

BIOLOGY

Ecosystem Interactions
& Dynamics

**How do
ecosystems work,
and how can
understanding
them help us
protect them?**



HIGH SCHOOL SCIENCE



TEACHER EDITION

How do ecosystems work, and how can understanding them help us protect them?

Ecosystem Interactions & Dynamics: Serengeti

OpenSciEd Unit B.1





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The development of this material was supported by the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Walton Family Foundation, and William and Flora Hewlett Foundation.

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UNIT OVERVIEW

How do ecosystems work, and how can understanding them help us protect them?

This unit is anchored by students exploring the 30 by 30 Initiative which 196 nations agreed to in 2022. The initiative sets out to preserve thirty percent of lands and waters by 2030. Although the United States is not part of this international agreement, several US states have adopted 30 by 30 initiatives or enacted other conservation plans. Students investigate human motivation for conservation and what that looks like in ecosystems around the US. They generate a number of questions about ecosystems and conservation and engage in deep investigation of the Serengeti ecosystem as a case study to help answer those questions. In Lesson Set 1 they figure out that the creation of the Serengeti National Park was motivated by a desire to protect the great migration of wildebeest and other animals across the system. They analyze data and develop and use models to figure out how limiting factors affect wildebeest carrying capacity over time. In Lesson Set 2, student models become more complex as they add additional populations and components and uncover mechanisms such as group behavior. They figure out how all the components interact as part of a complex system and how biodiversity can support ecosystem resilience. In Lesson Set 3, students consider the criteria humans use when making decisions about their interactions in the system and the impacts of their decisions. Students return to the US based systems they investigated in Lesson 1 and apply what they figured out to evaluate the efficacy of conservation in the US. They use this evaluation to make recommendations about how humans can preserve additional lands and waters in the future.

Throughout the unit students will do the following:

- Develop and use a model based on evidence to explain why wildebeest migrate.
- Use mathematics and computational thinking to explain how limiting factors such as food have impacted the wildebeest population over time including carrying capacity.
- Use a model to generate evidence and develop algorithms to explain how group behavior explains interaction between wildebeest and their predators.
- Obtain and communicate information about other components of the system in a complex model that can be used to predict future outcomes.
- Evaluate the potential outcomes of a proposed road through the Serengeti ecosystem including the criteria prioritized by different interest holders.
- Apply all the ecosystems and conservation ideas developed in the context of the Serengeti to and evaluation conservation efforts in the US.

Building Toward NGSS Performance Expectations

HS-ESS3-3:

Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

HS-LS2-1:

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2:

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-6:

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-8:

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

UNIT STORYLINE

Unit Question: How do ecosystems work, and how can understanding them help us protect them?

How students will engage with each of the phenomena



Lesson Set 1: How do populations interact with components of ecosystems?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 Lesson Set 1 4 days Why do ecosystems need protection, and how are they protected? Anchoring Phenomenon 	 <i>Lands and waters are protected in different ways based on different criteria.</i>	We heard about a plan called the 30 by 30 Initiative designed to preserve land and water locally and internationally. We brainstorm a list of criteria that motivates conservation. We look at examples of conservation and develop initial models of what happened in these places over time. We build a Driving Question Board and generate ideas for investigation. We figure out: - In US states and other countries, there is a plan to conserve 30% of lands and waters by 2030. - Humans have different reasons for conserving lands and waters. - Each system is composed of unique components and interactions that are affected by human interactions. - We can look at ecosystems that have been protected to understand how to protect systems in the future.	 National Park Service

↓ Navigation to Next Lesson: We figured out that people conserve places, lands, and waters for many different reasons in many different ways. We wonder how we can use what we figured out about multiple ecosystems to understand how to conserve lands and waters across the US.

LESSON 2 Lesson Set 1 2 days What can other cases of conservation help us understand about ecosystems and conservation? Investigation 	 <i>The Serengeti National Park was created to protect the great animal migration route and has a history of complicated human interactions.</i>	We watch a video and look at maps of the Serengeti ecosystem and read about the history of its conservation. We collect more information in a scavenger hunt. We create a consensus model and short explanation of why Serengeti National Park and surrounding reserves were created. We figure out: - The Serengeti is a unique ecosystem with high biodiversity, a unique large mammal migration, and endemic and endangered species. - The great migration is unique, and the park was established in part to protect it. - The great migration is dangerous, but the animals do it anyway. - As a protected space, human decision-making about the Serengeti ecosystem has been motivated by many different points of view and priorities.	
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Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
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↓ **Navigation to Next Lesson:** We figure out that Serengeti National Park and surrounding reserves were created to protect the migration of the wildebeest. We wonder why wildebeest go through such a long, dangerous migration.

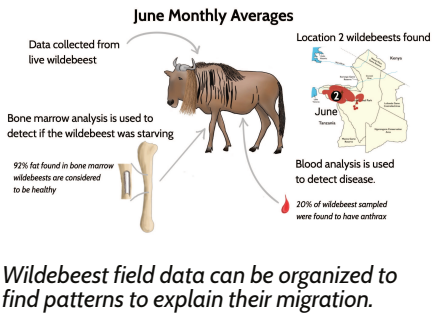
LESSON 3

Lesson Set 1

2 days

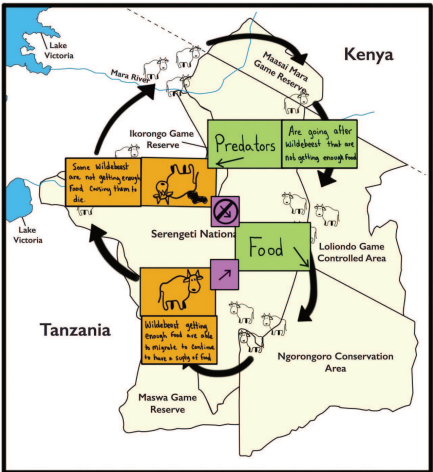
Why do the animals in the Serengeti migrate?

Investigation



We reflect on wildebeest migration and brainstorm why wildebeest migrate. We hear from a scientist about what he figured out from studying wildebeest. We look closer at wildebeest field data and organize it to look for patterns to explain wildebeest migration. We communicate what we figure out on data displays and co-construct a classroom consensus model to explain what we figured out about wildebeest migration. We figured out:

- Some wildebeest are killed by predators, but most wildebeest die of starvation.
- Food is the main factor that motivates the migration pattern.



↓ **Navigation to Next Lesson:** We figure out that there is evidence that the wildebeest migration is caused by food. We have a lot of questions about this connection between food and wildebeest moving from location to location.

LESSON 4

Lesson Set 1

3 days

How is food driving the wildebeest migration?

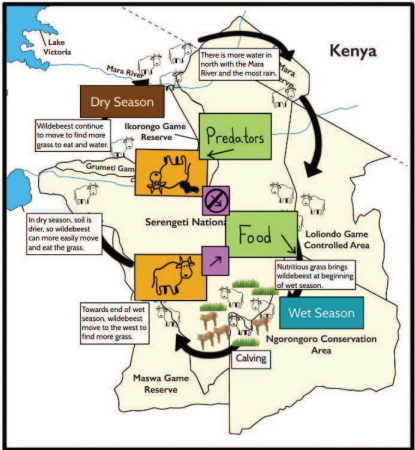
Investigation



Factors such as rain affect wildebeest migration in the Serengeti.

We decide to investigate how food drives the migration. We hear from a scientist that rain is a good way to understand food because it is a limiting factor that affects how much grass there can be. We figure out:

- There is a wet and a dry season in the Serengeti.
- Rain is related to location some of the time.
- Other factors limit wildebeest location at different times of the year.



Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
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↓ **Navigation to Next Lesson:** We figure out what the limiting factors are driving wildebeest migration, which makes us wonder about the large wildebeest population and how that can be so big.

LESSON 5

Lesson Set 1

2 days

How does food affect the population size?

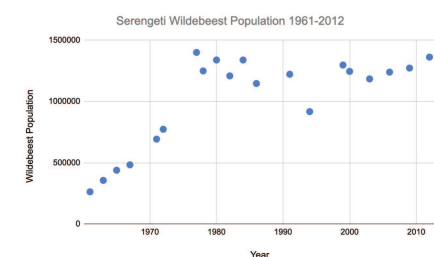
Investigation



The population of wildebeest is large when there is a lot of access to food (grass).

We decide to use a kinesthetic model to simulate what is happening with food and wildebeest in the Serengeti. We make sense of the data we collect to determine that the amount of food regulates how many wildebeest can survive. We conclude that more food is available because the wildebeest migrate. We figure out:

- Food availability is the main limiting factor that regulates the wildebeest population, when they run out of food they move or die.
- Migration increases the carrying capacity of the population.



Data Source: Hopcraft, G. et al. (2015)

↓ **Navigation to Next Lesson:** We figure out more food is available to wildebeest when they migrate. We wonder if we can apply everything we have figured out so far back to our conservation profiles.

LESSON 6

Lesson Set 1

2 days

Can we apply what we figured out about limiting factors and carrying capacity to a new scenario?

Putting Pieces Together



Scientists want to reintroduce African wild dogs from South Africa to a new national park in Malawi.

We apply the concepts of limiting factors and carrying capacity to a new scenario as we learn how to complete transfer tasks. We revisit the Driving Question Board to determine what else we need to know about the Serengeti ecosystem to learn how ecosystems work and protect them. We figure out:

- Space, food, and predation can be limiting factors for wild dogs.
- Data about limiting factors can be used to determine carrying capacity.
- Liwonde National Park can support one pack of African wild dogs.
- We need more information about the role of predators in the Serengeti ecosystem.

Ba) Sketch a graph of what you think will happen to the African wild dog population over the next ten years if the relocation is successful.

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	Graph rises at the beginning and levels off, but does not consider appropriate scale.	Graph includes at least four of the bullets listed in organized understanding.	Graph includes: • Starting pack size of 8 • Increase of 17 in year 1 • Goes up and down every year by about the same amount. • Carrying capacity is between 10 and 15 dogs. • Appropriate scale on axes (y axis to approximately 20 animals, x axis ends at 10 years) Optional: Pack size could increase for approximately 1-3 years before reaching carrying capacity.

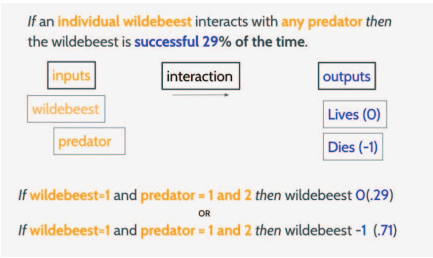
Suggestions for improvement (circle the relevant options or write your own):

- Revise scale on the ____ axis to ____.
- Change carrying capacity to ____.
- Change pattern on graph to ____.

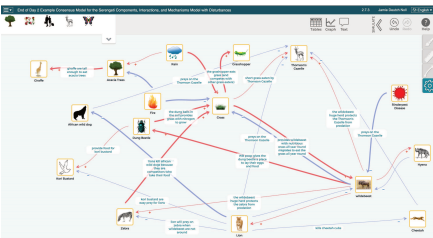
↓ **Navigation to Next Lesson:** We determine that we understand some of the limiting factors for the wildebeest, but we do not completely understand the role of their predators in the Serengeti ecosystem.

Lesson Set 2: How do all the living and non-living components interact in an ecosystem?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
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Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 Lesson Set 2 3 days How do predators interact with the wildebeest migration? Investigation 	 <i>Predators such as lions and spotted hyenas interact with the wildebeest migration.</i>	We investigate the role of predators in the migration. We read about the behaviors of wildebeest and their predators and relate them to rules in an agent-based modeling game. We play the game and analyze our data to determine that group behaviors increase survival for predators and prey. We realize our model is limited because we only investigated a few components and wonder how we can include more of the components. We figure out: - Behaviors in wildebeest and their predators can inform initial conditions and rules in a model. - Mathematical models, such as algorithms, provide evidence to explain interactions. - There is a pattern of group behavior increasing survival across multiple species. - Models have limits that can affect the kinds of conclusions we can make from our data.	

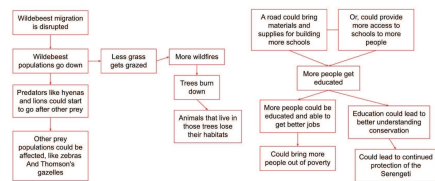
↓ **Navigation to Next Lesson:** We figure out that group behaviors increase survival and wonder about the rest of the components of the Serengeti system.

LESSON 8 Lesson Set 2 2 days What other components of the Serengeti system interact with the migration? Investigation 	 <i>The Serengeti successfully supports many different organisms.</i>	We investigate other components of the Serengeti ecosystem. We gather information to develop a model that includes mechanisms and mathematical representations of relationships. We use our models to predict outcomes of disturbances and figure out that biodiversity can support resilience in the system. We update our Progress Trackers and the DQB and complete an exit ticket to show what we have learned. We figure out: - Many components of the ecosystem connect to the wildebeest migration. - The mechanisms of their interactions include predator/prey, group behavior and competition. - The wildebeest is a keystone species, and their migration supports biodiversity across the entire Serengeti. - Biodiversity leads to greater stability within the ecosystem because with more species. - Biodiversity contributes to ecosystem resilience when a disturbance occurs.	 <i>Images generated using SageModeler (https://sagemodeler.concord.org/), developed at the Concord Consortium and Michigan State University.</i>
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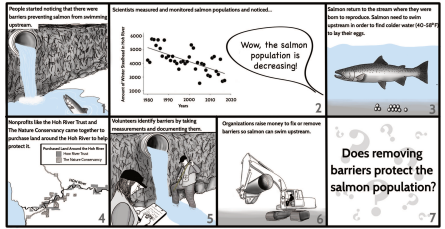
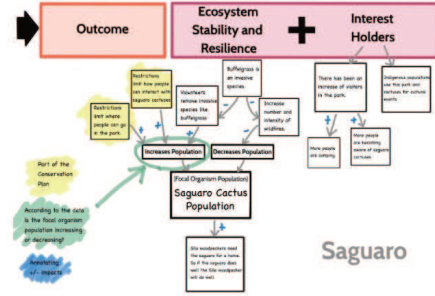
↓ **Navigation to Next Lesson:** We figure out that interactions between components based on the combined influences of competition, predation, and group behavior create biodiversity, which can lead to stability of the overall number of organisms in an ecosystem and resilience to disturbances. We wonder about the long-term effects of establishing Serengeti National Park affecting the resilience of the ecosystem.

Lesson Set 3: How can we use what we learned about ecosystems to protect them?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
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Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 Lesson Set 3 3 days How do humans interact with the Serengeti ecosystem? Investigation 	 <i>Tanzanians are considering building a road in the Serengeti.</i>	We explore how human interest holders interact with the Serengeti ecosystem and we add them to our models. We use our model to evaluate the Serengeti conservation plan and decide that it was successful in achieving its goals. We wonder what will happen in the future and investigate a proposal to build a road in the Serengeti. We evaluate road proposals and make a recommendation about the Serengeti conservation plan. We figure out: • Creating the park protected the wildebeest migration and protected the stability of the system. • Some interest holders benefit, but others are harmed, and not all human connections in the system are stable. • Successful conservation that supports a stable ecosystem also involves relationships between the conservation managers and the broader community. • There are numerous short-and long-term consequences that interest holders need to consider when making conservation decisions.	

Navigation to Next Lesson: We figured out how a possible road could affect humans and nonhumans in Serengeti National Park. We wonder about how we could protect ecosystems more broadly.

LESSON 10 Lesson Set 3 3 days How do we evaluate if a conservation effort is working? Putting Pieces Together 	 <i>Conservation success relies on the plan's goals being met while supporting ecosystem resilience and minimizing any negative impacts on interest holders.</i>	We return to our conservation profiles from Lesson 1. We evaluate the conservation plans in those systems by considering the impact the plan would have on organisms, the ecosystem overall, and other interest holders. We build understanding about what it means for conservation to be successful and how we can use what we learned to protect more lands and waters. We figure out: • Conservation success relies on the plan's goals being met while supporting ecosystem resilience and minimizing any negative impacts on interest holders. • Interest holders have different goals, and the criteria they judge success by may be different from the overall plan. • We can learn how to protect more places in the future by looking at conservation happening now.	
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Navigation to Next Lesson: We figure out that conservation success relies on the plan's goals being met while supporting ecosystem resilience and minimizing any negative impacts on interest holders. This makes us wonder if we can apply everything we figured out to new conservation plans from the 30 by 30 Initiative.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 Lesson Set 3 1 day Can we use everything we have figured out about ecosystems and conservation to expand conservation to new lands and waters? Putting Pieces Together 	 <i>The American Prairie Reserve aims to add new protected lands.</i>	We complete a transfer task about the American Prairie Preserve to demonstrate what we figured out throughout the unit about how ecosystems work and how understanding them can help us protect them. We figure out: • Human-caused changes can cause disruptions that change an ecosystem. • Some changes have greater or lesser effects and impact the stability of the system. • A change to a keystone species can affect the biodiversity of the system. • Humans consider many criteria when making decisions about conserving or using the natural world.	 <i>Zntrip, GPL</i>

↓ Navigation to Next Lesson: This is the last lesson in the unit.

LESSONS 1-11

27 days total

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices when conducting hands-on science investigations and demonstrations, whether in an instructional space (traditional laboratory or classroom) or in the field. To this end, teachers must be aware of any school or district safety policies, legal safety standards, and better professional safety practices that are applicable to the activities being undertaken.

Science safety practices in instructional spaces require engineering controls and personal protective equipment (e.g., sanitized safety goggles or safety glasses with side shields as appropriate, non-latex aprons and gloves, eyewash/shower station, fume hood, appropriate ventilation, and fire extinguishers). **Science investigations should always be directly supervised by qualified adults, who should review safety procedures annually, and also before initiating any hands-on activities or demonstrations.** Prior to each investigation, students should be reminded of the specific safety procedures they must follow. Each lesson within the OpenSciEd units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as disassembling, disposing of, and storing materials.

Prior to the first investigation of the year, a safety acknowledgement form for students and parents/guardians should be provided and signed. You can access a model safety acknowledgement form for high school activities here: <https://static.nsta.org/pdfs/SafetyAcknowledgmentForm-HighSchool.pdf>

Disclaimer: The safety precautions provided for each activity are based in part on use of the specifically recommended materials and instructions, as well as legal safety standards and better professional safety practices. Be aware that selecting alternative materials or procedures for these activities may affect the activity's level of safety, and is therefore at the user's own risk.

Please follow these lab safety recommendations for any science investigation:

1. Wear sanitized safety goggles (specifically, indirectly vented chemical splash goggles) or safety glasses with side shields, as appropriate, a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take-down segments of the activity.
2. Safety goggles are required when working with liquid biological or chemical hazards (e.g., microbes, acids, bases, etc.). Safety glasses with side shields or safety goggles may be used when working with physical hazards (sharps, springs, glass, projectiles, etc.).
3. Immediately wipe up any spilled liquid (e.g., water) and/or granules on the floor, as this is a slip-and-fall hazard.
4. Follow your *Teacher Guide* for instructions on disassembling and storing materials and disposing of waste materials.
5. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
6. Wash your hands with soap and water immediately after completing the activity.
7. Never eat any food items used in a lab activity.
8. Never taste any substance or chemical in the lab.
9. Use only GFCI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
10. Use caution when working with glassware, which can shatter if dropped and cut skin.
11. Use caution when using sharp [tools/materials], which can cut or puncture skin.
12. Never pour chemicals, either used or unused, back into their original container. Dispose of chemicals according to your teacher's instructions.
13. If you get a hazardous chemical on your clothing or have a clothing fire, use the emergency shower.
14. If you get a chemical in your eye, use an eyewash station immediately.
15. Point the test tubes, beakers, or other vessels away from yourself and other people when the vessels contain reactants or other substances.
16. When diluting acids or bases, the acid or base should be added to water and not water to the acid or base.
17. Projective trajectory zones must be well defined and free of any obstacles. No participant is to be in the zone during operation of the projectile..
18. Make sure the ventilation system meets the needs relative to removal of flammable vapors produced. Also make sure there are no active flames or sparks in the work zone.



Specific safety precautions are called out within the lesson using this icon and a call-out box.

Where does this unit fall within the OpenSciEd scope and sequence?

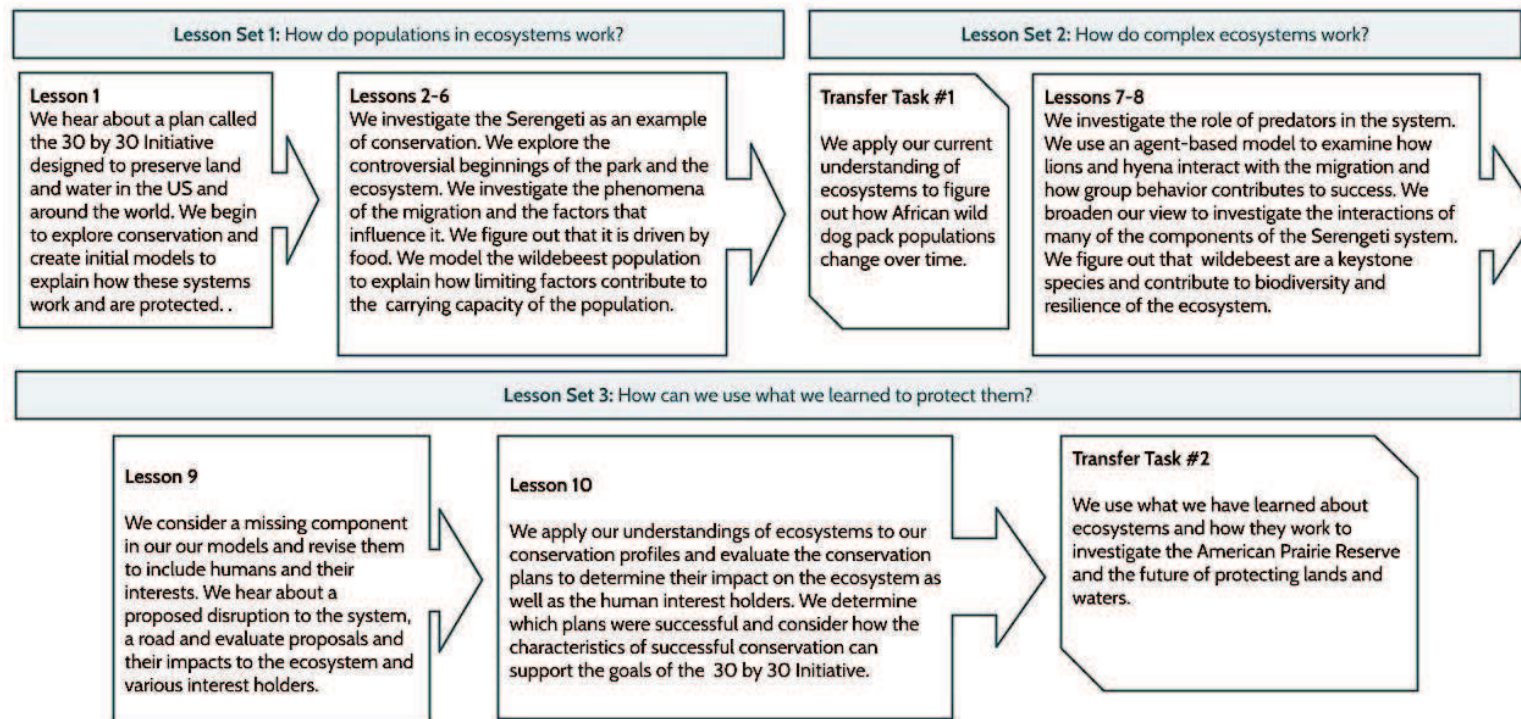
This unit is the first in the OpenSciEd High School Biology course sequence.

What is the anchoring phenomenon and why was it chosen?

In the anchoring phenomenon, students explore conservation in the context of the global 30 by 30 Initiative, which aims to conserve 30 percent of lands and waters by 2030. Students learn about the initiative and brainstorm criteria that people use when deciding to protect lands and waters. Students shift their perspective to consider conservation initiatives within the US, draw on their own experiences, and investigate four different conservation profiles in the US. They develop initial models to explain the system and why humans wanted to protect it. They generate questions that they need to answer to be able to fully explain their models. Students also notice unique and common features in each case and are motivated to learn more about how ecosystems work and how we can use what we learn to protect them. This phenomenon gives students a real-world context for thinking about ecosystems and their protection while at the same time helping them recognize that often what we learn about one ecosystem can be applied to another. This motivates the class to investigate a single case together, the Serengeti. The Serengeti was chosen as the focus of the majority of the lessons because it has been studied extensively for over 70 years and many long-term, comprehensive data sets are available for students to investigate. In addition, the Serengeti phenomenon generated high student interest across racial and gender identities in a national survey.

How is the unit structured?

The unit is organized into three lesson sets. Lesson Set 1 (Lessons 1-6) focuses on the populations within an ecosystem and the different factors that affect them. It ends with a transfer task about African wild dogs. Lesson Set 2 (Lessons 7-8) helps students begin to unravel the complexity of ecosystems as they discover the importance of keystone species in terms of ecosystem stability and resilience. Lesson Set 3 (Lessons 9-11) helps students use their understanding of ecosystems to evaluate their conservation in systems in the US. This unit culminates with a transfer task where they apply all of their understandings to the American Prairie and its conservation.



What elements of NGSS three dimensions are developed in this unit?

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This unit is designed to introduce students to **ecosystems, their dynamic nature, and the interactions** within them. **Developing and using models** is intentionally developed across **this unit**, beginning in Lesson 1, where students develop initial models to explain **ecosystems** they explore in their **conservation** profiles. In Lessons 3 and 4, students develop and revise a model of the great migration in the Serengeti. In Lesson 5, they use multiple models to explain **carrying capacity** in the wildebeest population. In Lesson 8, they use these models to generate data to explain predictions about **disturbances to the system**. Student models use **stability and change** to explain **interactions in the system**, and this crosscutting concept is **intentionally developed throughout the unit**.

The use of **mathematics and computational thinking** is intentionally developed in this unit. In **Lessons 4 and 5**, students use mathematical representations of phenomena. In **Lesson 5**, students use rates of change to understand how **limiting factors affect a population**. In **Lessons 5 and 7**, students develop **algorithms** to explain **relationships**. In **Lesson 8**, students use a mathematical model to explain and predict **interactions** in the Serengeti system.

Constructing explanations and designing solutions is also intentionally developed in this unit. In **Lesson 9**, students evaluate a real-world problem related to a proposal to **build a road** through the Serengeti. In **Lesson 10**, student explanations focus on the conservation profiles introduced in Lesson 1. Students use everything they have figured out throughout the unit to **evaluate conservation** in these systems.

While not intentionally developed, **obtaining, evaluating, and communicating information** is also key to the sensemaking in this unit. **Patterns**, and **systems and system models** are also key to the sensemaking in several lessons.

This unit builds toward these performance expectations:

HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-6* Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-7* Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS2-8* Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

HS-ETS1-3† Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

†This performance expectation is developed across multiple courses.

Science and Engineering Practices	Disciplinary Core Ideas*	Crosscutting Concepts
This unit intentionally develops students' engagement in these practice elements: Developing and Using Models 2.3 Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. 2.4 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. 2.5 Develop a complex model that allows for manipulation and testing of a proposed process or system. 2.6 Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. Using Mathematics and Computational Thinking: 5.2 Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Constructing Explanations: 6.5 Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. The following practices are also key to the sensemaking in this unit: Asking Questions and Defining Problems 1.1 Ask questions that arise from careful observation of phenomena or unexpected results to clarify and/or seek additional information. Analyzing and Interpreting Data 4.1 Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Obtaining, Evaluating, and Communicating Information 8.1 Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information	LS2.A: Interdependent Relationships in Ecosystems - Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and non-living resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) LS2.C: Ecosystem Dynamics, Functioning, and Resilience - A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2, HS-LS2-6) - Moreover, anthropogenic changes (induced by human activity) 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. (HS-LS2-7) LS2.D: Social Interactions and Group Behavior - Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8) LS4.D: Biodiversity and Humans - Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary) (HS-LS2-7) - Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and	This unit intentionally develops students' engagement in these crosscutting concept elements: Stability and Change: 7.1 Much of science deals with constructing explanations of how things change and how they remain stable. 7.2 Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. 7.4 Systems can be designed for greater or lesser stability. Systems and System Models: 4.1 Systems can be designed to do specific tasks. 4.3 Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 4.4 Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. The following crosscutting concepts are also key to the sensemaking in this unit: Patterns 1.4 Mathematical representations are needed to identify some patterns. 1.5 Empirical evidence is needed to identify patterns. Cause and Effect 2.1 Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. 2.2 Cause-and-effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system. Scale, Proportion, and Quantity 3.1 The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

presented in a text by paraphrasing them in simpler but still accurate terms. 8.2 Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. 8.5 Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).	productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS2-6, HS-LS2-7) ESS3.C: Biodiversity and Humans - The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources. (HS-ESS3-3) ETS1.B: Developing Possible Solutions - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. (HS-LS2-7, HS-ETS 1-3)	
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*“Disciplinary Core Ideas” are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. DOI: <https://doi.org/10.17226/13165>. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

Connections to the Nature of Science (NOS)

Connections to the Nature of Science (NOS)	
Which elements of NOS are developed in the unit?	How are they developed?
- Science knowledge is based on empirical evidence. (NOS-SEP) - Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (NOS-SEP) - Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (NOS-CCC) - Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge. (NOS-CCC)	- Students engage with empirical evidence in the form of scientific articles, data, and images throughout the unit. - Students gather multiple types of evidence (e.g., historical data, kinesthetic modeling, simulation-based data, data generated from agent-based models, etc.) to support their ideas. - Students hear from a variety of perspectives as they consider whether the proposed solutions would have a positive impact. - Students use their understandings gained from exploring the Serengeti as both an ecosystem and successful conservation plan to evaluate the success of the conservation plan for their conservation profile.

How does the unit build three-dimensional progressions across the course and the program?

This unit uses and builds upon **disciplinary core ideas (DCIs)** and other science ideas that students should have previously developed in OpenSciEd Middle School or another middle school science program.

- LS2.A. Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors. (*OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*)
- LS2.A. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (*Palm Oil Unit*)
- LS2.A. Growth of organisms and population increases are limited by access to resources. (*Palm Oil Unit*)

- LS2.A. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and non-living, are shared. (*Palm Oil Unit*)
- LS2.C. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (*Palm Oil Unit*)
- LS2.C. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. (*OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*)
- LS2.B. Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. (*OpenSciEd Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*)

This unit begins the development of **disciplinary core ideas (DCIs)** and other science ideas that students will utilize and continue building in subsequent units in the OpenSciEd Biology, Chemistry, and Physics courses:

This unit uses and builds upon high school level **Science and Engineering Practices (SEPs)** and **Crosscutting Concepts (CCCs)** that students should have previously developed in **OpenSciEd High School Biology and Chemistry** and will continue to build in future units. The progression of these practices and concepts across the program are as follows:

	Questions	Models	Investigations	Data	Math	Explanation	Argument	Obtaining
Biology	Cancer Unit	Serengeti Unit, Fires Unit	Fires Unit, Natural Selection Unit	Natural Selection Unit, Cancer Unit	Serengeti Unit	Fires Unit, Cancer Unit, Natural Selection Unit	Speciation Unit	Cancer Unit, Speciation Unit
Chemistry	Polar Ice Unit	Electrostatics Unit, Space Survival Unit, Oysters Unit	Polar Ice Unit	Fuels Unit	Polar Ice Unit	Fuels Unit	Oysters Unit, Fuels Unit	Electrostatics Unit, Space Survival Unit
Physics	Electricity Unit, Cosmology Unit	Electricity Unit, Microwave Unit	Microwave Unit	Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit, Meteors Unit	Vehicle Collisions Unit, Meteors Unit	Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit	Vehicle Collisions Unit	Cosmology Unit, Microwave Unit

	Patterns	Cause/Effect	Scale	Systems/Models	Energy/Matter	Structure/Function	Stability/Change
Biology	Natural Selection Unit, Speciation Unit	Cancer Unit, Natural Selection Unit, Speciation Unit, Serengeti Unit	Serengeti Unit	Fires Unit, Cancer Unit, Serengeti Unit	Fires Unit, Serengeti Unit	Cancer Unit	Speciation Unit, Serengeti Unit
Chemistry	Electrostatics Unit, Space Survival Unit	Electrostatics Unit, Oysters Unit	Oysters Unit	Polar Ice Unit	Polar Ice Unit, Fuels Unit	Space Survival Unit	Oysters Unit, Fuels Unit
Physics	Cosmology Unit, Vehicle Collisions Unit, Earth's Interior Unit	Vehicle Collisions Unit, Earth's Interior Unit	Meteors Unit, Earth's Interior Unit	Electricity Unit, Vehicle Collisions Unit, Microwave Unit	Electricity Unit, Earth's Interior Unit	Earth's Interior Unit, Vehicle Collisions Unit	Electricity Unit, Cosmology Unit

What are some common ideas that students might have?

Students will come into the unit with many ideas about conservation and ecosystems derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with nature, and the conversations they have had with parents, friends, and family members.

- Varying the size of a population of organisms will affect only those populations of organisms that are directly connected to it in a feeding relationship, not organisms that are one or more steps removed/away from it (Griffiths & Grant, 1985; Webb & Boltt, 1990).
- If the size of one population in a food web is altered, all other populations in the web will be altered in the same way (Griffiths & Grant, 1985).
- Plants do not compete for resources (AAAS Project 2061, n.d.)
- Populations exist in states of either constant growth or decline (Munson 1991).

It is valuable to think of ideas like these not as misconceptions that need to be replaced but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. For example, in Lesson 5, students develop both kinesthetic and mathematical models for wildebeest populations to compare to historical data from the Serengeti. Students need to build off their ideas about wildebeest either always increasing or decreasing to establish that carrying capacity is composed of those fluctuations around a relatively stable average rate of change. Additionally, in Lesson 8, students may have the idea that a disturbance to the ecosystem will affect all of the components equally, and this is needed to motivate looking at the effect of different disturbances. However, when manipulating the computational model for the Serengeti, students are able to deduce for themselves that certain components are affected differently.

How will I need to modify the unit if taught out of sequence?

This is the first unit of the High School Biology Course in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit later in the year. These include the following adjustments:

- As the first unit of the year, the lessons devote more time to developing and supporting classroom agreements. If the unit were to be taught later in the year, classroom community would need to be addressed elsewhere.
- The unit introduces students to transfer tasks, an assessment routine that is a key part of the OpenSciEd program's assessment system. In this unit, students are introduced to the routine and its purpose. Their engagement with this first transfer task is scaffolded through collaborative group work and peer and teacher feedback. Students also get to know the rubric structure for the task to increase their agency in the assessment process. If taught out of order, students would need to be introduced to transfer tasks in the first unit in which they experienced them.
- Developing and using models is a key practice in this unit and the OpenSciEd program. This unit introduces students to the practice of developing models by first including components and interactions in Lesson 1. In subsequent lessons, students explain the interactions in their models as mechanisms. Finally, students use their models to predict outcomes. If taught out of order, students would benefit from a scaffolded approach to developing their modeling practice.

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without eliminating important sensemaking for students:

- Lesson 2: Read the History of Serengeti aloud as a class instead of reading in small groups and then discussing again as a class.
- Lesson 10: Instead of having each group present their conservation profiles and plans to the class, a gallery walk of the presentations may help to streamline this portion of the lesson.

To extend or enhance the unit, consider the following:

- Lesson 6: The African wild dog pack in Liwonde had puppies! For updates on the pack, share the following resources:
 - Video of how they moved African wild dogs <https://www.youtube.com/watch?v=S1m00A6koEO>
 - Images of the pups born in Liwonde after relocation <https://www.facebook.com/watch/?v=605291120734360>
 - Updates on Liwonde National Park <https://www.africanparks.org/the-parks/liwonde>
- Lesson 7: Have students write algorithms for multiple agents.
- Lesson 8: Create additional *Serengeti Component Articles* for components your students' mention that are not already included in the lesson.
- Lesson 8: Engage the whole class in the citizen science project, Snapshot Serengeti. Found at <https://www.snapshotserengeti.org/>.

