations.</td>
</tr>
<tr>
<td>• What biomagnification is</td>
<td>• Justify why conserving bird habitat is critical to conserving bird populations.</td>
</tr>
<tr>
<td></td>
<td>• Describe biomagnification.</td>
</tr>
</tbody>
</table>

### PRIOR STUDENT KNOWLEDGE:
- Students should be familiar with the annual cycle of migratory birds.
- Students should understand the different types of tracking devices used for migratory birds.
- Students should be familiar with the components and terminology related to food webs and food chains.

### SCIENCE AND ENGINEERING PRACTICES:
- Asking questions
- Using mathematics and computational thinking
- Developing and using models
- Obtaining, evaluating and communicating information
- Analyzing and interpreting data
- Engaging in argument from evidence
- Constructing explanations

### CROSSCUTTING CONCEPTS:
- Patterns
- Systems and system models

### TERMS:
- biomagnification
- conservation

Refer to the Glossary in the Appendix.
TEACHER BACKGROUND INFORMATION

In this lesson, students will learn about how tracking data can be used to inform conservation. We will address two processes by which pollution can impact wildlife: acute toxicity and biomagnification.

This lesson will use examples from two species, the Swainson’s hawk and Pacific loon. Information about these species is available on the Follow that Bird! Website under Species Profiles. Students will be reading these descriptions in the lesson.

Students will first learn about Swainson’s hawk (Activities 1 and 2), which experienced a poisoning event in the Pampas region of Argentina. This event was caused by the application of a pesticide to kill grasshoppers. Tracking data led to this realization. This led to the banning of the pesticide in the region. Students will then learn about how persistent pollutants in the ecosystem can harm wildlife using the Pacific loon as an example.

Students then learn about how the biomagnification of pollutants can impact wildlife. We will use the example of how mercury, which is emitted from coal-fired power plants and accumulates at high latitudes, impacts the Pacific loon. In high concentrations, mercury can affect the cognitive ability, reproductive success, and immune functions. Biomagnification is the process by which contaminants such as pesticides or heavy metals are concentrated in the tissues of organisms as you go up the food chain. In the provided example, phytoplankton at the bottom of the food chain absorb mercury that is present in the water. The phytoplankton contain only low levels of the contaminant. When phytoplankton are eaten, the contaminant becomes more concentrated in the higher-level organism. This process repeats and contaminant concentrations increase up the food chain.

For more information about how pesticides can affect migratory bird populations, read Popular Pesticides Linked to Drops in Bird Populations, an article from Smithsonian.com.

MATERIALS:

Activity 1: ENGAGE
- Whiteboard, chalkboard or large paper to record student ideas

Activity 2: EXPLORE
- Internet access or printouts of the Swainson’s hawk description from the Follow that Bird! website

Activity 3: ELABORATE
- Colored plastic beads
- Test tube rack
- Tray
- 10 small test tubes per group
- 3 medium test tubes per group
- 1 large test tube per group
- 50 mL beaker per group
- Tape
- Markers

Activity 4: EVALUATE
- None
LESSON 3: HOW CAN TRACKING DATA INFORM CONSERVATION?

**ACTIVITY 1**

ENGAGE - How do we use tracking data to help us conserve migratory bird populations?

1. Activate students’ prior knowledge. Ask students to define conservation. Allow students to respond and record answers on the board. Prompt students with additional questions, i.e.:
   - What does it mean to conserve something?
   - How do you conserve water?
   - What might it mean to conserve wildlife?

2. Introduce the concept of conserving migratory birds.
   - Ask: Given what you now know about tracking devices, how can we use them to make wildlife conservation decisions? Record responses on the board. Students should record all these in their notebooks.
   - Tell students that they are going to try to solve the mystery of a migratory bird called the Swainson’s hawk. They are going to read about its annual cycle and look at tracking data.
   - Break students up into groups of two or three. Have groups navigate to the Follow that Bird! website to read about the Swainson’s hawk or print and hand out the description. The Swainson’s hawk description is located under the “Species Profiles” in the menu.

**ACTIVITY 2**

EXPLORE - What happened to the Swainson’s hawk?

1. Look at tracking data for the Swainson’s hawk using habitat and agriculture map layers.
   - Tell students to navigate to the tracking map by selecting “Migratory Birds Tracking Map” from the menu.
   - Once on the tracking map page, have students select Swainson’s hawk from the “Bird Species” drop-down bar.
   - Then tell students to click “Habitats” from the filters in the upper right-hand corner of the map. Have students note the type of habitat Swainson’s hawks use in their overwintering grounds.
   - Next, have students click “Agriculture” in the upper right-hand corner of the map.

2. Discuss as a large group.
   - Ask: Looking at the Swainson’s hawk data with the habitat layer, what type of habitat does Swainson’s hawk occupy in its winter range?
   - Ask: What do you think caused the population decline for Swainson’s hawks?

3. Read how tracking data helped inform Swainson’s hawk conservation.
   - From the Follow that Bird! website, select Swainson’s hawk from the “Species Profiles” in the menu.
   - Scroll to the bottom of the page profile to learn about how tracking data helped inform Swainson’s hawk conservation.
4. As a class, discuss the resolution to the Swainson’s hawk mystery. Ask:
   - What killed the hawks? (Eating a lot of grasshoppers that were laced with a pesticide)
   - How did Dr. Woodbridge figure out what was really happening to the hawks? (First, he put satellite tags on the birds to find out where exactly they were going. Then he went down there to see for himself)
   - How do you think the farmers reacted to this discovery?
   - What was the solution to this problem? (Many government and private organizations came together to ban the use of this pesticide)

3. Label the tubes and beakers.
   - Instruct groups to use the tape and marker to label the small test tubes with the first organism in the food chain (plankton).
   - Next, have groups label the medium test tubes with the second organism (small fish).
   - Have groups label the large test tube with the third organism (large fish).
   - Finally, instruct groups to label the 50 mL beaker with the fourth organism (Pacific loon).

4. Fill the test tubes.
   - Have groups place the ten small test tubes in a test-tube rack standing on a tray. Tell groups to fill the test tubes with beads to simulate mercury pollution until approximately 0.5 mL of beads have fallen into each test tube.
   - The medium-sized test tubes represent the second organism in the food chain developed by the class (e.g., the small fish). Continue the story: The small fishes eat three plants. Instruct groups to add the contents of three of the small test tubes to one of the medium-sized test tubes. Have groups repeat for each of the other two medium-sized test tubes and set aside the remaining small test tube (of the original ten). Tell students that the last small test tube will be used later.
   - The large test tube represents the third organism in the food chain (e.g., the large fish). Continue the story: The large fish eats three small fish. Instruct groups to add the beads from the three medium-sized test tubes to the large test tube.
   - Tell groups to add approximately 1.5 mL of beads to one of the medium-sized test tubes (small fish) and set aside to facilitate comparison of the amount of toxins in each organism at the end of the demonstration.

44
The 50 mL beaker represents the fourth organism (e.g., Pacific loon). Continue the story: The Pacific loon eats three large fish. Have groups place a mark on the large test tube at the level of the beads, and then transfer the beads from the large test tube to the 50 mL beaker. Tell groups to again add beads up to the line in the large test tube and then add it to the 50 mL beaker. Have groups repeat this action for a third time. Instruct groups to add beads up to the line in the large test tube one final time and set it aside for comparison later (do not add it to the 50 mL beaker).

5. Compare the contents of the four “organisms.”
   - Ask: Will all organisms at various levels in the food chain have the same toxin concentrations? Ask students to explain their answers to this question.
   - Answer: The higher the organism is in the food chain the more toxin will accumulate in its body. So the organisms higher in the food chain will have a higher concentration.
   - Introduce the term “biomagnification” and tell students they just demonstrated what biomagnification is. Give them a few minutes to come up with their own definition and share. Provide them with the formal definition (refer to the glossary) and have them record it in their journals/notebooks.

ACTIVITY 4

EVALUATION - Formative Assessment

1. Discuss habitat conservation.
   - Tell groups to discuss why conserving habitat is critical to conserving bird populations.
   - Have students individually write a paragraph explaining why in their own words.

EXTENDING THE LESSON

1. Watch the career connection video (page 46).
2. Discuss what students can do to protect birds (page 46).
ENJOY SOLVING MYSTERIES LIKE A DETECTIVE?
That’s what Kali Holder does as a Veterinary Pathologist at the Smithsonian’s National Zoo and Conservation Biology Institute. She looks at animals that have died and pieces together the cause of death. Uncovering the answer may be the missing link that helps to determine how we can better save species.

HOW CAN YOU HELP?
Taking Action to Protect Birds!

As you’ve learned in this lesson, habitat conservation is important for conserving bird populations. You also learned that pollution and pesticides are harmful to animals. Want to do more to protect birds and other wildlife? You can help by...

- Encouraging your family to skip the pesticides. Instead, create a great habitat for birds and they’ll do the work for you by eating lots of insects.
- Riding your bike, walking or taking public transportation. Car exhaust is one type of pollution. You can help by thinking of other ways to get from place to place without using a car.
LESSON 4:
What Impacts Migratory Birds?

