Modeling Population Decline

Objectives:
Students will be able to:
- Develop, use, and refine models to illustrate how anthropogenic changes in the environment (e.g., habitat destruction, pollution, introduction of invasive species, overexploitation, climate change) can disrupt an ecosystem and threaten the survival of some species.

Disciplinary Core Idea (9-12):
- LS2.C (9-12): Anthropogenic changes in the environment – including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change – can disrupt an ecosystem and threaten the survival of some species.

Science and Engineering Practices (9-12):
- Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.
- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Prerequisite Knowledge:
Students should be familiar with the general story of the passenger pigeon. See the lesson, "What is the Passenger Pigeon?" on the Project Passenger Pigeon website for a possible introductory lesson.

Materials List:
- 140 small counting chips, paperclips, popsicle sticks, or other small items that can be easily spread out and collected around the classroom

Background Information:
The passenger pigeon, once the most abundant bird in North America, was driven to extinction by human action in a matter of decades. In 1914, the last passenger pigeon, Martha, died, marking the end of the species. The passenger pigeon was not well-studied when it was alive, and thus many gaps exist in scientists' knowledge of the birds' lives and the factors contributing to the species' extinction. However, one fact is rarely disputed: overharvesting of passenger pigeons is largely responsible for the rapid elimination of the species.

When Europeans arrived in North America, passenger pigeon populations numbered in the billions. As stated by Joel Greenberg in *A Feathered River Across the Sky*, "The newly arrived Europeans looked at the masses of pigeons both with wonder and hunger" (p. 68). The large flocks of pigeons, sometimes with tens or hundreds of millions in a single flock, were awe-inspiring, and most people considered the pigeons to be inexhaustible given their large numbers. Pigeons were hunted to eat, to feed to livestock, and for sport, and the pigeon trade boomed as railroad systems grew.

Increased hunting of passenger pigeons happened concurrently with human deforestation of the birds' habitat. Passenger pigeons depended on trees for food, shelter, and nesting sites. Because little is known about the precise requirements for passenger pigeon survival and breeding, it is difficult to determine how (and to what extent) this habitat loss impacted the pigeon populations. As Greenberg suggests in his book, the pigeons were likely still able to find food, though the reduced areas for shelter could have made the birds easier targets for hunting (p. 194).

The factors contributing to the decline of the passenger pigeon were not problems of the past, and overharvesting and habitat destruction continue to play key roles in the decline of species in the present day. These two factors illustrate that humans' impacts on a certain population can be both direct (directly taking an organism's life; e.g., hunting) or indirect (not *directly* taking an organism's life, but impacting the organism's ability to survive, ultimately causing its death; e.g., reducing suitable habitat). A population will decline over time in any situation where the death rate outpaces the birth rate. In the passenger pigeons' case, pigeon breeding capacity was diminished as flock numbers declined and suitable habitat was eliminated, and hunting of the pigeons did not slow as the populations dwindled.

As illustrated by the passenger pigeons' story, it is sometimes possible to identify a single factor that plays the most significant role in reducing a population. However, rarely would a single factor be *solely* responsible for a population decline. Typically, a combination of factors, with some factors having more weight than others, contributes to a decline. Such factors can be natural or anthropogenic (caused by humans). Scientists might initially consider factors individually, attempting to understand the impact that the single factor has on a population. However, it is ultimately necessary to combine these factors into a more complex model to predict how the population will fare under certain conditions.

In this lesson, students develop and use models that can explain and predict changes to populations that are influenced by multiple factors. The lesson is begun by presenting students with an already-developed model of a single, isolated factor impacting passenger pigeon population declines. Following the use of this model, students will discuss its accuracies and limitations before designing a more accurate, complex model that considers the role of multiple factors. At the direction of the teacher, students can develop a model focusing on a species that is of current conservation concern, preferably a local species (e.g., little brown bat, honeybee, lake sturgeon, Blanding's turtle, short-eared owl, pitcher plant). (State departments of natural resources should have lists of local endangered and threatened species.) Alternatively, students could build off of the simulation in the lesson to develop a more complex model that illustrates the impact of *multiple factors* on passenger pigeon populations prior to their extinction.

Reference: Greenberg, J. (2014). *A feathered river across the sky: The passenger pigeon's flight to extinction*. New York, NY: Bloomsbury.

Procedure:

1. Review a brief history of the passenger pigeon and its extinction. (See Prerequisite Knowledge, above.) In particular, discuss that the most significant factor contributing to the passenger pigeon extinction was overharvesting by people.
2. Explain that students will now participate in a simplified simulation of how hunting contributed to passenger pigeon decline and eventual extinction. Tell students to make notes about how this simulation does and does not reflect a real-life situation.
3. To conduct the simulation, spread 100 counting chips on a table in the classroom, and select five

students to be "hunters." Explain that these hunters will hunt passenger pigeons (counting chips) at a prescribed rate (2 birds in Round 1, 5 birds in Round 2, 10 birds in Round 3). So, in Round 1, each of the five student hunters will collect 2 counting chips and return back to his/her desk. Any remaining chips left at the end of the round will form breeding pairs, and each pair (two) of birds can have one offspring. For every two birds remaining, add one chip to the table, and include these in the count of the ending population. Changes to the passenger pigeon populations will be noted throughout the simulation.