What mathematics concepts will students engage with in the unit?

This unit requires students to develop mathematical models, use mathematical representations, develop algorithms, and use rates of change. Making mathematical models is a Standard for Mathematical Practice, and specific modeling standards appear throughout the high school standards.

This unit does not assume students are fluent with the mathematical practices listed below, but that students develop these practices as part of the sensemaking. Thus, these standards are not so much prerequisites as co-requisites. If students are simultaneously developing the skills and vocabulary in math class, you can help by making explicit connections to the mathematical standards below.

Talk with the math teacher(s) to identify the strategies students are familiar with for developing algorithms with words or numbers, calculating rates of change, and constructing graphical representations of data.

Category	Code	Domain and Heading	Standard	Lesson
n/a	CCSS.MATH.PRACTICE.MP2	Mathematical Practice	Reason abstractly and quantitatively.	6, 7, 8
n/a	CCSS.MATH.PRACTICE.MP4	Mathematical Practice	Model with mathematics.	8
Number and Quantity	CCSS.MATH.CONTENT.HS.N-Q.1	Quantities: Reason quantitatively and use units to solve problems.	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.	6
Functions	CCSS.MATH.CONTENT.HS.F-IF.B.6	Interpreting Functions: Interpret functions that arise in applications in terms of the context.	Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.	5
Statistics and Probability	CCSS.MATH.CONTENT.HS.S-IC.B.3	Making Inferences and Justifying Conclusions: Make inferences and justify conclusions from sample surveys, experiments, and observational studies.	Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.	3

What strategies are available to support equitable science learning in this unit?

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies, which are integrated throughout the OpenSciEd routines and are intended to increase relevance and provide access to science learning for all students. OpenSciEd units support these equity goals through several specific strategies, such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and increase accessibility for students to engage in learning experiences; 2) developing and supporting classroom agreements that encourage a safe learning culture; 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and 4) specific strategies for supporting emerging multilingual students in science classrooms.

Many of these strategies are highlighted in the teacher guides in sidebar callout boxes with the headings of:

- Attending to Equity
- Supporting Emerging Multilingual Learners
- Supporting Universal Design for Learning
- Additional Guidance
- Alternate Activity
- Key Ideas
- Discussion Callouts

The example callout below highlights how an activity can be modified to support a wider variety of learners.

*** ATTENDING TO EQUITY- Universal Design for Learning:** If it is something familiar to your students or part of their education plans, consider allowing students to use a digital graphing tool such as a graphing calculator or spreadsheet software to help them create their graphs. Students can take the data table and enter it into graphing software. Allowing alternatives for use of tools such as a calculator can remove barriers for students in *expressing* their understanding by keeping the focus on the learning goal. Use of such tools can help provide a match between a student's abilities and the demands of the task.

What are recommended adult-level learning resources for the science concepts in this unit?

The OpenSciEd instructional model focuses on the teacher being a member of the classroom community, supporting students in figuring out scientific ideas motivated by their questions about phenomena. Students iteratively build their understanding of phenomena as the unit unfolds. To match the incremental build of a full scientific explanation across the unit, the science content background necessary for you to teach individual lessons incrementally builds too. Throughout the unit, we provide just-in-time science content background for you that is specific to the Disciplinary Core Ideas (DCIs) that will be figured out in a lesson. Places to look for this guidance include the “Where we are going” and “Where we are not going” sections for each lesson. Also, the expected student responses, keys, and rubrics illustrate important science ideas that should be developed in each lesson. The K-12 Science Framework is another great resource to learn more about the DCIs in this unit (**LS2.A: Interdependent Relationships in Ecosystems, LS2.C: Ecosystem Dynamics, Functioning, and Resilience, LS2.D: Social Interactions and Group Behavior, LS4.C: Adaptation, LS4.D: Biodiversity and Humans, and ETS1.B: Developing Possible Solutions**), including what students have learned previously and where they are headed in high school. In addition to the science content background information embedded in the lesson resources, we provide recommended resources below that can help build your understanding of phenomena and Performance Expectations bundle for this unit:

Articles and Books:

Edelson, D. C., Tarnoff, A., Schwille, K., Bruozas, M., & Switzer, A. (2006). Learning to make systematic decisions. *The Science Teacher*, 73(4), 40.

Estes, R. (2014). *The gnu's world: Serengeti wildebeest ecology and life history*. University of California Press.

Learning in Places Collaborative. (2020). Framework: Ethical Deliberation and Decision-Making in Socio-Ecological Systems. Bothell, Seattle, WA & Evanston, IL: Learning in Places.

Nijhuis, M. (2022). *Beloved beasts: Fighting for life in an age of extinction*. W. W. Norton & Company, Inc.

Sinclair, A.R.E & Byers, R. (2021). *A place like no other: Discovering the secrets of Serengeti*. Princeton University Press.

Sinclair, A. R. E., Hopcraft, J. G. C., Olff, H., Mduma, S. A., Galvin, K. A., & Sharam, G. J. (2008). Historical and future changes to the Serengeti ecosystem. *Serengeti III: Human impacts on ecosystem dynamics*, 7-46.

Sinclair, A. R. E., Metzger, K. L., Meduma, S. A. R., & Fryxell, J. M. (2015). *Serengeti IV: Sustaining biodiversity in a coupled human-natural system*. The University of Chicago Press.

Sinclair, A. R. E., & Norton-Griffiths, M. (1984). *Serengeti, dynamics of an ecosystem*. University of Chicago Press.

Videos:

History of Tanzania: <https://www.de.tzembassy.go.tz/tanzania/brief-history#:~:text=Tanzania%20is%20a%20result%20of,revolution%20on%2012th%20January%201964>

History of Serengeti National Park and Ngorongoro Conservation Area: <https://www.ngorongorocratertanzania.org/history-of-serengeti-national-park/>

How do I support students' emotional needs?

In this unit, students explore the challenges associated with creating conservation areas. These raise issues concerning land ownership, decision-making, and animal welfare. Students may have emotional needs related to two main issues:

- Trauma associated with history of colonization, and racism;
- Strong beliefs about animal well-being, such as anti-hunting sentiments.

Before beginning this unit, make sure to reach out to the counselor at your school for student-specific support and strategies that might be needed in regard to the students in your classroom. Consider asking the counselor to join you in the classroom at key moments, such as the discussion on the colonial history of colonization in **Lesson 2**. Also consider planning follow-up check-ins with the counselor in regard to any students who may need additional emotional support.

Educate yourself about the connection between the creation of conservation areas, such as the National Park System, and taking of lands from Indigenous Peoples. Plan ahead with ways to scaffold justice-oriented teaching. Consider the following websites:

- Resource: Learning for Justice: Critical Practices: <https://www.learningforjustice.org/frameworks/critical-practices>
- Facing History & Ourselves: <https://www.facinghistory.org/resource-library?search=colonialism>

Reach out to students' support systems at home before the unit using *Pre-Unit Letter Home*. This letter is a way to communicate with trusted adults and make them aware of the content of the unit. The letter also provides an opportunity for trusted adults to share important context with you about students' experiences and background that might be relevant.

Be aware that students who are struggling may demonstrate a variety of behaviors, including but not limited to: fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, and change in body language or tonation. If you notice a student might be struggling, share what you are observing and ask if they need some help.

Often in science classrooms, we are focused on evidence and data. When addressing a phenomenon or design solution that straddles the nature-cultural divide, like this one, supporting students in using an empathy or socio-emotional lens will also be important. Make space for students to process and validate their feelings and reactions. These opportunities were built in throughout the unit.

Furthermore, an important part of addressing controversial histories is that there has been change in how we approach these issues and there is hope. The 30 by 30 Initiative explicitly calls for honoring Tribal Sovereignty and supporting the priorities of Tribal Nations in decision-making about conservation.

What is the Learning in Places socio-ecological deliberation and decision-making framework?

This unit is informed by the Learning in Places complex socio-ecological systems framework. This framework involves sensemaking across five dimensions (species, kinds & behaviors; relationships; places, lands & waters, thinking across scales, and ethical deliberation and decision-making) under an umbrella of power and historicity. These dimensions include making sense of both human and other-than-human values, needs, and behaviors across multiple temporal and spatial scales. The framework guides learners towards designing actions or making decisions for making change in adaptive and resilient ways. Students use these dimensions to evaluate their conservation profiles as well as the Serengeti system. This allows them to raise questions about how conservation plans are created, who is and is not involved in decision-making, and what impacts those decisions have on humans and other-than-humans. It also facilitates thinking about these ecosystems at multiple scales over long periods of time.

Socio-ecological decisions are those made by individuals, communities, organizations, and institutions that are informed by and impact the natural world. These decisions are affected by relationships between humans and the natural world, which are called "nature-culture relations." Nature-culture relations often vary by culture, context, and society and affect which socio-ecological decisions are made and enacted. Understanding the different types of philosophical connections that exist between humans and the natural world is imperative for creating and sustaining socially and environmentally just decisions. **Lesson 2** introduces students to nature-culture relationships and helps them reason about how these philosophies drove the early decision-making to protect the Serengeti. Students keep these different perspectives in mind as they evaluate conservation plans in the final lessons of the unit.

For more about socio-ecological deliberation and decision-making, please visit <http://learninginplaces.org/>. Learning in Places Collaborative. (2022). Framework: Complex Socio-Ecological Systems. Bothell, Seattle, WA & Evanston, IL: Learning in Places.

Guidance for Developing Your Personal Glossaries

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a personal glossary at the back of their notebooks. These “definitions we co-develop” should be recorded using the students’ own words whenever possible. On the other hand, “definitions we encounter” are “given” to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes definitions we encounter are helpful just in that lesson and need not be recorded in students’ personal glossaries. However, if a word we encounter will be frequently referred to throughout the unit, it should be added.

It is best for students if you create consensus definitions in the moment, using phrases and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the meaning of the word, students “own” the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes defining a word is a challenge. The *Teacher Guide* provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate.

The definitions we co-construct and encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they’re trying to figure out.

Lesson	Definitions we co-construct	Definitions we encounter
L1		conservation, criteria**, ecosystem
L2		nature-culture relations, biodiversity, conservation plan
L3		empirical evidence, mortality factors
L4		limiting factor
L5	carrying capacity, algorithm	
L6		biomass
L7	group behavior	
L8	mechanism, resilience, keystone species, disturbance	biodiversity** (revisit)
L9		criteria (revisit), constraints**, interest holder
L10		
L11		

**Developed in the middle school grade band of NGSS

HOME COMMUNICATION

Dear Parents, Guardians, and Care-Givers,

Your child's high school biology class is starting a unit called *How do ecosystems work, and how can understanding them help us protect them?* as part of the OpenSciEd high school science curriculum. This unit is anchored by the 30 by 30 Initiative, which aims to protect thirty percent of lands and waters by 2030. This initiative provides a launching point for students to discover how ecosystems function and how and why humans protect them.

As part of this unit, students will investigate the Serengeti ecosystem in East Africa as a case study for learning about both ecosystems and conservation. This system is an ideal case study due to the comprehensive and long-term data sets available for investigation. In the first part of the unit, students will figure out that the creation of the Serengeti National Park was motivated by a desire to protect the great migration of wildebeest and other animals across the system. They will analyze data and develop and use models to figure out how limiting factors affect wildebeest carrying capacity over time. They will figure out how many components interact as part of a complex system and how biodiversity can support ecosystem resilience. In the final lessons of the unit, students consider the criteria humans use when making decisions about their interactions and the impacts of their decisions. Students will then apply what they figured out to US-based ecosystems to evaluate the efficacy of conservation in the US. They will use this evaluation to make recommendations about how humans can preserve additional lands and waters.

In this unit, students will explore the challenges associated with creating conservation areas. These raise issues concerning land ownership, decision-making, and animal welfare. Students may have emotional needs related to two main issues:

- Trauma associated with history of colonization, and racism;
- Strong beliefs about animal well-being, such as anti-hunting sentiments.

If you anticipate your child may find these topics challenging, please contact me at _____ if you are comfortable doing so. You can also contact the school counselor at _____. By knowing about these challenges in advance, we can be sensitive to students' needs and provide support for students if they experience any strong emotions during this unit.

Adolescents will sometimes develop difficult behaviors after a traumatic experience. It is important for trusted adults to understand that these behaviors and emotions are common when children experience trauma. Students may be more aggressive or withdrawn and go through periods of sadness, anger, or emotional "numbing." Contact a counselor if you see any of the following behaviors in your child:

- problems sleeping, nightmares,
- changes in school performance,
- truancy,
- risk-taking behavior,
- conflicts with peers,
- new or increasing psychosomatic complaints, including stomachaches and headaches,
- depression or suicidal thoughts.

Being able to talk to someone who is removed from the situation is often helpful to both adults and children after a traumatic event. After experiencing trauma, children are best supported when their parents or trusted caregivers accept their feelings and are open to listen and talk. Let your child come to you. Do not overwhelm your child if they are not ready to talk. Respect your child's need to take breaks.

If you have any questions about the content of this unit or would like to discuss anything further, I encourage you to reach out to me at _____.

Best,

Your Name or signature here

Estimados padres, tutores y cuidadores,

La clase de biología de la escuela secundaria de su hijo está comenzando una unidad llamada *¿Cómo funcionan los ecosistemas y cómo comprenderlos puede ayudarnos a protegerlos?* como parte del plan de estudios de ciencias de la escuela secundaria OpenSciEd. Esta unidad está anclada en la Iniciativa 3O para 3O que tiene como objetivo proteger el treinta por ciento de las tierras y aguas para 2030. Esta iniciativa proporciona un punto de partida para que los estudiantes descubran cómo funcionan los ecosistemas y cómo y por qué los humanos los protegen.

Como parte de esta unidad, los estudiantes investigarán el ecosistema del Serengeti en el este de África como un caso de estudio para aprender sobre los ecosistemas y la conservación. Este sistema es un caso de estudio ideal debido a los conjuntos de datos completos y de largo plazo disponibles para la investigación. En la primera parte de la unidad, los estudiantes descubrirán que la creación del Parque Nacional Serengeti fue motivada por el deseo de proteger la gran migración de ñus y otros animales a través del sistema. Analizarán datos y desarrollarán y utilizarán modelos para descubrir cómo los factores limitantes afectan la capacidad de carga de los ñus a lo largo del tiempo. Descubrirán cuántos componentes interactúan como parte de un sistema complejo y cómo la biodiversidad puede apoyar la resiliencia del ecosistema. En las lecciones finales de la unidad, los estudiantes considerarán los criterios que usan los humanos cuando toman decisiones sobre sus interacciones y los impactos de sus decisiones. Luego, los estudiantes aplicarán lo que descubrieron a los ecosistemas de los EE.UU. para evaluar la eficacia de la conservación en los EE.UU. Usarán esta evaluación para hacer recomendaciones sobre cómo los humanos pueden preservar tierras y aguas adicionales.

En esta unidad, los estudiantes explorarán los desafíos asociados con la creación de áreas de conservación. Estos plantean problemas relacionados con la propiedad de la tierra, la toma de decisiones y el bienestar animal. Los estudiantes pueden tener necesidades emocionales relacionadas con dos asuntos principales:

Trauma asociado con la historia de la colonización y el racismo;

Fuertes creencias sobre el bienestar animal, sentimientos contra la caza.

Si anticipa que su hijo puede encontrar estos temas desafiantes, comuníquese conmigo al _____, si se siente cómodo haciéndolo. También puede comunicarse con el consejero escolar al _____. Al conocer estos desafíos de antemano, podemos ser sensibles a las necesidades de los estudiantes y brindarles apoyo si experimentan emociones fuertes durante esta unidad.

Los adolescentes a veces desarrollan comportamientos difíciles después de una experiencia traumática. Es importante que los adultos de confianza entiendan que estos comportamientos y emociones son comunes cuando los niños experimentan un trauma. Los estudiantes pueden ser más agresivos o retraídos, y pasar por períodos de tristeza o enojo o "adormecimiento" emocional.

Comuníquese con un consejero si observa alguno de los siguientes comportamientos en su hijo:

- Problemas para dormir, pesadillas,
- cambios en el rendimiento escolar,
- absentismo escolar,
- comportamiento de riesgo,
- conflictos con los compañeros,
- quejas psicósomáticas nuevas o en aumento, incluidos dolores de estómago y de cabeza.

Poder hablar con alguien que está alejado de la situación suele ser útil tanto para adultos como para niños después de un evento traumático. Después de experimentar un trauma, los niños reciben mejor apoyo cuando sus padres o cuidadores de confianza aceptan sus sentimientos y están abiertos a escuchar y hablar. Deje que su hijo venga a usted. No abruma a su hijo si no está listo para hablar. Respete la necesidad de su hijo de tomar descansos.

Si tiene alguna pregunta sobre el contenido de esta unidad o le gustaría discutir algo más, lo invito a que se comuniqué conmigo al _____.

Gracias,

Su nombre o firma aquí

LESSON 1: Why do ecosystems need protection, and how are they protected?

PREVIOUS LESSON *There is no previous lesson.*

THIS LESSON

ANCHORING PHENOMENON

4 days



National Park Service

We hear about a plan called the 30 by 30 Initiative designed to preserve land and water locally and internationally. We brainstorm a list of criteria people use to motivate conservation. We look at examples of lands and waters that have been conserved and develop initial models of what happened in these places over time. We co-construct community agreements, build a Driving Question Board, and generate ideas for investigation.

NEXT LESSON

We will investigate the Serengeti National Park as an example of conservation and build understanding around why the park was created and how decisions were made about what areas of the ecosystem to protect and how humans can interact with the system.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

- 1.A Obtain information about how and why humans manage natural resources and communicate it as conservation criteria established to stabilize parts of the system. (SEP 8.1; DCI ESS 3.C.1; CCC 7.1)
- 1.B Develop a model based on evidence of an ecosystem that illustrates relationships between living and nonliving components and how they have changed over time as a result of human interactions. (SEP 2.3; DCI ESS 3.C.1; CCC 7.1)
- 1.C Ask questions to clarify or seek information about what causes humans to protect ecosystem functioning and productivity and what the effects of the protection are. (SEP 1.1; DCI LS 4.D.2; CCC 2.2)

WHAT STUDENTS WILL FIGURE OUT

- There is a plan adopted by many states and countries to conserve 30% of lands and waters by 2030.
- Humans have different reasons for conserving lands and waters, and there are many examples of conservation around us.
- Each system is composed of unique components and interactions.
- These components and interactions have changed or may change in the future due to human interactions.
- We can look at ecosystems that have been protected to understand how to protect systems in the future.
- We have to answer many questions about how the living and nonliving components interact in the system to understand how to best protect them.

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	12 min		INTRODUCE PHENOMENON-BASED LEARNING AND THE 30 BY 30 INITIATIVE Introduce a new phenomenon, the 30 by 30 Initiative.	A-E	<i>30 by 30 Initiative</i> , Optional: https://youtu.be/dD3RRX48ods
2	8 min		BRAINSTORM CRITERIA FOR CONSERVATION Facilitate brainstorm about conservation criteria.	F	<i>30 by 30 Initiative</i>
3	10 min		CO-CONSTRUCT COMMUNITY AGREEMENTS Facilitate discussion to co-construct Community Agreements.	G	<i>Community Agreements</i>
4	10 min		FACILITATE AN INITIAL IDEAS DISCUSSION ABOUT CONSERVATION CRITERIA Facilitate an Initial Ideas Discussion to generate a consensus list of conservation criteria.	H	whiteboard or chart paper, chart paper markers
5	5 min		NAVIGATE: EXPLORE RELATED PHENOMENON Share a home learning opportunity with students.	I-J	<i>Conservation Home Learning</i>
<i>End of day 1</i>					
6	10 min		NAVIGATE: RELATED PHENOMENA Facilitate student discussion about home learning.	K	
7	20 min		INTRODUCE CONSERVATION PROFILES Introduce students to four different conservation profiles.	L-M	<i>Conservation Profile Organizer</i> , internet connected device with access to conservation profile
8	13 min		DEVELOP INITIAL MODELS Support students in developing initial models.	N-O	internet connected device with access to conservation profile
9	2 min		NAVIGATE Ask students to complete an exit ticket.	P	
<i>End of day 2</i>					
10	5 min		NAVIGATE Facilitate a discussion about student exit tickets from the previous class.	Q	
11	18 min		REVISE INITIAL MODELS Revisit initial models and facilitate small group model revision.	R-S	initial models from day 1, chart paper, chart paper markers
12	12 min		INITIAL MODEL GALLERY WALK Organize a small group gallery walk.	T-U	
13	5 min		REVIEW MODEL SIMILARITIES AND DIFFERENCES Facilitate small groups in reviewing what they noticed was similar and different across models.	V	

Part	Duration		Summary	Slide	Materials
14	5 min		NAVIGATE	W	
<i>End of day 3</i>					
15	5 min		NAVIGATE Remind students of the ideas they had about how our conservation profiles can help us think about protecting ecosystems more broadly.	X	
16	25 min		CREATE OUR DRIVING QUESTION BOARD Introduce the purpose of a DQB and support students in building the DQB for the unit.	Y-Z	sticky notes, chart paper, chart paper markers
17	10 min		CONSIDER IDEAS FOR INVESTIGATION Brainstorm ideas for investigation to generate evidence to answer our questions.	AA	chart paper, chart paper markers
18	5 min		NAVIGATE Facilitate students brainstorming what question to investigate first.	BB	
<i>End of day 4</i>					

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>30 by 30 Initiative</i> • <i>Community Agreements</i> • <i>Conservation Home Learning</i> • <i>Conservation Profile Organizer</i> • initial models from day 1 • sticky notes	• internet connected device with access to conservation profile • chart paper • chart paper markers	• Optional: https://youtu.be/dD3RRX48ods • whiteboard or chart paper • chart paper markers • chart paper

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Plan to have internet connected devices available for small groups to interact with their conservation profiles.

Gather chart paper and chart paper markers for small groups to revise their models.

Gather chart paper, sticky notes, and chart paper markers for the Driving Question Board.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

This lesson introduces the unit by focusing on the disciplinary core idea: *The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources* (HS-ESS 3.C.1). This DCI element is well aligned to the anchoring phenomena as it specifies the roles and responsibilities of humans in managing ecosystems. Students build on a middle school level understanding about potential negative impacts of human populations on natural resources (MS-ESS3.C) and how changes in biodiversity can impact the ecosystem services humans rely on (MS-LS4.D).

Students use high school elements of the science practices *developing and using models* and *asking questions and defining problems*. The elements of the practices students use in this lesson are closely aligned to middle school elements, and students may be familiar with them from prior experience. If not, additional supports are suggested in the learning plan.

Students use high school elements of the crosscutting concepts *stability and change* and *cause and effect* as they begin to interact with the unit phenomenon.

Students will encounter several terms that are included in previous grade bands in the NGSS performance expectations in this lesson. These include: *conservation*, *ecosystems*, *criteria* and *biodiversity*. The lesson provides opportunities for students to record the definitions they encounter in their personal glossaries and additional support for teachers if students are unfamiliar with these terms.

Where We Are NOT Going

In the lesson, students develop and revise their initial models of the ecosystems they investigate in their Conservation Profiles. Here, they will define the system and its components and interactions. While the high school practice *developing and using models* involves identifying and explaining the mechanisms underlying interactions in a model, in this lesson, students do not identify mechanisms. Throughout the unit they will gather evidence to figure out these mechanisms and will include them in their models later in the unit.

LEARNING PLAN for LESSON 1

1 · INTRODUCE PHENOMENON-BASED LEARNING AND THE 30 BY 30 INITIATIVE

12 min

MATERIALS: science notebook, *30 by 30 Initiative*, Optional: <https://youtu.be/dD3RRX48ods>

Introduce phenomenon-based learning. Introduce the idea of phenomena-based learning. Say, *Our work in class this year is going to center on our questions about phenomena--events or things we can observe but not yet completely explain. Each unit will be anchored by a phenomenon, and the questions you all have about it will drive our work in this class for weeks to come as we try to figure them out. This may be different from other classes where someone taught you new ideas right away. As your questions will drive the direction of our work in this class, we are going to spend a few class periods exploring a phenomenon, trying to develop initial explanations about it, and considering other experiences we have had that could be related to it. This will help us pull different ideas and perspectives in and develop questions that reflect what we are all curious about.*

Introduce the 30 by 30 Initiative. Display slide A. Say, *In 2022, 196 nations created an agreement setting a goal of conserving 30% of land and water by 2030. This is a movement happening in several US states and beyond.* Help students think about the scale of 30% by discussing how much land or water would be conserved if that happened in your state or your city.

ADDITIONAL GUIDANCE

If students experienced *OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*, then they are familiar with conservation in the context of orangutans living in protected areas and oil palm farms. Students identified evidence and developed land use plans and PSAs to aid interest holders in decision-making. They also took an action within their community to address a local challenge, such as habitat restoration, monitoring biodiversity, or communicating with interest holders.

The NGSS introduces the idea of conservation in grades 3-5 by specifying how humans can protect Earth's resources and environment (3-LS4.D) and further develops ideas about conservation in middle school (e.g., MS DCI ESS3.C).

If your students do not have prior experience with the concept of conservation, take the time here to add to their personal glossaries with a definition we encounter for conservation such as *preserve or protect a space*. Students will continue to build an understanding of what conservation means through the rest of the unit.

Share additional data. Display slide B. Remind students that many other countries have committed to this initiative. Explain to students that a national survey of American voters was conducted, and the majority of voters support the 30 by 30 Initiative. *Optional:* Consider introducing Former Secretary of the Interior, Deb Haaland. Secretary Haaland was in charge of the Department of the Interior from 2021 to 2025. The Department of the Interior is responsible for protecting and managing natural resources and cultural heritage in the US. Show the optional video <https://youtu.be/dD3RRX48ods>.

Discuss US participation in the 30 x 30 initiative. Display slide C. Look at the map and identify the states that already have plans.

Compare two state 30 by 30 initiatives. Display slide D. Provide a minute for students to read the comparison of Hawaii and Maryland on their own. Then ask a few students to share what they notice and wonder about these initiatives. Listen for ideas such as:

- Hawaii is protecting water and Maryland is protecting land.
- Maryland already met their goal and is moving to protect more.
- What does it mean if the initiative is community-based and uses local knowledge?
- Who owns the land in Maryland if they are giving out loans?
- Why is Maryland so good at conserving?

Introduce a reading about the 30 by 30 Initiative. Display slide E. Instruct students to setup a two-column chart in their notebooks labeled with "Notice" on the left and "Wonder" on the right. Instruct students to record what they notice and wonder in their science notebooks as they read.. Distribute *30 by 30 Initiative*. * Give students time to read through the information on their own. Encourage them to mark up the

* ATTENDING TO EQUITY

Supporting emergent multilinguals

Students should be encouraged to record their ideas using linguistic (e.g., written words) and nonlinguistic modes (e.g., photographs, drawings, tables, graphs, mathematical equations, measurements). This is especially important for emergent multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of scientific phenomena.

reading using whatever strategy is in place in your classroom.

**SCIENCE
NOTEBOOK**



Keeping a science notebook allows students a space in which to reflect and communicate their developing understandings about science ideas and to track changes in their understandings. Each student should have a binder that will serve as their “science notebook” for the course. Students can use large dividers to indicate the start of a new unit. Students can use additional smaller dividers or sticky notes to create three sections within the unit for the Progress Tracker, unit materials, and personal glossary.

**ADDITIONAL
GUIDANCE**

If this is the students’ first Notice and Wonder chart, you may want to model for students a “notice” or observation and a “wonder” or question. Demonstrating an example will help students focus their noticings and wonderings on the phenomenon and not on distracting details.. Ask two or three students to share one thing they noticed and/or wondered about and write that on the board as an example of a noticing or wondering. Ask students if they understand what to record on each side of the chart.

Turn and Talk. Display **slide E**. After students have had a few minutes to individually record their noticings and wonderings, ask them to turn and talk to a partner to share their ideas. Each partner should share for one minute while the other student listens, and then they should switch. Call on a few pairs to share their ideas. Consider asking students to summarize in the whole group what their partner shared with them. Use the following prompts as a guide:

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you notice?</i>	We want to protect a lot more land than is protected right now. People support this plan. There are good reasons to support it because it benefits everyone. We need to be careful when making decisions to include lots of different voices.	<i>What is the 30 by 30 Initiative?</i> <i>How do Americans feel about it?</i>
<i>What do you wonder?</i>	Who is going to protect all these places? How do we know which places are the right places to protect? Can we learn anything from the places we have already protected? How do we protect these places?	<i>What are the plans and how will we know if they're working?</i>

2 · BRAINSTORM CRITERIA FOR CONSERVATION

8 min

MATERIALS: science notebook, 30 by 30 Initiative



Brainstorm criteria for conservation. Say, *It sounds like the majority of Americans and people in many other countries think it is a good idea to conserve lands and waters. Why do you think that is? What reasons do people have for wanting to conserve lands and waters?* Display **slide F**. Organize students into small groups of 3-4 and ask them to generate a list of criteria that they think people might consider when they think of conserving lands or waters.

ADDITIONAL GUIDANCE

If your students experienced OpenSciEd middle school, they defined criteria for solutions in units such as *OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, *OpenSciEd Unit 6.5: Where do natural hazards happen and how do we prepare for them? (Tsunami Unit)*, and *OpenSciEd Unit 7.2: How can we use chemical reactions to design a solution to a problem? (Homemade Heater Unit)*. Criteria are also part of the NGSS disciplinary core ideas in engineering, technology and the application of science (ETS) in the middle school grade band (e.g MS ETS1.B).

If this is the first time your students encounter brainstorming criteria, consider basing criteria in this lesson off MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. Say something like, *Any time we have an engineering challenge, we need to figure out a couple of things beforehand. First, we need to decide what requirements our design needs to meet to be considered successful. This is called our criteria. What are some criteria that you think we might include to protect or conserve lands and waters around us? Turn to a shoulder partner and share your ideas.* Students will further build out criteria at the high school level in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*, *OpenSciEd Unit C.4: Why are oysters dying, and how can we use chemistry to protect them? (Oysters Unit)*, and *OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit)*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: **Central ideas communicated** as conservation criteria: (SEP 8.1)

- Varied motivations for **humans to protect places, lands, and waters** to **stabilize the system** such as (DCI: ESS 3.C.1; CCC: 7.1):
 - natural beauty
 - recreation
 - ecosystem services
 - biodiversity
 - endangered/threatened species
 - cultural significance

What to do: If students are having trouble communicating the ideas from the reading as criteria, point them back to specific criteria in the text and ask them to summarize verbally or in writing the main idea of a single criteria.

Building towards: 1.A **Obtain information** about **how and why humans manage natural resources** and **communicate** it as conservation criteria established to **stabilize parts of the system**. (SEP 8.1; DCI ESS 3.C.1; CCC 7.1)

3 · CO-CONSTRUCT COMMUNITY AGREEMENTS

10 min

MATERIALS: *Community Agreements*

Consider why we should establish Community Agreements. Before facilitating the first formal discussion of the unit, take some time to prioritize and establish the classroom community. Navigate to this work with community agreements by saying something like, *We have already been working as scientists today as we obtained, evaluated, and communicated information and asked questions. Over the course of the school year, we will engage in these and other science practices together. Those can be difficult tasks, and we will need to practice them together. Scientific work is rarely done alone, and my goal for this class is to have us build a community where we can figure things out together.*

Display **slide G**. Direct students to stop and jot their responses to these prompts in their notebooks:*

- What are you hoping to get out of this class?
- How can working together help us get farther than we would on our own?
- What barriers may come up that would make it difficult for us to:
 - build a community?
 - accomplish our goals, both as individuals and as a class?
- How can we plan to address these barriers?

Develop community agreements. Distribute *Community Agreements* to each student and give them some individual time to fill in their ideas. Then discuss as a class and build a class set of agreements together.

ALTERNATE ACTIVITY

When setting up learning community agreements, students should understand how agreements help everyone in the community to know what is expected of them. Here are two approaches to setting up community agreements:

- Co-construct agreements with students (the default approach using *Community Agreements* or something similar). Explain what agreements are and why we need them for productive science talk and classroom culture. Have students co-construct agreements. As the teacher, you can add agreements that may be missing from the list. Be sure to explain to students how you think the agreement you added is helpful so that they are clear about why you are adding it to the list.
- Give students a set of agreements as a starting point (the alternate approach). Share a set of community agreements with students and provide space for students to edit or add to the agreements if they believe something is missing.

Consider the following questions, which can help you determine which approach is best for your situation:

- Do you want students to participate in co-constructing the agreements?
- Do you want the same set of agreements for every section of science you teach?
- Do you want to work with your team teachers to establish a shared set of agreements for students across all your classes?
- What kinds of consequences will you enforce if students do not follow the agreements?

* ATTENDING TO EQUITY

Building classroom culture: It is important to use this norm-building time to begin to cultivate an equitable learning community that promotes trusting and caring relationships. The community agreements should reinforce to students the value of (1) the diversity of thought among all classroom community members in pushing our learning forward and (2) providing a safe learning environment that ensures fair participation. In addition, classroom agreements should interrupt cultural norms or stereotypes that could make science experiences feel uncomfortable for some students (e.g., as being someone who is not intelligent enough to think like a scientist, who cannot do the relevant math, who cannot share their thinking). Example community agreements can be found in *Example Community Agreements*. Your version of the agreements should use wording and ideas co-constructed with your class.

4 · FACILITATE AN INITIAL IDEAS DISCUSSION ABOUT CONSERVATION CRITERIA

10 min

MATERIALS: science notebook, whiteboard or chart paper, chart paper markers

Facilitate an Initial Ideas Discussion. ** Display **slide H**. Call on one group to share their list of criteria and publicly record it on the whiteboard. Ask each additional group to indicate which criteria they have in common by adding a checkmark next to that criteria and add any new criteria to the list.

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

KEY IDEAS

Purpose of this discussion: To establish a public record of initial conservation criteria.

Listen for these ideas:

Listen for examples such as:

- important/unique features
- protecting non-human species
- places where a lot of species live
- endangered/threatened species
- resources we want to manage for use
- ecosystem services
- recreation
- protection from people/development/land use
- cultural importance

Reasons for eliciting students' initial ideas include:

- To get students' prior knowledge and experiences on the table.
- To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others).
- To promote curiosity by helping students realize that there are gaps in our understanding and to discuss what we could do next to figure something out.

* ATTENDING TO EQUITY

Supporting emergent multilinguals

Allow and encourage students to speak using both content-specific and everyday words and phrases when expressing their ideas. This helps students fully express themselves, allowing others to question, evaluate, and build off their ideas. Switching back and forth between different registers is especially important for emergent multilingual students because it helps them draw on their full range of meaning-making resources.

5 · NAVIGATE: EXPLORE RELATED PHENOMENON

5 min

MATERIALS: *Conservation Home Learning*

Explore related phenomena. Say, *It sounds like we have a lot of ideas about places that have been conserved around us, and we have a great list of criteria that we think people use when they are deciding to conserve land or water. Can you think of any lands or waters that you have visited, read about, or heard about that have been conserved?*

Turn and Talk. Display slide I and ask students to share their ideas with a partner. Then call on a few pairs to share their ideas.

Share a home learning opportunity with students. Say, *Wow, you all have a lot of great examples for your own experiences both in and outside of school.* Let students know that throughout our time together this year there will be opportunities for students to bring in their ideas and experiences from outside of our classroom community. One way that we will do this is to use home learning opportunities.

Pass out the home learning assignment. Display slide J. Let students know that they will complete *Conservation Home Learning* by talking to family members, friends, or neighbors about lands and waters that they know about that have been conserved or that people might be motivated to conserve.

HOME LEARNING OPPORTUNITY



Home learning is an important place to do cultural formative assessment (Penuel, Shepard, & Davidson, 2016), where students bring ideas generated in their home into school or vice versa. By encouraging students to go get ideas from their communities, you are blurring the boundaries of home and school learning and making for a more meaningful and integrated science experience.

End of day 1

6 · NAVIGATE: RELATED PHENOMENA

10 min

MATERIALS: science notebook

Welcome students back to class and ask them to share home learning. Display slide K. Organize students into small groups of 3-4 and ask them to share what they discovered through their home learning. Call on a few group members to share one example they heard from their group. Keep a public record of student contributions on the whiteboard.