Photo by © Nathan Cooper
LESSON 4: DISCOVERING THE IMPACTS OF ENVIRONMENTAL CHANGES ON MIGRATORY BIRDS

OVERVIEW
In Lesson Four, students will build a model that demonstrates how variables impact the population of the Kirtland’s warbler. They will begin by understanding what a model is and building a model that is familiar to them. Next, they will learn about the Kirtland’s warbler and look at variables that impact its population across its annual cycle. Students will share information and build a complete model in their small groups.

<table>
<thead>
<tr>
<th>ENGAGE</th>
<th>What is a model?</th>
<th>Create a familiar model with students: what impacts my grades?</th>
<th>15 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPLOR</td>
<td>How can a model illustrate impacts to the Kirtland’s warbler populations?</td>
<td>Students will learn about the Kirtland's warbler and look at a model of what might impact its population.</td>
<td>30 minutes</td>
</tr>
<tr>
<td></td>
<td>What are the impacts to Kirtland’s warblers at different stages of their annual cycle?</td>
<td>Students will add two to three impacts on warbler population to the class model. They will then add solutions to the impacts.</td>
<td>45 minutes</td>
</tr>
<tr>
<td>EXPLAIN</td>
<td>How will the model change when the new impacts are added?</td>
<td>Students will run a simulation of their model.</td>
<td>25 minutes</td>
</tr>
<tr>
<td>ELABOR</td>
<td>What does my model show?</td>
<td>Students will share their models with the class.</td>
<td>45 minutes</td>
</tr>
<tr>
<td>EVALUATE</td>
<td>Exit Ticket</td>
<td>Students share their final model with the class.</td>
<td>10 minutes</td>
</tr>
</tbody>
</table>

DISCIPLINARY CORE IDEAS
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

OVERARCHING UNDERSTANDING
We use models to help us understand complex scientific processes. Computer models are only as good as the inputs we put into them and it is important to understand the concepts we are trying to model so we can make appropriate conclusions.
## LESSON 4: DISCOVERING THE IMPACTS TO MIGRATORY BIRDS

### ESSENTIAL QUESTIONS
1. How can we predict the impact of threats and conservation actions on migratory bird populations?
2. Given what we know about a bird’s annual cycle, is there a way to see what would happen to the population if a variable changes?
3. What is a model and how can it help us understand the impacts on migratory bird populations?

### RELATED MISCONCEPTIONS
- Students may think a model is static, like a model airplane.
- Students may not understand how multiple variables interact to impact migratory bird populations.

### KNOWLEDGE
**Students will know...**
Various factors impact migratory bird populations.

### SKILLS
**Students will be able to...**
Use a model, based on scientific information, to understand how multiple variables can impact migratory bird populations.

### PRIOR STUDENT KNOWLEDGE:
- Students should understand the various factors of the annual cycle that can impact migratory birds.

### SCIENCE AND ENGINEERING PRACTICES:
- Asking questions
- Using mathematics and computational thinking
- Developing and using models
- Obtaining, evaluating, and communicating information
- Constructing explanations
- Engaging in argument from evidence
- Analyzing and interpreting data

### CROSSCUTTING CONCEPTS:
- Patterns
- Cause and effect
- Systems and system models

### MATERIALS:
**Activity 1: ENGAGE**
- None

**Activity 2: EXPLORE**
- Computers with Internet access
- Activity Sheet 1: What Impacts Kirtland’s Warbler Populations?

**Activity 3: EXPLAIN**
- Computers with Internet access
- Activity Sheet 1: What Impacts Kirtland’s Warbler Populations?

**Activity 4: ELABORATE**
- Computers with Internet access
- Activity Sheet 1: What Impacts Kirtland’s Warbler Populations?
- Activity Sheet 2: Making a Prediction

**Activity 5: EVALUATE**
- Computers with Internet access
- Activity Sheet 1: What Impacts Kirtland’s Warbler Populations?

### TERMS:
- dependent variable
- independent variable
- model

Refer to the Glossary in the Appendix.
Before you begin, view the Sage Modeler video to see how the modeler works. IMPORTANT NOTE: SageModeler works best on desktop or laptop computers and is not well suited on a tablet.

Review the following article for additional information on modeling:

Modeling for teachers
Scientists use computer models to help them think about complex phenomena. Visual representations can capture complexity in a single, organized image. This "structural level" of modeling a system, the level at which things are connected within a system or phenomenon, is crucial to the deeper understanding of how the system behaves.

System structure is interesting but static. For most scientific phenomena it is behavior that interests us, and behavior flows directly from structure. Structure dictates a pattern of influence, which is modulated by the combined effects of the “weighted” influences of system components on one another (see Activity 4). It is in the realm of behavior that computer modeling shows its real power. Not only can the modeler organize and display her mental understanding of system structure, but she can also incorporate assumptions and understandings about how things are connected, specifying precisely the impact of one system component on another. The power of using a computer to predict model behavior is its ability to consider all relationships simultaneously, a process that becomes exponentially more difficult for a human mind as the number of connections increases.
Simulation of a completed model allows the user to experiment with his or her mental assumptions about system structure and influence. SageModeler will compute the impact of all defined cause and effect or correlational connections in the model, and generate data showing variations in all dependent variables as a result of changes made to any independent variable. These data can be displayed in several ways: as tables of changing variable magnitude, as graphs showing comparative change in different variables, and as graphical representations showing the resulting value of any variable as a dependent variable is changed.

Simulating a model helps to challenge and refine our thinking. The data generated in a simulation can be compared with a variety of other data sets as the modeler seeks to gain better understanding.

1. **Simulation data can be compared to hypothetical data expected by the modeler.** This is a technique often used early in an investigation. When a model is first being tested, the scientist or engineer may have a “sense” of what is to be expected when some variable within a model is changed. The expectation is often hypothetical and based on incomplete knowledge, but serves as a starting point for modeling. When discrepancies between the model’s output and expectation arise, the investigator is challenged to revisit her hypothesis about how the world is constructed (the model structure) and the original behavioral expectations that went along with it.

2. **Simulation data can be compared to real-world data.** Discrepancies between simulation data and expected data will often lead a scientist to further research a question or phenomenon in order to better understand it. The research might involve an exploration of current literature and/or undertaking laboratory investigations, and uncover real-world data for the same phenomenon as that being modeled. A comparison of data patterns generated by the simulation to those from the real world can be used to evaluate a model and its ability to match reality, in turn increasing or decreasing the scientist’s confidence in the accuracy of her “thinking.” A good match can boost confidence and encourage the modeler to make only minor tweaks to a model (and the thinking behind it), in order to better match reality. A poor match can cause the modeler to challenge fundamental assumptions, undergo more background research, and completely overhaul a model (and the thinking behind it). It is the “back and forth” between changes to the model’s structure and its ability to simulate reality that helps the modeler refine and clarify her thinking about a phenomenon.

3. **Simulation data can be compared to data expected by or collected by others.** Science, at its best, is a collaborative effort. Model structure can be a very valuable way of expressing one’s beliefs about how the system underlying a phenomenon might be constructed. It allows for others to quickly visualize, question, and discuss another’s thinking. Simulation adds another dimension to collaboration as it can show behavioral data patterns that can be compared to the personal experience of others, enhancing critical debate and encouraging the sharing of ideas. In a classroom this can be very powerful. As students see that they are contributing to the learning of others as well as learning from them, they are encouraged to make collaboration important and to take greater responsibility for their own learning.

Good models respond to input in ways that match responses in real-world systems. A model that does not respond in ways that cohere with responses in real-world systems is an indication that the model is incomplete or incorrect, and, therefore, the thinking that went into its creation must be thoroughly examined.

**What to know about the modeling exercise**

Students will be building models that describe how the environment can impact Kirtland’s warbler populations. Pressures on Kirtland’s warblers’ survival and reproductive success are described in the text of the Kirtland’s warbler bird profile. Models that the students develop will be a subset of the **Full Population Model**.
Activity 1

Engage - What is a model?

1. Activate students’ prior knowledge. Discuss models as a class.
   - Ask: What does it mean to model something? What is a model? What are some examples of models? Record their responses so everyone can see.
   - Give students the formal definition.

2. As a class, build a model on the board.
   - Tell students they are going to build a model of things that might impact their grades. Give them a moment to think about the different things, or variables, that might impact their grades.
   - On the board, draw a circle in the middle with “Grades” written inside the circle.
   - As students provide their responses, write them down around the circle and draw an arrow to the “grades” circle. Responses should be on a scale from low to high impact. Responses may include, but are not limited to:
     - Following class and/or school rules
     - Turning in your homework
     - Studying for tests
     - Participating in class discussions
     - Having a good breakfast
   
   Note: if students offer responses such as “behavior,” try to get them to be more specific. What kind of behavior? Can they phrase it so it’s on a scale from low to high? For example: talking out of turn, making statements off topic, raising your hand to respond to questions, etc.