4. Each round of the simulation will begin with 100 passenger pigeons (counting chips), *not* with the number of pigeons left at the end of the previous round. The three rounds, then, are a comparison of three *separate* hunting rates, not a suggestion of chronological increases in hunting behavior. Students can discuss how this setup impacts the accuracy or limitations of the model during the discussion following the simulation.
5. Conduct the three rounds (Round 1: 2 birds per hunter, Round 2: 5 birds per hunter, Round 3: 10 birds per hunter), starting with 100 chips for each round. Record the starting and ending populations as well as the number of birds hunted and hatched in each round. (See Simulation Record Sheet) After each round, discuss whether the pigeon population would be sustained above the starting level if hunting continued at that rate.
6. Following completion of the three rounds, discuss the model with students.

Discussion Questions:

- What are the limitations of this model (simulation)? In particular, how do the reduced population sizes (looking at 100 birds instead of 3 *billion*) and predictable/standardized hunting rates and birth rates used here compare to what would have happened in the wild during the passenger pigeon extinction?

- Keeping those limitations in mind, which hunting rate of the three simulated here seems to be the best illustration of how passenger pigeon levels were impacted by human hunting? [10 birds per hunter is the only rate tested that shows a decline in the overall passenger pigeon population over time. A hunting rate of 10 birds per hunter was chosen for illustrative purposes but is not representative of hunting patterns in the late 1800s. In fact, some hunters were known to kill thousands of passenger pigeons at a time.] If you were going to develop a complex model to illustrate the factors that contributed to the decline of the passenger pigeon, would you include the 2 birds per hunter and 5 birds per hunter hunting rates in your simulation? Why or why not?

- This simulation did not include a hunting rate at which the ending population was the same as the starting population. How would you figure out what that hunting rate would be? [x = number of pigeons killed; 100 = [(100-x) + ½(100-x)]/5 (because there are five hunters); =6.67 pigeons per hunter (approximately 6 or 7 pigeons per hunter). Discuss that in order for a population to decline, the birth rate must be lower than the death rate.]

Discussion Questions, continued:

- Clearly, *excessive* hunting can have negative impacts on a population. However, hunters often play an integral role in conservation strategies. In this simulation, in which hunting is the *only* factor reducing population size, how would the population change over time with no or very limited hunting? [the population would rise at an excessive rate] What could be some implications of skyrocketing populations of a single species?
- Discuss other factors that may have impacted passenger pigeon population declines and whether those factors were incorporated into the model (simulation) in any way. Discuss how focusing on only a single factor limits the accuracy of the simulation. How could the simulation be improved to incorporate multiple factors?

7. Tell students that they will now be developing their own models to illustrate the factors influencing the decline of a local species of their choice. The species does not need to be endangered, but it should be a species that is currently experiencing a decline for anthropogenic reasons.
8. Students can develop any kind of model that they choose, for example, a diagram, a simulation, a game or a mathematical model. Students' models should be more complex than the passenger pigeon simulation example because students' models should include at least two factors that are influencing the population of their chosen species. As necessary, return to the last discussion question listed above (bulleted list) to discuss how the passenger pigeon model (simulation) could have been improved to incorporate multiple factors.
9. Give students time to research their selected organisms and develop their models (in pairs or groups if desired). Students should then present their models to the class and discuss the limitations and accuracies of the models.
10. If time allows, give students an opportunity to revise their models using feedback provided by other students. For example, another student may have a proposed adjustment to a model that addresses one of the model's limitations.
11. After students have presented their models, discuss trends students noticed in the anthropogenic forces that contribute to population declines. In particular, discuss that people often think that if they don't hunt then they're not contributing to species declines. Is this true? Discuss that directly harvesting or hunting is not always to blame for population declines, and other factors, such as habitat loss and pollution, are directly tied to many of the problems.
12. Conclude the discussion by talking about positive actions that people can take to minimize the negative impacts that students identified in their models. What actions would be helpful to threatened or endangered species in general, and which are specific to supporting the populations of a single species or group of species? (For example, using permeable surfaces instead of concrete is generally helpful because it reduces runoff water pollution. Properly cleaning clothing after exploring caves is rather specific to helping to limit the spread of the "white nose syndrome" currently impacting bat populations.) If desired, have each student complete an individual, written reflection on how positive actions by humans would change the model that the student developed.

Simulation Record Sheet:

Draw or post this record sheet where it is visible to all students.

Hunting: 2 birds per hunter

Starting Population	# of Pigeons Killed	# of Pigeons Hatched	Ending Population
100			

Discuss: Assuming no other factors act on the system, will the overall pigeon population decrease at this rate of human consumption?

Hunting: 5 birds per hunter

Starting Population	# of Pigeons Killed	# of Pigeons Hatched	Ending Population
100			

Discuss: Assuming no other factors act on the system, will the overall pigeon population decrease at this rate of human consumption?

Hunting: 10 birds per hunter

Starting Population	# of Pigeons Killed	# of Pigeons Hatched	Ending Population
100			

Discuss: Assuming no other factors act on the system, will the overall pigeon population decrease at this rate of human consumption?