7 · INTRODUCE CONSERVATION PROFILES

20 min

MATERIALS: *Conservation Profile Organizer*, internet connected device with access to conservation profile

Introduce conservation profiles. Say, *You all shared so many great conservation examples. Since we cannot possibly explore all of the examples we heard about in class, I have a set of conservation profiles for us to investigate that will include many of the features you shared in your examples.* Display slide L.

Display slide M. Let students know that they will be learning about their conservation profiles through a visual inquiry. Distribute a copy of *Conservation Profile Organizer* to each student. Let them know that they will record what they figure out from text, images, and videos in *Conservation Profile Organizer*. The prompts in the handout will ask them to look for specific information about the system, components, interactions, and decisions in their profile.



Support small group work. Organize students into groups of 3-5. Assign groups to work on one of the conservation profiles so that each profile is investigated by at least one group. Consider allowing students to choose the case study they are most interested in. Make sure each group has access to an internet connected device or downloaded version of the conservation profile for their group. Ask students to record what they figure out as they explore their conservation profiles.

ADDITIONAL GUIDANCE

The conservation profiles were designed to help students think through dimensions of complex socio-ecological systems. Students will obtain information to use in their initial models, including information about the system and the components and interactions. The prompts on the handout will help them complexify these categories. Please note this framework was adapted from: *Learning in Places Collaborative (2022). Framework: Complex Socio-Ecological Systems*. Bothell, Seattle, WA & Evanston, IL: Learning in Places. Please see <http://learninginplaces.org/frameworks/complex-socio-ecological-systems-framework/> for further information and guidance.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Summaries/central ideas obtained from information in conservation profiles in *Conservation Profile Organizer*.

- Biodiverse components (species and kinds) found within the system. (DCI ESS 3.C.1)
- Interactions/relationships between those components. (DCI ESS 3.C.1)
- Human activity/decision-making designed to change or stabilize some part of the system. (DCI ESS 3.C.1; CCC 7.1)

What to do: Consider collecting *Conservation Profile Organizer* at the end of day 2 with students' initial models. Provide students with written feedback that they can use when they develop their small group models. This may include pointing them back to specific components and/or interactions in their *Conservation Profile*.

Building toward 1.A.2. Obtain information about ecosystems featured in conservation profiles to identify the biodiverse components of the system and how humans have interacted through conservation to stabilize parts of the system. (SEP 8.1; DCI ESS 3.C.1; CCC 7.1)

8 · DEVELOP INITIAL MODELS

13 min

MATERIALS: science notebook, internet connected device with access to conservation profile

Discuss tools for making sense of ideas. Say, *It sounds like you have a lot of ideas and questions about your profile and how all the components interact.* Ask students if they can think of a way that we can make sense of all of the pieces that make up the conservation profile they investigated. Encourage them to draw on practices they have used in previous science classes. If students have not had an opportunity to engage in science practices, let them know that explanatory models are tools that scientists use to make sense of complex systems.

Introduce the elements of the model. Display **slide N**. Let students know that when we develop models in science class, we are using them to explain something we are working on understanding. * A good place to begin is to figure out what the system is that we are developing a model of, what the parts are, and how those parts work together. In this case, the system is an ecosystem. It can be difficult to know where to draw the boundaries of the system. In this case, the conservation profiles have defined what the system is for us.

ADDITIONAL GUIDANCE

Students will likely have experience with the term ecosystems. The NGSS introduces ecosystems in grades 3–5 and further develops ideas about ecosystems in middle school (e.g. MS LS2.B and MS ESS3.A). Now is a good time to come to consensus as a class on the definition of the term ecosystem. Ask students to consider how they have used this term or heard it used in the past and share their ideas for how to define it. Ask students to add **ecosystems** as a *definition we encounter* in their personal glossaries. One example of a definition of ecosystem is: *all the living and nonliving components of a system that interact together.*

* SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students use evidence from their conservation profiles to develop models to explain how the ecosystem works and why humans care to protect it.

The goal is to identify the components and the relationships between components using pictures, symbols, and/or words. We call these relationships interactions. There is no one correct way to develop a model. *Conservation Profile Models* includes several examples of different ways students might develop initial models.



Students develop individual initial models in small groups. Display **slide O** and give small groups time to develop their models in their science notebooks. While each student should develop their own model, encourage them to talk with their group members to share and build on each others' ideas. Remind students that there is no one correct way to develop a model and we should celebrate a diversity of different representations.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment:

- Models include evidence of components and interactions from conservation profiles. (SEP 2.3; DCI ESS 3.C.1)
- Models include interactions between human and non-human components that illustrate changes over time. (SEP 2.3; DCI ESS 3.C.1; CCC 7.1)
- Components and interactions illustrate a system that is biodiverse.

What to do:

Collect individual student models and provide written feedback. If students are struggling to identify components and interactions, direct them back to their conservation profiles. Consider the following prompts, both verbal and written on the models, to facilitate revision:

- What are the living and nonliving components of your ecosystem?
- Pick two components that you think interact with each other. How can you show in your model with pictures/symbols and/or words how those two components interact?
- Does your system have high biodiversity? Why is this important to humans?

Ask students specific questions about their model. For example, *what organism do alligators/salmon/saguaro/quagga mussels interact with? How can you show that relationship in pictures and words?*

Building towards: 1.B.1 Develop an evidence-based model of an ecosystem that illustrates relationships between living and nonliving components and how they have changed over time as a result of human interactions. (SEP 2.3; DCI ESS 3.C.1; CCC 7.1)

9 · NAVIGATE

2 min

MATERIALS: science notebook

Complete an exit ticket. Display slide P. Ask each student to turn to a clean sheet of loose leaf paper and tear it in half. Then ask them to write down one thing they figured out and one question they still have about their conservation profile.

ADDITIONAL GUIDANCE

As you sort students' exit tickets, look for patterns and/or themes that identify common factors across conservation profiles in terms of what students figured out and questions they still have. For example, did students from multiple groups identify similar kinds of interactions such as predator/prey or competition? Pay attention to these patterns so you can call them out at the start of the next class to help students see how learning about one ecosystem can help them understand ecosystems more broadly.

End of day 2

10 · NAVIGATE

5 min

MATERIALS: None

Share exit ticket data. Display slide Q. Say, *I reviewed your exit tickets and noticed some interesting patterns in your responses.* Summarize for students any patterns that you noticed in their responses to what they figured out and questions they still have. Pay attention to any common themes across the different conservation profiles. Call on a few students to share responses that illustrate the patterns you noticed.

These could include commonalities in ways humans interacted with components of the system or ways that components interacted with each other.

For example:

- In several of the conservation profiles humans were originally attracted to the ecosystem because of the abundant resources (water, biodiversity, food, trees etc.) found there.
- Humans decided to act to protect the system after they noticed that their interactions were causing harm to other components,
- All of the systems have a lot of biodiversity.

11 · REVISE INITIAL MODELS

18 min

MATERIALS: initial models from day 1, chart paper, chart paper markers

Review students' initial models. Display **slide R**. Return initial models to each student. Give students a few moments to review your feedback and consider how they might revise their models in response. Encourage them to mark up the models with their revision ideas.

Small group model development. Display **slide S**. Let students know that they will bring their individual initial models to their small groups as a resource to build a small group model that everyone contributes to and agrees on. Organize students into their conservation profile groups. Distribute large pieces of paper and chart paper markers for students to use to develop their small group models.

ADDITIONAL GUIDANCE

Students will work to come to consensus many times throughout the course of the year. Sometimes they will do this with a small group, and other times they will work with the whole class. There will likely be some aspects they agree on and others where they disagree. Revisit the community agreements as necessary to remind students of ways to work together. Encourage them to make note of the places where they can not yet come to consensus or need more evidence. They can indicate these with a question mark or an asterisk that they explain in a key.

12 · INITIAL MODEL GALLERY WALK

12 min

MATERIALS: science notebook

Introduce the stay and stray protocol. Display **slide T**. Explain to students that they will be participating in a gallery walk using a stay and stray protocol. Two students will stay with the group's model and two students will stray to visit other groups' models. After students have had time to visit at least two other models, ask those who stayed to switch with those that strayed so everyone has a chance to see different groups' models. Adjust the number of students that stay and stray based on group sizes.



Gallery walk to share group models. Display **slide U**. Explain to students that when they are visiting other groups they should be looking for components and interactions that are similar to and different from the components and interactions in the system they worked with. Ask students to set up a table in their science notebooks to record this information and review some of the sample sentence starters on the slide. Students will have 2.5 minutes to visit with each group and will need to use their time efficiently.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Additional evidence of components and interactions not present in individual models such as:

- Models with arrows that illustrate relationships between living and nonliving components. (SEP 2.3; DCI ESS 3.C.1)
- Change over time as a result of human interactions. (DCI ESS 3.C.1; CCC 7.1)

What to do: Support groups of students by asking probing questions about how the components of the models are related, prompting them to predict what could happen to one component when a change occurs in another component. Use language of stability and change such as “What caused this change?” or “What would it mean if the components remained stable?”

Building towards: 1.B.2 Develop an evidence-based model of an ecosystem that illustrates relationships between living and nonliving components and how they have changed over time as a result of human interactions. (SEP 2.3; DCI ESS 3.C.1; CCC 7.1)

13 · REVIEW MODEL SIMILARITIES AND DIFFERENCES

5 min

MATERIALS: science notebook

Small group discussion about common components and interactions across systems. Display slide V. Ask students to return to their small groups and share what they found was similar and different across each of the group models and what they noticed stayed the same or changed over time.

14 · NAVIGATE

5 min

MATERIALS: None

Reflect on our lesson question. Say, *Now that we have a sense of some of the features of different ecosystems that we investigated in our conservation profiles, how can we use what we figured out about different systems to help us answer our lesson question: Why do ecosystems need protection and how are they protected?*

Stop and Jot. Display slide W. Ask students to respond to the question: *What common elements did you notice across all of the cases that can help us figure out how to protect ecosystems more generally?*

End of day 3

15 · NAVIGATE

5 min

MATERIALS: science notebook

Reflect on navigation from the last class. Display slide X. Ask students to open their science notebooks to the questions ideas they recorded at the end of the last class. Ask them to turn and talk to a partner to share the patterns they noticed across cases. Call on a few students to share their responses with the class.

MATERIALS: sticky notes, chart paper, chart paper markers

Write initial questions for the Driving Question Board. Pass out three sticky notes to each student. Display **slide Y**. Say, *We have a lot of great questions about how the ecosystems in our conservation profiles work and how they were protected. We noticed some common elements across the profiles that can help us understand how we can conserve lands and waters across the US, but we still have questions! This means we are ready to create our Driving Question Board (DQB).* Let students know that the DQB is a tool we will use in all of our units. It will give us a place to make our questions public and will help keep the class organized and keep track of what we want to know and what we figure out throughout the unit. Instruct them to write up to three questions each, one per sticky note.

ADDITIONAL GUIDANCE

If students have not had experience with science practices in prior science classes, they may need additional support as they learn how to ask questions that clarify and/or seek additional information based on what they have observed in the anchoring phenomenon. If this is the case, consider giving students time to workshop their questions in small groups or pairs using and providing individual feedback using *Supporting Questioning*.

Gather in a Scientists Circle. Ask students to form a Scientists Circle, a horseshoe shape oriented toward the DQB, and to bring their sticky notes with them.



Support students in building the DQB. Explain that you would like students to take the lead on the process of establishing the DQB. You might want to choose the first volunteer to begin the process and then step back. Step in when necessary to point students to some of the class norms to encourage equitable participation. The student-facing directions for assembling the DQB are on **slide Z** and include the following:

1. The first student reads their question and puts it on the DQB
2. Raise your hand if you have a question that is related or the same.
3. The first student selects the next student whose hand is raised. The student who is called on reads the related question, says why or how it relates, and then moves it onto the DQB with the original question.
4. That student selects the next student, who will read another related sticky note, move it, and then call on the next student.
5. Continue until the class agrees that all the related questions have been placed and that they are organized in a way that makes sense.
6. Continue until everyone has shared at least one question.

Organize student questions. Once all the questions have been added to the DQB, ask students to think about how they might label each of the clusters of questions. Encourage them to consider what the questions have in common (i.e., questions about humans, questions about predator-prey interactions, questions about endangered species). *

SCIENTISTS CIRCLE



You will form a Scientists Circle in this lesson and many future lessons. Setting up the norms and logistics for forming, equitably participating in, and breaking down that space is important. Having students sit in a circle or half circle so they can see and face one another can help build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where they need to go next will be an important tool in helping the class take on greater agency in steering the direction of their learning. This circle will also help build a sense of pride in their work. You may want to inform students that professional scientists also collaborate with one another to brainstorm, discuss, and review their work.

* SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

As students create this Driving Question Board, they ask questions that arise from careful observation of phenomena, as called for in Appendix F of the NGSS for high school students.

Over the course of this school year, students will learn more about asking productive, testable questions. Productive questions are those that can help us deepen our understanding of how or why a phenomenon occurs. Be mindful of the kinds of questions students ask in this initial lesson; for example, pay attention to how many are open (i.e., not a yes/no answer) versus closed (i.e., yes/no answer).

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Questions to clarify and seek information about (SEP 1.1):

- causes or motivations of conservation. (DCI: 4.D.2)
 - Why or how was a place protected?
 - Who protected it?
- the components and/or interactions of the systems that are being conserved.
 - Which components interact and in what ways?
 - How do these components interact?
- effects of the conservation on stability and change (CCC: 2.2) of:
 - What happened to living and nonliving components of the ecosystem before and/or after it was protected? (DCI: 4.D.2)
 - How did the interactions change?. (DCI: 4.D.2)
 - What caused the interactions to change? (DCI: 4.D.2)

What to do: If students struggle to identify questions, encourage them to revisit their notes from the lesson and their initial models. Ask students to recall the things they have done so far in the lesson to refresh their memories about what questions they had.

Building towards: 1.C Ask questions to clarify or seek information about what causes humans to protect ecosystem functioning and productivity and what the effects of the protection are. (SEP: 1.1; DCI: 4.D.2; CCC: 2.2)

17 · CONSIDER IDEAS FOR INVESTIGATION

10 min

MATERIALS: chart paper, chart paper markers

Generate ideas for investigation. Congratulate students on generating a productive board full of great questions. Let them know that the next step is to brainstorm ideas that will help us figure out how to answer those questions. As this may be a new practice for students, they should focus on one question at a time and generate ideas for how they could go about answering each question. Their first instinct may be to “do research”. Prompt them to be more specific and answer questions about what specific data they would need to answer each question. Consider modeling an example to get them started. Prompt students by asking them how they have figured out ideas in their previous science classes or in other aspects of their lives.

Display **slide AA**. Give students two minutes to generate ideas for investigation in their science notebooks. Encourage students to think about how we might generate the evidence we need to answer the questions that we have. If there is time, give them a minute to talk with a partner before sharing with the whole class.

Publicly display students’ ideas for investigation. Ask individual students or pairs of students to share their ideas for investigation. Publicly display student ideas for investigation on the whiteboard or on a piece of chart paper for the class to have as a reference.

18 · NAVIGATE

5 min

MATERIALS: science notebook

Facilitate a discussion to determine next steps. Guide students in determining where to go next. Display **slide BB**. Say, *We have a lot of questions that we want to try to find the answers to over the next several weeks. We also have a great list of ideas for how to investigate those questions. How can we work together as a class to answer all of our questions about so many ecosystems? How can we learn how to protect new lands and waters that have not had protection?*

Additional Lesson 1 Teacher Guidance

**SUPPORTING
STUDENTS IN
MAKING
CONNECTIONS IN
ELA**

CCSS.ELA-LITERACY.RST.11-12.2

Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

LESSON 2: What can other cases of conservation help us understand about ecosystems and conservation?

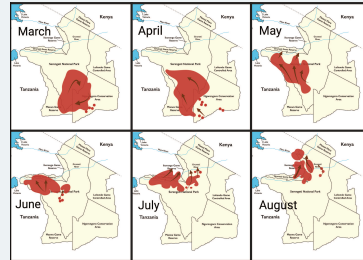
PREVIOUS LESSON

We heard about a plan called the 30 by 30 Initiative designed to preserve land and water locally and internationally. We brainstormed a list of criteria people use to motivate conservation. We looked at examples of lands and waters that have been conserved and developed initial models of what happened in these places over time. We co-constructed community agreements, built a Driving Question Board, and generated ideas for investigation.

THIS LESSON

INVESTIGATION

2 days



We are introduced to the Serengeti National Park as a case study. We read about the creation of the park and the controversial decisions made over which areas the park should protect. We participate in an information scavenger hunt to figure out what species live in the park with emphasis on the migrating herds of wildebeest. We create a consensus model to explain why the park was created and who decided how humans could use the park.

NEXT LESSON

We will revisit wildebeest migration and brainstorm reasons for why they are migrating. We will watch a video, look at data and identify patterns to use as evidence to connect our predictions about why wildebeest migrate. We will create data displays to show our findings and share them.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

2.A Integrate information presented in different formats about the **factors that prompted humans to create the** Serengeti National Park and how the protected area boundaries **changed or stayed the same**. (SEP 8.2; DCI: LS2.C.2; CCC: 7.1)

2.B Develop a model based on evidence to explain how the Serengeti National Park system was **designed for the stability** of the **migrating populations as valuable to humans in various ways**. (SEP 2.3; DCI: ESS 3.C.1; CCC: 7.4)

WHAT STUDENTS WILL FIGURE OUT

- The Serengeti is a unique ecosystem with many different organisms, and a unique large mammal migration.
- The great migration is unique, and the park was established in part to protect it.
- The great migration is dangerous, but the animals do it anyway.
- As a protected space, human decision-making about the Serengeti ecosystem has been motivated by many different points of view and priorities.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Review the DQB and decisions about what to figure out next.	A	Driving Question Board
2	10 min		INTRODUCE THE SERENGETI ECOSYSTEM Watch a video about the Serengeti and identify the past and present location of Serengeti National Park.	B-G	https://youtu.be/Pg35n6eIF3Y
3	10 min		READ HISTORY OF SERENGETI Read and take notes on reasons for the founding of Serengeti National Park.	H-J	<i>A Brief History of the Serengeti</i>
4	8 min		DISCUSS HISTORY OF SERENGETI Discuss the differing philosophies of conservation surrounding the founding of Serengeti National Park.	K-N	<i>A Brief History of the Serengeti</i> , chart paper, chart paper markers
5	10 min		INFORMATION SCAVENGER HUNT Students search for information to answer two questions about the formation of Serengeti National Park.	O	<i>Scavenger Hunt Notes</i> , Laminated scavenger hunt images or print outs of https://docs.google.com/presentation/d/IOEpkHOqu3MGfndVqpFvaGDOEaovsTAMZgbKL3HZ_mEO/edit?usp=share_link , three computers, https://www.youtube.com/watch?v=ipYb3Gw6fBY , https://www.youtube.com/watch?v=cVj4883yzeO , https://www.youtube.com/watch?v=7JOk6ivcuco
6	4 min		NAVIGATE Write an exit ticket summarizing what students learned from the information scavenger hunt.	P	<i>Scavenger Hunt Notes</i> , scavenger hunt images, two computers
<i>End of day 1</i>					
7	3 min		NAVIGATE: PREPARE TO SHARE SCAVENGER HUNT INFORMATION Students share information learned in the scavenger hunt as they complete the Graphic Organizer.	Q-R	<i>Scavenger Hunt Notes</i>
8	10 min		SHARE SCAVENGER HUNT INFORMATION Work in small groups to complete the Graphic Organizer about why and how the Serengeti ecosystem was protected.	S	<i>Scavenger Hunt Notes</i> , <i>Graphic Organizer</i> , <i>Graphic Organizer Scavenger Hunt Key</i> , scavenger hunt images

Part	Duration		Summary	Slide	Materials
9	3 min		SELF-REFLECTION Students reflect on their scavenger hunt notes and their ability to concisely and accurately share what they learned with their peers.	T	<i>Obtaining and Communicating Information Self-Assessment</i>
10	12 min		CONSENSUS DISCUSSION ABOUT CONSERVATION OF SNP Facilitate a class discussion about what areas of the Serengeti were protected and why.	U-Y	<i>Graphic Organizer</i> , laminated Serengeti map poster or <i>Serengeti Map</i> , dry erase markers and eraser, chart paper, chart paper markers, scavenger hunt images
11	12 min		COMPLETE PROGRESS TRACKER Introduce the Progress Tracker and complete the first entry.	Z-BB	<i>Progress Tracker</i> , <i>Conservation Profile Organizer</i> , initial models from Lesson 1
12	5 min		NAVIGATE Revisit the DQB and call out the question that remains unanswered about the Serengeti: <i>Why are the animals moving?</i>	CC-DD	sticky notes

End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>A Brief History of the Serengeti</i> - Scavenger Hunt Notes - Graphic Organizer <i>Obtaining and Communicating Information Self-Assessment</i> - Progress Tracker - Conservation Profile Organizer - initial models from Lesson 1 - sticky notes		- Driving Question Board https://youtu.be/Pg35n6eIF3Y - chart paper - chart paper markers - Laminated scavenger hunt images or print outs of https://docs.google.com/presentation/d/1OEpkH0qu3MGfndVqpFvaGDOEaovsTAMZgbKL3HZ_mEO/edit?usp=share_link - three computers https://www.youtube.com/watch?v=ipYb3Gw6fBY https://www.youtube.com/watch?v=cVj4883yzeO https://www.youtube.com/watch?v=7JOk6ivcuco - scavenger hunt images - two computers - Graphic Organizer Scavenger Hunt Key - laminated Serengeti map poster or <i>Serengeti Map</i> - dry erase markers and eraser

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Day 1:

- If you do not have the kit, print each page from https://docs.google.com/presentation/d/1OEpkH0qu3MGfndVqpFvaGDOEaovsTAMZgbKL3HZ_mEO/edit?usp=share_link
- Tape scavenger hunt images on the wall in their respective groupings around the room with a sign listing the five categories: Habitats, Biodiversity, Movement of Animals, Conservation Areas, and People of the Serengeti.
- Set up a computer cued to <https://www.youtube.com/watch?v=ipYb3Gw6fBY> and <https://www.youtube.com/watch?v=7JOk6ivcuco> at the Movement of Animals station and <https://www.youtube.com/watch?v=cVj4883yzeO> at the People of the Serengeti station.
- Leave the scavenger hunt images on the wall to use during day 2.

Day 2:

- Read the exit tickets from day 1 and organize students into teams of 3-4 based on questions and take-away statements so they can learn from one another.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

Students are introduced to the unique Serengeti National Park and reserve system as a model of conservation. They figure out there are multiple interest holders in the Serengeti, how some historically exploited the ecosystem and others decided to protect it. Students also consider how different philosophies that consider humans as part of or apart from an ecosystem impact the approach to conservation. Through frequent use of maps, students also become familiar with the geography of the Serengeti, which will be useful in future lessons.

Students build towards an understanding of disciplinary core idea LS4.D: Biodiversity and Humans: *Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.*

Students use elements of the crosscutting concept: *stability and change* throughout the unit. In this lesson, students begin to consider the complex decision-making and debates people have when deciding how to determine the boundaries of conservation areas in order to create conditions for a stable ecosystem. Through investigation of the creation of Serengeti National Park, they learn how the shape of the park changed and additional reserves were added as scientists better understood the annual migration of the wildebeest, as well as human needs, as part of the ecosystem. Lesson 5 will further connect stability and change to the motivations for migration.

Students also apply what they figure out about stability and change of the Serengeti to their selected Conservation Profile from Lesson 1.

This lesson builds on elements of science practice *obtaining, evaluating, and communicating information* from middle school (see *OpenSciEd Unit 8.5: Why are living things different from one another? (Muscles Unit)* for an example) to obtain, summarize, and communicate information from readings, video, images, and maps about the park. As was also seen in lesson one, the high school level phenomena are more complex and require students to sift through more information presented in multiple formats to integrate new information from multiple data sources as they begin to use the element 8.2: *Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.*

Students then use science practice *developing and using models* to explain how and why the park and surrounding reserve areas were established. Students will be able to revise and create a more supported explanation later in the unit as they add more scientific evidence and figure out the driving forces for migration.

In this lesson, students will encounter the term *nature-culture relationship* and will co-construct a definition for *conservation plan*. If it comes up, students may also add *biodiversity* to their personal glossaries. If not, this term will be added in Lesson 8.

Where We Are NOT Going

This lesson does not explore the full history of the formation of Serengeti National Park and the surrounding reserves, which continue to change to this day. Although the colonial history of the region is important to the conservation story, this lesson does not discuss these social, political, and economic issues in depth. Those wanting to investigate more about the colonial history of the Serengeti and the various inhabitants and interest holders could investigate the following:

- History of Serengeti National Park and Ngorongoro Conservation Area: <https://www.ngorongorocratertanzania.org/history-of-serengeti-national-park/>
- Estes, R. (2014). Serengeti Shall Not Die? Africa's Most Iconic World Heritage Site under Siege. In *The Gnu's World: Serengeti Wildebeest Ecology and Life History* (pp. 263-316). Berkeley: University of California Press.
- History of Tanzania: <https://www.de.tzembassy.go.tz/tanzania/brief-history#:~:text=Tanzania%20is%20a%20result%20of,revolution%20on%2012th%20January%201964>

LEARNING PLAN for LESSON 2

1 · NAVIGATE

3 min

MATERIALS: Driving Question Board

Navigate. Display **slide A**. Ask students to quietly revisit the DQB and remind themselves of what they wanted to figure out at the end of Lesson 1. Say, *After our work yesterday, many of you mentioned that you wanted to know more about the conservation of ecosystems to help us answer questions.*

2 · INTRODUCE THE SERENGETI ECOSYSTEM

10 min

MATERIALS: science notebook, <https://youtu.be/Pg35n6eIF3Y>

Introduce the Serengeti ecosystem in East Africa. Display **slide B**. Say, *I found an ecosystem that can serve as a case study to help us answer our questions. Serengeti National Park (SNP) is recognized around the world as a unique, valuable ecosystem. One of the reasons the Serengeti can help us understand other ecosystems is that it has been studied extensively since it was established in 1951, and there are large comprehensive data sets for us to investigate to figure out how and why humans have interacted with the ecosystem.*

Watch a Serengeti video. Display **slide C**. Explain that you are going to watch a short, two-minute video that provides an overview of the Serengeti ecosystem. Before they begin, ask them to create a new Notice and Wonder chart in their science notebooks for recording what they see in the video. Show <https://youtu.be/Pg35n6eIF3Y> on **slide D**. Display **slide E**. Ask students to share with the class what they noticed in the video about the Serengeti and ask them to add anything else they already know about the area.

Suggested prompt	Sample student response
What did you notice in the video?	We saw a lot of adult and young animals, including: wildebeest, lions, ostriches, cheetahs, birds of prey, giraffes, elephants, hyenas, zebras, hippopotamuses... There are huge herds of animals. Lions attacked an animal (buffalo). There was grass, a few trees, and some forest. It was sunny and looked dry. It rained. The landscape was mostly flat and open with some rivers. There were a few big rocks and hills. There was someone driving a jeep.
What else do you know about the Serengeti?	Answers will vary.

Locate the Serengeti. Display **slide F** and help students locate the whole Serengeti ecosystem within Africa. Take time to look at the map of the full extent of the Serengeti ecosystem, noticing that most of the ecosystem is in Tanzania, but some is also in Kenya. The whole ecosystem covers 25,000 square kilometers, about the same area as Vermont. Point out to students that the entire ecosystem has a

different boundary than the park system.

Locate Serengeti National Park. Display **slide G**. Say, *Here are two maps I found of the Serengeti National Park. Ask, What do you notice? What questions do you have?* Ask students to turn and talk to a shoulder partner. After one minute, ask a few students to share what they notice and wonder about the maps. Ask them to speculate on the reason the park boundaries changed.

Suggested prompt	Sample student response
<i>What do you notice?</i>	The SNP does not cover the whole Serengeti ecosystem. The map boundary changed between the two maps. Both maps protect the area to the south, but then they took away an area to the east and added more to the north.
<i>What questions do you have?</i>	Why did they not protect the whole ecosystem? Why did the boundary change? How did they decide what to protect? Who decided where to put the park? Does the park protect all of the animals?
<i>Why do you think they might have changed the park boundary?</i>	Answers will vary. Accept all responses. They figured out where the migrating animals went. They got money to buy more land. They gave land back to the African people/Maasai.

3 · READ HISTORY OF SERENGETI

10 min

MATERIALS: *A Brief History of the Serengeti*

Read an introduction to the history of the Serengeti National Park (SNP). Say, *I gathered some resources that explain a little bit about the history of the formation of the SNP that may help answer some of our questions.* Display **slide H**. Direct students to create a new Notice and Wonder chart in their science notebooks to use for note-taking.

Support learning around difficult topics. Say, *Before we break into small groups to read, I want to let you know that there was and still is quite a bit of controversy over the conservation of the Serengeti ecosystem. You will be reading about some events that happened over a century ago, and you may not agree with the behaviors, actions, or decisions people made.* Display **slide I**. Remind students of the classroom agreements they co-constructed in the last lesson and discuss ways to investigate different perspectives and points of view in a respectful manner.

* ATTENDING TO EQUITY

Universal Design for Learning: This is an important opportunity to emphasize that each individual has contributions to make to their community of learners and that course materials will also present a diversity of perspectives. It is through differences in thinking and expression that the class will grow their knowledge together. The Community Agreements should remind students to value the diversity of classroom community members and equity in the

ADDITIONAL GUIDANCE

Before handing out the reading, consider letting students know that the class will be discussing colonialism and racism to give them time to process and raise any concerns they have. Be mindful that reading about and discussing these topics can bring up past or recurring trauma for students. The following websites have resources to scaffold justice-oriented teaching:

- Resource: Learning for Justice: Critical Practices: <https://www.learningforjustice.org/frameworks/critical-practices>
- Facing History & Ourselves: <https://www.facinghistory.org/resource-library?search=colonialism>

Show slide J. Divide students into groups of 2-3 to read *A Brief History of the Serengeti*. They should write in their Notice and Wonder charts as they read, looking for answers to the questions they raised earlier. * *

sensemaking work they will do together this school year. It is critical that the norms support safe and fair participation and interrupt cultural norms or stereotypes that could make science experiences feel uncomfortable to students.

* SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Throughout the day students are developing and practicing strategies for obtaining and integrating information and ideas to answer their questions about the formation of Serengeti National Park. The goal is to be able to integrate different forms of information today and record it so they can communicate what they learned when they share this information during the next class. Students will first read *A Brief History of the Serengeti* and then integrate new information from the scavenger hunt to deepen their understanding of the issue.

* ATTENDING TO EQUITY

Provide students with a reading strategy that builds community and teaches students to work together to understand a challenging reading. The Reading for Gist comprehension strategy is well-suited to *A Brief History of the Serengeti*. A description of the Reading for Gist method can be found in the *OpenSciEd Teacher Handbook: High School Science*. Encourage students to read the text together. They can stop after each paragraph to paraphrase what they understood and identify items to write in the “Notice” column of their notebooks. If they have questions as they read, they should ask their group members. If no one knows the answer, it would be a good candidate for the “Wonder” column of their notes.

4 • DISCUSS HISTORY OF SERENGETI

8 min

MATERIALS: science notebook, *A Brief History of the Serengeti*, chart paper, chart paper markers

Facilitate a discussion about the reading. Display slide K. Ask students to share their noticings and wonderings about the reading with the class.

Suggested prompt	Sample student response
<i>What did we figure out about the reason the SNP was created?</i>	It was a European idea. To protect great herds of animals. To protect the movement of animals. To protect animals like lions from overhunting.
<i>What did we figure out about who made decisions about creating the park?</i>	The British were in charge of deciding boundaries. There were conflicts over whether local Africans can live in the park.
<i>What did we figure out about why the park boundaries changed?</i>	Boundaries changed because of disagreements about who can be in the park and how they can use it.
<i>Does this historical conflict remind you of any other events you have learned about?</i>	Answers will vary. The United States was a British colony. The United States stole land from Indigenous people. The Spanish stole land from Mexican people. Jim Crow laws excluded Black people from using the same resources as white people in the US. Black people were also prevented from fully participating in decision-making.

ADDITIONAL GUIDANCE

If students are unable to find information from the reading to contribute to discussion, use the following prompts:

- In paragraphs 2 and 3, what reasons did they give for needing to protect the Serengeti?
- In paragraph 3, what does the person who said “a natural landscape as yet relatively unspoiled by man” believe about conservation? What do they think of the Africans who live there?
- In paragraph 6, what is a reason people were not happy with the boundaries of the park?

Discuss the conservation philosophies. Say, *You mentioned that there were conflicts when they were setting up the park and deciding whether local Africans could live there. You also described some similar historical examples of conflicts related to the use and ownership of land or resources.* Display slide L and discuss the prompt with students.

Suggested prompt	Sample student response

*** SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE**

Stability and change is a focal crosscutting concept for this unit. In this lesson, when students identify questions raised by the park creation story, they will identify components of the system that have changed or remained the same over time. Encourage students to ask questions about what else they need to know to understand the migrating animals referred to in the text to support their thinking about the migration and the population of wildebeest change and/or stay the same over time.

Suggested prompt	Sample student response
What beliefs did people in the Serengeti example have about the relationship between humans and nature when they set up the park?	Some believed in protection of a natural area separate from people. Others believed that some people can live with nature as they always had, but not everyone.
Add nature-culture relations to personal glossaries. Discuss slide M, which shows two views of nature-culture relationships. Say, <i>This is a term we have not encountered before. Let's take a moment to add a definition to our personal glossaries.</i> Pause and give students an opportunity to share ideas for what should be included in the definition. Draw on student ideas to generate a definition for the class.	
ADDITIONAL GUIDANCE	In the Learning in Places framework, the term nature-culture relations helps us think about <i>how our unique cultures impact the decisions we make about human relations and the natural world.</i> Your class definition may vary but should capture this definition. <i>Learning in Places Collaborative (2022). Nature-Culture Relationships Framework.</i> Bothell, Seattle, WA & Evanston, IL: Learning in Places. P. 1. Read more about this at: http://learninginplaces.org/wp-content/uploads/2021/10/framework_Nature_Culture_Relations_rev101321.pdf
Whole class discussion about nature-culture relations. Ask, <i>Which image looks more like the European view at the time the park was formed?</i> Ask students how the differences between these two philosophies might influence someone's view of conservation.	
ADDITIONAL GUIDANCE	The diagram on slide M comes from the Learning in Places Nature-Culture Relationships Framework cited below. It describes two main models of nature-culture relations: "1) humans "apart from" the natural world, or what we call nature-culture divides; and 2) humans are "a part of" the natural world, or what we call nature-culture complementarities. In nature-culture divides, humans are generally positioned as apart from or on top of the natural world." This puts people in a position of power to control all other parts of the natural world. This system values protection of the natural world but generally does this by setting aside spaces humans can visit, but cannot live in. "The..."apart from" models also tend to reflect powered social systems particularly with respect to gender and race." "In nature-culture complementarities, humans are generally positioned as a part of the natural world. These "a part of" relationships tend to position humans as one of many actors in the natural world and often reflect deferential or reciprocally powered relationships and tend to extend dignity and rights to more than human life." <i>Learning in Places Collaborative (2022). Nature-Culture Relationships Framework.</i> Bothell, Seattle, WA & Evanston, IL: Learning in Places. P. 1. Read more about this at: http://learninginplaces.org/wp-content/uploads/2021/10/framework_Nature_Culture_Relations_rev101321.pdf
Say, <i>This explains part of the story of the creation of Serengeti National Park, but it leaves out some details. What else do you want to know?</i> Show slide N. Create a list of student questions on a piece of chart paper. This will be revisited on day 2 of the lesson. *	

Suggested prompt	Sample student response
<i>What questions does this raise?</i>	Who seems to be involved? What places are involved? What animals were they protecting? What do they mean by great herds/great masses and movement of animals? Why are animals moving? Where are the animals going when they move? Why did the British get to decide what happened? Why did the park boundaries keep changing? What are people allowed to do in the reserves and conservation areas? Would the African groups hurt the animals? Why would they kick the Africans out of the park area?