3. Discuss the model you built as a large group and introduce the next activity.
   - Reiterate/reinforce the importance of variables being on a scale from low to high impact on a given subject.
   - Looking at your class’ model, ask students to identify which are the independent variables and which are the dependent variables. Label each on the board.
   - Tell students they are going to build their own computer models for migratory birds.
   - If time allows, open Sage Modeler and build your class model as a demonstration.

Activity 2

Explore - How can a model illustrate impacts to the Kirtland’s warbler populations?

Have students read for understanding about the Kirtland’s warbler.
   - As groups or individually, have students navigate to the Follow that Bird! website and select Kirtland’s warbler from the Follow that Bird! Species Profiles. If you prefer, print out the reading and distribute.
   - Give students time to read about the Kirtland’s warbler.
   - Check for understanding
     - How do scientists track the warblers?
     - What does it mean for an animal to be endangered?
     - What is the relationship between the warblers and Jack Pine trees?
     - What is the relationship between cowbirds and warblers?
     - How has managing Jack Pine habitat helped the warblers?
   
   Next, tell students they will build their own computer model about Kirtland’s warblers.
LESSON 4: DISCOVERING THE IMPACTS TO MIGRATORY BIRDS

1. Show students the intro video and pre-programmed model.
   • Watch the SageModeler How-To video as a class. Tell them they are going to build a model based on what they know about Kirtland’s warblers.
   • Distribute Activity Sheet 1: What Impacts Kirtland’s Warbler Populations?
   • Go to the Follow that Bird! model builder application. You may also navigate to this page using the link at the bottom of the Kirtland’s warbler species description page.
   • Walk students through the variables on the screen:
     • The dependent variable in the center is labeled “population size.” This variable refers to the population of the Kirtland’s warbler. Ask students if they can identify another dependent variable: “reproductive success” (of the Kirtland’s warbler).
     • Independent variables are “cowbird population size” and “warbler survival”.
   • Read the sentence to students: An increase in cowbird population size causes reproductive success (of the warbler) to...
     • Show them the drop-down menu with the options they have.
     • Ask: How much do you think this variable (cowbird population size) impacts reproductive success?
   • Ask students to explain their answer. Why do you think so? This is the most important question! Students need to justify their reasoning for selecting the options they did. Discuss as a class to formulate a response. Refer back to the Kirtland’s warbler reading, if needed.
   • Students should record their responses on Activity 1: Building a Model.
   • As a class, repeat this exercise for the other variables and make sure students record their responses. Tell students they will add their own variables next.
   • Sample responses could include:
     • An increase in reproductive success causes population size of the warbler to increase because as the warblers have more offspring there will be more hatching, thereby increasing the population.
     • An increase in warbler survival will cause an increase in the population size because there will be more birds to add to the population.

2. Instruct students to click once on the arrow that connects “cowbird population size” and “reproductive success” to highlight it. Then double click it. The window below opens.
EXPLORE – What are the impacts to Kirtland’s warblers at different stages of their annual cycle?

1. Assign students to one of three groups: Breeding Season, Migration, or Wintering.
   - Break students up into groups of three or four.
   - Assign each group one of the three parts of an annual cycle: Breeding Season, Migration, or Wintering. Have groups refer to the Kirtland’s warbler description again to determine two to three other factors that could impact Kirtland’s warbler populations as it relates to their topic. Tell students to record the factors they came up with and justify their responses.

2. In small groups, customize the existing model.
   - Tell groups to open the Follow that Bird! starting model. Remember that you can also access this link at the bottom of the Kirtland’s warbler description.
   - Following the directions on the student hand out, instruct groups to add one or two variables to this model based on their topic (Breeding Season, Migration, or Wintering).

3. In small groups, come up with conservation solutions.
   - In the species description narrative, a conservation measure is given for each stage of the annual cycle and potential factor impacting the population.
   - Once students have listed two to three impacts on the population, have them add solutions to their models. Make sure they fill out the relationship dialog box to fully explain and justify their reasoning.
   - Example: Cowbird populations negatively affect reproductive success. A box can be added that describes cowbird population control efforts. This will reduce the cowbird population size. Students will observe increased Kirtland’s warbler population size as a result.

Note: If you run out of time, make sure students save or share their models.

ELABORATE - How will the model change when the new impacts are added?

1. Develop a hypothesis.
   - Have students gather in their groups from Activity 3 and open their models.
   - Hand out Activity Sheet 2: Making a Prediction and have them formulate a hypothesis for one of their independent variables. Tell groups to also sketch a graph of how they think their hypothesis would look. Allow students five minutes to work.
   - Ask a few groups to share their hypotheses and graphs. Possible questions to ask:
     - Why is the direction of your prediction graph sloped that way?
     - Why did you choose to make the steepness of the line the way you did?
     - If there is a curve to the prediction, why is it there?
     - If there is an inflection point, or sudden change in the line, what is happening at that point?

2. Open and explain the simulation tool in SageModeler.
   - Tell students to watch closely so they know how to run the simulation when they open their models.
   - Walk students through the steps for running a simulation of their model:
     - Click the Simulate arrow at the top of the model window. The simulation control bar opens.
• Point out the important components in the simulation control bar:
  - **Experiment #** - Simulation data is collected in “batches” or experiments. If you make changes to independent variables WITHOUT CHANGING the experiment number, data for all of the changes will be recorded in one “batch” and it may be difficult to isolate the results of one change from the results of another. To avoid this issue assign a new experiment # each time you make changes by clicking on the “+” sign or directly on the number shown in the box. This will allow you to conduct “experiments” on your model by saving the data from each experiment in its own individual dataset.
  - **Record 1 Data Point** - Choosing “Record 1 Data Point” is like taking a snapshot of the current state of the model. If you choose “Record 1 Data Point,” then adjust an independent variable and repeat, you will see that the output data differs from one row of the output table to the next.
  - **Record Data Stream** - Choosing “Record Data Stream” will automatically record snapshots of the model state as you adjust the independent variables. You can make changes to independent variables by using the sliders located next to each variable.

3. Run a simple simulation.
   • Show students how to adjust levels of the independent variables. Explain that once they open the simulation bar, they will notice bars next to each independent variable that they can adjust up and down (high and low impact).
   • Demonstrate this by adjusting the level of cowbird population size. Have students observe how this changes reproductive success and warbler population size.
   • Repeat the demonstration using “warbler survival.”
   • Roll your mouse over “cowbird population size” and click on the graph icon.
   • Change “Steps” to “Reproductive success” by clicking on “Steps” → **Samples** ➔ **Reproductive success**.
4. Students run their own simple simulation.
   - In their groups, have students run their own simulations. You may need to go through some of the steps again. Allow enough time for them to understand the relationships being modeled.

5. Create a “data stream” and recording in a data table.
   - Now, have students follow along using their own models.
   - Under simulation, tell groups to click once on the “Record Data Stream” button. Explain that they are now recording their model - the button will become highlighted and its text will change to say “Stop Recording.” Students will also see that the orange “record light” will turn on and pulse, and the bars in the indicators next to all variables in the model will turn to orange if their value is above zero.
   - To create a data table in streaming mode, students must adjust the value of an independent variable. Have students try this out by moving the slider next to a chosen variable. Once students are done collecting data, tell them to select the “Stop Recording” button.
     - Show students that if they sweep the slider from low to high and back to low again, a table will appear that displays data for each model variable. Students will notice multiple rows, each one containing the values of all variables in the model based on the values you are setting by moving the slider for one of them.

6. Examine the data.
   - Have students examine the graphs and the table they created with the simulation. Reading graphs can be a difficult task for middle school students. Assist them in deciphering what the graphs and tables are showing. Allow students time to compare the graph generated by Sage Modeler from step 3 to the one they created. The axes may be different, so they will need to adjust.

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This table shows some of the results from a data stream in which the “Cowbird population size” variable was changed from low to high.
ACTIVITY 5
EVALUATE - Sharing Models

1. Groups present their final model to the class.
   • Give groups the option to present their hand-drawn sketch or their computer model.
   • Ask them to focus on explaining the relationships. How did increasing or decreasing the impact on one variable change the other variables?
   • Provide feedback about the accuracy of their relationships and if they need to change any variables (label them to be in a high to low format).
   • As a class, review some of the variables common among all the presentations. If time allows, have students explain the relationships they created between variables.
   • Use the provided Student Model Scoring Rubric to score each group’s model. Adapt the rubric as needed to fit your class.

2. Check for understanding. Have students respond to the following questions:
   • What is a model?
   • How can a model help me understand the impacts on migratory bird populations?

EXTENDING THE LESSON

1. Watch the career connection video (page 58).
2. Discuss what students can do to protect birds (page 58).
3. Have students complete the Bird-Friendly Schoolyard extension (page 59).
GOOD AT RECOGNIZING PATTERNS AND SOLVING PUZZLES?
Meet Dr. Emily Cohen, a Research Ecologist at the Smithsonian Migratory Bird Center who is solving mysteries about animal migration. In this career connection video, find out how she uses tools like weather radar maps to piece together the puzzle of a migratory bird’s annual cycle.