5 • INFORMATION SCAVENGER HUNT

10 min

MATERIALS: *Scavenger Hunt Notes*, Laminated scavenger hunt images or print outs of https://docs.google.com/presentation/d/1OEpkHOqu3MGfndVqpFvaGDOEaovsTAMZgbKL3HZ_mEO/edit?usp=share_link, three computers, <https://www.youtube.com/watch?v=ipYb3Gw6fBY>, <https://www.youtube.com/watch?v=cVj4883yzeQ>, <https://www.youtube.com/watch?v=7JOk6ivcuco>

Facilitate an information scavenger hunt. Pass out *Scavenger Hunt Notes* to each student, which has a map of the Serengeti on one side and a place for notes on the other. Show **slide O**. Ask students to choose two questions from the class list they want to try to answer. They should copy those questions to the first column on their worksheet. Explain that you have put additional information about the formation of Serengeti National Park around the room using the headings: Habitats, Biodiversity, Movement of Animals, Conservation Areas, and People of the Serengeti. Point out the video option at the Movement of Animals and People of the Serengeti stations.

ADDITIONAL GUIDANCE

Set up a computer cued to <https://www.youtube.com/watch?v=ipYb3Gw6fBY> and <https://www.youtube.com/watch?v=7JOk6ivcuco> at the Movement of Animals station and <https://www.youtube.com/watch?v=cVj4883yzeQ> at the People of the Serengeti station.



Students should visit the stations they believe will help them gather more information to answer their questions. As they find information during the scavenger hunt, they should take notes about what they learn using the map and table on *Scavenger Hunt Notes*. Before they visit the stations, talk about strategies for obtaining and summarizing what they will see at the stations. Say, *One of the practices scientists work on is their ability to clearly and accurately share what they learn with others. It is unlikely that you will have time to investigate everything in the scavenger hunt, so we will need to pool our knowledge next time we meet.* * Discuss ways to effectively record information on *Scavenger Hunt Notes*. *

Suggested prompt

Sample student response

* ATTENDING TO EQUITY

Alternative strategies for recording this information in different modalities for students with disabilities or multilingual learners could include voice memos or taking photos of key ideas to review later. Students who need more time to process or translate information before writing can review these recordings and fill in *Scavenger Hunt Notes* at home before the next class.

Suggested prompt	Sample student response
What are some strategies for recording what you see quickly but accurately on Scavenger Hunt Notes?	Make a sketch. Abbreviate information like SNP for Serengeti National Park. Draw on the map instead of writing it out. Put a number on the map and then write about it next to the number to remember where it happened. Write down numbers.
ADDITIONAL GUIDANCE	Students may notice the term <i>biodiversity</i> in the scavenger hunt and begin to use it. This term will be further explored in Lesson 8, but if students already have some ideas and/or questions about what it means, pause to add it to the personal glossary and revisit and revise in Lesson 8. A sample definition may look like: <i>the number of different kinds of organisms in an ecosystem.</i>
ASSESSMENT OPPORTUNITY	What to look for/listen for in the moment: During the scavenger hunt when students integrate information from <i>Scavenger Hunt Notes</i> with new information they learn from the information stations (SEP 8.2) about the following: • Serengeti National Park (SNP) was created to protect the movement of huge herds of animals. (DCI: LS2.C.2; CCC: 7.1) • SNP protected animal populations from disappearing due to overhunting. (DCI: LS2.C.2; CCC: 7.1) • People disagreed about the role humans play in the Serengeti ecosystem. (DCI: LS2.C.2; CCC: 7.1) • People disagreed about what part of the ecosystem to protect, and boundaries changed over time. (DCI: LS2.C.2; CCC: 7.1) What to do: Refer students back to the reading. • Ask students what new information they gain from this map compared to the one from <i>Scavenger Hunt Notes</i>. • Ask how this new information connects with what they already learned. • Ask how this information helps them answer their target question. Building toward 2.A. Integrate information presented in different formats about the factors that prompted humans to create the Serengeti National Park and how the protected area boundaries changed or stayed the same. (SEP 8.2; DCI: LS2.C.2; CCC: 7.1)

6 · NAVIGATE

4 min

MATERIALS: *Scavenger Hunt Notes*, scavenger hunt images, two computers

Complete exit ticket. Say, *It sounds like you uncovered some interesting information in your scavenger hunt! Before you leave, I would like you to summarize your findings by answering the question at the bottom of Scavenger Hunt Notes. Also, tell me what you are unable to find and still need answered.* Display slide P. Ask students to complete the questions and turn *Scavenger Hunt Notes* in to you as they leave.

ADDITIONAL GUIDANCE

Read through the exit tickets as a formative assessment of student understanding about the changes that occurred to protect the Serengeti ecosystem. Check for individual students' ability to integrate new information into their notes to consider how to support students with more strategies in future lessons. If students copy information word for word on their handout, suggest that they work to paraphrase in their own words. For example, "The National Park is not the only protected area in the Serengeti ecosystem. Many additional areas were added between 1951 and 2000." could be paraphrased as "1950-2000 more areas protected"

Use the exit tickets as a way to group students for day 2 of the lesson, creating groups of students who investigated different questions and can share complementary information.

End of day 1

7 · NAVIGATE: PREPARE TO SHARE SCAVENGER HUNT INFORMATION

3 min

MATERIALS: *Scavenger Hunt Notes*

Reflect on clarity of summaries. Display **slide Q**. Return *Scavenger Hunt Notes* to students. and ask them to review what they wrote. Say, *From reading your exit tickets from last class, it seems like you were individually able to answer some of the questions we raised after we read A Brief History of the Serengeti during the scavenger hunt, but you still had questions about other aspects of conservation of the Serengeti. I noticed that other members of the class had the answers some of you were still seeking because they had time to collect different information in the scavenger hunt. I want to give you some time to share what you learned yesterday, so we will be working in small groups.*

Also, remember that we talked yesterday about strategies to write quickly but accurately. During your group work today, make a mental note to yourself about how easy it is to read what you wrote and whether it helps you paraphrase what you learned when you get in your groups.

Revisit Community Agreements. Display **slide R**. Before students get together to share, revisit the agreements your class wrote for supporting one another in groups and discuss productive ways to learn together.

* ATTENDING TO EQUITY

Universal Design for Learning: This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking and expression that the class will grow their knowledge together. The Community Agreements should remind students to value the diversity of classroom community members and equity in the sensemaking work they will do together this school year. It is critical that the norms support safe and fair participation and interrupt cultural norms or stereotypes that could make science experiences feel uncomfortable to students.

8 · SHARE SCAVENGER HUNT INFORMATION

10 min

MATERIALS: *Scavenger Hunt Notes, Graphic Organizer, Graphic Organizer Scavenger Hunt Key, scavenger hunt images*

Share the results of their information scavenger hunt. Display **slide S**. Organize students into teams of 3-4 based on questions and take-away statements from their exit tickets so they can learn from one another. Distribute *Graphic Organizer*. Explain that as a group, they should use what they learned in the scavenger hunt and wrote on *Scavenger Hunt Notes* to complete the *Graphic Organizer* focusing on the overarching questions: *Why did people decide to protect the Serengeti? How did they decide what to protect?* Keep track of the most important locations on the map on the back of the page.

ALTERNATE ACTIVITY

Allow students to self-organize into groups to share information. Encourage them to find individuals who focused on different questions during the information scavenger hunt. This allows students to work within the classroom agreements with agency and choice, building trust in the classroom community.

ADDITIONAL GUIDANCE

Leave the scavenger hunt images on the wall on day 2 so they are available as a reference during all activities. If students realize they forgot to write something down, they can look for it briefly, but during the self-reflection that follows they should consider how they could improve their ability to obtain information and record it for later use. Images may also be helpful references during the Scientists Circle.

9 · SELF-REFLECTION

3 min

MATERIALS: *Obtaining and Communicating Information Self-Assessment*

Prompt students to self-reflect on their ability to share. Display slide T. Distribute *Obtaining and Communicating Information Self-Assessment*. Say, *How do you feel about your ability to record what you learn and then share this with others? What do you do well? What do you need to work on?* Provide two minutes to complete the self-reflection.

ADDITIONAL GUIDANCE

Consider collecting student self-reflections to gain insight into how students are feeling about group work early in the class. It could help you monitor certain groups more than others to facilitate growth in equitable teamwork.

Ask students to refer back to these reflections when opportunities arise for note-taking and group work in the future to remind themselves of personal strengths and areas for improvement.

10 · CONSENSUS DISCUSSION ABOUT CONSERVATION OF SNP

12 min

MATERIALS: *Graphic Organizer*, science notebook, laminated Serengeti map poster or *Serengeti Map*, dry erase markers and eraser, chart paper, chart paper markers, scavenger hunt images



Gather in a Scientists Circle for a Consensus Discussion. Display slide U. Ask students to form a Scientists Circle, a horseshoe shape oriented toward the front of the room, and to bring *Graphic Organizer* and their science notebooks with them. Bring the class together and use the prompts below to facilitate a Consensus Discussion.

Suggested prompt

Why did people decide to protect the Serengeti?

How did they decide what to protect?

Sample student response

To protect the migration route of wildebeest and other animals.

To protect a wide variety of species.

To keep the ecosystem free from harm from humans.

To protect lions and other animals from hunting.

The British and Europeans decided without asking the locals what they wanted.

Create a class consensus model. As you discuss, create a consensus model using the laminated map and/or chart paper and a whiteboard of how the SNP protects herds of migrating animals and a bulleted list to the side of important points in the discussion. *

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

A Consensus Discussion is different from other kinds of discussions because the purpose of the discussion is to converge on one idea or more ideas that the whole class agrees upon. In this discussion, your classroom community is pressing toward a common (class-level) explanation, model, or model representation. During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Helpful prompts include:

- What ideas are we in agreement about?

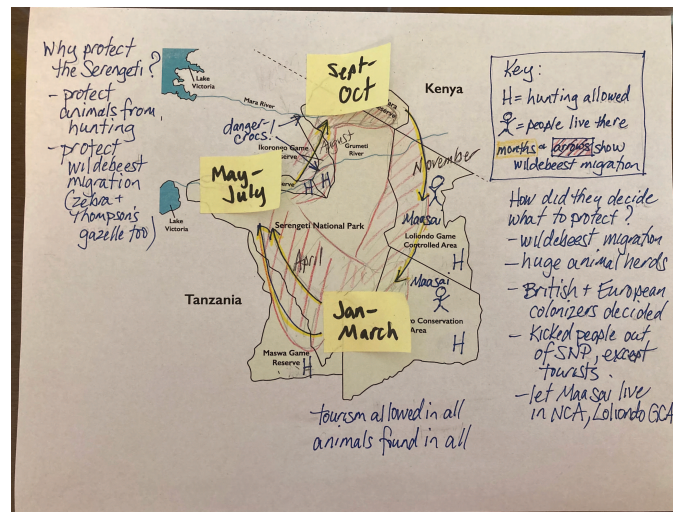
Take a photograph of the finished map and bullets for each class period to reference in later lessons as needed.

KEY IDEAS

Purpose of this discussion: There are three goals of this discussion: 1) to describe why people decided to protect the Serengeti by creating Serengeti National Park (SNP), 2) to describe the wildebeest migration route, and 3) to raise questions about why the wildebeest migrate.

Listen for these ideas:

- SNP was created to protect the migration route for huge herds of wildebeest, zebra, and Thomson's gazelles. (DCI: ESS 3.C.1; CCC: 7.4)
- Show the wildebeest migration route on the base map.
- SNP and the reserve system were created to protect a large diversity of animals. (DCI: ESS 3.C.1; CCC: 7.4)
- The SNP does not protect the full migration route. (DCI: ESS 3.C.1; CCC: 7.4)
- The British and Europeans often made decisions without including people in Tanzania/Tanganyika, which may not protect the ecosystem. (DCI: ESS 3.C.1; CCC: 7.4)
- Reserves protect the animals, but also allow people to live, hunt, and graze livestock. (DCI: ESS 3.C.1; CCC: 7.4)
- The SNP protects the animals and excludes humans from living or taking resources. (DCI: ESS 3.C.1; CCC: 7.4)
- Question why wildebeest migrate, especially if it is dangerous. (DCI: ESS 3.C.1; CCC: 7.4)
- Create a map similar to the one below.



- Would anyone have put this point a different way?
- Who feels like their idea is not quite represented here?
- Are there still places where we disagree? Can we clarify these?

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: During the Scientists Circle, students will [construct a consensus model and explanation using evidence \(SEP 2.3\)](#) to explain the following:
See Key Ideas above.

What to do:

- Ask students if SNP meets the goal of protecting wildebeest herds.
- Compare the Serengeti ecosystem map to the park and reserve boundaries from **slide V**.
- Show the 12-panel map of migration on **slide W** during the discussion and discuss how the animals move in and out of the park into other reserves.
- Ask how they can show the wildebeest migration route on one map.
- Ask why the SNP does not protect the entire route of the wildebeest.
- Look at **slide X** and ask students to speculate about why wildebeest move to different areas of the ecosystem.
- Ask students what protections the wildebeest have in each conservation area.

Building toward 2.B. [Develop a model based on evidence](#) to explain how the Serengeti National Park system was [designed for the stability](#) of the [migrating populations as valuable to humans in various ways](#).(SEP 2.3; DCI: ESS 3.C.1; CCC: 7.4)

Co-construct conservation plan. Say, *What you all just described is what scientists call a conservation plan.* Display **slide Y**. Ask students to share their ideas for what a definition of observation plan would include. Once the class has come to consensus, ask each student to add the definition to their personal glossaries.

ADDITIONAL GUIDANCE

A sample definition for conservation plan may look like this: *a plan to conserve a natural place, ecosystem, and/or organism that details how it will be protected with goals and outcomes.* Encourage students to add their definition in their personal glossary.

11 · COMPLETE PROGRESS TRACKER

12 min

MATERIALS: *Progress Tracker, Conservation Profile Organizer, initial models from Lesson 1, science notebook*

Propose starting a Progress Tracker to keep track of ideas. Say, *As we look at what we learned about the conservation of the Serengeti ecosystem, let's remember our overall goals. We decided to look at the Serengeti as a model of conservation that will help us better understand our conservation profiles and eventually think about ways to meet the goals of the 30 by 30 Initiative in the United States. It would be helpful to have a way to keep track of what we are learning.*

Distribute Progress Tracker. Display **slide Z**. Direct students to add the unit question from the DQB to the top box on *Progress Tracker*. Explain the organization of the Progress Tracker. Say, *After certain lessons, we can record the big ideas we learned about the Serengeti in column one. Then we can look back at our conservation profile notes in Conservation Profile Organizer and initial models from Lesson 1 and describe the connections we see between what we figured out about the Serengeti and our conservation profile in column 2. I imagine that sometimes we will already have what we need written in the conservation profile notes, and sometimes we will need to do more research to find the connection. The last column is a place for us to write down questions or pieces of information we will need to find later on to explain how your ecosystem works and why humans are protecting it. After we finish learning about the Serengeti, we can come back to these questions and do more research about these ecosystems.*

ADDITIONAL GUIDANCE

Reassure students that the Progress Tracker is not graded but is a way for students to communicate with you about what they are learning and what they still have questions about. Explain that we are all learning about these ecosystems together, you expect that the Progress Trackers will show increasing understanding over time, and you hope they will always have more questions they want to investigate.

The Progress Tracker can be a valuable tool for formative assessment, giving you a clear picture of students' thinking and allowing you to direct your instruction accordingly. However, Progress Tracker entries should not be scored or graded (other than possibly for completion), because doing so would invalidate their purpose—to be a safe space for students to process and record their thoughts honestly and without worry about evaluation.

Complete Progress Trackers. Help students complete the first row. Explain that each time we use the tracker, they should fill in the lesson number and the question or topic they are writing about in the first cell of the row of *Progress Tracker*. Ask them to turn and talk about the questions on **slide AA** to complete the first column that describes what they learned about the Serengeti. Remind them of the question list they created on day one of the lesson after reading *A Brief History of the Serengeti* to help them figure out which questions they can now answer. Ask one or two students to share with the class to check for understanding on how to use the Progress Tracker.

Next, ask students to get out *Conservation Profile Organizer*. Show **slide BB** and talk through the types of questions students should be able to answer about their profile. An example is shown in the table below.

Suggested prompt	Sample student response
<i>How can we use what we know about Serengeti National Park to understand your conservation profile?</i>	We could describe what was protected. We could describe why the ecosystem was protected or needed protecting. We could explain if people changed their minds about what part of the ecosystem was protected and why. We could describe who decided how to conserve the ecosystem and who was left out. We could describe the rules for who uses the conservation area.

	What did I figure out about the Serengeti?	What in my profile connects to ideas we figured out about the Serengeti?	What information do I need/questions do I have about how to protect ecosystems?
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Lesson 2 Why was the Serengeti protected?	The Serengeti is diverse. The park and reserves protect wildebeest on their migration. Conservation area boundaries changed because humans wanted to use the ecosystem for a variety of purposes. The park boundaries changed because the Maasai had been excluded from their land.	The Everglades is diverse and has endangered species, like the alligator, manatee, wood stork, and Florida panther. The Everglades was protected because it provides fresh drinking water to people.	The Everglades is diverse and has endangered species, like the alligator, manatee, wood stork, and Florida panther. The Everglades was protected because it provides fresh drinking water to people.
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Provide time for students to read through their notes and look at their initial models from Lesson 1. They should answer what they can in column 2. Anything they cannot find should be written as a question or note for further investigation in column 3. Questions that remain from the Serengeti should be written here as well. Ask for one example from each conservation profile.

ADDITIONAL GUIDANCE

Over the course of this unit, students will use the Progress Tracker for two immediate purposes: first, to summarize and keep track of the big ideas they learned from a particular lesson or set of lessons; and second, to connect and generalize what they learned about the Serengeti ecosystem to their conservation profile. For the purposes of the full unit, students will review their notes from the Progress Tracker in Lesson 10 when they do additional research on their conservation profile. The Progress Tracker will remind them about what they already know about the ecosystem and its conservation and will contain a set of focus questions for further inquiry.

12 · NAVIGATE

5 min

MATERIALS: sticky notes

Revisit DQB. Display **slide CC**. Say, *OK, we have recorded information about the Serengeti and our conservation profile. Have we answered any of our initial questions on the DQB?* If any questions have been answered, put checks on any questions that have been answered (not many will be answered yet).

Say, *We know why these areas were protected, but I saw you write down additional questions. There are still things we do not know about how these ecosystems function if we want to be sure they are properly protected. Let's focus on our Serengeti-related questions since we are using it as a case study to help us figure out how all ecosystems work.* Ask students to share questions from their Progress Trackers and add them to the Driving Question Board.

ADDITIONAL GUIDANCE

If no one brings up the question, *Why do wildebeest migrate?*, return to the list of questions students made after reading *A Brief History of the Serengeti*, leading into the information scavenger hunt. Check off the questions that were answered. Call out the questions that remain, including, *Why are the animals moving?*

Determine next steps. Display slide DD. Say, *Our consensus models show where the wildebeest migrate, but we do not know why they take such a long, dangerous journey. There must be some motivation for over a million animals to travel such a long way and cross rivers where they might be attacked by crocodiles. How could we figure this out?*

Suggested prompt	Sample student response
How could we figure out why wildebeest migrate?	Visit the Serengeti and watch the wildebeest and see what they do and what they interact with in each area. Find video of the wildebeest migration. Talk to scientists who study the Serengeti. Talk to people who live in the Serengeti.

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

Students use evidence from *A Brief History of the Serengeti* to uncover the reasons for formation of Serengeti National Park and who had the power to make decisions about the park and attend to differing philosophies of conservation discussed in the text.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Students integrate and evaluate information from *A Brief History of the Serengeti* and their information scavenger hunt, which contains quotes, images, captions, and video to deepen their understanding of why Serengeti National Park and surrounding reserves were created and who made decisions about why the park formed.

LESSON 3: Why do the animals in the Serengeti migrate?

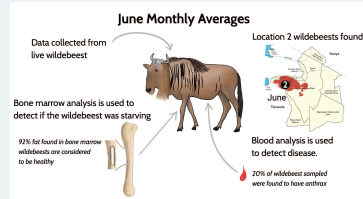
PREVIOUS LESSON

We were introduced to the Serengeti National Park as a case study. We read about the creation of the park and the controversial decisions made over which areas the park should protect. We participated in an information scavenger hunt to learn about the many different species of the park with emphasis on the migrating herds of wildebeest. We created a consensus model to explain why the park was created and who decided how humans could use the park.

THIS LESSON

INVESTIGATION

2 days



We revisit wildebeest migration and brainstorm reasons for why they are migrating. We watch a video of researcher Dr. Simon Mduma to hear what he observed and what data he collected. We look at wildebeest field data cards for patterns to use as evidence to connect our predictions about why wildebeest migrate. We create data displays to show our findings and share them. We notice a connection between nutritional health and wildebeest migration. We wonder how food could be causing wildebeest migration.

NEXT LESSON

We will investigate the relationship between food and wildebeest location by looking for patterns in rainfall as well as other factors that affect the migration.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

3.A Communicate information about patterns in factors that affect wildebeest migration. (SEP: 8.5; DCI: LS2.A.1; CCC: 1.5)

3.B Develop a model of wildebeest migration using patterns found in empirical evidence about factors such as predation and food availability. (SEP: 2.3; DCI: LS2.A.1; CCC: 1.5)

WHAT STUDENTS WILL FIGURE OUT

- Some wildebeest are killed by predators, but starvation is the leading cause of death in wildebeest.
- Food is the main factor that motivates the wildebeest migration.

Lesson 3 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE: BRAINSTORM REASONS WILDEBEEST MIGRATE Look back at the map of the great migration and lead a discussion about why wildebeest are migrating.	A	laminated migration map
2	8 min		WATCH AND DISCUSS A VIDEO INTERVIEW OF A SCIENTIST WHO STUDIES WILDEBEEST Watch a video and annotate a transcript to discuss what scientists wanted to know about wildebeest and how scientists studied them.	B-E	<i>Transcript: Mduma Interview</i> , https://www.youtube.com/watch?v=PGGslSmDICI
3	10 min		INTRODUCE WILDEBEEST FIELD RESEARCH DATA CARDS Observe and discuss the data found on the wildebeest field research data cards.	F-G	<i>Analyzing Wildebeest Data Cards</i>
4	15 min		EXAMINE WILDEBEEST FIELD RESEARCH DATA CARDS Organize <i>Wildebeest Data Cards</i> as assigned to find patterns in the data that provide evidence to explain why wildebeest migrate.	H	<i>Analyzing Wildebeest Data Cards</i> , laminated <i>Wildebeest Data Cards</i>
5	7 min		NAVIGATE	I	<i>Analyzing Wildebeest Data Cards</i>
<i>End of day 1</i>					
6	3 min		NAVIGATE Discuss different ways scientists communicate what they figure out from their research.	J	
7	10 min		CREATE DATA DISPLAYS Create a data display that communicates evidence for why wildebeest are migrating.	K	<i>Analyzing Wildebeest Data Cards</i> , chart paper or small whiteboards
8	10 min		COMPARE AND CONTRAST DATA DISPLAYS Share, discuss, and compare the data displays with other groups.	L	data displays
9	15 min		FACILITATE A CONSENSUS DISCUSSION ABOUT WILDEBEEST MIGRATION Lead a discussion about how patterns of evidence could explain the wildebeest migration.	M-N	<i>Analyzing Wildebeest Data Cards</i> , data display, 6" x 8" sticky notes, 3" x 3" sticky notes, markers, laminated Serengeti Map
10	5 min		DISCUSS WHETHER MIGRATION HELPS WILDEBEEST SURVIVE Observe and discuss population data to determine if wildebeest migration is helping their survival.	O	
11	2 min		NAVIGATE Reflect on the connection between food and migration. Students record new questions they have about this connection in their science notebooks.	P	
<i>End of day 2</i>					

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials	• <i>Transcript: Mduma Interview</i> • <i>Analyzing Wildebeest Data Cards</i> • science notebook	• laminated <i>Wildebeest Data Cards</i> • chart paper or small whiteboards • data displays • data display	• laminated migration map • https://www.youtube.com/watch?v=PGGsISmDlCI • 6" x 8" sticky notes • 3" x 3" sticky notes • markers • laminated Serengeti Map

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If you are not using a unit kit, cut out *Wildebeest Data Cards* for each student group. If you have access to a color printer and laminator, then these cards can be used for multiple classes.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

This lesson introduces the disciplinary core idea: *Ecosystems have carrying capacities, which are limits to the number of organisms and population they can support. These limits result from such factors as availability of living and nonliving resources and from challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem* (HS-LS2.A.1) Students engage in a portion of this DCI element as they explore and explain why wildebeest are migrating. Students will build out the rest of this DCI element in the following lessons. Here students build on middle school level understanding of different ecosystem interactions (MS-LS1.B.3 and MS-LS2.A.2).

Students engage in the high school element of the science practice *Developing and using models*. Students will start co-constructing an explanatory classroom consensus model in a class discussion to explain wildebeest migration.

Students will use the high school elements of the crosscutting concept *Patterns*. Students will see that patterns and absence of patterns in data can be used as evidence in constructing explanations. Several of the prompts and handouts use pattern language to highlight this for students.

In this lesson, students will encounter *empirical evidence* and *mortality factors* and will add definitions to their personal glossaries.

Where We Are NOT Going

While students investigate the migration in this lesson, they are introduced to wildebeest population data. This data is used to help students compare the relative proportion of dead wildebeest to the overall population. They should recognize that investigating dead wildebeest can help them understand what factors influence the migration and that most of the wildebeest are surviving the migration. In future lessons students will investigate population data to figure ideas about population dynamics and carrying capacity.

LEARNING PLAN for LESSON 3

1 · NAVIGATE: BRAINSTORM REASONS WILDEBEEST MIGRATE

5 min

MATERIALS: laminated migration map

Briefly navigate into today's work. Say, *In the previous class we learned a lot about the Serengeti National Park and why it was conserved. We also observed that wildebeest and other animals migrate in the park throughout the year. Let's return to a map of this migration. Display slide A.*

Suggested prompt	Sample student response
<i>Not all animals migrate in the Serengeti, but in the previous lesson we observed the great wildebeest migration. What do you notice about the migration maps?</i>	The wildebeest go a far distance. They are in different places at different times of year. They go around in a circle.
<i>What do you wonder about wildebeest migration from looking at the maps?</i>	Why do they do this? Is it always the same? How long does it take?
<i>What are some possible reasons animals like wildebeest migrate?</i>	It could be because of predators. Maybe they run out of food. Maybe diseases are in one place and they want to get away.
<i>What do you think we would see if predators, food or disease cause the wildebeest migration?</i>	If it was predators, we would see a lot of wildebeest being killed by lions. they would be running away from the lions and the lions would not be migrating. If it was food, we would see the food running out in an area, then the population moving to areas with more food. If it was disease, we would see a disease maybe break out and wildebeest move from the area in order to not be sick.

2 · WATCH AND DISCUSS A VIDEO INTERVIEW OF A SCIENTIST WHO STUDIES WILDEBEEST

8 min

MATERIALS: Transcript: Mduma Interview, <https://www.youtube.com/watch?v=PGGslSmDlCI>

Watch a clip from an interview with a scientist who studies wildebeest. Display **slide B**. Say, *I was able to find an interview with a scientist who studied wildebeest populations in the Serengeti. Let's first take a look at a short biography that highlights some of the things he has accomplished and consider how hearing from this scientist and looking at his research could help us understand more about wildebeest migration.* Allow students a few minutes to read over the slide, then have a short discussion about how Dr. Mduma's research could be useful.

Suggested prompt	Sample student response
<i>How do you think Dr. Mduma's research could help us answer our questions?</i>	His research might give us some data to help us figure out why the wildebeest migrate or answer other questions we have about wildebeest.
<i>What would you want to know about his research?</i>	We want to know what data he collected and what he figured out.

Play <https://www.youtube.com/watch?v=PGGslSmDlCI> once, allowing students to watch and listen to the video. Display **slide C** and distribute *Transcript: Mduma Interview*. Then play the video again. For the second viewing, have students annotate the transcript by underlining ideas that could help us understand wildebeest migration, circling ideas about data Dr. Simon Mduma looked at and drawing question marks where they have questions.

Turn and talk with a partner about the questions on the slide. Display **slide D**. Give students a minute to discuss the questions on the slides using their annotated transcripts. Then facilitate a whole-class discussion, allowing student pairs to share with the whole class.

Suggested prompt	Sample student response
<i>What interested Dr. Mduma and other scientists about studying wildebeest?</i>	They were interested in understanding if poaching was affecting the population.
<i>What did Dr. Mduma determine about poaching? How did he come to this conclusion??</i>	The scientists looked at population data. They say that while poaching was continuing the population was not decreasing. They looked at mortality factors.
<i>What did they decide to investigate next?</i>	They decided to investigate mortality factors.
<i>How could these mortality factors connect to our ideas about wildebeest migration?</i>	We think that the wildebeest are migrating because if they stay in an area then they might die. If we understand why some are dying, we might be able to explain why the rest are moving.

* ATTENDING TO EQUITY

Supporting emergent multilinguals: When developing new vocabulary, strategies that may benefit emergent multilingual learners are to use student-friendly definitions, make connections to cognate words when possible, and encourage students to include a visual representation of the word. Use these strategies throughout the unit for both "definitions we co-construct" and "definitions we encounter."

* SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

In this lesson, students analyze data to identify patterns. These patterns will serve as evidence to support explanations. At the high school level, it is important that students build an understanding of and use empirical data as evidence. Empirical data will serve as evidence not only as they identify patterns, but also as they support arguments and make claims about cause and effect in biology and across disciplines.

Update personal glossaries. * * Display **slide E**. Say, *What I heard you saying was that Dr. Mduma had evidence from population data that poaching was not a factor. Scientists call this kind of data, from observation and experimentation, **empirical evidence**.* Pause and give students a moment to update their personal glossaries by adding an entry for empirical evidence as a definition they encountered. Additionally, if your students do not have prior experience with the concept of mortality factors, take the time here to add to their personal glossaries as a definition we encounter such as *factors that affect survival or cause death*.

3 · INTRODUCE WILDEBEEST FIELD RESEARCH DATA CARDS

10 min

MATERIALS: *Analyzing Wildebeest Data Cards*

Introduce the wildebeest field data cards. Display **slide F**. Say, *I was able to gather some of the data from Dr. Mduma’s research to create some wildebeest data cards. You will notice that we do not have data for every month out of the year. I selected months where there were enough dead wildebeest to be able to compare with living wildebeest.*

Distribute a copy of *Analyzing Wildebeest Data Cards* to each student. Tell students that this tool is going to help organize, analyze, and make sense of the data from *Wildebeest Data Cards*. Orient students to part one, which helps define the purpose for using the wildebeest data. Have students individually read over the questions in part one. Then use the prompts below to facilitate a whole-class discussion about what the class decides to record in this table.

Suggested prompt	Sample student response
<i>Dr. Mduma was researching wildebeest at first to understand the effects of poaching on the wildebeest population. What question are we trying to figure out about the wildebeest?</i>	We want to understand why wildebeest are migrating.
<i>What were some possible reasons we came up with earlier to explain why wildebeest migrate?</i>	It could be because of predators. It could be for food. It could be related to diseases.
<i>Dr. Mduma mentioned that he decided to look closer at wildebeest mortality factors. How do you go about observing mortality factors?</i>	We look at the difference between living and dead wildebeest.
<i>How do mortality factors connect the ideas we came up with that could explain wildebeest migration?</i>	We think that the wildebeest migration is connected to their survival, so understanding what is killing some of them may explain why they are moving.

Have students individually read over the questions in part two, then display **slide G**. Have students observe the information found on the slide and consider which of the data collected might connect to our possible answers. Then use the prompts below to continue the whole-class discussion about what the class decides to record in the table in part two.

Suggested prompts	Sample student responses	Follow-up questions
<i>What type of data is found on the data cards?</i>	Whether the data came from a living or dead wildebeest. When the data was collected. Where the wildebeest were found. The nutritional health of the wildebeest by looking at its bone marrow. The amount of wildebeest that were found with anthrax, a disease.	
<i>What data might connect to our ideas about why wildebeest are migrating?</i>	The data telling us if it came from a living or dead wildebeest. The nutritional health of the wildebeest using bone marrow. The amount of wildebeest that were found with anthrax.	<i>What could comparing living and dead wildebeest tell us about wildebeest migration?</i> <i>What could nutritional health tell us about wildebeest migration?</i> <i>What could diseases like anthrax tell us about wildebeest migration?</i>
<i>There is a lot of data on these cards. What are some ways we can make sense of the data?</i>	We could group/organize the wildebeest data cards to look for patterns.	
<i>What are some ways we could organize/group these cards?</i>	We could organize them by living, killed by predators, and not killed by predators. We could organize them by the different nutritional health categories. We could organize them by anthrax/no anthrax. We could organize them by month. We could compare them by location.	<i>How might organizing the cards this way be helpful to understanding wildebeest migration?</i>
Record the different ways to organize the cards on the board. Make a public record of the different ways the cards could be organized on the board so that they can be assigned to different groups of students to analyze. For example, the cards could be organized by: • Status of wildebeest (death by predator, death not by predators, living) • Nutritional health • Anthrax/disease • Month • Location		

4 · EXAMINE WILDEBEEST FIELD RESEARCH DATA CARDS

15 min

MATERIALS: *Analyzing Wildebeest Data Cards*, laminated *Wildebeest Data Cards*

Support students in identifying patterns. Say, *However your group is organizing your cards, you will be looking for patterns in the data. What are we looking for when we look for patterns?* Listen for students to say they are looking for things to repeat.



Analyze wildebeest field data in groups. Organize students into small groups of 3-5. * As a class, assign one way each group will organize their cards to look for patterns. Make sure that all the ways to organize the cards that you listed have been assigned and are covered by at least one group. Then distribute *Wildebeest Data Cards* for each pair or small group of students. Say, *Let's take a moment to organize the wildebeest data cards, then look for patterns. Remember a lot of our potential ideas related to the survival of the wildebeest, so once you organize them as you were assigned, compare the living and dead wildebeest to see if there are similarities or differences between them. Record all your findings in part three on Analyzing Wildebeest Data Cards.* Make sure each student records their findings on their handout.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Evidence communicated in Part 3 of *Analyzing Wildebeest Data Cards* (SEP 8.5) about the following patterns (CCC 1.5) that affect wildebeest migration (DCI: LS2.A.1):

- Bone marrow health showing that wildebeest killed by predators have slightly better bone marrow health than wildebeest that did not die from predators. (DCI: LS2.A.1)
- Live wildebeest have a higher percentage of fat in their bone marrow than dead wildebeest. (DCI: LS2.A.1)
- June and July were the only months where anthrax was found in the population. (DCI: LS2.A.1)
- There was no difference of anthrax infection percentages between living and dead wildebeest. (DCI: LS2.A.1)
- In some months/locations there were bigger differences between living and dead wildebeest's bone marrow fat (June–October) than other months (May). (DCI: LS2.A.1)

What to do: Collect *Analyzing Wildebeest Data Cards* from each student. Use *Data Cards Patterns Key* as a guide to help you identify the appropriate evidence. Use the suggested feedback in the key to provide written feedback to individual students.

Building toward 3.A.1 Communicate information about patterns in factors that affect wildebeest migration. (SEP 8.5; CCC 1.5; DCI: LS2.A.1)

Display slide H. Allow students the remaining 12 minutes to organize and group the data cards as they were assigned to look for patterns between living and dead wildebeest. Have them record the patterns and lack of patterns they see in part three of *Analyzing Wildebeest Data Cards*.

ADDITIONAL GUIDANCE

The data students are working with came from several different research studies. While students will have to sift through data in order to find patterns to be used as evidence to explain wildebeest migration, this data has been intentionally selected to help highlight the key pattern found on *Data Cards Patterns Key*. Remember that these patterns and absence of patterns should be identified by the collective class and no single group should be expected to figure them all out. If you or your students have more questions about the data, the patterns, or the larger data sets which this lesson is based on, you can refer to *Data and Sources*.

* SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

In this lesson, students focus on identifying patterns of empirical evidence to help answer questions about why the wildebeest migrate. For example, live wildebeest have a higher percentage of fat in their bone marrow than dead wildebeest. This evidence becomes a pattern when we see it repeat in multiple months. Both finding patterns and the absence of a pattern provide the class with meaningful evidence to help explain why wildebeest are migrating. Encourage groups that do not find patterns to think about what that tells them about wildebeest migration.

ADDITIONAL GUIDANCE

You may want to demonstrate this activity by sorting the cards using one of the ways on the class list. Model your thinking aloud for students to show them how you look for patterns between the different cards in each pile.

To support the diverse learners in your class, it may be helpful to guide groups to sort the data based on complexity. Sorting by disease (anthrax) is least complex followed by predation, nutritional health, month, and location. Note that sorting by month and by location will yield the same results. It may be helpful to work directly with groups that have sorted the cards by location or by month. In these groups there are several piles of cards, which might make it overwhelming for some groups to search for patterns. Suggest to those groups to jigsaw these card piles. Have each group member take one pile of cards and record what they notice between living and dead wildebeest, then come back together as a group to share and record what they noticed between these different card piles.

5 • NAVIGATE

7 min

MATERIALS: *Analyzing Wildebeest Data Cards*

Draw conclusions from the data. Say, *A lot of the ideas about wildebeest migration are connected to wildebeest survival. Let's take a moment to reflect in our groups about the data patterns and lack of patterns we observed. What do these patterns and lack of patterns mean, and how might they connect to our ideas about wildebeest migration.* Display **slide I**. Have students record their conclusions in part four of *Analyzing Wildebeest Data Cards* as they consider the questions on the slide.

End of day 1

6 • NAVIGATE

3 min

MATERIALS: None

Introduce how to communicate your findings using data. Say, *We all have had the chance to organize and look for meaningful patterns using the data on Wildebeest Data Cards. The patterns we observed may be used to help us construct an explanation about why the wildebeest migrate. When scientists figure something out, they do not keep it to themselves.*

Scientists share their findings to help advance science learning and knowledge. Other scientists see their work and can learn, challenge, and/or add to it. Let's discuss what we should communicate from our data and how. Display **slide J**. Facilitate a discussion using the following prompts as a guide:

Suggested prompt	Sample student response
<i>We all organized and grouped the Wildebeest Data Cards differently. What should be communicated by our data displays?</i>	We should communicate what patterns we observed when we organized the data cards.
<i>There is a lot of different data and information on the Wildebeest Data Cards. Should we display all the information on the cards? What criteria should we use to decide what should go in our data display?</i>	No, we should only include the data that connects to ideas about wildebeest migration.

Suggested prompt	Sample student response
What are some different ways scientists display data to communicate what they figured out?	Scientists use tables, graphs, charts, diagrams, and models.

7 · CREATE DATA DISPLAYS

10 min

MATERIALS: *Analyzing Wildebeest Data Cards*, chart paper or small whiteboards

***Create a data display with your small group.** Display *slide K*. Provide each group with a piece of chart paper. Ask students to use the piece of chart paper to create a data display that highlights any and all patterns students noticed as they worked on *Analyzing Wildebeest Data Cards*. If a group did not find any patterns from how their cards are grouped, have them provide examples and create a display that shows what a lack of patterns means.

* ATTENDING TO EQUITY

Universal Design for Learning: Allow students to use multiple ways of expression in describing the patterns or lack of patterns they found from organizing *Wildebeest Data Cards*. Students may choose to communicate their findings using tables, graphs, charts, diagrams, or models.

8 · COMPARE AND CONTRAST DATA DISPLAYS

10 min

MATERIALS: science notebook, data displays



Share data display. Display *slide L*. Tell students to make a T-chart in their science notebooks to record similarities and differences between the different groups' data displays. Explain the instructions for *Stand Up, Hand Up, Group Up* and give students about 5 minutes to mingle and compare data displays with different groups. * Students should record similarities and differences on the tables they created in their science notebooks as they compare data displays with different groups. Remind students that while they are sharing and recording they are looking for patterns that connect the data to the wildebeest migration. If questions come up as they are sharing, have students write down these questions in their science notebooks.

* ATTENDING TO EQUITY

Supporting emergent multilinguals: It can be very helpful for all students, and particularly emergent multilinguals, to provide some context, purpose, and support in how to share and discuss the data displays. Remind students that our goal is to observe and record the similar and different patterns that connect to our ideas and predictions about wildebeest migration. While there are some physical similarities and differences in how different groups chose to display their patterns, we want to focus and record the patterns that connect to wildebeest migration. To further help students discuss these patterns, provide them with the following sentence starters:

- Sentence starters for discussing similarities:
 - Both data displays had similar patterns showing _____.
 - The pattern _____ was similar in both data displays showing _____.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Visit each group to assess how they **communicate (SEP 8.5)** about patterns in **(CCC: 1.5)**:

- Bone marrow health showing that **wildebeest killed by predators have slightly better bone marrow health** than wildebeest that did not die from predators. (DCI: LS2.A.1)
- **Live wildebeest have a higher percentage of fat in their bone marrow than dead wildebeest.** (DCI: LS2.A.1)
- June and July were the only months where **anthrax was found in the population.** (DCI: LS2.A.1)
- There was no difference of anthrax infection percentages between **living and dead wildebeest.** (DCI: LS2.A.1)
- In some months/locations there were bigger **differences between living and dead wildebeest's bone marrow fat** (June–October) than other months (May). (DCI: LS2.A.1)

What to do: Look for students to recognize patterns and absence of patterns to be used as evidence to explain wildebeest migration. See examples in *Data Cards Patterns Key*. Use the following questions to help push student thinking:

- What empirical evidence did you find to help explain why the wildebeest migrate?
- What patterns did you find?
- Where did you see that evidence repeated?

Building toward 3.A.2 Communicate information about **patterns in factors that affect wildebeest migration.** (SEP: 8.5; CCC: 1.5; DCI: LS2.A.1)

COLLABORATION



Stand Up, Hand Up, Group Up is a partner/group sharing and discussing protocol. In this protocol, when the teacher says “Go,” student groups stand up together and hold their hand up in the air (with their data display, science notebook, and writing utensil in their other hand). They look around the room for another group with their hands up. Then, as a group, they move to the other, and both groups will put their hands down. Together the groups will share and discuss each other's data displays. Students will also record the similarities and differences in their science notebooks. After each group has recorded the similarities and differences, each group will raise their hands again and look for another group that has their hands up that they have not shared with. Students continue this until the teacher says “Stop,” and then students return to their seats.

ALTERNATE ACTIVITY

If students' data displays are too large to move around the class, you could have students do a modified gallery walk using the 2 stay, 2 stray protocol where two students stay at their data display and the other group members rotate to other data displays to share and discuss the similarities and differences in the patterns they observed and why they chose to display them in the way they did.

- _____ was a similar pattern seen in both data displays telling us _____ about wildebeest migration.

- Sentence starters for discussing differences:
 - _____ was a new/different pattern observed in _____ group's data display.
 - The patterns found between _____ group and our group were different because _____.

9 • FACILITATE A CONSENSUS DISCUSSION ABOUT WILDEBEEST MIGRATION

15 min

MATERIALS: *Analyzing Wildebeest Data Cards*, data display, 6" x 8" sticky notes, 3" x 3" sticky notes, markers, laminated Serengeti Map



Meet in a Scientists Circle to create a classroom consensus model to explain how the wildebeest data connects to migration. Gather everyone together with their data displays and *Analyzing Wildebeest Data Cards* to share what they figured out while you record students' thinking on sticky notes that can be added to the Serengeti poster from Lesson 2. Display **slide M**. Use prompts such as those that follow to facilitate this discussion.

* ATTENDING TO EQUITY

You probably have students or students with family members who do not have regular access to nutritious food. Discussion about

KEY IDEAS

Purpose of this discussion: Come to consensus about the patterns we saw in grouping the *Wildebeest Data Cards* and use these patterns as evidence for an explanatory classroom consensus model about wildebeest migration.

Listen for these ideas:

- Living wildebeest have better nutritional health than both wildebeest killed by predation and those not killed by predation.
- There are no differences between living and dead wildebeest when it comes to anthrax.
- Later months, like September and October, seem to have bigger nutritional health differences than months like May.
- We have evidence that nutritional health seems to be an important factor in wildebeest survival.
- We think that food might be the driver for wildebeest migration.

wildebeest dying from a lack of nutrition and access to food could be triggering for anyone who has experienced food insecurity. If a student shares with you that they are experiencing food insecurity, be prepared to listen and refer them to supportive resources. Talk to a school counselor or school social worker about what specific supportive resources your school can provide to students and families who may be experiencing food insecurity.

Suggested prompt

At the beginning of this lesson, we returned to a map showing the wildebeest migration. What did we want to figure out?

What possible ideas did we come up with that could explain the wildebeest migration?

Sample student response

We wanted to understand why wildebeest were migrating.

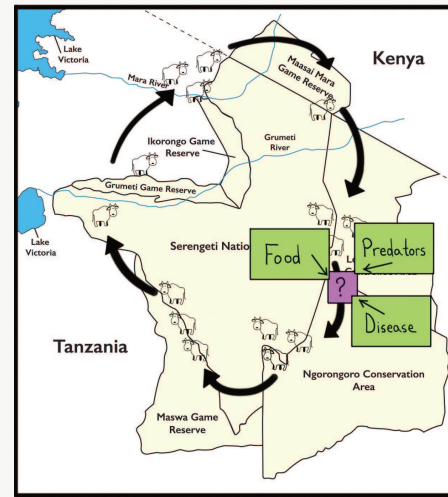
It could be because of predators.

It could be for food.

It could be related to diseases.

Update class consensus model. At this point, add sticky notes to the Serengeti class poster to indicate the class's ideas about what is causing the migration. Use 6" x 8" sticky notes to add all the different class ideas that students think could be causing the migration. Use 3" x 3" sticky notes to draw question marks where the class has questions. Your classroom consensus model may look like the example shown here.

Continue the discussion to identify the data patterns about the disease anthrax. Discuss whether patterns of disease can be used as evidence to help support ideas about wildebeest migration. Say, *A lot of our ideas about wildebeest migration connect to survival. Let's first discuss what disease patterns we observed between living and nonliving wildebeest when we organized Wildebeest Data Cards.*



Data Source: Sinclair, A. R. E. (2021). A place like no other : Discovering the secrets of Serengeti. Princeton University Press.

Suggested prompt

What patterns or lack of patterns did we notice with the disease anthrax?

If a disease, like anthrax, was causing wildebeest migration, what would we expect to see between living and nonliving wildebeest?

Can the anthrax data help us explain wildebeest migration? Why or why not?

Sample student response

There was no difference between living and dead wildebeest data when it came to anthrax.

They all were 0% except in the months of June and July, when 20% of living and dead wildebeest had anthrax.

We would see that some of the living population would have the disease periodically every time right before they migrated.

Most of the dead wildebeest not killed by predators would have died from the disease.

No, because the migration happened throughout the year, and the anthrax disease seemed to only affect them one time a year. Also, there was no real difference between living and dead wildebeest.

Continue the discussion to identify the data patterns about predation. Remove the sticky note that is labeled *Disease* and say, *We did not find any patterns that would connect disease to the wildebeest migration. Let's next discuss what predation patterns we observed between living and nonliving wildebeest when we organized Wildebeest Data Cards.*

Suggested prompt

Sample student response

Suggested prompt	Sample student response
<i>What patterns or lack of patterns did we notice with wildebeest that were killed by predators versus those that were not?</i>	The only patterns we observed had to do with nutritional health. The nutritional health of dead wildebeest was worse than those that were living. The nutritional health of wildebeest killed by lions and hyenas was better than those not killed by predators.
<i>If the nutritional health of the wildebeest was not a factor, then the percent of fat in the bone marrow would be the same for all wildebeest. What does it tell us about the predators that this bone marrow data was different between living and dead wildebeest?</i>	That lions and hyenas were killing wildebeest that had a worse nutritional health.
<i>What do you mean when you say the wildebeest had worse nutritional health?</i>	Maybe they did not get enough food. Maybe they were old or young and not as healthy and strong as the others.
<i>I have some additional age-at-death data that were collected from wildebeest in the field. If nutritional health is tied to age, what should we expect to see?</i>	We should expect to see most of the ones that are dying to be really old or really young.
Turn and talk about age data. Display slide N. Allow students to discuss with an elbow partner what this new information tells us about the wildebeest that are killed by predators. Then have students share with the whole group.	

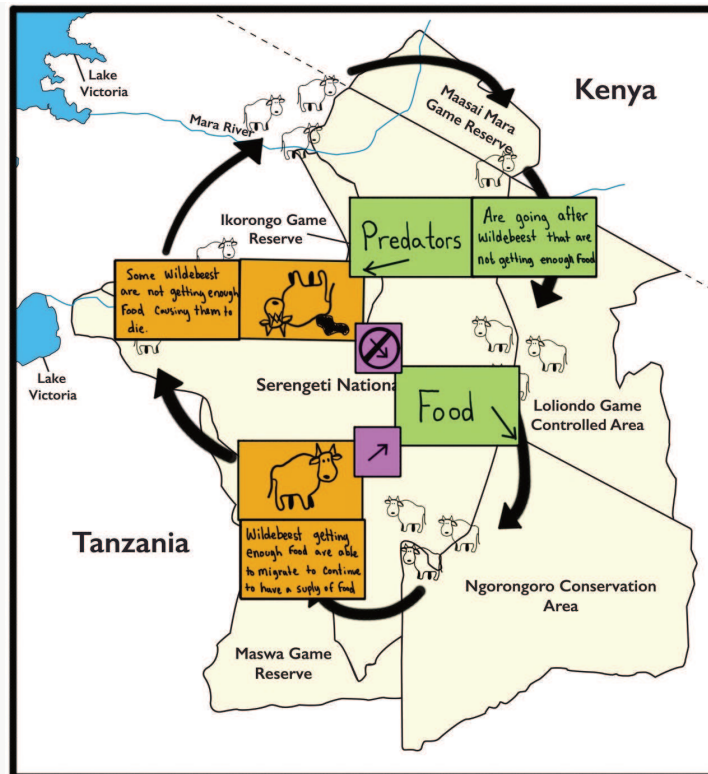
Suggested prompt	Sample student response
<i>What patterns do we notice about the wildebeest that are being killed by lions or hyenas?</i>	Most of the ones that were dying were middle-aged.
<i>How could middle-aged wildebeest be nutritionally weak?</i>	They must not be getting enough food somehow, and that is causing them to be nutritionally deficient.

Continue the discussion to identify the data patterns about food. Move the sticky note that is labeled *Predators* to the side and say, *We did not find any patterns that would only connect predators to the wildebeest migration. Let's discuss what food patterns we observed when we looked at bone marrow fat between living and nonliving wildebeest.*

Suggested prompt	Sample student response
<i>What patterns or lack of patterns did we notice with nutritional health/food?</i>	We noticed that the nutritional health between living and dead wildebeest were similar in May, but then from June to October the wildebeest that were dying had poor nutrition.

Suggested prompt	Sample student response
<i>*What does it mean that some wildebeest were nutritionally at risk?</i> <i>If you went out to a restaurant with a bunch of friends or family and the restaurant did not have enough room to seat everyone, what would you and your friends do?</i> <i>Why would you go to a different place to eat?</i> <i>Connecting this restaurant story to the patterns we observed with the wildebeest nutritional health, how could food cause wildebeest migration?</i> <i>We have seen that there is a pattern here that can be used as evidence to support a connection between food and wildebeest migration. How do we use what we figured out to update our model?</i>	That some wildebeest were not getting enough food. We would probably try to go to a different restaurant or place to get some food. Because we all want to eat and do not want to leave anyone out. This could show that wildebeest needed to keep moving in order to make sure that more of them would have food to survive. We could add another sticky note that shows that the wildebeest that are surviving are getting food. We could add another sticky note that shows wildebeest that die are not getting food. We could also move the predation sticky note and connect it to the wildebeest not getting food.

The following image is an example of what your classroom consensus model could look like.



ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- An **absence of patterns** in the data to show that there is **no evidence** to **connect predation and disease to migration**. (SEP: 2.3; CCC: 1.5; DCI: LS2.A.1)
- **Patterns** in the data to use as **evidence** to **model** the connection **between food and migration**. (SEP: 2.3; CCC: 1.5; DCI: LS2.A.1)

What to do: If students have trouble connecting the patterns they observed to wildebeest migration, point them back to the different ideas on the model (disease, predation, food). Have students remind the class why they thought each of the different ideas could be responsible for wildebeest migration. Then have students connect these ideas with the patterns they observed.

3.B Develop a model of wildebeest migration using patterns found in empirical evidence about factors such as predation and food availability. (SEP: 2.3; CCC: 1.5; DCI: LS2.A.1)

10 · DISCUSS WHETHER MIGRATION HELPS WILDEBEEST SURVIVE

5 min

MATERIALS: None

Observe and discuss population data to determine if migration is working. Say, *We now have a model to help us answer the question of why the wildebeest migrate. Our model shows that wildebeest are migrating because of food. We have been looking at data from both living and dead wildebeest. How would we know if the migration is actually helping the wildebeest survive? What evidence would we need to show that migration is helping wildebeest survival?*

***Students should suggest zooming out to look at wildebeest population data.** Display **slide O**. Say, *Let's take a closer look by zooming out from the few wildebeest that were sampled to consider the entire population. Let's look at this data and try to make sense of what it is telling us.* Allow students to observe the data and then bring the class back together for a short discussion.

* SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

This is an opportunity to help students recognize that the significance of a phenomena is dependent on the scale on which it occurs. Throughout the lesson, students have been trying to understand wildebeest migration by looking at a few wildebeest that died. While we figured out a lot of ideas about migration from looking at these wildebeest, students could come to a wrong conclusion that many or most wildebeest are dying. Zooming back out to look at the entire population reminds students that migration is helping most of the wildebeest survive.

Suggested prompt	Sample student response
<i>What do you notice about the overall wildebeest population during this period?</i>	There are a lot of wildebeest!
<i>Dr. Mduma and other scientists collected data from 126 wildebeest carcasses. Do you think they collected data from all the dead wildebeest during that time?</i>	No, they probably missed some, or some of them may have been too far decomposed to collect useful data.
<i>The scientists were only able to collect data from 126 carcasses from 1968-1973. What does that tell you about the number of wildebeest dying in comparison to the size of the total population?</i>	That the number of wildebeest dying must be really small in comparison to the size of the entire population.
<i>Is predation a major factor limiting the wildebeest population? How do you know?</i>	No, predation is not a major factor. Compared to the size of the population, few wildebeest are dying from predation.

11 · NAVIGATE

2 min

MATERIALS: science notebook

Navigate to the next lesson by generating questions about how food connects to wildebeest migration. Display **slide P**. Say, *Okay it seems like we have evidence that shows that most of the wildebeest population is surviving. We also have evidence that the ones that are moving have better nutritional health. We think they are moving because there is not enough food for all of them. Let's think about what questions we need to answer in order to have evidence to show how food is causing the wildebeest migration.* Have students independently capture their new questions in their science notebooks.

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.CONTENT.HSS.IC.B.3 Recognize the purpose of and differences among sample surveys, experiments, and observational studies. ~~explain how randomization relates to each.~~

LESSON 4: How is food driving the wildebeest migration?

PREVIOUS LESSON

We revisited wildebeest migration and brainstormed reasons for why they are migrating. We watched a video of researcher Dr. Simon Mduma to hear what he observed and what data he collected. We looked at wildebeest field data cards for patterns to use as evidence to connect our predictions about why wildebeest migrate. We created data displays to show our findings and shared them. We noticed a connection between nutritional health and wildebeest migration. We wondered how food could be causing wildebeest migration.

THIS LESSON

INVESTIGATION

3 days



Daniel Rosengren

We decide to investigate how food drives the migration. We hear from a scientist that rain is a good way to understand food because it is a limiting factor that affects how much grass there can be. We figure out that there is a wet season and a dry season in the Serengeti and investigate the relationship between rain and wildebeest location. We discover that rain is related to location some of the time but that other factors affect wildebeest location at different times of the year. There are so many factors involved that we wonder how there can be so many wildebeest and decide to investigate this next.

NEXT LESSON

We will use a kinesthetic model to simulate what is happening with food and wildebeest in the Serengeti. We will map our model to the Serengeti system. We will make sense of data collected during our simulation to determine that the amount of food regulates how many wildebeest can survive. We will analyze data from wildebeest populations, which will lead us to conclude that wildebeest migrate to have more food available.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

- 4.A Analyze data using CODAP to determine how seasonal changes in rainfall limit food availability in the Serengeti. (SEP 4.1; DCI: LS2.A.1; CCC: 7.1)
- 4.B Use mathematical representations of empirical evidence related to rainfall and wildebeest location to support claims about the cause of the migration. (SEP: 5.2; DCI: LS2.A.1; CCC: 2.1)
- 4.C Revise a model to include new evidence about factors that affect wildebeest survival to illustrate the patterns and relationships and limits of resources that the wildebeest migration depends on. (SEP 2.3; DCI: LS2.A.1; CCC 3.1)

WHAT STUDENTS WILL FIGURE OUT

- There is a pattern of wet and dry seasons in the Serengeti that repeats each year.
- Rain is a limiting factor that determines how much grass grows, and grass is food for wildebeest.
- There is more rain in the north throughout the year as compared to the rest of the Serengeti.
- Where wildebeest are at each point of the year can be explained by rainfall/food at some points of the year.
- Rainfall does not predict wildebeest presence in all regions of the Serengeti at all times of the year.
- Additional factors that limit and support wildebeest needs explain patterns in their migration.

Lesson 4 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Revisit students' questions about the connection between food and wildebeest migration.	A-C	
2	4 min		INTRODUCE SCIENTIST DR. TONY SINCLAIR Share a video of Dr. Tony Sinclair discussing how he collected data about grass as food for wildebeest.	D-F	
3	4 min		INTRODUCE RAINFALL DATA Share a thirty-year rainfall data set for students to notice and wonder about.	G-I	<i>Investigating Rainfall Data</i>
4	10 min		INTRODUCE DATA EXCURSION PART 1 Introduce students to the Serengeti rainfall data set in CODAP	J-L	computer with internet access, <i>Investigating Rainfall Data</i>
5	12 min		DATA EXCURSION PART 1 Organize students for small-group work with the data set.	M-N	computer with internet access, <i>Investigating Rainfall Data</i>
6	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT RAIN AND FOOD Facilitate a Building Understandings Discussion about the relationship between rainfall and food.	O-P	<i>Investigating Rainfall Data</i>
7	2 min		NAVIGATE Facilitate students in determining next steps.	Q	
<i>End of day 1</i>					
8	3 min		NAVIGATE Lead a brief discussion to determine next steps.	R	<i>Investigating Rainfall Data</i>
9	12 min		INTRODUCE A NEW INVESTIGATION ABOUT RAIN AND WILDEBEEST LOCATION Support students in determining an investigation question and making predictions.	S-U	computer with internet access, <i>Wildebeest and Rainfall</i> , <i>Wildebeest Migration Map</i> , links to students' graphs from day 1, <i>Class Migration Map</i>
10	10 min		WHOLE-CLASS DISCUSSION ABOUT RAINFALL AND WILDEBEEST LOCATION Facilitate a whole-class discussion about the relationship between wildebeest location and rainfall.	V-W	<i>Wildebeest and Rainfall</i> , <i>Class Migration Map</i>
11	5 min		INTRODUCE A NEW DATA SET Introduce students to an additional data set that includes rain and wildebeest location.	X-Z	<i>Wildebeest and Rainfall</i>

Part	Duration		Summary	Slide	Materials
12	10 min		DATA EXCURSION PART 2 Introduce Data Excursion Part 2 in CODAP	AA-BB	<i>Wildebeest and Rainfall</i>
13	5 min		NAVIGATE Ask students to complete an exit ticket by using patterns to support claims.	CC	<i>Wildebeest and Rainfall</i>
<i>End of day 2</i>					
14	2 min		NAVIGATE Facilitate students in determining graphical relationships.		<i>Wildebeest and Rainfall</i>
15	5 min		MAKE SENSE OF RELATIONSHIPS IN GRAPHS Support students in describing relationships in graphs.	DD-FF	
16	3 min		INDIVIDUALLY REVISE RESPONSES Ask students to revise their responses to the day 2 exit ticket.	GG	<i>Wildebeest and Rainfall</i>
17	5 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT RAINFALL AND WILDEBEEST MIGRATION Facilitate a Building Understandings Discussion about the relationship between rainfall and wildebeest location.	HH	<i>Wildebeest and Rainfall</i>
18	10 min		EXPLORE MORE ABOUT EACH REGION Organize small groups to make sense of regional data.	II-JJ	<i>Regional Data Notecatcher, Regional Data Cards, Regional Data Cards</i>
19	8 min		CONSENSUS DISCUSSION ABOUT DIFFERENCES IN REGIONS Facilitate a Consensus Discussion to answer our lesson question.	KK	<i>Regional Data Notecatcher</i>
20	8 min		UPDATE CLASS CONSENSUS MODEL Ask students to update the class consensus model.	LL	<i>Regional Data Notecatcher, class consensus model</i>
21	4 min		NAVIGATE Celebrate figuring out what drives the migration and motivate thinking about the size of the wildebeest population.	MM	
<i>End of day 3</i>					

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Investigating Rainfall Data</i> • computer with internet access • <i>Wildebeest and Rainfall</i> • <i>Regional Data Notecatcher</i>	• <i>Wildebeest Migration Map</i> • <i>Regional Data Cards</i> • Regional Data Cards	• links to students' graphs from day 1 • Class Migration Map • class consensus model

Materials preparation (40 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole punch all handouts so that they can be added to students' notebooks.

Make sure you can open the CODAP files <https://www.openscienced.org/general/dataexcursion1/> and <https://www.openscienced.org/general/dataexcursion2/> on student devices. Spend some time familiarizing yourself with the contents of the datasets and possible visualizations for completing the data excursions. In addition, familiarize yourself with relevant features of CODAP by watching <https://youtu.be/Y18TcxbiAk>.

Ensure that there is an internet-connected device that can run CODAP for groups of three students to share.

Watch <https://www.youtube.com/watch?v=75W8OB9xPE8> to familiarize yourself with the provided Google Form system for saving student CODAP files found here: https://docs.google.com/forms/d/1ikJBSMgDTlxrw4Zi2fraTMXMD5Aolj3qA_OY39kckjs/copy

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build on a middle school understanding about how the growth of organisms and populations is limited by access to resources (MS LS2.A) to understand how these limits result from the availability of living and nonliving factors. ~~Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.~~ (HS LS2.A)

Mathematics and computational thinking are intentionally developed in this lesson as students use mathematical representations (graphs) to support claims and explanations. They build on the middle school grade band use of this practice, in which students use the representations to support and describe their conclusions. Scaffolds are built in to help students identify relationships in scatter plots that can be used as evidence.

Students also use *stability and change* to look at seasonal changes over time to recognize patterns that repeat each year. They build on middle school use of this crosscutting concept, in which they examine changes over time and at different scales and build on their prior use in this unit. Students worked with *stability and change* in Lessons 2 and 3 to make sense of changes over time and instances of stability in the Serengeti system.

Students co-construct a definition for limiting factors. Students should co-construct this definition after they have developed a shared understanding of its meaning.

Where We Are NOT Going

Students are not identifying the carrying capacity of the wildebeest population. They will use the ideas they figured out in this lesson and in Lesson 3 about limiting factors to build a complete understanding of carrying capacity and HS LS2.A in Lesson 5.

When students create a graphical representation in CODAP, it is not necessary that they identify the independent and dependent variables or focus on which variables should go on which axis. In later units, students will develop their use of analyzing and interpreting data and cause-and-effect and will figure out how variables can be selected to model relationships in graphs.

LEARNING PLAN for LESSON 4

1 · NAVIGATE

5 min

MATERIALS: science notebook

Revisit students' questions about the connection between food and wildebeest migration. Display **slide A**, which represents a model of what students have figured out so far about what drives the wildebeest migration. If your classroom model is different, refer to the model your students developed during Lesson 3.

Turn and Talk. Have students open their science notebooks, take two minutes to discuss with a partner what they figured out during the last class, and share the questions they had about the connection between food and wildebeest migration.

Whole-class discussion. Use the following prompts to facilitate a short, whole-class discussion. Display **slide B**, which shows images of wildebeest grazing on grass, as a visual reminder to the class that wildebeest eat grass. Lead a whole-class discussion using the prompts below and on **slide C**.

Suggested prompt	Sample student response
<i>What did we figure out last time about the factors that drive the wildebeest migration?</i>	We figured out that disease and predation are not likely main causes of the wildebeest migration. We figured out that food/nutrition seems to drive wildebeest migration. The wildebeest that died were not getting enough food, so we thought they might be moving to get more food.
<i>What questions did we have about food and wildebeest migration?</i>	What do wildebeest eat? Does it matter what kind of grass wildebeest eat? When we looked at the habitat map, it seemed like there is grass everywhere, so why do the wildebeest have to migrate? How exactly does food cause wildebeest to migrate?
<i>We think that wildebeest migrate to get more food and that the migration happens in the same pattern every year. What could be causing the pattern? Why do they go to the same place at the same time of year?</i>	Maybe there is more food in certain places at certain times. Maybe the grass grows at different times of years in different places. Maybe there is something in the way (like a mountain or forest) that keeps them from going anywhere else or that keeps grass from growing.

Suggested prompt	Sample student response
<i>Which factors could we investigate to help us understand this pattern of migration?</i>	Maybe the seasons are causing the pattern. Maybe grass only grows in certain places. Rain. Temperature.

2 · INTRODUCE SCIENTIST DR. TONY SINCLAIR

4 min

MATERIALS: science notebook

Introduce Dr. Tony Sinclair. Display **slide D**. Let students know that Dr. Sinclair spent his whole career as a scientist studying the Serengeti and that he worked with Dr. Simon Mduma, whom we heard from in Lesson 2. Say, *Just like you, Dr. Sinclair and some of the other Serengeti scientists had some ideas about how rain might help them understand food.*

Share a video of an interview with Dr. Sinclair. Display **slide E**. Ask students to take out their science notebooks and create a Notice and Wonder chart to jot down their ideas during the video. Ask them to pay attention to anything Dr. Sinclair shares that could help them answer the lesson question about how food drives the wildebeest migration. Play <https://www.youtube.com/watch?v=XIFCc8gsl9Q>.

Whole-class discussion about the video. Display **slide F**. Lead the class in a short discussion to share the ideas they heard in the video.

Suggested prompt	Sample student response
<i>What ideas did Dr. Tony Sinclair share that can help us make progress on our question: How does food drive the wildebeest migration?</i>	Rainfall is easier to measure than grass in a large area like the Serengeti. Scientists established that more rainfall causes more grass to grow. Rainfall can help us know how much food there is for the wildebeest. Rainfall was measured using a set of rain gauges in an area.
<i>What is the relationship between food (grass) and rain in the Serengeti?</i>	The rain is something the grass needs to grow. The amount of grass depends on the amount of rain.
<i>Today, scientists can measure food, by fencing off a small area and studying it. What might make it hard to measure food directly even today across the whole Serengeti?</i>	The scales are very different, and we cannot likely measure all of the Serengeti. We would have to sample, because the scale of the Serengeti is so big.

3 · INTRODUCE RAINFALL DATA

4 min

MATERIALS: science notebook, *Investigating Rainfall Data*

Introduce rain gauge locations for data collection. Say, *Since we have this idea that rain can help us figure out how much food there is, I found some data from the rain gauges around the Serengeti. Even with rainfall, we have to select a few carefully chosen locations to measure rainfall, because the scale of the Serengeti is so big. These locations were chosen because they look very different from one another but all have wildebeest at some times in the year.* Display **slide G** and let students know that you found a data set that measured rainfall data over 30 years in the Serengeti at three different locations. Point to the stars on the map, which indicate the locations the rain data was collected. The three locations are:

- Simiyu in the south
- Handejega in the west
- Kotentende in the north

Whole-class sensemaking of rainfall data set. Display **slide H**. Distribute *Investigating Rainfall Data* to each student. Give students a moment to review the graph on the slide and jot down ideas they have to answer question 1. Then call on a few students to share. Listen for students to share that each data point represents the average amount of rain that fell in the Serengeti at that location during that month over the 30-year period from 1961-1990.

Individual sensemaking of rainfall data. Display **slide I**. Give students a moment to jot down answers to questions 2 and 3 on their handouts individually and call on a few students to share their thinking.

Suggested prompt	Sample student response
<i>What do you notice?</i>	There is a pattern of several months with a lot of rain and a pattern of several months with a little rain. There is more and less rain at different times of the year. There is a lot of rain in April and very little rain in July.
<i>What questions can this data help us answer about grass (wildebeest food)?</i>	Is there more food (grass) in April and less in July? Is there more food for wildebeest at certain times of the year?

ADDITIONAL GUIDANCE

To help students make sense of the rainfall data, consider asking them about local seasonal rainfall patterns where you live. Ask, *Is there a season that has more or less rain than another? And, How much rainfall do we get here during different seasons?* Rainfall data for many states can be found at <https://hdsc.nws.noaa.gov/hdsc/pfds/>

For additional information about rainfall data in the Serengeti see <https://climateknowledgeportal.worldbank.org/>.

4 · INTRODUCE DATA EXCURSION PART 1

10 min

MATERIALS: computer with internet access, *Investigating Rainfall Data*

Reorient to rain data collection location. Say, *Now we know that our ideas about rain are similar to the ideas scientists had about how rain can help us understand food. We looked at rainfall data from Handajega in the west and saw that there was a pattern, but what about the rest of the Serengeti?* Display **slide J** and remind them of the location of the rain gauges. Remind them that we have two additional data collection sites in the Serengeti where rainfall data was collected.

Introduce CODAP. Let students know that they will be using a digital data platform called CODAP to make sense of data. Display **slide K** and play <https://youtu.be/1Y18TcxbiAk> to demonstrate to students how to build a graph using CODAP.

Model relevant CODAP features. To provide students with enough knowledge of CODAP to start their investigation, you may want to walk through some of the key steps with students once they are in their groups and have CODAP open on their computers. Use the following as a guide of what to demonstrate to students:

1. Add an attribute to the X or Y axis.
2. Add "location" at the top of the graph in order to show the data for each location in a separate graph arranged next to one another.
3. Select or hide cases.
4. Encourage students to make multiple graphs; tell them that CODAP allows you to have multiple graphs on the screen at once.
5. Show how to minimize graphs so you can save multiple graphs on the same screen.
6. Demonstrate how to make a shareable link and how to copy and paste that link into a Word or Google document for later access or make a copy of the Google form https://docs.google.com/forms/d/1ikjBSMgDT1xrw4Zi2fraTMXMD5Aoji3qA_OY39kckjs/copy

Decide on an investigation question as a class. Display **slide L**. Say, *Earlier you had ideas about what questions the rainfall data could help us answer. Now that we have a data set with 30 years of rainfall data from three locations to investigate, what question should we answer?* Discuss as a class what question(s) can be answered by adding in the other two locations. Possible questions include:

- What are the annual rainfall patterns across different regions of the Serengeti?
- How is rainfall the same or different in different regions of the Serengeti?

Once the class has decided on a question, ask students to record it in *Investigating Rainfall Data* under question 5.

* SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Support students in generating investigation questions that are open. Open questions cannot be answered with a simple yes or no and give you space to figure out more things. Students may pose an investigation question such as, *Do the wildebeest follow the rain?* Support them in revising this question to be more open with the following sentence stems.
How does ... ?
Why does ... ?
What happens when ... ?
What happens if ... ?
Refer to *Supporting Questioning* for additional support.