HOW CAN YOU HELP?
Taking Action to Protect Birds!

As you’ve learned in this lesson, there are many variables that impact a bird’s population size. Cats are the largest threat to birds, killing billions of birds each year. You can help by keeping your cat indoors. Not only are birds safer when cats stay indoors, but cats live longer, healthier lives, too! If your cat currently is an outdoor cat, your vet can give you advice on how to transition your cat to a happy indoor life.
BIRD-FRIENDLY SCHOOLYARD
WHAT YOU NEED TO MAKE YOUR SCHOOLYARD ATTRACTIVE TO BIRDS

FOR THE BIRDS...

As you now know, habitat is very important for migratory birds. See if your schoolyard has good bird habitat. If there are areas that need improvement, what can you do to change it? Use the checklist below as a starting point.

1. **Choose native plants.** Plants that are adapted to the climate in your area probably also attract a lot of birds that are used to having those plants as resources. Native plants provide food, shelter, and nesting habitat for migrating and wintering birds.

<table>
<thead>
<tr>
<th>Do you see...</th>
<th>Because...</th>
<th>Yes ✔</th>
<th>No ✔</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bugs</td>
<td>Native trees and plants host caterpillars and other insects that are an important part of a bird’s diet, especially during the breeding season. Look for oaks, willows, birches, maples, goldenrod, milkweed, and sunflowers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit</td>
<td>Shrubs and small trees provide berries that ripen at just the right time for the birds to eat at various times of the year. Look for serviceberry, dogwood, spicebush, cedar, and holly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuts and Seeds</td>
<td>Finches and sparrows love to feast on various nuts and seeds. Some people will put up bird feeders and fill them with nuts and seeds to attract birds. You can find them on oaks, hickories, and walnuts. Sunflowers, asters, and coneflowers also produce tiny seeds that birds love to eat.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nectar</td>
<td>Pollinators such as hummingbirds, butterflies, moths, and bees need nectar. Look for red tubular flowers such as columbine, penstemon, and honeysuckle. Also, asters and Joe-Pye weed will attract these birds and insects.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LESSON 4: EXTENDING THE LESSON

2. Plan your habitat. Now that you know what’s on your schoolyard – what’s next? Now comes the fun part - You get to plan your bird-friendly habitat! Use these tips to help you:
   - Research the native plants for your area. Decide what kinds of birds you want to attract and make a list of appropriate plants.
   - Take inventory of your space:
     - Where is there sun or shade and at what times of the day?
     - Where is the ground wet or dry? Are you going to have to water frequently? If so, what will happen during summer vacation?
     - What is your soil like? Is it sandy or full of clay? Do some experiments and see how different soil types hold water. If there is a lot of clay, will you have to add new soil so the new plants can take root?
   - Draw a map of your space. Try to draw it to scale.
   - Create “layers” of habitat:
     - Large canopy trees provide roosting spots (great for spotting prey), nesting cavities, and food.
     - Shrubs and small trees are preferred by some songbirds for nesting, shelter, and foraging.
     - Herbaceous plants, such as groundcovers, annuals, and perennials provide food and habitat for pollinators.
     - Decaying leaves, wood, detritus, and soil are the base of your habitat. Yards that are too manicured do not provide birds with good habitat. This is where birds will find many insects, worms, and protein-rich caterpillars. Yum!
   - Convert green, high-maintenance grass to bird-friendly habitat. Come up with a fun garden shape that cuts down on timely lawn maintenance. Often, those lawns are devoid of wildlife. Be sure to work with your maintenance crew on selecting a good space!
   - Cluster your plants. Group five or more of the same plants together. These same-color clusters attract more pollinators.
   - About the plants: think about the height of each plant and how wide each one will grow. While you can prune later, you might save time and money by giving each plant the appropriate amount of space to grow.
   - Water year-round. All good habitats will have a water source. How will your birds get water in the summer? Planting your habitat near a rain barrel will help with plant maintenance. Consider a solar-powered drip bath or fountain feature – many birds are attracted to the sound of running water.

3. Prepare your habitat. Remove any grass or invasive species before you begin planting. Lay down newspaper or landscape fabric to keep out weeds. Use 4-6 inches of mulch to reduce weed growth and retain moisture. Edging around your habitat area will help keep grass from inching its way in.

4. Planting. Ok, NOW is the really fun part! Plant in the fall or the spring on cooler days. Follow planning instructions and water well. Check on your new space frequently. Native plants should require less maintenance, but all plants needs need extra care until they are well established.

NOTE: Once you have your new habitat, compare the number of insects, birds, and mammals you find in your habitat to the maintained lawn area.
5. Care for your habitat year-round. Again, a native plant garden should be less maintenance, but keep these things in mind as you observe your new space:

- **WEEDING** – remove non-native and invasive weeds. While this may seem like a chore, it’s also a great time to make observations about your space:
  - *What insects do you see populating the area? How is it changing over time?*
  - *What is the soil like? Does it need more water? Less water?*
  - *Are certain plants growing well while others sluggish? Perhaps they need to be moved to a different spot?*

- **LEAVE THE LEAVES** – leaves and woody debris are an important habitat layer and serve as a natural mulch. They also carry important nutrients that will help “feed” your plants.

- **LEAVE THE SEEDS** – don’t worry about pruning your perennials or “dead-heading” annuals. They can re-seed themselves and put nutrients back into the soil.

- **LEAVE THE BRANCHES AND DEAD TREES** – fallen branches and dead trees are great habitat for birds and insects. Some birds only nest in hollowed out dead trees. Insects also find these great homes, so birds find them to be great restaurants!

- **SKIP THE PESTICIDES** – a bug-friendly garden is a bird-friendly garden. Providing a variety of foods and habitats will bring a variety of birds for you to observe.

6. Use your space! Now that you’ve got this great space, get out there and use it! Some ways might include:

- Create a photo collage of the space throughout the different seasons.
- Make sketches of plants, insects, and birds.
- Count the different types of insects attracted to this space. Does it change over the seasons? Years?
- Add a space for people to sit quietly and read or reflect.
- Observe what happens during a rain event.
- How else can you use this space? The possibilities are endless!

**FINAL TIPS!**

Don’t forget to include the following people when planning your garden:

- Principal and other administrative staff. They may help with watering over the summer break.
- Grounds maintenance staff. They’ll need to know what not to mow and may have insight on where to plant your habitat.
- Other classrooms. Introduce the new habitat to them and ways they can benefit from it.

**RESOURCES:**

- Audubon – [How to Make Your Yard Bird-Friendly](#)
Making a Prediction

Your challenge is to propose a hypothesis and make a prediction about Kirtland’s warbler populations. Both hypothesis and prediction should be based upon the model seen here and address the question for the model, What impacts Kirtland’s warbler populations?

You were assigned to focus on Breeding, Migration, or Wintering for the Kirtland’s warbler. Write down what you predict will happen to warbler populations based on what your group came up with.

For example, your hypothesis might be:
*If cowbird populations “X” (increase/decrease), then reproductive success (of the warbler) will “Y” (increase/decrease).*

1. Your hypothesis:

   If __________________________________________________________.

   then _________________________________________________________.

   Draw a graph of your prediction. Be sure to provide a title for your graph and label the axes.

2. Following your teacher’s instructions, run the simulation and see if your hypothesis was accurate.
   - You may see a data table that says “Sage Simulation”. If it is in the way, move it to the side.
   - Look at the graph that is created. Does it resemble your graph?
     If not, why?

   - Expand the Sage Simulation box and look at the two variables you tested. What happened to the dependent variable when you increased or decreased the independent variable?

Be sure to save or create a link for your model before you close out!
What Impacts Kirtland’s Warbler Populations?

Computer models are useful tools for helping us understand and visualize complex relationships in nature. We will use a computer model to look at different variables that impact Kirtland’s warbler populations. However, you should note that computer models are only as good as the inputs that we put in there. We have to make sure that the information we put in there is accurate.

PART 1: STARTING THE MODEL

Define dependent variable:

Define independent variable:

1. An increase in cowbird population size causes reproductive success (of the Kirtland’s warbler) to (circle one): increase decrease vary
   by (circle one): about the same a lot a little more and more less and less
   Why do you think so?

Fill in the graph:
2. An increase in reproductive success (of the Kirtland’s warbler) causes population size to (circle one): increase  decrease  vary.
   by (circle one): about the same  a lot  a little  more and more  less and less.
   Why do you think so?

Fill in the graph:

3. An increase in warbler survival causes population size (of the Kirtland’s warbler) to (circle one): increase  decrease  vary.
   by (circle one): about the same  a lot  a little  more and more  less and less.
   Why do you think so?

Fill in the graph:
PART 2: BUILDING THE MODEL

1. As you work in your small groups, think of two to three other factors that might impact Kirtland’s warbler populations (either positively or negatively). Write down your ideas here. Be sure to (a) indicate if the population will increase, decrease, or vary and (b) by how much. Also, be sure to (c) justify your response. (d) Draw a graph to predict how you think the impact will look.

2. Open the starting model and add your variables
   - Go to the Follow that Bird! Starting Model
   - In the menu bar, click on the down arrow. Search for an image that best represents your variable. Drag and drop it to your workspace.

   ![Diagram of the model]

   - Label the image by clicking once on it and changing the label. Be sure your label includes the high to low description. For example, don’t just call it “pine trees”; call it “acres of young pine trees” or “number of young pine trees.”
   - Create the relationship of that variable to another variable.
     - Hold the cursor over the relationship tool: Click, hold and drag the arrow to the other variable.
     - Next, click once on the arrow you just created to highlight it. Now double-click it. The relationship box you saw earlier when your teacher was demonstrating will now pop up.
     - Make sure you choose all of the options and, most importantly, fill in your justification.
     - Record your relationship here and repeat this process for your second variable, if you have one.
3. Which group are you (circle one)? Breeding Season  Migration  Wintering

**VARIABLE 1:**
An increase in __________________________ causes __________________________
to (circle one): increase  decrease  vary
by (circle one): about the same  a lot  a little  more and more  less and less
Why do you think so?

Fill in the graph:

![Graph](image)

**VARIABLE 2** (if you have one):
An increase in __________________________ causes __________________________
to (circle one): increase  decrease  vary
by (circle one): about the same  a lot  a little  more and more  less and less
Why do you think so?

Fill in the graph:

![Graph](image)

4. Add some conservation solutions to your model. Be sure to justify the relationships that you create. Draw a sketch of your final model:
### Student Model Scoring Rubric

<table>
<thead>
<tr>
<th>EXCEEDS EXPECTATIONS (4-5 points)</th>
<th>MEETS EXPECTATIONS (2-3 points)</th>
<th>DOES NOT MEET EXPECTATIONS (0-1 points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The variables are labeled appropriately (have a low to high scale and are descriptive)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each relationship is ecologically accurate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each relationship is completely filled out with justification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A sketch of the graph of the relationship is included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The simulation has the appropriate variables tested</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Kirtland's Warbler breeding habitat
Photo by Nathan Cooper
LESSON 5:
Conservation Challenge
LESSON 5: CONSERVATION CHALLENGE

OVERVIEW
Lesson Five will allow students to apply what they have learned about tracking in order to design a project that will appropriately answer a conservation/research question about a particular migratory bird species.

| ENGAGE | What are some things a scientist has to consider when choosing a tracking device(s)? | Review what was learned in previous activities about tracking devices and their uses, why we track birds, what research questions we can answer with which devices. | 10 minutes |
| ELABORATE | Which tracking device will best help us answer a given conservation/research question? | Students will be given an ecological story regarding a species of bird that may be in decline and will have to ask a scientific question and determine the appropriate tracking technology in order to make conservation decisions. | Several class periods or time spent outside of class |
| EVALUATE | Group write-up | Group write-up and justification for using their chosen tracking device. | N/A |

DISCIPLINARY CORE IDEAS

MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

OVERARCHING UNDERSTANDING
The type of tracking technology to use depends on many factors including the research question, cost, and species of bird.

Photo by Tim Romano, Smithsonian’s National Zoo
### LESSON 5: CONSERVATION CHALLENGE

<table>
<thead>
<tr>
<th>ESSENTIAL QUESTIONS</th>
<th>RELATED MISCONCEPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do scientists decide which tracking technology to</td>
<td>Students may think technology is so advanced that we could put any kind of device on</td>
</tr>
<tr>
<td>use when they are conducting research on migratory</td>
<td>any bird (not taking into account size of bird, type of data we need, etc.).</td>
</tr>
<tr>
<td>birds?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KNOWLEDGE</th>
<th>SKILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will know...</td>
<td>Formulate their own research questions about a particular migratory bird species and</td>
</tr>
<tr>
<td></td>
<td>choose an appropriate tracking device to investigate or answer the question or problem</td>
</tr>
<tr>
<td></td>
<td>based on several constraints/parameters.</td>
</tr>
</tbody>
</table>

N/A - No new information in this lesson.  

<table>
<thead>
<tr>
<th>PRIOR STUDENT KNOWLEDGE:</th>
<th>MATERIALS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be familiar with several tracking devices</td>
<td>Activity 1: ENGAGE</td>
</tr>
<tr>
<td>and their uses from Lesson 2.</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>Activity 2: ELABORATE</td>
</tr>
<tr>
<td></td>
<td>• Internet access</td>
</tr>
<tr>
<td></td>
<td>• Ecological Stories</td>
</tr>
<tr>
<td></td>
<td>• Supply Sheet</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
<tr>
<td></td>
<td>Activity 3: EVALUATE</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCIENCE AND ENGINEERING PRACTICES:</th>
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<tbody>
<tr>
<td>Students will be familiar with several tracking devices</td>
<td></td>
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<tr>
<td>and their uses from Lesson 2.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activity 1: ENGAGE</td>
</tr>
<tr>
<td></td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>Activity 2: ELABORATE</td>
</tr>
<tr>
<td></td>
<td>• Internet access</td>
</tr>
<tr>
<td></td>
<td>• Ecological Stories</td>
</tr>
<tr>
<td></td>
<td>• Supply Sheet</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
<tr>
<td></td>
<td>Activity 3: EVALUATE</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CROSSCUTTING CONCEPTS:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be familiar with several tracking devices</td>
<td></td>
</tr>
<tr>
<td>and their uses from Lesson 2.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activity 1: ENGAGE</td>
</tr>
<tr>
<td></td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>Activity 2: ELABORATE</td>
</tr>
<tr>
<td></td>
<td>• Internet access</td>
</tr>
<tr>
<td></td>
<td>• Ecological Stories</td>
</tr>
<tr>
<td></td>
<td>• Supply Sheet</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
<tr>
<td></td>
<td>Activity 3: EVALUATE</td>
</tr>
<tr>
<td></td>
<td>• Scoring Rubric</td>
</tr>
</tbody>
</table>

|                                                            |                                                                                        |
|                                                          | Students will be familiar with several tracking devices and their uses from Lesson 2. |
**LESSON 5: CONSERVATION CHALLENGE**

**ACTIVITY 1**
ENGAGE - What are some things a scientist has to consider when choosing a tracking device(s)?

As a large group, discuss how scientists choose tracking devices. Ask:
- Based on what you have learned about tracking migratory birds, what type of questions can be addressed by the different devices?
- What are some things a scientist has to consider when choosing tracking devices to use in his/her research?

![Long-billed curlew wearing an argos tag. Photo by Tim Romano, Smithsonian's National Zoo](image)

**ACTIVITY 2**
ELABORATE - Which tracking device will best help us answer a given conservation/research question?

Work in groups to design a tracking project.
- Tell students that they will be working in groups to design a tracking project to conserve a migratory bird.
- Give each group one of the Ecological Stories that describes a conservation mystery. Tell groups they will develop a research plan to address the mystery they are presented with.
- Provide each student with a Supply Sheet containing budget guidelines the students will use for their research project.
- Have the group formulate a scientific question that they believe will assist scientists in learning the “story” of their migratory bird and eventually aid in making conservation decisions regarding their bird species.
- Once the group has agreed on a scientific question, have them then work together to determine the appropriate tracking technology to use. Then, “give” students a budget of $10,000 for their project. Groups need to consider which technology will help them best answer their particular research question and consequently make conservation decisions. Decisions on the appropriate technology to use will include (but not be limited to):
  - The scientific question being asked (the most important of the considerations)
  - The weight of the device
  - The cost per device (they may not realize they will need more than one device!)
  - Battery life, if applicable
  - Location accuracy
  - Storage vs. transmitting devices
  - Other budgetary things to consider - staff costs, materials (nets, etc.)
- Remind students to think back to Lesson 2: Tracking the Annual Cycle of Migratory Birds and consider the advantages and challenges are to each type of technology. Allow students to access the [Follow that Bird! website](#) for reference.
- Before students begin, share the Scoring Rubric for their final write-up with them.

**ACTIVITY 3**
EVALUATE - Assess group write-ups.

Use the provided Scoring Rubric to assess the group write-ups. Adapt the rubric as needed to fit your class.

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**EXTENDING THE LESSON**

1. Watch the career connection video (page 73).
2. Discuss what students can do to protect birds (page 73).
EVER WONDER WHAT IT WOULD BE LIKE TO BE AN ANIMAL KEEPER?
Eric Slovak is the Assistant Curator of Birds at the Smithsonian’s National Zoo and Conservation Biology Institute. That means that he, along with the Curator, oversees the care of birds at the Zoo’s Bird House exhibit. In this career connection video, you will learn what it takes to look after a wild flock of birds and keepers!

HOW CAN YOU HELP?
Taking Action to Protect Birds!

As you’ve learned in Follow that Bird!, it takes a “flock” of people and research to study and save migratory birds. One of the largest threats to birds is window collisions, when a bird can’t see glass and flies into windows of houses and other buildings. You can help by making windows in your home more visible to birds. Do this by...