5 · DATA EXCURSION PART 1

12 min

MATERIALS: computer with internet access, science notebook, *Investigating Rainfall Data*

Small groups work on Data Excursion Part 1. Organize students into small groups of 2-4. Make sure each group has access to an internet-connected device that can run CODAP. Display **slide M** and point students to the tinyURL address for <https://www.openscienced.org/general/dataexcursion1/>. Give small groups about 10 minutes to create graphs that show rainfall across the three locations, and record their ideas for questions 6-8 in *Investigating Rainfall Data*. Tell students to be prepared to share the graph(s) that helped them answer the investigation question.

Save student CODAP files. Display **slide N**. Direct groups to make a shared link of their CODAP file and copy and paste it in a document that you can access. One way to do this is by using the links found in the Google form link: https://docs.google.com/forms/d/1ikjBSMgDT1xrw4Zi2fraTMXMD5Aoji3qA_OY39kckjs/copy. If you decide to collect files using the Google form, watch <https://www.youtube.com/watch?v=75W8OB9xPE8> to familiarize yourself with a provided system for collecting and organizing student links. This can be a way for you to access students' graphs in order to display them as they share. Students may also use their saved files on day 2.

6 • BUILDING UNDERSTANDINGS DISCUSSION ABOUT RAIN AND FOOD

8 min

MATERIALS: *Investigating Rainfall Data*

Facilitate a Building Understandings Discussion. * Display slide O. Use the prompts below to guide the class in sharing their responses to the questions on *Investigating Rainfall Data*.

Suggested prompt	Sample student response
What patterns do you notice?	I see two clusters. There seems to be more rainfall from January to May and less rainfall from June to December. There is a steady increase in rain amount from October to December.
What questions can this data help us answer about the relationship between rainfall and grass?	There are some months with less rain than others. This could mean there are months with more or less grass, depending on the amount of rainfall. These data tell us that there is little rain in the plains from June to September, which means that there could be less grass then.

KEY IDEAS

Purpose of this discussion: To identify patterns in rainfall that can be used as evidence to support claims about the availability of grass.

Listen for these ideas:

- There is a wet season and a dry season.
- There is more rain between November and April.
- There is less rain between May and October.
- There is always more rain in the north.
- If there are seasonal differences in rain, there will be seasonal differences in grass availability.

Update personal glossaries. Display slide P. Say, *As you talked about the relationship between rainfall and grass, you all described how rainfall is a factor that determines how much grass can grow. Scientists call these **limiting factors**.* Give students a moment to jot down ideas for what they would include in a definition of limiting factors. Call on a few students to share their thinking and build a class definition of limiting factors on a public space like the whiteboard. Give all students a moment to record the class definition in their personal glossaries.

ADDITIONAL GUIDANCE

A sample personal glossary entry for limiting factors may look like:
A limiting factor is a resource that lets something living grow if there is a lot of it or keeps it from growing if there is not a lot of it. Rain is a limiting factor for grass.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence. As students share, encourage them to use evidence from the graphs they generated in CODAP to support their ideas. Your role during the discussion is to invite students to share conclusions and claims and push them to support their conclusions and claims with evidence. Students can disagree with each other, and the class does not need to reach consensus on all ideas shared. Areas of disagreement can motivate future investigations. Helpful prompts during these kind of discussions include:

- What can we conclude?
- How did you arrive at that conclusion?
- What's your evidence?
- Does any group have evidence to support Group A's claim?
- What data do we have that challenges Group B's claim?

7 · NAVIGATE

2 min

MATERIALS: science notebook



Complete exit ticket. Ask students to turn to a blank sheet of paper in their science notebooks. Display **slide Q**, which contains four candidate claims that students could answer using the data they investigated in today's lesson. Students should write the letter of the option they can support and then provide evidence to support their choice. Once students have had time to make their choice and explain their evidence, ask students to write down what they think we still need to know to figure out how food drives the wildebeest migration. Have students turn in their responses to these two prompts.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Evidence to support the following claims (SEP 4.1):

- A. There is a **wet season** and a **dry season** that **repeat each year**, with the most rain around April and the least around July. **More rain means more grass and vice versa.** (DCI LS2.A.1; CCC 7.1)
- B. There is no evidence to support this claim.
- C. The pattern was similar for all three regions but the **rainfall amounts were always slightly higher** for the north in each month, so there should be **more grass there** all year long. (DCI LS2.A.1; CCC 7.1)

What to do:

Collect student exit tickets. Sort them into at least three piles.

Pile 1: Students do not correctly identify options A and C as claims they can support with evidence.

Pile 2: Students correctly identify options A and C but do not provide adequate evidence.

Pile 3: Students correctly identify options A and C and provide adequate evidence.

Use the piles to strategically group students into heterogeneous groups on day 2.

Building toward 4.A Analyze data using CODAP to determine how **seasonal changes** in **rainfall limit food availability** in the Serengeti. (SEP 4.1; DCI LS2.A.1; CCC 7.1)

End of day 1

8 · NAVIGATE

3 min

MATERIALS: science notebook, *Investigating Rainfall Data*

Connect to students' ideas from yesterday. Draw upon students' responses to the exit ticket. Say, *Yesterday, we were able to figure out from the data that there is a wet and a dry season and that there is more rain in the north. You all said you wanted to find out how the rain data connected to the wildebeest migration. What ideas do you have for how we will investigate that?* Display **slide R** and use the prompts below as a guide.

Suggested prompt

What did we figure out yesterday from the data we investigated?

Sample student response

There is a wet and a dry season each year.

Some months are rainier than others.

It is always more rainy in the north.

Suggested prompt	Sample student response
<i>What did we decide to investigate next?</i>	We wanted to find out how the rain was related to the location of the wildebeest.
<i>What ideas do you have for how to investigate that?</i>	We can use the maps we saw in Lesson 2 to figure out where they are during different months. We can find out more about where the wildebeest are at different times of the year.

9 · INTRODUCE A NEW INVESTIGATION ABOUT RAIN AND WILDEBEEST LOCATION

12 min

MATERIALS: computer with internet access, *Wildebeest and Rainfall*, *Wildebeest Migration Map*, links to students' graphs from day 1, Class Migration Map

Decide on an investigation question as a class. Display slide S. Distribute *Wildebeest and Rainfall*. Remind students that when we investigated data on day 1, we started with an investigation question. Ask students to recall the qualities of a good investigation question (i.e., open vs. closed). Possible investigation questions include:

- What is the relationship between wildebeest location and rain?
- How can the rainfall help predict where the wildebeest will be?

Once the class has agreed on a question, record it on the whiteboard or other public space and have students record the question in *Wildebeest and Rainfall* under question 1.

Make a prediction about where the wildebeest will be based on rainfall data. Display slide T, which shows the rainfall data students investigated on day 1 with all three locations on the same graph. Students can also reference the graphs they made on day 1 in CODAP. Say, *Let's make a prediction using the rainfall data. Is there a data point or a trend we can draw upon to start our prediction?* Support students in starting with something that they now know based on the rainfall data to make a prediction about something they do not know yet. One suggestion is to start with the highest data point - April - and then say, *We can see how April has the highest amount of rainfall in the Serengeti. Where would you predict the wildebeest would be in April?*

ADDITIONAL GUIDANCE

Starting with the April data point is just one suggestion for guiding this conversation. If students are interested in starting with a different pattern or data point, support them in making predictions related to that point and adjust the image on slide T accordingly.

Student predictions will likely focus on the relationship between rain/food and the wildebeest. If students choose April, they will likely predict that the wildebeest will be in Kogatende, the north, where the rainfall is highest in that month.

Record predictions. Ask students to write down their prediction in *Wildebeest and Rainfall* and then call on a few students to share their ideas. Then ask students to think about how they can find evidence to support their predictions. Listen for students to identify the migration map as a place to look.

Turn and talk about the migration map. Display slide U and reference the laminated classroom migration map. Ask the students to turn and talk to a partner about how the evidence in the migration map relates to their prediction. If available, hand out *Wildebeest Migration Map* to each pair.

Complete Making Sense questions. Ask students to complete the Making Sense questions in *Wildebeest and Rainfall*. Call on a few pairs to share.

Suggested prompt	Sample student response
How does the migration map relate to your prediction?	We predicted that the wildebeest would be in the north in April because April has the most rain and there is more rain in the north. We thought there would be more rain where there was more food, so they would be in the north in April. We found out that there are wildebeest in the south in April, even though there is less rain.
Does quantity of rain matter for whether we can find wildebeest in a region in a given month?	No, we do not see a clear quantitative relationship here. It is more complex than that. The exact quantity does not help us explain migration patterns.

Mark up the migration map as a class. Say, *It sounds like the evidence from the map did not answer our investigation question. Let's take a minute to mark up the map with what we do know. What can we add to the migration map?* Listen for responses such as:

- June to November is the dry season and December to May is the wet season.
- The dry season probably has less grass and the wet season probably has more grass.
- April is the rainiest month, and the north is the rainiest area.

Illustrations created by OpenSciEd in BioRender, Data Source: Giovanni Tombazzi's Serengeti maps in cooperation with Hoopoe Adventure Tours

10 · WHOLE-CLASS DISCUSSION ABOUT RAINFALL AND WILDEBEEST LOCATION

10 min

MATERIALS: *Wildebeest and Rainfall*, Class Migration Map

Whole-class discussion. Display **slide V**. Use the prompts below to guide the class in sharing their responses related to the investigation question on *Wildebeest and Rainfall*.

Suggested prompt	Sample student response
<i>What did we come up with as an answer to our investigation question?</i>	We do not seem to see a relationship between rainfall and where the wildebeest will be. The pattern of rainfall does not seem to help us predict where the wildebeest will be.
<i>What were we able to figure out by looking at the rainfall data with the migration map together?</i>	The wildebeest are in the south during the wet season and in the west and the north in the dry season.

Turn and Talk. Display **slide W**, which shows the map with the rain gauges next to the map of the migration. Say, *The rainfall data was measured at three locations, and the wildebeest location is all over the Serengeti, which is 5,700 square miles. The wildebeest data was observational, so we know generally where they were at different times, but we do not have a count. What additional data could help us answer our question about the relationship between rainfall and wildebeest location?* Give students time to discuss these questions with a partner and call on a few pairs to share.

Listen for response such as:

- We need more rainfall data from more places.
- We need a count of the wildebeest.

11 · INTRODUCE A NEW DATA SET

5 min

MATERIALS: science notebook, *Wildebeest and Rainfall*

Introduce a new data set. Say, *You suggested investigating with more data. I found a data set that had more rain gauge data, and it counted exactly where the wildebeest were each month for 13 years.* Review the features of the data set shown on **slide X**.

Turn and talk to make sense of the data set. Display **slide Y** and review what one row in the data set means. For example, in a single year when there was 1160 mm of rainfall in the south, the wildebeest were there 52% of the time. Ask students to turn and talk to a partner and record the meaning of the data in words for the west and the north in their science notebooks. Call on a few students to share their thinking and support students on building consensus toward the following:

- In a single year when there was 1180 mm of rainfall in the west, the wildebeest were there 26% of the time.
- In a single year when there was 1310 mm of rainfall in the north, the wildebeest were there 6% of the time.

Introduce Data Excursion Part 2 in CODAP. Display **slide Z** and let students know that you have imported the data set for the data they just reviewed into CODAP. Say, *We know that rainfall predicts grass, or the wildebeest's food. We think that food should predict where the wildebeest will be, but so far we have not seen evidence to support that relationship. Let's remind ourselves of our investigation question and jot that down in *Wildebeest and Rainfall* under Data Excursion Part 2.* You can use the same investigation question used with the previous activity of looking at the map data. An example of what this question looks like is, *What is the relationship between rainfall (food) and wildebeest location?*

ADDITIONAL GUIDANCE

This data set was generated from aggregated rainfall and wildebeest location data displayed as scatter plots in Figure 12 in Pennycuick (1975). For more information see: Pennycuick, L. (1975). Movements of the migratory wildebeest population in the Serengeti area between 1960 and 1973. *African Journal of Ecology*, 13(1), 65-87.

12 · DATA EXCURSION PART 2

10 min

MATERIALS: *Wildebeest and Rainfall*

Small groups work on Data Excursion Part 2. Organize students into small groups of 2–4; consider drawing on the exit ticket responses to form heterogeneous groups based on students' abilities to support claims with adequate evidence. Make sure each group has access to an internet-connected device that can run CODAP. Display **slide AA** and point students to <https://www.openscienced.org/general/dataexcursion2/>. Give small groups about 5 minutes to create graphs that show annual rainfall and wildebeest percentage occupancy across the three locations, and record their observations in question 6 in *Wildebeest and Rainfall*. Tell students to be prepared to share the graph(s) that helped them answer the investigation question. *

Save student CODAP files. Display **slide BB**. Direct groups to make a shared link of their CODAP file and copy and paste it in a document that you can access or use the same Google form you used on day 1. This can be a way for you to access students' graphs in order to display them as they share. Students may also use their saved files on day 3.

* SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students use empirical evidence collected from observations of wildebeest occupancy and rainfall. Remind them that they used empirical evidence in Lesson 3 when they investigated mortality patterns. Here, students begin to distinguish between *correlation*, that rainfall pattern and wildebeest location are related, and *cause*, that the rainfall pattern causes wildebeest migration.

13 · NAVIGATE

5 min

MATERIALS: *Wildebeest and Rainfall*



Complete exit ticket. Display **slide CC**. Have students discuss question 7 in *Wildebeest and Rainfall* with their small groups and then complete it individually. Students will need to draw upon the patterns they see in the graphs they made to support or contradict the two claims about annual rainfall and wildebeest location.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Evidence to support or contradict the following claims drawing on patterns identified from mathematical representations (SEP 5.2; CCC 2.1):

- The scatter plot for the south region shows a positive relationship between annual rainfall and wildebeest occupancy, so this claim is supported by the data. Students do NOT need to use the word positive, but look for the conceptual recognition of the upward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1)
- The scatter plot for the west and north regions show a negative relationship between annual rainfall and wildebeest occupancy, so this claim is not supported by the data. Students do NOT need to use the word negative, but look for the conceptual recognition of the downward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1)
- When comparing the scatter plots for all three regions, we can see that the wildebeest are spending more time in the west and in the south based on the higher values for wildebeest percentage occupancy. (SEP 5.2; DCI LS2.A.1; CCC 2.1)

What to do:

- Collect *Wildebeest and Rainfall* from each student. Circle places where students missed opportunities to identify patterns or relationships as represented in the graphs to support or contradict claims in question 7. Students will have an opportunity to revise their responses on day 3.
- At the beginning of day 3, use slides DD-EE to support students in understanding positive and negative relationships to help describe the pattern in the data.

Building toward 4.B.1 4.B Use mathematical representations of empirical evidence related to rainfall and wildebeest location to support claims about the cause of the migration. (SEP: 5.2; DCI: LS2.A.1; CCC: 2.1)

End of day 2

14 · NAVIGATE

2 min

MATERIALS: *Wildebeest and Rainfall*

Connect to students' ideas from yesterday. Return *Wildebeest and Rainfall* to students collected at the end of day 2. Say, *We ended yesterday by seeing if we could notice the patterns in the data that could help us support or contradict claims about the relationship between rainfall and wildebeest percentage occupancy for each region. Let's come to consensus on how to describe the patterns or relationships we see in our graphs.*

15 · MAKE SENSE OF RELATIONSHIPS IN GRAPHS

5 min

MATERIALS: None

Describing graphical relationships. Say, *In your responses yesterday in your exit tickets, some of you described relationships as being positive or negative.* Display slide DD and ask students to describe the relationships they see on the graph. Listen for students to describe the relationships as positive, negative, and no relationship.

Display slide EE and say, *Another thing I saw in some of your responses were descriptions such as stronger and weaker. Let's take a look at some examples. What are the differences between stronger and weaker relationships?* Listen for student responses such as:

- The stronger ones are more in a line.
- The weaker ones are more spread out.

* SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

For students who quickly grasp the idea of positive and negative relationships between variables in graphs, you can prompt them to consider how the slope of a best fit line differs between graphs and how they could

Turn and talk about relationships in graphs. Display slide FF, which shows a sample set of graphs created in CODAP for Data Excursion Part 2. Ask students to turn and talk to a partner about the kinds of relationships they see in the graph for each region. Then call on a few pairs to share using the prompts below. *

Suggested prompts	Sample student responses	Follow-up questions
<i>What relationship do you see in the north?</i>	It looks like there is a negative relationship between the wildebeest percentage occupancy and the total annual rainfall. This negative relationship appears to be stronger than the one in the west because the points seem to be clustered closer together.	<i>What everyday examples can you think of where two things are related in the same way as in the graph?</i> <i>Can you think of two things that decrease together?</i> <i>How is the day of the week (Monday-Friday) related to the amount of energy you have?</i>
<i>What relationship do you see in the south?</i>	It looks like there is a strong positive relationship between the wildebeest percentage occupancy and the total annual rainfall.	<i>What everyday examples can you think of where two things are related in the same way as in the graph?</i> <i>Can you think of two things that increase together?</i> <i>How are time of day and temperature related?</i>
<i>What relationships do you see in the west?</i>	It looks like there is a negative relationship between the wildebeest percentage occupancy and the total annual rainfall. The relationship is weaker than the relationship in the north.	<i>Which one of the other locations is it similar to?</i> <i>How is it different from the relationship in the north?</i>
<i>What did you notice about wildebeest percentage occupancy for each region?</i>	I see that the highest values for wildebeest percentage occupancy are in the south, followed by the west, then the north.	<i>What is the range of values for wildebeest percentage occupancy for each region?</i>
<i>What can we infer from data at the regional scale across all three regions that can help us understand the phenomenon of migration across regions?"</i>	The relationships are variable across regions, so it is hard to tell. There is a greater quantity of rain and water in general, where there is a weak or negative relationship between rainfall; and percentage occupancy. Maybe that is evidence that rainfall still matters for the overall pattern, even though it is different by region.	<i>Why is it important to look at data at both the scale of a region and the scale of the whole system?</i>

interpret that difference. For example, both the west and north have negative slopes, but the north has a slightly greater value (-0.015) than the west (-0.012). The slope for the positive relationship in the north is 0.03 . Prompt students to think about the meaning of those differences and how the scatter of the points factors into interpreting each relationship. Ask them to consider which graph has more scatter around a best fit line.

Students can also use CODAP to plot the function by selecting the ruler tool and choosing the plotted function checkbox.

ADDITIONAL GUIDANCE

If your students need additional scaffolding in interpreting mathematical representations, draw on everyday examples by asking them to think about two things that increase or decrease together.

Possible examples:

- Positive: time of day (morning to afternoon) and temperature; number of flowers in a garden and number of pollinators; number of ice cream sales and number of visitors to swimming pools.
- Negative: week day (Monday -> Friday) and amount of energy I have; number of hot cocoa sales and number of ice cream sales.
- No relationship: amount of homework I have and how much my cat meows.

When returning to the graphs for each region in the Serengeti on **slide FF**, support students in considering what an informal line of best fit would look like in the graphs for each region. This can help students see an overall pattern or trend in the scatter plot for each region.

16 · INDIVIDUALLY REVISE RESPONSES

3 min

MATERIALS: *Wildebeest and Rainfall*



Students individually revise their responses. Display **slide GG**. Now that the class has developed some shared language around describing graphical relationships, give students a few minutes to revise their responses to question 7 in *Wildebeest and Rainfall*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Evidence to support or contradict the following claims drawing on patterns identified from mathematical representations (SEP 5.2; CCC 1.4):

- The scatter plot for the south region shows a positive relationship between annual rainfall and wildebeest occupancy, so this claim is supported by the data. Students do need to use the word "positive," but look for the conceptual recognition of the upward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1)
- The scatter plots for the west and north regions show a negative relationship between annual rainfall and wildebeest occupancy, so this claim is not supported by the data. Students do need to use the word "negative," but look for the conceptual recognition of the downward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1)
- When comparing the scatter plots for all three regions, we can see that the wildebeest are spending more time in the west and in the south based on the higher values for wildebeest percentage occupancy. (SEP 5.2; DCI LS2.A.1; CCC 2.1)

What to do:

- Collect *Wildebeest and Rainfall* from each student. Provide written feedback to students related to the evidence they used from the graphs to support or contradict each claim. For example:
 - Is the relationship positive or negative, and how do you know?
- If students need additional support, partner them with a peer to review feedback and revise.
- Provide students with an opportunity to describe the relationship verbally, rather than in writing.

Building toward 4.B.2 4.B Use mathematical representations of empirical evidence related to rainfall and wildebeest location to support claims about the cause of the migration. (SEP: 5.2; DCI: LS2.A.1; CCC: 2.1)

17 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT RAINFALL AND WILDEBEEST MIGRATION

5 min

MATERIALS: *Wildebeest and Rainfall*

Facilitate a Building Understandings Discussion. Say, *Let's make sense of the relationships we described in our graphs and figure out what they can tell us about the migration.* Display **slide HH** and use the prompts below as a guide.

Suggested prompt	Sample student response
<i>What relationships did we see in our graphs?</i>	In the south region, there is a positive relationship between annual rainfall and wildebeest occupancy. In the north and west, there is a negative relationship between annual rainfall and wildebeest occupancy. The wildebeest spend the least amount of time in the north and the most amount of time in the south.
<i>What can these relationships at the scale of the region tell us about wildebeest, rain, and food across the whole Serengeti?</i>	Wildebeest spend the wet season in the south, even though that is not the place with the most rain. Wildebeest leave the south when the wet season ends and head to the west and then the north before returning. They go to the north last, which has more rain all the time even when it is dry.
<i>What do we still need to figure out?</i>	Is there something special about the south related to why they are there in the wet season even when there is more rain in the north? Why would the wildebeest leave the north, where there is more rainfall all year?
<i>How can we find answers to these questions?</i>	We can read more about these different regions. We can look at data from each of these regions to try to figure out how they are different.

18 · EXPLORE MORE ABOUT EACH REGION

10 min

MATERIALS: *Regional Data Notecatcher, Regional Data Cards, Regional Data Cards*

Introduce Regional Data Cards. Say, *It sounds like you want to investigate more about each one of these regions so we can find out more about them.* Distribute *Regional Data Notecatcher* to each student and let students know you found additional information for them to investigate. Display **slide II**.

Small-group sensemaking about regional data. Display **slide JJ**. Organize students into small groups of 3-4 and give each group a set of laminated cards or print outs you made from *Regional Data Cards*. Instruct groups to use the material on the cards to answer the questions on *Regional Data Notecatcher*.

19 · CONSENSUS DISCUSSION ABOUT DIFFERENCES IN REGIONS

8 min

MATERIALS: *Regional Data Notecatcher*

Say, *Let's come to a consensus on how this new information, combined with what we learned from the Data Excursions helps us answer our lesson question, How is food driving the wildebeest migration?* Display **slide KK** and use the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>We had already described the relationship between wildebeest location and rain in each region. Can someone summarize that for us?</i> <i>We had questions about what was special about each of the regions. What did you find out about the north?</i>	It was positive in the south and negative in the north and the west. There is more rain there all the time. There is a river for drinking water. The grass is not as nutritious. The wildebeest leave the north for the south when the wet season starts.	<i>What do wildebeest do when they are in this region?</i> <i>What factors limit how long the wildebeest stay in this region?</i>
<i>What did you find out about the west?</i>	The grass is more nutritious during the dry season than during the wet season because when the soil is drier, the grass stores nutrients in the blades rather than in the roots. In the wet season, it is muddy and hard for the wildebeest to walk. The wildebeest leave when fires happen in July or the food dries up. There are predators.	<i>What do wildebeest do when they are in this region?</i> <i>What factors limit how long the wildebeest stay in this region?</i>
<i>What did you find out about the south?</i>	The grass is the most nutritious here because the best soil is here. The wildebeest all give birth here. They are more protected from predators.	<i>What do wildebeest do when they are in this region?</i> <i>What factors limit how long the wildebeest stay in this region?</i>

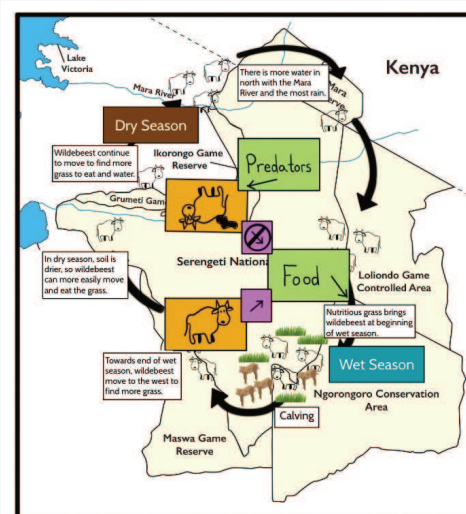
Suggested prompts	Sample student responses	Follow-up questions
<i>How can we put that all together to answer our lesson question, How is food driving the wildebeest migration?</i>	Rain/food drives the migration, but it is a little more complicated than that. The wildebeest are in the south when it is the wet season because that is where the nutritious grass is and they can give birth safely. They move to the west and eat some nutritious grass there, but there are predators and fire, and they run out of grass. They go to the north because there is water there and more rain, but the grass is not nutritious, so as soon as it starts raining, they leave for the south.	<i>If there was not a wet and a dry season and it rained a little all year, what do you think would happen?</i> <i>How can you put together what you figured out from data at the regional scale to understand the migration at the scale of the whole system?</i>

20 · UPDATE CLASS CONSENSUS MODEL

8 min

MATERIALS: *Regional Data Notecatcher*, class consensus model

 **Revise the class consensus model.** Display slide LL. Say, *What can we add to our class consensus model to help us see how all of this fits together and how we better understand what drives the wildebeest migration?* Give students a few moments to turn and talk to a partner and then call on a few pairs to share.



ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Model revisions that include the following evidence: (SEP 2.3)

- Wildebeest are in the south during the wet season, even though that is not where the most rain is. (DCI LS2.A.1; CCC 3.1)
- Wildebeest give birth in the south during the wet season, and that is where the best, most nutritious food is due to the richest soil and also where they can see their predators. (DCI LS2.A.1; CCC 3.1)
- The wildebeest move on to the west when the wet season is ending in search of other grass. (DCI LS2.A.1; CCC 3.1)
- During the dry season, the soil in the west is drier, making it easier for the wildebeest to walk through and making the grass more nutritious during that time. (DCI LS2.A.1; CCC 3.1)
- The north has the most rain, but it has less nutritious grass, so the wildebeest only go there in the dry season, when there is no food in the south. (DCI LS2.A.1; CCC 3.1)
- The Mara River is in the north, which provides water year round. (DCI LS2.A.1; CCC 3.1)
- Looking at small-scale relationships can help us understand the pattern of migration at the scale of the Serengeti ecosystem. (CCC 3.1)

What to do:

Have students refer back to their responses in *Regional Data Notecatcher*; ask,

Why might the wildebeest go to each region?

What limits how many wildebeest this region can support?

Why do they leave? Support students in noticing the limiting factors of each region that contribute to the wildebeest migration.

Consider also connecting back to the takeaways from Data Excursion Part 2 to recall that there is a positive relationship between wildebeest location and rain in the south during the wet season and a negative relationship between location and rain in the west and the north, indicating that they are in these regions during the dry season.

Building toward 4.C Revise a model to include new evidence about factors that affect wildebeest survival to illustrate the patterns and relationships and limits of resources that the wildebeest migration depends on. (SEP 2.3; DCI LS2.A.1; CCC 3.1)

21 · NAVIGATE

4 min

MATERIALS: None

Celebrate with students that the class figured out what drives the migration. Say, *You all figured out the migration was much more complicated than the wildebeest simply following the rain.*

Display slide MM. Say, *We figured out the rain is the limiting factor that determines how much grass there could be and that the quality of the soil, the nutritional quality of the grass, how the landscape made it easier or harder to escape predation, and when the wildebeest give birth are also all limiting factors. So, if there are so many limiting factors, how can there be so many wildebeest? We learned in Lesson 2 that there are 1.3 million of them - that is a lot!* Ask students to stop and jot their answers to how there can be so many wildebeest in their science notebooks.

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.CONTENT.HSF.IF.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.

Students create graphical representations based on real-world data. They analyze and interpret those graphical representations, using the scale to facilitate interpretation. Students also describe the relationship between two quantities - rainfall and wildebeest percentage occupancy - as negative or positive, along with looking at relative maximums and minimums to understand the relationship between rainfall and where the wildebeest go for three locations in the Serengeti.

LESSON 5: How does food affect the population size?

PREVIOUS LESSON

We decided to investigate how food drives the migration. We heard from a scientist that rain is a good way to understand food because it is a limiting factor that affects how much grass there can be. We figured out that there is a wet season and a dry season in the Serengeti. We investigated the relationship between rain and wildebeest location and discovered that rain is related to location some of the time but that other factors limit wildebeest location at different times of the year. There are so many factors involved that we wondered how there can be so many wildebeest and decided to investigate this next.

THIS LESSON

INVESTIGATION

2 days



Anthony R.E. Sinclair

We decide to use a kinesthetic model to simulate what is happening with food and wildebeest in the Serengeti. We map our model to the Serengeti system. We make sense of data collected during our simulation to determine that the amount of food regulates how many wildebeest can survive. We self-assess our engagement in discussions. We analyze data from wildebeest populations, which leads us to conclude that more food is available because the wildebeest migrate.

NEXT LESSON

We will apply our knowledge of limiting factors and carrying capacity to a new transfer task. We will self-assess the quality of our responses to that task. We will determine which questions we have answered on the DQB and where to go next.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

5.A Develop and use a kinesthetic and mathematical model to generate evidence to explain how grass is a limiting factor that affects carrying capacity of wildebeest populations within the conditions of the Serengeti ecosystem. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3)

5.B Use mathematical representations of data to quantify rates of population change over time to support explanations about the effect of limiting factors on population size. (SEP: 5.2; DCI: LS2.A.1; CCC: 7.2)

WHAT STUDENTS WILL FIGURE OUT

- Food availability is the main limiting factor that regulates the wildebeest population.
- When the wildebeest population is low, there is abundant food, resulting in rapid population growth.
- When the wildebeest population is large, there is competition for food, and the population growth slows.
- When resources like food are limited through competition, the population stabilizes; the number of births is roughly equal to the number of deaths.
- Rates of change can help us see how limiting factors affect population growth.
- Migration increases carrying capacity. Food is the limiting factor/food regulates wildebeest. When they run out of food, they move or die.
- Other limiting factors also affect wildebeest populations.

Lesson 5 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Facilitate a discussion about what we figured out about food.	A	
2	7 min		MAPPING THE SYSTEM TO THE SERENGETI Identify the parts of the system the simulation needs to account for and map them to the real world.	B	whiteboard or chart paper (optional), chart paper markers (optional)
3	13 min		USE A KINESTHETIC MODEL TO SIMULATE THE SERENGETI Work as a class to simulate the Serengeti using a kinesthetic model.	C	<i>Serengeti Kinesthetic Model</i> , open space, whiteboard or chart paper (optional), chart paper markers (optional)
4	7 min		MAKE SENSE OF KINESTHETIC MODEL OF THE SERENGETI Work in small groups to make sense of the data collected in <i>Serengeti Kinesthetic Model</i> .	D	<i>Serengeti Kinesthetic Model</i>
5	10 min		SUPPORT ALGORITHM DEVELOPMENT Support students in developing algorithms to make sense in wildebeest population changes.	E-G	<i>Serengeti Kinesthetic Model</i>
6	5 min		NAVIGATE Determine takeaways and next steps.	H	<i>Serengeti Kinesthetic Model</i>
<i>End of day 1</i>					
7	3 min		NAVIGATE Turn and talk about what we figured out last time.	I	Community Agreements (from Lesson 1)
8	12 min		ANALYZE AND MAKE SENSE OF WILDEBEEST POPULATION DATA Work in small groups using mathematics to analyze stability and change in wildebeest populations.	J-L	<i>Wildebeest Population Data</i> , whiteboard or chart paper (optional), chart paper markers (optional)
9	12 min		FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ABOUT WILDEBEEST CARRYING CAPACITY Move to a Scientists Circle. Lead a Building Understandings Discussion to make sense of the relationships in the system.	M-P	<i>Serengeti Kinesthetic Model</i> , Community Agreements (from Lesson 1)
10	8 min		UPDATE PROGRESS TRACKER Support students in updating their Progress Trackers.	Q	<i>Progress Tracker</i> , <i>Conservation Profile Organizer</i>
11	5 min		NAVIGATE Facilitate a brief discussion to help navigate into Lesson 6.	R	Community Agreements (from Lesson 1)

Part	Duration		Summary	Slide	Materials
12	5 min		COMPLETE AN EXIT TICKET Students complete an electronic exit ticket to sum up learning and apply it to a new situation.	S	https://docs.google.com/forms/d/12Petr5l51VuOuM9rj6xHlQBI8FCatMF2kZC5zrNyw1M/copy

End of day 2

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Serengeti Kinesthetic Model</i> <i>Wildebeest Population Data</i> <i>Progress Tracker</i> <i>Conservation Profile Organizer</i> https://docs.google.com/forms/d/12Petr5I51VuOuM9rj6xHIQBI8FCatMF2kZC5zrNyw1M/copy		- whiteboard or chart paper (optional) - chart paper markers (optional) - open space - Community Agreements (from Lesson 1)

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure the classroom Community Agreements (from Lesson 1) are accessible.

Ensure that you can secure a hallway, large room, or outdoor space for the *Serengeti Kinesthetic Model* where students can all stand with about 15 feet between them and move around. You can also move furniture in your classroom to make space.

If you think your students will suggest identifying the wildebeest and grass in the simulation with something other than their hands or bodies, have supplies available to identify wildebeest and grass, such as 3x3 sticky notes, colored paper, or copy paper and markers.

For the exit ticket, make a copy of <https://docs.google.com/forms/d/12Petr5I51VuOuM9rj6xHIQBI8FCatMF2kZC5zrNyw1M/copy> and make the link to your local copy of the form accessible to students. See *Exit Ticket Guidance* for additional guidance.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build an understanding of DCI: HS-LS 2.A.1: *Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.* In Lessons 3–4, they made sense of limiting factors and how they might affect the population of migrating wildebeest. Here they build on the idea of limiting factors as they figure out how they impact carrying capacity.

In addition to learning from prior lessons, students draw on a middle school level understanding about LS2.A: Interdependent Relationships in Ecosystems:

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.

Students use science practices, *developing and using models* and *mathematics and computational thinking*. They develop multiple types of models, including a kinesthetic and mathematical model, to provide evidence for the mechanism of wildebeest population change and predict what will happen to the population in the future. In previous lessons, students worked with explanatory models, which build on their middle school modeling practice.

Students should be familiar with using graphs, algorithms, and rates from middle school practice as well as mathematical representations in the form of graphs in Lesson 4 to support conclusions about the relationship between variables. Here they use these aspects of the *mathematics and computational thinking* practice to support their explanations.

Students use high school elements of the crosscutting concepts *systems and system models* and *stability and change* as they interact with the kinesthetic and mathematical models and historical wildebeest population data.

Students are familiar with inputs and outputs of systems in middle school and expand the use of *systems and system models* by identifying the initial conditions of their kinesthetic model system.

Students should be familiar with using *stability and change* over time in explanations from middle school and from its use in Lessons 1,2 and 4. In this lesson, students add the use of rates of population change to serve as evidence to support explanations about limiting factors in populations over different time periods.

Students will co-construct definitions included in the NGSS performance expectations, including *carrying capacity*. This lesson provides opportunities for students to co-construct and record the definitions they build together in their personal glossaries and additional support for teachers if students are unfamiliar with these terms.

Where We Are NOT Going

In this lesson, students do not investigate other organisms in the Serengeti or other limiting factors that affect those organisms. The unit will further explore those ideas in Lesson Set 2. Additionally, students will investigate more about the matter and energy flow in ecosystems and specifically trophic levels in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

LEARNING PLAN for LESSON 5

1 · NAVIGATE

3 min

MATERIALS: science notebook

Navigate to the lesson by considering where we left off. Display **slide A** and have students turn and talk with a partner about the prompts on the slide. Have partners give a visual cue (e.g., stand up or raise their hands) when they are ready. Call on a few pairs of students to share their thoughts. *

Suggested prompt	Sample student response
<i>What did we figure out last time?</i>	We figured out that the migration of the wildebeest is happening because of food. Wildebeest are always moving to where the grass is in patterns based on rain and the kinds of grass available.
<i>What were we wondering about?</i>	We keep hearing that there are 1.3 million wildebeest, but in 1970 there were only 500,000. Why/how are there so many wildebeest? The amount of rain did not change that much, so how did there get to be so many wildebeest? If there is a wet and a dry season, how is there enough grass for all those wildebeest?
<i>How could we investigate what we are wondering about the wildebeest population?</i>	We could look at real wildebeest population data in the Serengeti over a long time. We could model or simulate what is happening with wildebeest and food. We could get more data on other organisms in the Serengeti. We could use math to analyze what is happening between the wildebeest and grass.