• Breaking up window reflections with stickers, window decals or tape.
• Using blinds.
LESSON 5: ECOLOGICAL STORIES

The following ecological story is a narrative that describes a real mystery that bird researchers have encountered when trying to solve a conservation problem. The researchers are looking for your help! They want you to come up with a solution to this scenario using tracking technology. With your team, read the story of your selected species. Pay careful attention to the problem you are trying to address, as well as any details about the biology of the species that may allow for or limit the use of a certain tracking device.

RUSTY BLACKBIRD

Rusty blackbirds have experienced one of the strongest declines ever documented among North American birds in recent times. Long-term survey data suggest that rusty blackbird numbers have plummeted by 85 to 95% since the mid-1900s. They are a migratory bird with a wingspan of 18 inches (47 cm) and weight of 1.6 to 2.8 ounces (47-80 grams). Rusty blackbirds live in large flocks, often with other species of blackbirds, during the summer breeding and migratory periods.

A loss of wetland habitats is considered to have a big impact on rusty blackbird populations. At each stage of their annual cycle, Rusty blackbirds rely on wetlands for their survival. These habitats are ideal because they provide lots of insects, which make up the bulk of their diet throughout the year. In the southern United States, where the blackbirds overwinter, wetland habitats have been lost due to agriculture, urban development, and efforts to control flooding on rivers and streams. On the blackbirds’ breeding grounds in Canada and the northern United States, wetlands have become prone to drying out due to climate change.

Loss of wetlands may not be the only cause for rusty blackbird decline. On their breeding ground, they may be exposed to high levels of pollution. One of the pollutants they are exposed to is mercury, a heavy metal that is emitted from burning of fossil fuels. Mercury has harmful effects on the immune systems and general health of rusty blackbirds. Mercury pollution is found to be highest directly downwind of coal-fired power plants and increases the closer you get to the North Pole.

Your team studies an overwintering population of rusty blackbirds along the banks of the Mississippi River in Louisiana. You tested samples of blackbird feathers, collected while banding the birds, and found that some showed high levels of mercury. You suspect that mercury poisoning on the breeding grounds may be harming your population, adding to the problem of habitat loss. Your team wants to find out if the breeding region of your population is in an area that is prone to mercury pollution.
LESSON 5: ECOLOGICAL STORIES

The following ecological story is a narrative that describes a real mystery that bird researchers have encountered when trying to solve a conservation problem. The researchers are looking for your help! They want you to come up with a solution to this scenario using tracking technology. With your team, read the story of your selected species. Pay careful attention to the problem you are trying to address, as well as any details about the biology of the species that may allow for or limit the use of a certain tracking device.

BACHMAN’S SPARROW

The Bachman’s sparrow is a grassland bird species that has been declining since the 1930s. Their population is currently declining at a rate of about 15% per decade. They have a wingspan of less than eight inches (20 cm) and weigh less than one ounce (20 grams). They feed on a diet of insects during the breeding season, and eat seeds during the winter. Due to this change in diet, the amount of habitat they use during the breeding season is quite small, about the size of three football fields, but they require much more habitat in the winter to support their population.

The Bachman’s sparrow is a resident species that lives exclusively in pine savannahs in the southeastern United States. Pine savannahs are a type of grassland habitat that have a low density of pine trees. Pine savannahs were at one time the most common type of habitat in the southeastern United States coastal plain, a large region of the eastern United States that is characterized by low elevation and flat appearance. These habitats were created by frequent wildfires that would kill young trees and shrubs, but leave larger pines standing. Due to the needs of development, agriculture, and logging, humans began suppressing these fires and, over time, the savannahs transformed into dense forests of oak and pine.

Preserving Bachman’s sparrow habitat requires the reintroduction of fire. Land managers use small, controlled fires to reduce forest growth within pine savannahs. Today, very little pine savannah is left and what remains requires a lot of maintenance. Because of this, it is often unclear whether land managers are maintaining enough habitat to support healthy populations of Bachman’s sparrows.

Your team wants to use tracking technology to determine if the amount of habitat being managed is enough to support the overwintering sparrow population. You will study a population of Bachman’s sparrow in North Carolina to determine whether the amount of habitat being managed matches the amount of habitat the sparrows require during the winter months.
LESSON 5: ECOLOGICAL STORIES

The following ecological story is a narrative that describes a real mystery that bird researchers have encountered when trying to solve a conservation problem. The researchers are looking for your help! They want you to come up with a solution to this scenario using tracking technology. With your team, read the story of your selected species. Pay careful attention to the problem you are trying to address, as well as any details about the biology of the species that may allow for or limit the use of a certain tracking device.

GOLDEN EAGLE

The golden eagle is a large bird – one of the biggest raptors in North America. This eagle’s wingspan can be over seven feet across (185-220 cm) and it can weigh over 13 pounds (3000–6125 grams). Golden eagles are incredible predators. They eat mostly small mammals like rabbits, but have been known to also eat larger mammals, such as seals and domestic livestock, and birds as large as swans.

While golden eagles in the northwestern United States are resident birds, most golden eagles migrate. Their breeding range is very large, stretching from northern Canada and Alaska to northern Mexico. They can be found in the winter in all but the southeastern corner of the United States. Migration between breeding and overwintering grounds usually occurs along mountain ranges and hills.

Due in part to a law passed in 1962 to protect the golden and bald eagles, golden eagle populations are stable. Human impact on golden eagle populations is still a concern, however, as most of their observed deaths are a result of human actions. One of the primary causes of death is collision with man-made structures, like buildings and wind turbines.

A bird conservation organization has become concerned that wind farms along the Appalachian Mountain chain are negatively impacting golden eagle populations. Your team has been hired by the organization to determine the migratory route of golden eagles living in Virginia and Maryland. The results of your efforts will determine whether wind farms are located along the migratory route of golden eagles and ensure that new wind farms are not placed in the path of their migratory route.
LESSON 5: ECOLOGICAL STORIES

The following ecological story is a narrative that describes a real mystery that bird researchers have encountered when trying to solve a conservation problem. The researchers are looking for your help! They want you to come up with a solution to this scenario using tracking technology. With your team, read the story of your selected species. Pay careful attention to the problem you are trying to address, as well as any details about the biology of the species that may allow for or limit the use of a certain tracking device.

NORTHERN CARDINAL

The northern cardinal is a species of bird that is common to all sorts of habitats in the eastern and central United States. Cardinals are a medium-sized songbird, with a wingspan of up to one foot (21-23 cm) and a weight of about 1.5 ounces (40 to 50 grams). They are a resident bird with a seasonal diet – they eat mostly insects when caring for the young, and mostly fruits and seeds during the rest of the year. Their nests can be found in the bushes and shrubs common to suburban and urban yards.

The cardinal is not a species in decline. In fact, their range (that is, the area in which they live) has expanded to the north and west over the last 50 years. There are different theories as to what has caused or made it possible for them to move into areas where they didn’t used to live. One theory is that the expansion of urban and suburban environments in the 20th century created lots of shrubby habitat, the kind of habitat they use to raise their young and find food. Another theory is that bird feeders have allowed cardinals to live in areas where they otherwise would not be able to survive. This is especially true for cardinals overwintering in the north, where bird feeders can provide food throughout the colder winter months when the natural food supply is limited.

Studying the ecology of a species that benefits from people can help scientists better understand why some species can be harmed by human activity. Your team will conduct a study to determine whether bird feeders have helped cardinals survive harsh northern winters. Your team will observe individuals in the winter in Springfield, Massachusetts. You will compare the winter survival of individuals that live near bird feeders with those that do not.
# Supply Sheet

<table>
<thead>
<tr>
<th>SUPPLY</th>
<th>EXPLANATION</th>
<th>QUANTITY</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nets</td>
<td>For catching the birds you will study</td>
<td>You will need at least 3</td>
<td>$100</td>
</tr>
<tr>
<td>Banding toolkit</td>
<td>The tools you will need to set up your net and place the bands on the birds</td>
<td>You will only need 1 toolkit</td>
<td>$500</td>
</tr>
<tr>
<td>Color bands (for 1 bird)</td>
<td>The colored bands you use to identify individual birds by sight</td>
<td>However many birds you choose to study</td>
<td>$1</td>
</tr>
<tr>
<td>Aluminum bands</td>
<td>The numbered bands you will use to identify individual birds</td>
<td>However many birds you choose to study</td>
<td>$0</td>
</tr>
<tr>
<td>PIT tag</td>
<td>Tag you will place on the birds you choose to study</td>
<td>However many birds you choose to study</td>
<td>$2</td>
</tr>
<tr>
<td>PIT tag receiver</td>
<td>Receiver that picks up the signal of a nearby PIT tag</td>
<td>You will only need 1 receiver</td>
<td>$40</td>
</tr>
<tr>
<td>Radio telemetry tag</td>
<td>The tag you will place on the birds you want to study</td>
<td>However many birds you choose to study</td>
<td>$180</td>
</tr>
<tr>
<td>Radio telemetry antenna</td>
<td>The device that allows you to locate the bird you are studying</td>
<td>You will only need 1 antenna</td>
<td>$300</td>
</tr>
<tr>
<td>Radio telemetry receiver</td>
<td>The device that allows you to locate the bird you are studying</td>
<td>You will only need 1 receiver</td>
<td>$700</td>
</tr>
<tr>
<td>Light-level geolocator</td>
<td>The tag you will place on the birds you want to study</td>
<td>However many birds you choose to study</td>
<td>$200</td>
</tr>
<tr>
<td>Satellite transmitter</td>
<td>Tag that you will place on the birds you want to study</td>
<td>However many birds you choose to study</td>
<td>$3,000</td>
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<tr>
<td>Intern (1 month salary)</td>
<td>The field assistant who will help you carry out your study</td>
<td>You may choose to employ 1 or more interns depending on the type of technology you choose.</td>
<td>$1,000</td>
</tr>
</tbody>
</table>
### Scoring Rubric

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>15 points</th>
<th>11 points</th>
<th>7 points</th>
<th>3 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction/ Thesis</td>
<td>Exceptional introduction that grabs the reader’s interest and clearly states the topic. Thesis is exceptionally clear, well-developed, and a definitive statement.</td>
<td>Proficient introduction that is interesting and states topic. Thesis is clear and arguable statement of position.</td>
<td>Basic introduction that states topic but lacks interest. Thesis is somewhat clear and arguable.</td>
<td>Weak or no introduction of topic. Paper’s purpose is unclear/thesis is weak or missing.</td>
</tr>
<tr>
<td>Content Knowledge: Quality of Research</td>
<td>Paper is exceptionally researched: contains 3 peer reviewed articles and the 3 articles relate to the thesis argument in a logical manner. References are correctly cited.</td>
<td>Information relates to the main topic. Paper, is well-researched in detail and from 3 good sources. References are correctly cited.</td>
<td>Information relates to the main topic, but few details and/or examples are given. Shows a limited variety of sources. References are not cited correctly.</td>
<td>Information has little or nothing to do with the thesis. Information has weak or no connection to the thesis. References are not cited correctly.</td>
</tr>
<tr>
<td>Writing</td>
<td>Writing is clear and relevant, with no grammatical and/or spelling errors – polished and professional. Reference section properly formatted.</td>
<td>Most ideas are stated clearly and are related to the topic, with only minor grammatical and/or spelling errors. Reference section adequate.</td>
<td>Many ideas require clarification and/or are off-topic or have marginal relevance to the assignment. Many grammatical and/or spellings errors throughout the paper. The paper is very challenging to read due to poor writing flow. Improper reference section.</td>
<td>Paper does not meet the criteria for the assignment (too short or incomplete, too long, and/or completely off-topic). Reference section missing.</td>
</tr>
</tbody>
</table>
APPENDIX
## APPENDIX:
### GLOSSARY OF TERMS

<table>
<thead>
<tr>
<th>TERM</th>
<th>LESSON</th>
<th>PART OF SPEECH</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algal blooms</td>
<td>3</td>
<td>Noun</td>
<td>A large, rapid increase in the amount of algae in a body of water caused by excess nutrients from outside sources (such as fertilizers or sewage), and sometimes having harmful effects on humans and wildlife.</td>
</tr>
<tr>
<td>Ambush</td>
<td>3</td>
<td>Verb</td>
<td>To make a surprise attack from a hidden position.</td>
</tr>
<tr>
<td>Annual cycle</td>
<td>1</td>
<td>Noun</td>
<td>The phases that occur in an animal’s life over the course of a year. For migratory birds, the annual cycle consists of a breeding season, a non-breeding season, and two migration periods.</td>
</tr>
<tr>
<td>Archival GPS tags</td>
<td>2</td>
<td>Noun</td>
<td>A small device that receives signals from orbiting satellites and stores this information on a tiny computer located inside of the tag. When attached to an animal these devices allow researchers to track the animal’s movements.</td>
</tr>
<tr>
<td>Argos tag</td>
<td>2</td>
<td>Noun</td>
<td>A tracking device that transmits signals to a system of satellites called Argos orbiting in space. The satellites transfer information about the location of the tracking device to computers on earth.</td>
</tr>
<tr>
<td>Biomagnification</td>
<td>3</td>
<td>Noun</td>
<td>The accumulation of substance, such as a pesticide or other chemical, as it is eaten by organisms progressively higher up the food chain.</td>
</tr>
<tr>
<td>Biome</td>
<td>1</td>
<td>Noun</td>
<td>A region of the Earth with a characteristic climate and plant life.</td>
</tr>
<tr>
<td>Bird band</td>
<td>2</td>
<td>Noun</td>
<td>A small, individually numbered metal or plastic tag that is attached to the leg or wing of a wild bird to enable individual identification. Colored bands are often added to enable identification without having to recapture the bird. By re-sighting (color band only) or recapturing (metal band) individuals we can determine how long a bird survives and observe its movements.</td>
</tr>
<tr>
<td>Bird-safe glass</td>
<td>4</td>
<td>Noun</td>
<td>Glass designed to be more visible to birds so that birds do not flying into it and get injured or killed.</td>
</tr>
<tr>
<td>Breeding grounds</td>
<td>1</td>
<td>Noun</td>
<td>The region where an animal lives while reproducing.</td>
</tr>
<tr>
<td>TERM</td>
<td>LESSON</td>
<td>PART OF SPEECH</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>----------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Brood</td>
<td>4</td>
<td>Noun</td>
<td>A group of eggs or nestlings in a nest.</td>
</tr>
<tr>
<td>Cannon net</td>
<td>2</td>
<td>Noun</td>
<td>A large net that is shot out of small cannon so that it lands over a group of birds on the ground, trapping them underneath.</td>
</tr>
<tr>
<td>Climate</td>
<td>1</td>
<td>Noun</td>
<td>Weather conditions averaged over a long period of time.</td>
</tr>
<tr>
<td>Clutch</td>
<td>1, 3</td>
<td>Noun</td>
<td>The group of eggs laid in a nest.</td>
</tr>
<tr>
<td>Conservation</td>
<td>3</td>
<td>Noun</td>
<td>The act of protecting the natural environment for species preservation, recreation, or economic reasons.</td>
</tr>
<tr>
<td>Dependent Variable</td>
<td>3</td>
<td>Noun</td>
<td>A community of organisms and their physical environment.</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>3</td>
<td>Noun</td>
<td>A community of organisms and their physical environment.</td>
</tr>
<tr>
<td>Electromagnetic wave</td>
<td>2</td>
<td>Noun</td>
<td>A form of energy that moves as electric and magnetic waves. Examples include radio waves, which cannot be seen, and visible light.</td>
</tr>
<tr>
<td>Endangered</td>
<td>4</td>
<td>Noun</td>
<td>At great risk of extinction.</td>
</tr>
<tr>
<td>Estuary</td>
<td>1</td>
<td>Noun</td>
<td>A body of water where fresh water from a river mixes with salt water from the ocean.</td>
</tr>
<tr>
<td>Fledging</td>
<td>1</td>
<td>Verb</td>
<td>The time in a young bird’s life when its wings and muscles have developed enough for it to leave the nest and begin flying. A bird that has reached this stage is called a fledgling.</td>
</tr>
<tr>
<td>Foraging</td>
<td>1</td>
<td>Verb</td>
<td>Searching for food.</td>
</tr>
<tr>
<td>Full annual cycle</td>
<td>1</td>
<td>Noun</td>
<td>See annual cycle.</td>
</tr>
<tr>
<td>Game bird</td>
<td>1</td>
<td>Noun</td>
<td>A bird hunted for sport or food.</td>
</tr>
<tr>
<td>Global Positioning System (GPS)</td>
<td>2</td>
<td>Noun</td>
<td>A system of satellites and receiving devices used to determine the location of something on Earth.</td>
</tr>
<tr>
<td>Habitat</td>
<td>1</td>
<td>Noun</td>
<td>The natural home or environment of a living organism.</td>
</tr>
<tr>
<td>TERM</td>
<td>LESSON</td>
<td>PART OF SPEECH</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>------------------------</td>
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<td>----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Homing method</td>
<td>2</td>
<td>Noun</td>
<td>A method of directly locating an animal by using an antenna and receiver to follow radio signals coming from a transmitter attached to an animal.</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>1</td>
<td>Noun</td>
<td>A serious condition that occurs when the body temperature gets too low.</td>
</tr>
<tr>
<td>Incubate</td>
<td>1, 3</td>
<td>Verb</td>
<td>To keep eggs warm so that the young inside can develop.</td>
</tr>
<tr>
<td>Independent Variable</td>
<td>4</td>
<td>Noun</td>
<td>A variable whose variation does not depend on that of another. Often denoted by x and demonstrated on the x-axis.</td>
</tr>
<tr>
<td>Latitude</td>
<td>1</td>
<td>Noun</td>
<td>Imaginary lines around the Earth that are parallel to the equator and are used to describe the distance of a point north or south of the equator. Expressed in degrees, latitude ranges from 0° at the equator to 90° at the North Pole and -90° at the South Pole.</td>
</tr>
<tr>
<td>Lichen</td>
<td>1</td>
<td>Noun</td>
<td>A composite organism that is composed of an algae and fungus.</td>
</tr>
<tr>
<td>Light-level geolocator</td>
<td>2</td>
<td>Noun</td>
<td>A lightweight, electronic tracking device, usually used in bird migration research to map migration routes, identify important staging areas, and sometimes provide additional ecological information. A geolocator periodically records ambient light level to determine location.</td>
</tr>
<tr>
<td>Longitude</td>
<td>1</td>
<td>Noun</td>
<td>Imaginary lines from pole to pole around the earth that are used to describe the distance of a point east or west of a line called the prime meridian. Expressed in degrees, longitude ranges from 0° at the prime meridian to 180° east of this line and -180° west of this line.</td>
</tr>
<tr>
<td>Mangrove forest</td>
<td>1</td>
<td>Noun</td>
<td>A coastal forest habitat that can grow in salt water. Mangrove help control flooding and are known for hosting a high diversity of animal life.</td>
</tr>
<tr>
<td>Migration</td>
<td>1</td>
<td>Noun</td>
<td>Seasonal movement of animals between one region where breeding takes place and another.</td>
</tr>
<tr>
<td>Migratory birds</td>
<td>1</td>
<td>Noun</td>
<td>Birds that move between one region where breeding takes place and another in response to seasonal changes in the availability of food.</td>
</tr>
<tr>
<td>Migratory connectivity</td>
<td>1</td>
<td>Noun</td>
<td>Links between the breeding, migration, and overwintering phases of a migratory animal’s annual cycle.</td>
</tr>
</tbody>
</table>
## APPENDIX: GLOSSARY OF TERMS