* ATTENDING TO EQUITY

Universal Design for Learning: Allowing students to *express* their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas. Consider agreeing on a set of non-verbal signals to use as a class (e.g., head nods, thumbs up, ASL signs) for signaling non-verbal agreement, disagreement, and wondering/questioning as a way to ensure equitable participation by giving students additional modalities with which to *express* themselves.

2 · MAPPING THE SYSTEM TO THE SERENGETI

7 min

MATERIALS: whiteboard or chart paper (optional), chart paper markers (optional)

Emphasize the need to simulate the wildebeest in the Serengeti Ecosystem. Say, *I heard many of you say we need a way to simulate what is happening in the Serengeti with wildebeest and food. If we were to do this, what are all the parts of the system we would want to include to help us figure out how the wildebeest population can be so big?* Listen for students to identify wildebeest and grass as components. Record these on

* SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND

whiteboard or chart paper.

Introduce the mapping tool. Display **slide B** to present the *Mapping the Model to the Serengeti System* chart. Explain that we can use this tool to help us to develop a model to simulate what is happening in the Serengeti and what each part represents in the real Serengeti system. Tell students that we will develop what is called a kinesthetic model, where we take on roles that represent components of the system and act out the interactions.

ADDITIONAL GUIDANCE

Mapping the model is a tool to support Developing and Using Models often used in OpenSciEd Middle School. This is built into *OpenSciEd Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*, *OpenSciEd Unit 6.6: How do living things heal? (Healing Unit)*, *OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*, *OpenSciEd Unit 8.2: How can a sound make something move? (Sound Unit)*, *OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, and *OpenSciEd Unit 8.4: How are we connected to the patterns we see in the sky and space? (Space Unit)*. If your students have experience with those units in middle school, consider having them take a more active role in the co-construction of this tool, such as having them do it with a partner or in small groups instead of a whole class.

Compare the model to the Serengeti. Have students identify where each part of the Serengeti is represented in the kinesthetic model and fill it out on the slide or on a piece of chart paper/whiteboard.

1. Begin by filling in the second column with ideas that students brainstormed in the previous activity, such as wildebeest and grass. Then brainstorm how the parts in the model are similar to and different from the real world, completing as much as you can in the right two columns of the mapping tool.

2. Then, co-construct the first column with students. Ask students how they could represent the different parts of the system in the kinesthetic model. Say, *If we were going to take on the role of a wildebeest, what would that look like?* Suggestions might include representing the grass and wildebeest with hand signals, colored pieces of paper, paper with letters or words, or signs they could hang around their necks.

3. Next, fill in the third column with how part of the model is similar to the real world.

4. Finally, fill in the last column with the limitations or differences between that part of the model and the real world.

5. Repeat this for each part of the system. If students get stuck on wanting to include parts of the system other than those listed, ask them to remind you what we figured out in Lesson 4 about rain as a limiting factor for grass and grass being an important resource for wildebeest.

See one example below:

This part of the kinesthetic model ...	is like this part of the real world ...	because ...	and is not like it because ...
Person with hands on head like horns.	Wildebeest	Wildebeest primarily eat grass when they can.	Wildebeest could need more to survive than just grass.
Person with hands pressed together shaped like grass.	Grass	Grass grows in the Serengeti.	There are different types and stages/parts of grass. Grass growth depends on different factors, like rain.

USING MODELS

Use this opportunity to make explicit the benefits and limitations of using physical/kinesthetic representations (i.e., scale models, interactives, etc.) and mathematical representations (graphs, algorithms, mathematical statements, etc.) for explaining phenomena in the real world. Ask students to think of the benefits and limitations as you are mapping the model to the system. Such benefits might include being able to simulate many years in a short amount of time and not having to go all the way to the Serengeti. A limitation might include that other factors are not accounted for in the simulation or that we are not using real wildebeest or grass.

* ATTENDING TO EQUITY

Universal Design for Learning
To increase access, you can print the slide of the mapping tool and provide it as a handout to students who may need more scaffolding in developing and using models.

Years in the Serengeti.	Time	Years go by, and the population changes based on what is happening that year.	Time is going to pass much faster in our simulation so we can gather more data.
Lack of other factors.	Other factors	Sometimes, it might just be food as the biggest factor.	There is likely more than one thing that affects the wildebeest population.

For answers that students are uncertain about, leave those blank and revisit after carrying out the *Kinesthetic Model: Simulating the Serengeti System*.* *

3 · USE A KINESTHETIC MODEL TO SIMULATE THE SERENGETI

13 min

MATERIALS: *Serengeti Kinesthetic Model*, open space, whiteboard or chart paper (optional), chart paper markers (optional)

Prepare to enact the kinesthetic model. Display **slide C**. Distribute *Serengeti Kinesthetic Model*.

Teacher Instructions for Wildebeest Food Simulation

1. Spread desks/tables apart so that the wildebeest can be on one side of the classroom and the grass can be on the other side of the classroom. Alternatively, take the class to a safe outdoor open space, gymnasium, or large room and have students stand about 15 feet apart.
2. Choose one to two students to be the observers for the class. Divide the rest of your class into two groups, one group representing the wildebeest and one group representing the limiting factor (food/grass). This kinesthetic model will only account for the limiting factor of food (grass). Make sure you start with only two of your students as wildebeest and the remaining students as grass. For example, if you have 22 students, 2 will be observers, 2 will be wildebeest, and 18 will be grass.
3. Ask the observers to record the starting number of wildebeest for Round 1 on *Serengeti Kinesthetic Model*. This should be two.
4. Students should be reminded that there is no running or shoving or the game will end.
5. Review the instructions with students: If a wildebeest gets grass, it survives and has the potential to reproduce. Since wildebeest are mammals and only approximately half of them are females, only 50% can reproduce. Multiply the number of surviving wildebeest by .5 and add that number to the next generation. Round down when you have a decimal since you cannot have half of a wildebeest.
 - a. If you are a wildebeest, you will hold your hands up to the top of your head like horns.
 - b. If you are grass, you will put your hands in front of your chest, pressed together to represent the grass. Alternatively, you could use two colors of paper or a sticky note for each student, with W for wildebeest or G for grass.

6. At this point, give a signal that you are starting Round 1 and give instructions for the two wildebeest to move to the grass.
 - a. Both groups will have their signal visible, and the wildebeest will go to the grass and pair up with a student representing grass.
 - b. The wildebeest then brings the "grass" student back with them. Since that wildebeest eats, it survives. Once all of the wildebeest have had a chance to find food, multiply the number of surviving wildebeest by .5. For example, if 2 wildebeest survive $2 \times .5 = 1$, and 1 wildebeest will be added to the population for a total of 3. One grass then becomes wildebeest in the next round.
 - c. Any wildebeest that did not get grass dies and becomes grass. Any grass that did not get eaten by a wildebeest in Round 1 remains grass.
 - d. If you are using paper or 3x3 sticky notes, students will need to exchange them for the opposite sticky note when they transition from being grass to wildebeest and vice versa.
7. Before starting the next round, count the number of surviving wildebeest and have the observers record the number of surviving wildebeest in Round 1. They should calculate and record the number of offspring and add them together to record the number of wildebeest for the beginning of the next round. At some point, there will be more wildebeest than grass, and not all the wildebeest will survive.
8. Keep repeating rounds as desired and watch the pattern that develops. 10-15 rounds should be adequate.

ALTERNATE ACTIVITY

Consider recording the class data on a whiteboard or chart paper and then have students transfer it to *Serengeti Kinesthetic Model* or just have them make the graph from the class data.

4 · MAKE SENSE OF KINESTHETIC MODEL OF THE SERENGETI

7 min

MATERIALS: *Serengeti Kinesthetic Model*



Make sense of the simulation in small groups. Display slide D. Remind students they are using the data collected by the observers on *Serengeti Kinesthetic Model* and working together to make sense of what happened in the simulation by answering the questions in Part 1.*

* ATTENDING TO EQUITY

Universal Design for Learning: If it is something familiar to your students or part of their education plans, consider allowing students to use a digital graphing tool such as a graphing calculator or spreadsheet software to help them create their graphs. Students can take the data table and enter it into graphing software. Allowing alternatives for use of tools such as a calculator can remove barriers for students in *expressing* their understanding by keeping the focus on the learning goal. Use of such tools can help provide a match between a student's abilities and the demands of the task.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment:

- Graphs that model an increase in population that levels off and is replaced by a cycle of ups and downs around an average. (SEP: 2.4)
- Availability of grass and competition for food allowed for growth and then limited the wildebeest population in the Serengeti. (CCC 4.3, DCI: LS2.A.1)
- When the population was increasing, wildebeest got enough food to survive and reproduce. (SEP: 2.4, DCI: LS2.A.1)
- When the population was decreasing, there was not enough food for the number of wildebeest, and some died. (SEP: 2.4, DCI: LS2.A.1)

What to do: Orient students to the initial conditions by asking them what they started with in the simulation and how the components changed over time. Point students back to their data as evidence to support their responses. Encourage them to chunk the graph into smaller segments and describe verbally what happened in the kinesthetic model when the population was increasing, when it decreased, and when it increased again.

Building toward 5.A.1 Develop and use a kinesthetic and mathematical model to generate evidence to explain how grass is a limiting factor that affects carrying capacity of wildebeest populations within the conditions of the Serengeti ecosystem. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3)

5 · SUPPORT ALGORITHM DEVELOPMENT

10 min

MATERIALS: Serengeti Kinesthetic Model

Discuss mathematical representations. While students remain seated in their small groups, ask them to pause for a brief whole-class discussion. Display slide E. Say, *You all developed a mathematical representation of our data by creating a graph and making sense of the patterns it can help us see. Can you think of other kinds of mathematical representations?* Listen for ideas such as equations or formulas. Say, *One kind of mathematical representation that might help us make sense of our data is an algorithm.* Pause to generate ideas about possible definitions for algorithms.

Co-construct a definition for algorithm. Display slide F.

ADDITIONAL GUIDANCE

Take a moment to allow students to add a definition for algorithm to their personal glossaries. A sample definition could be *a process, rule, or set of instructions*.

Draw on students' prior knowledge from middle school, their mathematics classes, and their everyday lives. In middle school, they may have engaged in mathematics and computational thinking (SEP 5) by creating algorithms as a series of ordered steps to solve a problem (NGSS Appendix F). In their everyday lives, students may be familiar with algorithms that determine what posts they see in their social media feed or which songs they hear in a playlist in a music app. Remind them that these algorithms are based on data generated by the components of a system (them!).

If students already have experience with algorithms, skip slide F and ask them to generate both algorithms.



Support students in developing an algorithm to describe what happens to the wildebeest population from year to year. Say, *An algorithm is another way for us to understand the patterns that we see in the data from one generation to the next. One way we can write them is in if-then statements.* Display slide G. Review the algorithm for grass. Give students an opportunity to ask questions about the algorithm and then ask them to work on Part 2 Serengeti Kinesthetic Model individually while using their small groups for support. They should work through developing an algorithm for what happens when the number of wildebeest is greater than the number of grass. *

* ATTENDING TO EQUITY

Universal Design for Learning: Allowing students to express their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas. *Serengeti Kinesthetic Model Key* provides some different ways students could express their algorithm.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment:

- Algorithms that include if-then statements about the relationship between wildebeest, grass, and wildebeest population growth. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3)
- An explanation using evidence from the algorithm or graph to explain the relationship between wildebeest, grass, and wildebeest population growth. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3)

What to do: Provide students with different mathematics experience with options for developing algorithms. Students who have less experience may want to try developing if-then statements with words or arrows. Students with more experience may want to try adding numbers and functions. See *Serengeti Kinesthetic Model Key* for guidance related to student responses.

Building toward 5.A.2 Develop and use a kinesthetic and mathematical model to generate evidence to explain how grass is a limiting factor that affects the carrying capacity of wildebeest populations within the conditions of the Serengeti ecosystem. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3)

ADDITIONAL GUIDANCE

Some students may be ready to convert the algorithms they developed into symbols and numbers. The example the class reviewed together - *If the number of wildebeest is less than the number of grass, then all of the wildebeest survive and 50% of them reproduce.* - could be written as *If $W < G$ then $W_2 = W_1 + (W_1 \cdot .5)$ where Wildebeest = W , Grass = G , Subscript=year.*

6 · NAVIGATE

5 min

MATERIALS: science notebook, *Serengeti Kinesthetic Model*

Reflect on takeaways and determine next steps. Display slide H.

Suggested prompts	Sample student response	Follow-up questions
<i>What is one major takeaway from simulating the Serengeti using kinesthetic and mathematical models?</i>	If there are few wildebeest and a lot of grass, the population grows fast. If there are a lot of wildebeest and a little grass, it grows slowly or might decrease. The number of wildebeest depends on or is limited by the number of grass.	<i>How does our data from the kinesthetic or mathematical model support what you are saying about the relationship between grass and wildebeest?</i>

Suggested prompts	Sample student response	Follow-up questions
What are some limitations to our models?	A limitation of the model was that for every two wildebeest, you could only reproduce or die, not survive without reproducing. Fifty percent of the population reproduced every year, but that is probably higher than in real life. The limit of our model was that we were only talking about food. Can we talk about any other limiting factors?	How would these limits affect our outcomes?
Since our kinesthetic model of the Serengeti had some limitations, how can we gather more evidence to help us understand wildebeest population growth?	We could look more closely at real wildebeest population data from the Serengeti. We could look at data from other populations or other limiting factors. We could look at data for wildebeest populations from a longer period of time.	How would that help us figure out what is happening with the migration of the wildebeest population in the Serengeti?
Say, <i>These are great ideas! Let's start the next lesson by digging deeper into what is really happening with the wildebeest population and grass in the Serengeti.</i> Collect <i>Serengeti Kinesthetic Model</i>. Ask students to submit <i>Serengeti Kinesthetic Model</i> at the end of the class period to assess individual student progress from day 1. Use <i>Serengeti Kinesthetic Model Key</i> to help you provide feedback before day 2.		
ADDITIONAL GUIDANCE	As you review student responses in <i>Serengeti Kinesthetic Model</i>, look for evidence from Part 1 that students understand the role of food as a limiting factor for wildebeest population growth. In Part 2, look for evidence that indicates students' comfort and experiences with mathematical thinking. Consider creating heterogeneous groups on day 2 that include students who provided more evidence of an understanding of both limiting factors and mathematical thinking with students who provided less evidence.	

End of day 1

7 • NAVIGATE

3 min

MATERIALS: science notebook, Community Agreements (from Lesson 1)

Navigate into today's work. Display [slide 1](#). If you collected *Serengeti Kinesthetic Model* at the end of last class period, hand it back to students with feedback.

Turn and Talk. Ask students to turn to a shoulder partner to discuss the questions below and on the slide. Allow students to access their science notebooks to refer back to data and other ideas from earlier in the lesson or unit. Circulate around the room as students talk in pairs to highlight where we can go next.

Suggested prompts	Sample student responses	Follow-up questions
What did we figure out last time?	Grass was the limiting factor in the kinesthetic and mathematical models that indicated how big the wildebeest population was at a given time.	<i>In Lesson 4, we figured out that rain was the limiting factor that determined how much grass there could be. What was the limiting factor that determined how many wildebeest there could be?</i>
How did the scale of the wildebeest population and time (the number of rounds we simulated) limit our understanding of the system?	We could only have as many wildebeest as there were students in the class. We could only simulate a few years so we do not know what happens over long periods of time.	<i>What could we do to address this limitation?</i> <i>What data would help our understanding of the system at the scale of the Serengeti ecosystem over long periods of time?</i>
What do you predict we would see if we looked at historical data for the wildebeest population in the Serengeti?	We predict the historical data would be similar to our models but maybe have more variation due to other limiting factors or things that the simulation did not account for, such as weather, etc.	

Say, *It sounds like we have an idea that grass is a limiting factor for wildebeest just like rain was a limiting factor for grass. Let's investigate how that really worked in the Serengeti.*

8 • ANALYZE AND MAKE SENSE OF WILDEBEEST POPULATION DATA

12 min

MATERIALS: *Wildebeest Population Data*, whiteboard or chart paper (optional), chart paper markers (optional)

Explain data collection in the Serengeti. Display **slide J**. Let students know that scientists like Dr. Simon Mduma and Dr. Tony Sinclair helped collect wildebeest population data in the Serengeti. Data has been collected annually since the early 1950s.

ADDITIONAL GUIDANCE

The annual wildebeest survey has typically been done each year during the wet season when wildebeest are concentrated in the plains in the south. A small plane flies low in parallel lines over the herd. Animals in each area are counted and photographs are taken. Some data is also collected from wildebeest that are radio collared. In recent years, new technology (using algorithms) has been developed that can count wildebeest in photos, and citizen science programs have been used as well. For more information about the methodology used in the wildebeest count, see the following references:

Norton-Griffiths, M. (1973). Counting the Serengeti migratory wildebeest using two-stage sampling. *African Journal of Ecology*, 11, 135–149. <https://doi-org.colorado.idm.oclc.org/10.1111/j.1365-2028.1973.tb00079.x>

Torney, CJ, Lloyd-Jones, DJ, Chevallier, M, et al. A comparison of deep learning and citizen science techniques for counting wildlife in aerial survey images. *Methods Ecol Evol*. 2019; 10: 779–787. <https://doi.org/10.1111/2041-210X.13165>

* ATTENDING TO EQUITY

Emergent Multilingual Learners: It is helpful to intentionally group emerging multilingual students with certain peers. Sometimes this could be peers who know the same languages as them, while other times it could be peers whose English language development is slightly more advanced. It is important that this grouping be thoughtful and that it varies throughout the course of a unit so that students benefit from working with different peers.

* SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING



Investigate wildebeest population data in the Serengeti. Display slide K. Distribute *Wildebeest Population Data*. Tell students they will use this data to analyze the graphs and answer the prompts on the handout with a partner. *Wildebeest Population Data Key* provides guidance on expected student responses. Note that on *Wildebeest Population Data*, students will explain what was actually happening in the Serengeti from 1961 to 2010. There are two events in the data that students will notice had effects on the population. Prior to 1963, wildebeest and other Serengeti animals had been battling a disease called rinderpest that increased the mortality rate. Additionally, from 1993-1995 there was also a historic drought in the Serengeti. * *

ADDITIONAL GUIDANCE

If your students need additional scaffolding in using mathematical representations, use a strategy already in place in your school such as the I^2 strategy used in OpenSciEd Middle School. See *OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, *The Identify and Interpret (I^2) Strategy - Student Guide* for more information. Additionally, you can check with mathematics teachers at your school to see how they have been teaching graphical data analysis and rates of change.

Here is an example:

1. Find the coordinates of the given points (the x and y values) for the beginning and end of the time period.
2. Find the difference (change) between the y values.
3. Find the difference (change) between the x values.
4. Divide the change in y values by the change in x values.
5. The number you get will be the average rate of change for that time period.

See the example on *Wildebeest Population Data Key* for additional guidance.

Co-construct wildebeest population rates of change. Display slide L after students make sense of the data on *Wildebeest Population Data* for about 5 minutes. Say, *We can use something you often do in math class to help us quantify what is happening with the wildebeest populations.*

Consider how to support students in calculating rates of change based on the needs of your students. One option is to work through an example of how to calculate the rate of change for a single time period as a class and then allow small groups to complete the rest of the calculations. Another option is to assign each group to calculate one rate of change and then share calculations across the class.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment:

See *Wildebeest Population Data Key* for guidance on student responses.

What to do: Ask probing questions to ensure students' understanding of how the graph models the change in population at different points and how the rate of change corresponds to different limiting factors.

- How is the graph different at _____ time span versus _____ time span?
- What do you notice about the rate of change of the graph at _____ time span versus _____ time span?
- What was happening in the Serengeti during the _____ time span versus _____ time span?
- What happened before or after at _____ time span versus _____ time span?

Building toward 5.B.1 Use mathematical representations of data to quantify rates of population change over time to support explanations about the effect of limiting factors on population size. (SEP: 5.2; DCI: LS2.A.1; CCC 7.2)

If students struggle to use mathematical and computational thinking to analyze their data, support them by helping them visualize the data numerically or with words. Have students use various groupings, like breaking down the graph into 5-year spans. Once students have identified the change during those five years, have them write it directly on their graphs and move on to the next 5-year span. Alternatively, you could have students explain orally, and you could scribe their thinking for them. Display slide L to assist with the rate of change calculations.

9 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ABOUT WILDEBEEST CARRYING CAPACITY

12 min

MATERIALS: *Serengeti Kinesthetic Model*, Community Agreements (from Lesson 1)

Revisit Community Agreements to support upcoming discussions. Display slide M. Say, *We have these shared Community Agreements that we created as a class. How can these agreements support us as we work together in upcoming discussions?* *

Turn and talk about Community Agreements. Direct students to turn and talk to a neighbor about which agreements they think we can rely on to support our class community through future discussions. Listen in on partner talk. Then invite students to briefly share their ideas with the class.

Begin by discussing the wildebeest data. Display slide N. Have students turn and talk to get their ideas flowing before a whole-group discussion. Ask, *What are some initial noticings you and your partner had about the wildebeest population data?* Listen for students to say things such as: *When we look at the populations of the wildebeest over time, we notice big changes in the wildebeest population.* *

Lead a Building Understandings Discussion about the relationship between the wildebeest population and grass. Display slide O. Gather the class in a Scientists Circle with *Serengeti Kinesthetic Model* and *Wildebeest Population Data*. *

Use the "Key Ideas" box and prompts below to facilitate this discussion. Work with the class to use their data to show what is happening as students share. You might have students stay seated, stand and hold *Serengeti Kinesthetic Model* or *Serengeti Kinesthetic Model* up, tape them to the wall or board, put them under a document camera, or even lay them on the floor of the circle.

KEY IDEAS

Purpose of this discussion: To establish that the wildebeest population size is limited by the amount of food available. The wildebeest population can only reach a certain number before the population decreases and then fluctuates around that point (carrying capacity), going up and down slightly. Following this discussion, students will co-construct a definition for carrying capacity.

The discussion is structured to help students use evidence from the data in the graphs and rates of change to support their arguments.

Listen for these ideas:

- See the responses below and *Wildebeest Population Data Key*.

Suggested prompts	Sample student responses	Follow-up questions
How did the historical data compare to the data we collected and analyzed from the kinesthetic model?	The actual data for wildebeest populations looked very similar to the data we collected in the simulation. Both sets of data increased rapidly at first and then reached a high point. In the next few years, the population went down and up slightly but stayed relatively the same with small fluctuations.	

* ATTENDING TO EQUITY

Building classroom culture: This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout the rest of this unit, students engage in discussions to make sense of how what they have figured out about the Serengeti influences their conservation profiles. Being open to sharing knowledge products that depict their current thinking and listening to classmates who share their knowledge will help move the community's understanding forward.

* ATTENDING TO EQUITY

Universal Design for Learning: It is important to organize activities in ways that create opportunities to support student *engagement* in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to emergent multilingual students. For this reason, partner talk or small-group talk should precede whole-group discussion whenever possible to give students an opportunity to share their ideas with one or two peers before going public with the whole class. Throughout this unit, there will be instances in which the students immediately engage in whole-group discussion. Insert a partner talk prior to the whole-group discussion if you believe this would benefit your students' ability to communicate and *express* their ideas.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Be explicit with students about your role in this discussion, which is to press students for evidence when they bring up ideas for what was happening in the Serengeti system. Tell students explicitly, *My role in this discussion is to press for evidence. You might hear me ask,*

Suggested prompts	Sample student responses	Follow-up questions
What was happening with the wildebeest population for the first 17 years (1961-1977)? Why do we think that was the case?	Due to rinderpest disease as a limiting factor, the wildebeest population started really low, around 250,000. In 17 years, the population grew to almost 1.5 million with a rate of change of +71,853. But since the system started with so much food, there was little competition for grass, so the population could keep growing and growing. Food was not a limiting factor at this time.	What happened with the rate of change? Was it negative or positive? What does it tell us that the rate of change was positive? Were there any factors limiting the population?
What happened with the wildebeest from 1977-1978? Why do we think that was the case?	The population decreased and had a negative rate of change. There were too many wildebeest and not enough food. There was competition for food and not all the wildebeest survived. Food was a limiting factor.	What happened with the rate of change? Was it negative or positive? What does it tell us that the rate of change was negative? Were there any factors limiting the population?
What happened with the wildebeest from 1978-2004? Why do we think that was the case?	The population went up and down. Overall it stayed about the same. The number of births and deaths evened out. The rate of change was close to zero. When the population got too big, there was not enough food, and food limited the population. There was a drought in 1993 that affected the population, and many wildebeest died.	What happened with the rate of change? Was it negative or positive? * What does it tell us that the rate of change was negative? Were there any factors limiting the population?
What do you think would happen in the next 20 years after the data ends? Why do we think that would be the case?	We think we would see the population go up and down a little bit like between 1975-1990, as long as nothing else changed in the ecosystem.	Why does the population not keep growing? What do you think is the right number of wildebeest for this ecosystem?

During the discussion, students will likely bring up the idea that there can only be so many wildebeest in the system due to the amount of grass. When that happens, add that we hear that scientists call this idea **carrying capacity**.

Add key terms to personal glossaries. Display slide P. Ask, *What word(s) should we add to our personal glossaries that were essential to making sense of what is happening in the model of the Serengeti system?*

"Where did you see that?" It is my job to push us as a class to articulate the evidence we have to support our ideas.

* SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

Students calculate rates and use them as part of their mathematical model of wildebeest population change to support their explanations about limiting factors and carrying capacity. Their explanations should include mathematical evidence, such as when the population was increasing, the rate of change was positive and the population was not limited by food. When the population was decreasing, the rate of change was negative and the population was limited by food.

* ATTENDING TO EQUITY

Universal Design for Learning: Using a show of hands helps support students' *action and expression* by varying the way students are responding to questions. If you have students who are not in agreement, ask them to share why they do not agree. Have a quick discussion around their reasoning. By highlighting student differences in ideas, you are supporting students' *engagement* by making space to increase mastery-oriented feedback. You could have students quickly turn and talk with an elbow partner about what evidence there is to support or refute the statement. After this quick Turn and Talk, have students share their discussions with the class. Prompt students to point to specific pieces of evidence from the simulation and actual wildebeest data. Highlight that the evidence students are sharing all points to supporting the statement.

ADDITIONAL GUIDANCE

A sample personal glossary entry for *carrying capacity* may look like:

- *Carrying capacity: The number of organisms a system can hold or support. In the case of the wildebeest, the carrying capacity is around 1.3 million.*

Continue the Building Understandings Discussion to establish the relationship between carrying capacity and migration. The second part of this Building Understandings Discussion is intended to help students come to the tentative conclusion that the migrating wildebeest can have such a high carrying capacity because migration makes more food available.

Suggested prompts	Sample student responses	Follow-up questions
<i>You all said you think the carrying capacity for wildebeest is around 1.3 million. That is A LOT of wildebeest. How can it be so high?</i>	We remember that even though the rain changed seasonally, there were no big changes in the rain (food) from year to year. Under stable conditions, the carrying capacity is quite high because there is not as much competition as when there is drought or something else limiting the population. The wildebeest carrying capacity is so high because they can migrate to get more food.	
<i>What would happen if the wildebeest did not migrate?</i>	The carrying capacity would be much lower. They would stay in one place and run out of grass, and a lot of them would die.	<i>How does migration relate to grass as a limiting factor?</i> <i>How does migration affect carrying capacity?</i>

Conclude the discussion by saying, *It sounds like we are pretty confident about migration is a factor that allows the population to be so big (high carrying capacity).* Ask students to show if they agree by raising their hands. Then call on several students to support these ideas with evidence. Then say, *So we saw that migration increases carrying capacity due to food availability, What other ways might migration increase survival?* Listen for students to bring in ideas such as evading predators or interactions with other organisms. If students struggle to connect what was happening in the wildebeest population data to earlier lessons, ask them to look back in *Progress Tracker*. *

ADDITIONAL GUIDANCE

In this lesson, we are only looking at wildebeest populations because they are the main migrator. However, we will look at a larger variety of organisms in Lessons 7 and 8. Additionally, students will investigate more about the matter and energy flow in ecosystems and specifically trophic levels in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

10 · UPDATE PROGRESS TRACKER

8 min

MATERIALS: *Progress Tracker*, *Conservation Profile Organizer*

Complete Progress Trackers. Have students move into their conservation profile groups. Remind them that each time we use the tracker, they should fill in the lesson number and the question or topic they are writing about in the fifth row (Lesson 5) of *Progress Tracker*.

Ask them to turn and talk about the questions in the column that describes what they learned about the Serengeti.

Next, ask students to get out *Conservation Profile Organizer*. Show **slide Q** and talk through the types of questions students should be able to answer about their profile. Provide time for students to read through their notebooks and look through earlier models and investigations. They should answer what they can in column 2. Anything they cannot find should be written as a question or note for further investigation in column 3. Walk around as students are working on columns 2 and 3 and ask questions like the one below to prompt student thinking.

Suggested prompt	Sample student response
What have we figured out about wildebeest and grass (or other limiting factors) that might be applied back to our conservation profiles?	There must be limiting factors in our conservation profiles that interact to cause carrying capacities for different organisms. In our conservation profile, that means that there is a limit to the number of _____(insert organism of choice) that the system can support. Maybe some of our systems are not doing well because there are too many organisms and not enough food, like in the Great Lakes.

One possible representation of a completed Progress Tracker is shown below.

	What did I figure out about the Serengeti?	What in my profile connects to ideas we figured out about the Serengeti?	What information do I need/questions do I have about how to protect ecosystems?

Lesson 5 How does food affect the population size?	Wildebeest populations can have very large carrying capacities because food does not become a limiting factor when they migrate and make food available all year round.	Everglades: There are a certain number of alligators that the ecosystem can support. Due to human hunting and habitat destruction, the alligator population was below carrying capacity. Now it is protected, and the population has increased. Saguaro: Saguaro grow really slowly and need nurse trees for protection as they grow. Saguaro also needs to have rain to get big. Hoh: The conservation area protects the salmon migration. The river has a certain carrying capacity for salmon, but human factors reduce the number of salmon living there by adding dams etc. Lake Michigan: Quagga mussel population grew at a high rate after being introduced to Lake Michigan because they had a lot of phytoplankton to eat and few predators.	What (other) limiting factors exist in my profile? Are there other limiting factors for the wildebeest? What are the factors that affect carrying capacity in _____ system? What are the limiting factors for _____?
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11 • NAVIGATE

5 min

MATERIALS: Community Agreements (from Lesson 1)

Help students navigate to the next lesson. Display **slide R** and lead students in a brief discussion using the prompts on the slide and additional prompts in the table.

Suggested prompt	Sample student response
<i>How did we do in attending to our Community Agreements that we discussed earlier?</i>	Accept all responses. Listen for students to refer to specific Community Agreements mentioned before the Building Understandings Discussion.
<i>What did we figure out in this lesson?</i>	We figured out a lot about limiting factors and carrying capacity in the Serengeti.

Suggested prompt	Sample student response
How can we apply what we have figured out back to our conservation profiles?	We need to see what limiting factors affect carrying capacity in our conservation profiles.
What are we wondering about?	We have questions about our conservation profiles. We want to know more about what is happening with other limiting factors, such as predators. We wonder about other kids on limiting factors that affect other systems.. What are the carrying capacities of the other key organisms that live there?
ALTERNATE ACTIVITY If time allows, consider doing a stand up, hand up, pair up. Have all students stand up. Then have all students raise their hands until they find a partner. Once students are paired up, they should put their hands down. Then have students turn and talk to each other about the first question. Repeat this process for each of the following questions. Say, <i>It sounds like it would be productive to put together all the pieces we have figured out about the Serengeti and revisit our conservation profiles in the next lesson!</i> Thank students for their great ideas.	

12 · COMPLETE AN EXIT TICKET

5 min

MATERIALS: science notebook, <https://docs.google.com/forms/d/12Petr5L51VuOuM9rj6xHlQBI8FCatMF2kZC5zrNyw1M/copy>



Complete an exit ticket. Display slide S. Have students complete <https://docs.google.com/forms/d/12Petr5L51VuOuM9rj6xHlQBI8FCatMF2kZC5zrNyw1M/copy>. Encourage students to use their notes and models to help them answer the questions on the electronic exit ticket.

ASSESSMENT OPPORTUNITY	What to look/listen for in the moment: See <i>L5 Electronic Exit Ticket Key</i> for guidance. What to do: See <i>L5 Electronic Exit Ticket Key</i> for guidance. Building toward: 5.B.2 Use mathematical representations of data to quantify rates of population change over time to support explanations about the effect of limiting factors on population size. (SEP: 5.2; DCI: LS2.A.1; CCC: 4.3)
ADDITIONAL GUIDANCE	See <i>Exit Ticket Guidance</i> for instructions on how to make the electronic exit ticket.

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.CONTENT.HSF.IF.B.6 Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

Students use historical data from the graph on *Wildebeest Population Data* to calculate the rate of change for the wildebeest population at three specified time intervals to deepen their understanding of limiting factors and carrying capacity in the Serengeti.

LESSON 6: Can we apply what we figured out about limiting factors and carrying capacity to a new scenario?

PREVIOUS LESSON

We decided to use a kinesthetic model to simulate what is happening with food and wildebeest in the Serengeti. We mapped our model to the Serengeti system. We made sense of data collected during our simulation to determine that the amount of food regulates how many wildebeest can survive. We analyzed data from wildebeest populations, which led us to conclude that wildebeest migrate to have more food available. We self-assessed our engagement in discussions.

THIS LESSON

PUTTING PIECES TOGETHER

2 days



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We apply our knowledge about limiting factors and carrying capacity to a new scenario in a transfer task in small groups. We self-assess our responses and discuss ways to revise. We revisit the DQB to determine what questions we have answered about how ecosystems work, how to protect them, and what further information we need. We decide to investigate the role of predators in the Serengeti ecosystem more deeply.

NEXT LESSON

We will investigate the role of predators in the migration through agent-based modeling and how group size influences survival in the Serengeti.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

6.A Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. (SEP: 5.2; DCI: LS2.A.1; CCC 3.1)

WHAT STUDENTS WILL FIGURE OUT

- Space, food, and predation can be limiting factors for wild dogs.
- Data about limiting factors can be used to determine carrying capacity.
- Liwonde National Park can support one pack of African wild dogs.
- We need more information about the role of predators in the Serengeti ecosystem.