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Mist net</td>
<td>2</td>
<td>Noun</td>
<td>Tall, long nets used to trap birds for research purposes. Nets are made out of very fine threads making them difficult for birds to see.</td>
</tr>
<tr>
<td>Model</td>
<td>4</td>
<td>Noun</td>
<td>A model represents a person, thing, or system. A computer model is a program designed to simulate what might or did happen in a situation.</td>
</tr>
<tr>
<td>Morphology</td>
<td>3</td>
<td>Noun</td>
<td>The size, shape and structure of a living thing.</td>
</tr>
<tr>
<td>Mudflat</td>
<td>1</td>
<td>Noun</td>
<td>A flat area of muddy land near the sea that is exposed when the tide goes out.</td>
</tr>
<tr>
<td>Overwinter</td>
<td>1</td>
<td>Verb</td>
<td>To spend the winter.</td>
</tr>
<tr>
<td>Passive Integrated Transponder (PIT Tag)</td>
<td>2</td>
<td>Noun</td>
<td>An electronic microchip that can be glued to a bird band, attached to a bird’s leg, or inserted surgically under the bird’s skin. PIT tags require no batteries, so can theoretically last for a bird’s entire life. PIT tags can only be read a very short distance from receiving stations.</td>
</tr>
<tr>
<td>Permafrost</td>
<td>1</td>
<td>Noun</td>
<td>A layer of soil that remains frozen throughout the year.</td>
</tr>
<tr>
<td>Pine stands</td>
<td>4</td>
<td>Noun</td>
<td>A growth of pine trees covering a specific area that are the same species with similar size compared to the rest of the forest area.</td>
</tr>
<tr>
<td>Qualitative</td>
<td>4</td>
<td>Adjective</td>
<td>Relating to a non-numeric measurement.</td>
</tr>
<tr>
<td>Radio antenna</td>
<td>2</td>
<td>Noun</td>
<td>A device that captures or transmits radio waves.</td>
</tr>
<tr>
<td>Radio receiver</td>
<td>2</td>
<td>Noun</td>
<td>A device that picks up a signal or information. In radio telemetry, the receiver picks up a signal in the form of an electromagnetic wave and converts it into a sound.</td>
</tr>
<tr>
<td>Radio telemetry</td>
<td>2</td>
<td>Noun</td>
<td>A tracking technique that uses an antenna and receiver to locate an animal wearing a device that transmits radio signals.</td>
</tr>
<tr>
<td>Radio transmitter</td>
<td>2</td>
<td>Noun</td>
<td>A device that produces and sends out a signal or information.</td>
</tr>
<tr>
<td>Raptor</td>
<td>3</td>
<td>Noun</td>
<td>A type of bird of prey that often has strong talons and keen vision or hearing.</td>
</tr>
</tbody>
</table>
## APPENDIX: GLOSSARY OF TERMS

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<tbody>
<tr>
<td>Reproductive success</td>
<td>4</td>
<td>Noun</td>
<td>The number of offspring produced by an individual or pair.</td>
</tr>
<tr>
<td>Satellite telemetry</td>
<td>2</td>
<td>Noun</td>
<td>Following an object on the Earth’s surface through the use of orbiting satellites. A Platform Terminal Transmitter (PTT) is attached to the bird. The PTT sends a signal full of information to an orbiting satellite. The satellite re-transmits the data to a receiving station, which researchers then access through their computer.</td>
</tr>
<tr>
<td>Satellite transmitter</td>
<td>2</td>
<td>Noun</td>
<td>A device that emits signals to orbiting satellites. When attached to an animal, these devices allow researchers to track the animal’s movements.</td>
</tr>
<tr>
<td>Scrub habitat</td>
<td>4</td>
<td>Noun</td>
<td>Habitats dominated by shrubs.</td>
</tr>
<tr>
<td>Schematic</td>
<td>2</td>
<td>Noun</td>
<td>A diagram that displays how something is made.</td>
</tr>
<tr>
<td>Suppression</td>
<td>4</td>
<td>Noun</td>
<td>Keeping something from happening.</td>
</tr>
<tr>
<td>Tracking technology</td>
<td>2</td>
<td>Noun</td>
<td>Methods used to determine the location and follow the movements of something or someone.</td>
</tr>
<tr>
<td>Tree canopy</td>
<td>2</td>
<td>Noun</td>
<td>The upper branches and leaves of trees.</td>
</tr>
<tr>
<td>Triangulation</td>
<td>2</td>
<td>Noun</td>
<td>A method of indirectly estimating the location of a radio transmitter attached to an animal. Starting from three different locations, the direction radio signals are coming from are observed and then drawn as lines on a map. Where the lines intersect indicates the location of the animal.</td>
</tr>
<tr>
<td>Wintering grounds</td>
<td>1</td>
<td>Noun</td>
<td>The region where an animal spends the winter. For migratory birds this refers to where they migrate to and live during the time of year when they are not nesting and raising young.</td>
</tr>
</tbody>
</table>
APPENDIX:
WEBSITES REFERENCED

LESSON 1
• Follow that Bird! Website
  https://nationalzoo.si.edu/migratory-birds/follow-bird
• Migratory Connectivity Project
  http://www.migratoryconnectivityproject.org/
• Smithsonian Insider Article: Satellite Tracking Helps with Curlew Conservation
  http://insider.si.edu/2015/05/satellite-tracking-helps-with-curlew-conservation/
• Smithsonian’s National Museum of Natural History Black-bellied Plover Info Sheet
  https://dcbirds.si.edu/bird/black-bellied-plover
• Smithsonian’s National Zoo and Conservation Biology Institute Black-crowned Night Heron Fact Sheet
  https://nationalzoo.si.edu/animals/black-crowned-night-heron
• Smithsonian’s National Zoo and Conservation Biology Institute Brown Pelican Fact Sheet
  https://nationalzoo.si.edu/animals/brown-pelican
• Smithsonian’s National Zoo and Conservation Biology Institute Texas Shorebird Expedition Blog
  https://nationalzoo.si.edu/migratory-birds/news/texas-shorebird-expedition-blog

LESSON 2
• LoJack
  https://www.lojack.com/
• NOAA Solar Calculator
  https://www.esrl.noaa.gov/gmd/grad/solcalc/
• Smithsonian Channel “Wild Inside the National Zoo” Video on Black-crowned Night Herons

LESSON 3
• Smithsonian.com Article: Popular Pesticides Linked to Drops in Bird Populations

LESSON 4
• SageModeler
  https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=16233
• SageModeler - Intro Video
  https://drive.google.com/file/d/0ByX3PPKyWVhHUEJYbFRIX0hxUEk/view
• SageModeler - Kirtland’s Warbler Application
• SageModeler - Full Population Model
  https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=31780

OTHER
• Smithsonian’s National Zoo and Conservation Biology Institute
  https://nationalzoo.si.edu/
• Smithsonian Migratory Bird Center
  https://nationalzoo.si.edu/migratory-birds
• Experience Migration Exhibit
  https://nationalzoo.si.edu/animals/exhibits/experience-migration
THE END
THANK YOU FOR PARTICIPATING IN FOLLOW THAT BIRD! A SCIENCE AND TECHNOLOGY UNIT ON TRACKING BIRDS. WE HOPE YOU AND YOUR STUDENTS HAD A WILD TIME WITH IT!

Questions or feedback? Email FONZed&volunteers@si.edu

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