Lesson 6 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Review Progress Tracker updates from the previous lesson and prepare for the transfer task.	A	<i>Progress Tracker</i>
2	10 min		PREPARE FOR TRANSFER TASK Introduce students to the idea of a transfer task and help them prepare.	B-F	<i>African Wild Dog Transfer Task, Progress Tracker, Investigating Rainfall Data, Wildebeest Population Data</i>
3	25 min		COMPLETE THE TRANSFER TASK Students work in pairs to complete the transfer task.	G	<i>African Wild Dog Transfer Task, Progress Tracker, Investigating Rainfall Data, Wildebeest Population Data</i>
4	5 min		DEBRIEF OF TRANSFER TASK Discuss strategies for answering one transfer task question.	H-I	<i>African Wild Dog Transfer Task</i>
5	2 min		NAVIGATE Students complete an exit ticket to share how well they collaborated with their partner during the transfer task.	J	3x3 sticky notes or scrap paper
<i>End of day 1</i>					
6	6 min		NAVIGATE Prepare for the individual portion of the transfer task.	K-L	<i>African Wild Dog Transfer Task</i>
7	12 min		COMPLETE TRANSFER TASK QUESTION 8 Students individually complete question 8 on the transfer task.	M	<i>African Wild Dog Transfer Task</i>
8	16 min		PEER ASSESSMENT AND REVISION OF TRANSFER TASK Partners use a rubric to evaluate answers on one question from the transfer task and suggest ways to improve the quality of their responses.	N-P	<i>African Wild Dog Transfer Task, Peer Rubric, Transfer Task Key</i>
9	3 min		FEEDBACK EXIT TICKET Students describe their comfort level giving and receiving feedback on the transfer task.	Q	3x3 sticky notes or scrap paper
10	8 min		NAVIGATE: REVIST THE DQB Facilitate a discussion about the questions on the DQB.	R	Driving Question Board, 3x3 sticky notes
<i>End of day 2</i>					

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Progress Tracker</i> • <i>African Wild Dog Transfer Task</i> • science notebooks • <i>Investigating Rainfall Data</i> • <i>Wildebeest Population Data</i> • 3x3 sticky notes or scrap paper • <i>Peer Rubric</i> • <i>Transfer Task Key</i>	• <i>African Wild Dog Transfer Task</i>	• Driving Question Board • 3x3 sticky notes

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1

- Organize heterogeneous pairs for the transfer task based on student strengths and needs.
- When you copy *African Wild Dog Transfer Task* for day 1, only staple together questions 1-7. Copy question 8 on separate paper to hand out on day 2.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

This assessment targets **HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.**

By completing a transfer task about relocating a pack of African wild dogs, students demonstrate their understanding of **LS2.A Interdependent Relationships in Ecosystems: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation and competition and disease.** Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. This is a summative task designed to assess student learning in Lesson Set 1.

Students use *mathematics and computational thinking* to interpret data presented in graphical and table form in order to support explanations about carrying capacity, then create their own graphs to support their explanation for hypothetical outcomes in the African wild dog population.

The practice *constructing explanations* is intentionally developed as students construct one set of explanations with a peer, debrief as a class, and then write a new explanation on their own. They then revise their individual explanation based on feedback from peers and a teacher-provided rubric.

Students use *scale, proportion, and quantity* to describe how it will take many years for a new population to reach carrying capacity. They also discuss the need to replicate the relocation process on a large scale in order to support wild dog conservation across Africa.

Students encounter the definition for biomass in the Transfer Task, however, students will not build an understanding of biomass from an energy and matter perspective until *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*

Where We Are NOT Going

The evidence presented in the transfer task does not discuss the reasons for the loss of African wild dog habitat nor the ongoing human conflicts that impact the success of recovery operations. Liwonde National Park is fenced in to keep the dogs contained in the park and reduce interactions with humans. Park managers have also noticed that dogs utilize the fence as a hunting tool to trap prey, but this is not considered in determining limiting factors or carrying capacity for dogs.

This lesson does not fully explore interactions between predators and prey and group hunting behaviors. These topics will be addressed in Lesson 7.

This lesson does not consider the genetic diversity of the pack and the need for managing movement of animals between isolated reserves to maintain heterogeneity in the population. Some of these ideas will be considered in *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)*.

Students who want to know more about the fate of the introduced wild dogs can explore the following websites:

- Video of how they moved African wild dogs <https://www.youtube.com/watch?v=S1m00A6koEO>
- Images of the pups born in Liwonde after relocation <https://www.facebook.com/watch/?v=605291120734360>
- Updates on Liwonde National Park <https://www.africanparks.org/the-parks/liwonde>

LEARNING PLAN for LESSON 6

1 · NAVIGATE

3 min

MATERIALS: science notebook, *Progress Tracker*

Review progress to date. Display **slide A**. Facilitate a brief discussion to review concepts students wrote about in their Progress Trackers in the previous lesson. Recap how the ideas in the Progress Tracker help them answer the unit question related to understanding ecosystems and how to protect them.

Suggested prompt	Sample student response
<i>What big ideas did we learn related to protecting ecosystems?</i>	Limiting factors Carrying capacity
<i>How did these ideas connect to your conservation profiles?</i>	We figured out that we need to research the carrying capacity for the featured species in our ecosystem. • Lake Michigan: quagga mussel • Everglades: alligator • Hoh Rainforest: salmon • Saguaro: saguaro cactus We are curious about limiting factors for our featured species. • Quagga mussels: round goby or food? • Alligator: hunting or habitat destruction? • Salmon: enough habitat or fishing? • Saguaro cactus: buffel grass or rain?

2 · PREPARE FOR TRANSFER TASK

10 min

MATERIALS: *African Wild Dog Transfer Task*, science notebooks, *Progress Tracker*, *Investigating Rainfall Data*, *Wildebeest Population Data*

Prepare students for the transfer task. Say, *Before we return to our conservation profiles later in the unit, we can practice connecting what we know to a new scenario. I have information about an endangered animal that lives in a different ecosystem that needs protection. Today you will work on a transfer task, which is a kind of assessment task where you will be able to show what you have learned about limiting factors and carrying capacity and see how it applies to this new situation.* Display **slide B**.

Because this may be your first time completing a transfer task, you will work with a partner to complete the first portion of the task. You will also be able to use all of your notes, models, and readings to help answer the questions. Tomorrow, you will use everything you do today to complete the final question of the task on your own.

* ATTENDING TO EQUITY

Universal Design for Learning. Making sense of the new scenario together reduces a barrier for students. Providing an opportunity for students to make sense of a new scenario they will encounter on the assessment before they see the transfer task reduces the chance that students will do better or worse given their prior knowledge of the new scenario and instead ensures the assessment focuses transferring what students have learned throughout the unit.

ADDITIONAL GUIDANCE

The OpenSciEd curriculum includes transfer tasks as a key part of the assessment system. These curriculum-embedded assessment tasks are organized around a novel context that allows students to apply their learning. While the context may be new to students, they will recognize items that ask them to use science practices and crosscutting concepts to explain science ideas. Students may not have experienced these kinds of assessment. This lesson is designed to support them as they learn to demonstrate their learning on transfer tasks. For more information about transfer tasks see:

Penuel, WR, Turner, ML, Jacobs, JK, Van Horne, K, Sumner, T. Developing tasks to assess phenomenon-based science learning: Challenges and lessons learned from building proximal transfer tasks. *Science Education*. 2019; 103: 1367– 1395.

Read the background information as a class. * Distribute the day one set of *African Wild Dog Transfer Task* (everything but question 8) and have students read through page one: the background information of the new scenario. Students should focus on understanding what the scenario is – the who, what, where, and when. Students can jot down notes in their science notebooks or annotate the page as they read. Watch the one minute <https://www.youtube.com/watch?v=uC88arp4kvg> together on **slide C** to see footage of the African wild dogs. Slides and the background information can be used during the discussion.

Facilitate a discussion about the task scenario. Check for understanding about the scenario from students after their review. See the prompts below for suggestions. Orient students to where this scenario is taking place using the map of Africa from *African Wild Dog Transfer Task*. Point out South Africa and Malawi on the map on **slide D**. If necessary, remind them that the Serengeti ecosystem is in Tanzania, which is near Malawi. Ask students what clarifying questions they still have. Then ask students to think about what resources may be helpful to apply what they have learned to this new scenario. Elicit responses from a few students. Point out any other resources that were not mentioned. Say, *You will be able to use all your unit materials in your science notebook while you complete the transfer task. I am confident you will all do great and show me and yourselves all you have learned about ecosystems and conservation in the context of a new scenario.*

Suggested prompt	Sample student response
Where is the scenario/dilemma taking place?	Malawi, South Africa
What is the dilemma?	African wild dogs are endangered because they lost habitat. Scientists want to increase the number of dogs and are moving some from one country to another to try to get them to spread out and reproduce in more places. We have to figure out how many African wild dogs the new reserve in Malawi can support.
What is the time period of this dilemma?	African wild dogs were listed as endangered in 1990. The reintroduction started in July 2021.
Who are the people involved with this dilemma?	The people who reintroduced the African wild dogs. The people in conflict with the African wild dogs.

* SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

When students bring the materials that they developed to the assessment, they are engaging in a practice akin to that of the scientific community, where scientists gather information from a variety of sources and apply the scientific principles they know to explain new situations.

* ATTENDING TO EQUITY

Universal Design for Learning: Students should consider the strengths of each partner and how best to leverage equal participation when completing the tasks. This is an opportunity to support one another going into the individual transfer task on day 2. It is critical that the agreements support safe and fair participation and interrupt cultural norms or stereotypes in role assignments within the group.

- Only one final copy of the task will be turned in, but both students should record answers on their own copy and turn in the most complete version. Each student will need their own copy of the answers to complete the individual portion of the transfer task on day 2.
- For students who utilize accommodations related to written work, provide a copy of their partner's answers to return to them on day 2 of the task.
- Students who have developed strong mathematical reasoning practices should make sure they explain their reasoning to their partners. The partners may be able to translate that information into writing to support their answer.

Suggested prompt	Sample student response
What questions do you still have about this new scenario?	Where is Malawi? What is reintroduction? Why do people care about African wild dogs? How do they move the dogs from one country to another? Is the habitat of the African wild dog the same as the Serengeti?
What resources may be helpful to apply what you have learned to this new scenario?	The Progress Tracker. Our class map/model. Our science notebooks. The data we investigated in Lessons 3–5.

ADDITIONAL GUIDANCE

The purpose of this discussion is to provide an opportunity for students to make sense of the new scenario and conservation dilemma they will encounter on the transfer task.

Although future transfer tasks will typically be completed individually, this is a chance to establish the routine for how the class will engage with transfer tasks in the future.

Organize materials to use on the transfer task. * Display **slide E** and ask students to take out their science notebooks, which should include *Progress Tracker*, *Investigating Rainfall Data*, *Wildebeest Population Data*.

Revisit classroom agreements. Display **slide F**. Before students move into pairs, revisit the agreements your class wrote for group work – for example, our commitment to an equitable classroom community where everyone’s participation and ideas are valuable – and discuss productive ways to complete the transfer task together. It is important to involve both partners in writing all answers rather than dividing up the questions between them because the transfer task is a story that builds. Before writing an answer, they should discuss their strategy or intention with their partner. If they are making a calculation, they can write it down to show their partner what they are trying to do, so the other person can check the work and discuss alternatives. They might assign one person to read and one person to write. The person who reads could also be sure to reread the question once the answer is “complete” to make sure they answered all portions of the question and supported the answer as appropriate.

3 · COMPLETE THE TRANSFER TASK

25 min

MATERIALS: *African Wild Dog Transfer Task*, science notebooks, *Progress Tracker*, *Investigating Rainfall Data*, *Wildebeest Population Data*



Complete the transfer task. Display **slide G**. Organize students into pairs to complete the task. Remind them that they should write answers on their own copy of the task, but will only turn in one. Collect one copy of each assessment from each pair to return on day 2.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Walk around the room during the transfer task. Students should be engaging with the graphs and data tables to explain:

- Space, prey biomass, and lions are limiting factors for African wild dogs. (DCI LS2.A)
- How each limiting factor can be used to determine carrying capacity. (DCI LS2.A)
- Carrying capacity cannot be determined in only three years. (DCI LS2.A; CCC 3.1)

What to do:

Collect one completed transfer task from each pair. Review the task before it is returned on day 2 in order to provide feedback that indicates where more detail is needed. Use *Transfer Task Key* as a guide. For example ask, *What is the smallest amount of space a pack requires according to the graph?*, *Is this a positive or negative relationship?* or *What evidence does the graph provide to determine carrying capacity?*

If students need more support in developing their ideas before completing the individual assessment item on day 2, take some additional time prior to the individual assessment to review the answers to this first part of the task as a class and perhaps revisit the connections of each question to supporting documents from previous tasks.

Building toward 6.A. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. (SEP 5.2; DCI LS2.A; CCC 3.1)

4 • DEBRIEF OF TRANSFER TASK

5 min

MATERIALS: science notebook, *African Wild Dog Transfer Task*

Assess students' reaction to the transfer task. Students should remain seated with their transfer task partners with the one remaining copy of *African Wild Dog Transfer Task* shared between them. Display **slide H**. Ask students to hold up the number of fingers that matches how they feel to quickly tell you how they felt after completing the first part of the transfer task. Make a note to yourself about their reactions and use this to guide the amount of encouragement or validation you need to provide students during the strategy conversation.

Discuss strategies for answering question 2. Say, *Remember this is an introduction to successfully completing transfer tasks.* Display **slide I**. Let's look at question 2 together and talk about how you used what you learned about the Serengeti to answer questions about African wild dogs. Facilitate a conversation about the connections students recognized between the two scenarios, the resources they accessed to assist them in writing their answers, and reminders for describing data and making scientific explanations.

Suggested prompt

What connections did you see between what you figured out about the Serengeti and the wild dogs?

Sample student response

They both happened in Africa.

It reminded me of investigating the wildebeest, when we were trying to determine the limiting factors on the population.

Carrying capacity was related to food in both.

Suggested prompt	Sample student response
<i>What was easy and what was hard about using the key ideas and practices you have figured out to explain a new phenomenon?</i>	It was easy to interpret the graph in question 2 because it was almost the same as the wildebeest. It was hard to decide which limiting factor was more important for the African wild dogs because the data did not always show a clear relationship. My science notebook was not organized, so I could not find the answers I wanted even though I knew we talked about it.
<i>What resources did you use to support you as you explained your thinking?</i>	I had definitions of limiting factors and carrying capacity in my science notebook. I reminded myself about examples of limiting factors and carrying capacity in Progress Tracker. Many of the graphs look like the ones from Investigating Rainfall Data. Question 2 is like the graph in Wildebeest Population Data.
<i>What details should be included for describing graphs for 2a?</i>	Use math to figure out how much the population rises and falls each year. Do not just say it goes up or it goes down. Use terms like “positive relationship” or “slope increases.”
<i>What details should be included in a thorough response when asked to write a scientific explanation for 2b?</i>	Make sure you answer all parts of the question, not just part of it (give reasons for ups AND downs, not just ups). Support your reasoning with data, numbers, and measurements from the graph. If you are unsure of a relationship because the data is not clear, it is ok to say so.
Remind students that they will complete question 8 of the task tomorrow, which brings together everything they learned so far to help scientists relocate the wild dogs to a location in Malawi. Encourage them to organize their science notebooks so they have what they need readily available.	

5 • NAVIGATE

2 min

MATERIALS: 3x3 sticky notes or scrap paper

Complete exit ticket about collaboration. Display [slide J](#) and distribute one sticky note or piece of scrap paper to each student. Ask them to answer the questions and to bring you the exit ticket as they leave.

ADDITIONAL GUIDANCE

Use the exit ticket to gauge student progress working in pairs so you can revisit the Community Agreements about equitable participation and moving science thinking forward and emphasize particular practices as needed. The exit ticket also provides a way for students who want to let you know about problems with collaboration during the transfer task that may need to be addressed.

End of day 1

6 · NAVIGATE

6 min

MATERIALS: *African Wild Dog Transfer Task*, science notebook

Prepare for the transfer task. Display slide K. Return the transfer task to students as they confer with their partners from day 1 about the preparation suggestions on the slide for one minute. Display slide L. Hand out question 8 to all students and read through the question together. Facilitate a brief discussion of the resources they will need to answer the questions and craft a well supported explanation.

Suggested prompt	Sample student response
<i>What is the problem presented here?</i>	Scientists want to know if they can establish a new population of African wild dogs in Liwonde National Park in Malawi.
<i>What information will you use to inform your answer?</i>	We know the starting pack size. We know the average litter size for wild dogs. We know the minimum territory size and amount of prey biomass needed for pack survival. We know the size of the new park and the amount of prey available. We know there are lions in the new park and that lions can be a problem for African wild dogs.
<i>What details should be included in a thorough response when asked to write a scientific explanation?</i>	Make sure you answer all parts of the question, not just part of it (carrying capacity, limiting factors). Support your reasoning with data, numbers, and measurements from the graph. If you are unsure of a relationship because the data is not clear, it is ok to say so.

7 · COMPLETE TRANSFER TASK QUESTION 8

12 min

MATERIALS: *African Wild Dog Transfer Task*, science notebook

Students complete question 8 of the transfer task. Display **slide M**. Give students 12 minutes to complete question 8 of the transfer task. They should hold onto their answers when they finish.

8 · PEER ASSESSMENT AND REVISION OF TRANSFER TASK

16 min

MATERIALS: *African Wild Dog Transfer Task*, *Peer Rubric*, science notebook, *Transfer Task Key*



Facilitate peer assessment of transfer task. Remind students that the transfer task may be a new type of assessment for them. The goal last class was for them to learn about the expectations for a transfer task. They completed the first seven questions with a partner to learn strategies from one another to successfully respond to questions. If you made suggestions on question 1-7, point out that they do not need to correct answers but should keep the suggestions in mind as they write responses to question 8.

Before they turn in the transfer task to you, they will have one more chance to make revisions. Hand out *Peer Rubric* and explain that this is the same rubric you will use to evaluate their answer to question 8. Display **slide N**. They will trade responses with their partners and use the rubric to review the strengths of the response and places where more detail is needed. Walk students through the rubric for 8a, pointing out the column headings and the list of expectations for a thorough response in the Organized Understanding column. Point out the place provided for them to add suggestions. *

ADDITIONAL GUIDANCE

Note that the rubric uses color to identify the three dimensions of NGSS. You may wish to briefly mention that this task evaluates not just students' understanding of limiting factors and carrying capacity but also how they use science practices related to using mathematical and/or computational representations to support explanations as well as their use of scale. It would be a useful extension for students to revisit their performance based on each dimension after the task is graded to self-assess their progress.

Display **slide O**. Explain the steps of the peer review. Provide students with 5 minutes to quietly review their partner's task and fill out the rubric. Then provide one minute for each student to explain their suggestions to their partner.

Revise the task. Display **slide P**. Provide 6 minutes for students to work independently to incorporate the peer feedback into a revision of their original answer to question 8. Collect all copies of the transfer task (question 1-8) and the peer rubric from both partners. Evaluate question 8 using *Transfer Task Key*.

* SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Explain that writing, consulting with peers, and revision are a regular part of scientific work. Scientists receive feedback from peers who may have different interpretations of the data, and they learn from one another, which improves the quality of the science as well as the quality of the communication.

The explanations they write should be based on the concepts they have learned about limiting factors and carrying capacity, which apply to populations of animals around the world. The limiting factors and carrying capacity may change in the future, but predictions can be made about the African wild dog population in Liwonde National Park based on what they know from data about what has happened in the past.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: During the self-assessment of the transfer task in groups, students will engage with the graphs and data tables to explain (SEP 5.2) to meet the criteria on *Peer Rubric*, including the following:

- Create a graphical representation of population changes in African wild dogs over 10 years. (SEP 6.2; DCI LS2.A; CCC 3.1)
- Describe the minimum space and prey biomass requirements for African wild dogs. (DCI LS2.A)
- Describe how each limiting factor is used to determine carrying capacity for the National Park. (DCI LS2.A)
- Liwonde National Park can support one pack of 11-12 African wild dogs. (DCI LS2.A)
- It is necessary to scale up this project dozens to hundred of times over to greatly increase the population of African wild dogs. (DCI LS2.A; CCC 3.1)

What do do: Prompt students in their groups to:

- Check off items in the Organized Understanding column of the rubric.
- Revisit *Wildebeest Population Data*, which explains why populations fluctuate annually, what causes them to reach carrying capacity, and how many years it takes to reach.
- Reexamine figure 3 and examine the units on the graph to determine the minimum territory size one pack needs.
- Reexamine figure 4 and examine the units on the graph to determine the minimum amount of prey biomass one pack needs.
- Compare the data provided in table B from Liwonde with figures 3 and 4 from South Africa.
- Consider if one limiting factor seems more important than another.
- Ask how knowing that lions are below carrying capacity might impact wild dogs.
- Consider how the lion population might change over time and how that would impact the carrying capacity of wild dogs (Extending).
- Consider what human interactions could raise or lower the carrying capacity of African wild dogs (Extending).

Building toward 6.B. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. (SEP 5.2; DCI LS2.A.1; CCC 3.1)

9 · FEEDBACK EXIT TICKET

3 min

MATERIALS: 3x3 sticky notes or scrap paper

Collect student feedback on giving and receiving feedback. Display **slide Q**. Hand out one sticky note or scrap paper to each student and ask them to rate how comfortable they were giving and receiving feedback. Match their self-score to what you see on the peer rubrics they turn in with the transfer task. Use their responses to guide future opportunities for discussion when you use peer feedback as described in the previous guidance callout.

ALTERNATE ACTIVITY

The African wild dog pack in Liwonde had puppies! For updates on the pack, share the following resources:

- Video of how they moved African wild dogs <https://www.youtube.com/watch?v=S1m00A6koEO>
- Images of the pups born in Liwonde after relocation <https://www.facebook.com/watch/?v=605291120734360>
- Updates on Liwonde National Park <https://www.africanparks.org/the-parks/liwonde>

* SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Look through the peer rubric to see if students were able to correctly identify items listed in the Organized Understanding column and therefore provide useful feedback to their peers. Also notice if students revised their original answers to question 8 based on that feedback. If students struggle with this task, it may be useful to share an anonymous response to the transfer task with the class and use the rubric together to score and revise an answer to help them improve their effectiveness in this scientific practice.

10 · NAVIGATE: REVIST THE DQB

8 min

MATERIALS: Driving Question Board, 3x3 sticky notes

Revisit the DQB. Display **slide R** and bring students together to form a Scientists Circle. Say, *At this point, you all have demonstrated your understanding of limiting factors and carrying capacity. Let's celebrate what we have learned! Has what we have figured out so far in the unit helped us answer any of the questions from the Driving Question Board? What questions have not been answered yet?* Put checks on questions that have been answered. Discuss whether the remaining questions need to be reorganized.

Say, *Our unit question is about how ecosystems work and how understanding them helps us protect them. We were using the Serengeti ecosystem as a model to help answer these questions. Show students the consensus map created at the end of Lesson 4. Say, Let's review the consensus model we made earlier and remind ourselves of what we understood and where we still had questions. Do we need to add any additional questions to our Driving Question Board?* Use sticky notes to add any additional questions to the DQB.

Suggested prompt

What additional questions should we add to our DQB?

Sample student response

How do predators interact with migrating wildebeest?

Why are predators not a more serious limiting factor for wildebeest?

Do predators migrate too?

Say, *It sounds like we need to understand more about the role of predators in the Serengeti ecosystem. We can investigate that in our next class.*

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.2

Write explanatory texts, including technical processes.(HS-LS2-1)

Students will write explanations of how they applied scientific information from previous lessons to describe a new scenario.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

Students will use quantitative reasoning to predict abstract future events.

CCSS.MATH.CONTENT.HS.N-Q.1 ~~Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays~~
Students will interpret the scale of multiple graphs and choose the appropriate scale to build two graphs to answer questions in *African Wild Dog Transfer Task*.

LESSON 7: How do predators interact with the wildebeest migration?

PREVIOUS LESSON We applied our knowledge about limiting factors and carrying capacity to a new scenario in a transfer task in small groups. We self-assessed our responses and discussed ways to revise. We revisited the DQB to determine what questions we have answered about how ecosystems work, how to protect them, and what further information we need. We decided to investigate the role of predators in the Serengeti ecosystem more deeply.

THIS LESSON

INVESTIGATION

3 days



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We decide to investigate the role of predators in the migration. We read about the behaviors of wildebeest and their predators and relate them to rules in an agent-based modeling game. We play the game and analyze our data to figure out that group behaviors increase survival for predators and prey. We realize our model is limited because we only investigated a few components and wonder how we can include more of the components.

NEXT LESSON We will investigate other components of the Serengeti ecosystem and their interactions and mechanisms to develop our models. We will use our models to predict outcomes of disturbances and figure out that biodiversity can support resilience in the system. We will update our Progress Trackers and the DQB and complete an exit ticket to show what we learned.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

- 7A.** Read informational text to obtain and communicate information about how the rules of the game are designed to model behavior in the Serengeti system. (SEP: 8.1; DCI: LS2.D.1; CCC: 4.1)
- 7B.** Use a model to predict interactions in the Serengeti system to generate data to support explanations about group behavior. (SEP: 2.6; DCI: LS2.D.1; CCC: 4.4)
- 7C.** Use an algorithmic representation to support explanations about how group behavior increases survival by identifying patterns in mathematical representations. (SEP: 5.2, DCI: LS2.D.1, CCC: 1.4)

WHAT STUDENTS WILL FIGURE OUT

- Behaviors in wildebeest and their predators can inform initial conditions and rules in a model.
- Mathematical models, such as algorithms, provide evidence to explain interactions.
- There is a pattern of group behavior increasing survival across multiple species.
- Models have limits that can affect the kinds of conclusions we can make from our data.

Lesson 7 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review learning from previous lessons to motivate investigating predators.	A	
2	5 min		INTRODUCE AGENT-BASED MODELING Relate agent-based modeling to traditional forms of modeling to introduce students to the Serengeti Board Game.	B-D	
3	8 min		INTRODUCE, SELECT, AND READ ABOUT AGENTS Introduce students to the agents they will represent in the game.	E-F	<i>Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
4	9 min		CONNECT BEHAVIORS TO INITIAL CONDITIONS Read about agents and relate behavior to the initial conditions.	G	<i>Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
5	13 min		MAKE SENSE OF THE GAME RULES Read about agents and relate behavior to the game rules.	H	<i>Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
6	5 min		NAVIGATE Facilitate small-group discussion about our investigation question.	I	<i>Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
End of day 1					
7	5 min		NAVIGATE Review predictions about interactions between agents.	J	<i>Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
8	7 min		SET UP SERENGETI BOARD GAME Demonstrate Serengeti Board Game set-up.	K-N	<i>Game Data Collection, General Game Instructions, Serengeti Board Game, game tokens, cards, dice (colors A and B), Example Community Agreements</i>
9	28 min		PLAY SERENGETI BOARD GAME	O	<i>Game Data Collection, Serengeti Board Game, game tokens, cards, dice (colors A and B), General Game Instructions, Agent-Based Modeling</i>
10	5 min		NAVIGATE Lead students through individual reflection about data and game play on an exit ticket.	P	loose leaf paper
End of day 2					
11	5 min		NAVIGATE Ask students to share a reflection of game play with a partner.	Q	
12	20 min		DATA ANALYSIS, PART 1 Analyze the data from the game to determine the relationship between group behavior and survival.	R-U	<i>Game Data Collection, Data Analysis, Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>

Part	Duration		Summary	Slide	Materials
13	15 min		BUILDING UNDERSTANDINGS DISCUSSION Lead a discussion that supports the class in using the evidence to answer the lesson question.	V-W	<i>Data Analysis, Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena</i>
14	5 min		NAVIGATE Review what we figured out and motivate next steps with an exit ticket.	X	

End of day 3

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Meet Your Wildebeest</i> <i>Meet Your Lion</i> <i>Meet Your Hyena</i> <i>Game Data Collection</i> <i>General Game Instructions</i> - loose leaf paper <i>Data Analysis</i>	<i>Meet Your Wildebeest</i> <i>Meet Your Lion</i> <i>Meet Your Hyena</i>	- Serengeti Board Game - game tokens - cards - dice (colors A and B) <i>Example Community Agreements</i> <i>General Game Instructions</i> <i>Agent-Based Modeling</i>

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Prior to class, organize game materials into group sets based on the size of your class. See *General Game Instructions* for more information. Watch <https://www.youtube.com/watch?v=6-ooaGN1lSk&list=PLSLDxqPb5NQmn2o4Z6bgFkQsqplvedyro&index=24> for additional guidance.

If a classroom kit is not available, print, cut, and separate the event cards into three different decks. See *Event Cards*. Print one copy of *General Game Instructions* for each set. In order to increase longevity, laminate the cards and directions.

Juego de Serengeti is designed to be printed on 18"x 24" paper.

If you need to make your own game tokens, use sticker template https://drive.google.com/file/d/1vMEgPhbi2otE_N3ZEQcWqTF9cbPo-74M/view?usp=share_link

The stickers were designed to be printed on Avery label 94500 and placed on one inch poker like chips.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build on what they figured out in Lessons 2-5 about limiting factors and carrying capacity to explain the interactions between wildebeest and their predators in the Serengeti, specifically, disciplinary core idea HS-LS2.D.1: *Group behavior membership can increase the chances of survival for individuals and their genetic relatives*. This DCI explains the mechanism behind outcomes that result from interactions between wildebeest and their predators in the Serengeti. Students build on a middle school understanding that *animals engage in characteristic behaviors that increase the odds of reproduction* (MS-LS1.B).

To make sense of group behavior, students *obtain and communicate information*, *use a model*, and use *mathematics and computational thinking* to explain predator-prey interactions in the Serengeti. They build on both their middle school use of these practices as well as their earlier use in the unit. This lesson gives them an opportunity to use an agent-based model, which incorporates mathematics and computational thinking. These elements are incorporated into the design of the game and also into the outcomes. Students will use the data they generate in the game to both explain the phenomenon and predict future outcomes.

The crosscutting concept *systems and system models* helps students figure out how the game was designed to do certain tasks as they relate the characteristics and behaviors of agents to the rules of the game. They also use the game model to simulate the Serengeti system, including the interactions within the system.

As students make sense of the data they generate throughout the game, they will draw on their experiences in Lesson 5 with algorithms to look for patterns, predict relationships, and predict future outcomes.

In this lesson, students co-construct a definition for group behavior as it provides a mechanism to explain the outcomes of predator-prey interactions.

Where We Are NOT Going

We will not be exploring the evolutionary component of HS-LS2.D.1 which states that *group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives*. Evolutionary relationships will be explored in both *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects?* (Urbanization Unit) and *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes?* (Speciation Unit).

While this lesson focuses on group behavior, group behavior does not explain all interactions between components in the system. Lesson 8 will provide students with an opportunity to investigate additional mechanisms.

LEARNING PLAN for LESSON 7

1 · NAVIGATE

5 min

MATERIALS: science notebook

Turn and Talk. Display **slide A**. Ask students to review their science notebooks and recall what they figured out in the last lesson. Then ask them to turn and talk to a partner using the prompts below as a guide. Once students have had a chance to discuss, call on a few pairs to share their responses. *

* ATTENDING TO EQUITY

Supporting Emergent Multilinguals: Before students engage in whole-class discussions, it can be helpful to first provide them with the opportunity to work with others - either in pairs, triads, or small groups - on ideas related to their reasoning. These smaller group structures can be especially helpful for emerging multilingual students because they offer students a chance to engage in sensemaking with their peers and also offer them the space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources too).

Suggested prompts	Sample student responses	Follow-up questions
<i>What did we figure out about how wildebeest are affected by food availability?</i>	The migration route is determined by rainfall and where the most nutritious grass is. There are so many wildebeest because the migration makes more food available to them.	
<i>What did the transfer task about the African wild dogs make us wonder about the Serengeti system?</i>	We know a lot about food and grass, but we do not know much about other limiting factors, like predators. We learned a little bit about the lions and how they are predators of and competitors to the wild dogs. What about lions and the wildebeest?	
<i>What do we need to figure out today?</i>	What are other factors that affect the wildebeest population and the migration. How are predators involved in the migration?	
<i>What do we already know about predators?</i>	We know lions and hyena prey on wildebeest. Predators are some of the reasons wildebeest are in certain locations at certain times of the year. They give birth in the south, where the risk of predation is lower. They leave the west, in part because there are a lot of predators.	<i>What did we find out about predators when we investigated the data cards in Lesson 3?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What are some ways we could investigate interactions between the wildebeest and their predators when we cannot be there in real time?</i>	We could watch a video. We could read about it. We could look at data. We could make a model. We could simulate it somehow.	<i>What practices have we used in previous lessons to investigate parts of the system that we cannot visit or observe directly?</i> <i>How did we investigate the relationship between the wildebeest and the grass?</i>

2 · INTRODUCE AGENT-BASED MODELING

5 min

MATERIALS: science notebook

Revist modeling as a practice. Say, *These are some really great ideas! Today, we will use some of your ideas and investigate the role of predators with a different kind of simulation. We will use a model that is set up as a game to help us simulate what is happening in the Serengeti.* Display slide B and use the prompts below as a guide.

Suggested prompt	Sample student response
<i>How have you developed or used models in the past?</i>	We used them to explain our conservation profiles. We have been using our big map as a consensus model to explain the migration.
<i>How have the models helped you make sense of what you were figuring out?</i>	It helped us organize all the parts. The system was really big, so it helped to model it. It helped us see relationships/interactions that were hard to see.
<i>What parts of the models were included when you developed models in the past?</i>	There are components. Those components interact with each other.

Introduce agent-based models. Display slide C. Say, *Today we are going to explore a new kind of model called an agent-based model. Agent-based models are based on computer simulations of complex systems. They include an environment, agents, and rules that describe how the agents and environment should interact. Typically, the rules are written as algorithms in a formula that computers can understand. Many agent-based models run on a computer and use code.* * Today we are going to use an agent-based model that looks like a board game and uses game rules. Even though it is not on a computer, it still uses math and numbers as rules for game play.

Consider the components of our game/model. Display slide D. Say, *Our game/model will help us answer questions about interactions in the Serengeti by simulating them. The game will simulate the great migration over a year in the Serengeti. It will include wildebeest, spotted hyenas, and lions as the agents.* Ask students to consider the parts of the model they identified earlier in the unit and how they might relate to the game

* SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

In Lesson 5, students used mathematical and algorithmic representations to explain carrying capacity in the Serengeti wildebeest population. Students can use this experience as they think about how algorithms, like the ones they developed, could be used as the rules for an agent-based model. See *Agent-Based Modeling* for an extended explanation of agent-based modeling.

using the prompts below:

Suggested prompt	Sample student response
<i>What components would the game include if it helped us explain how predators interact with wildebeest in the Serengeti?</i>	The agents (lions, spotted hyenas, wildebeest). Grass. Rain or water.
<i>How would some of the components interact with each other?</i>	Lions and spotted hyenas eat wildebeest. Wildebeest eat grass. Wildebeest might try to run away from the predators.
<i>How can the model/game help us answer our question?</i>	We could simulate how animals interact in the Serengeti since we cannot go there. We could simulate what happens with these animals in the Serengeti during the migration.
<i>If we are going to play this game, what are our next steps?</i>	We need to understand the rules and all the parts.

3 · INTRODUCE, SELECT, AND READ ABOUT AGENTS

8 min

MATERIALS: science notebook, *Meet Your Wildebeest*, *Meet Your Lion*, *Meet Your Hyena*

Introduce students to the game board. Display **slide E** and review the general features of the game.

Introduce the game agents. Say, *It sounds like our first step is to figure out the rules so we can play the game.* Display **slide F**. Divide the class into groups of 3–5 students. In each group, have students choose an agent (lion, spotted hyena, or wildebeest). If three students are in a group, each student will choose one agent. If there are more than three students, students may pair up as a team of lions, spotted hyenas, or wildebeest.

Students read about their assigned agents. Distribute *Meet Your Wildebeest*, *Meet Your Lion*, and *Meet Your Hyena* to each group and ensure students have the correct handout for the agent they have selected (lion, spotted hyena, or wildebeest). Give students several minutes to read the *Agent Background* section in their handout. Encourage them to annotate or mark up the reading using whatever reading strategy is in place in your classroom. *

* ATTENDING TO EQUITY

Struggling readers: If students struggle with a passage from the reading, ask them to circle words or segments that are unclear to them. Encourage them to reword difficult sentences, and if there are terms they are not familiar with, help them define these in their own words. Using content-specific and everyday vocabulary to express ideas is an effective strategy for supporting emerging multilingual learners.

4 · CONNECT BEHAVIORS TO INITIAL CONDITIONS

9 min

MATERIALS: *Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena*

Whole-class discussion to identify factors that explain the initial conditions. Display **slide G** and review the initial conditions row in the table with the whole class. Explain that there are rules for the initial conditions based on the real behaviors of the agents in the Serengeti system. Students will figure out what behaviors the initial conditions are based on. Say, *Let's identify an initial condition together as an example.* Ask students for the information that should go in Table 1 to make sense of these ideas together.

Suggested prompt	Sample student response
<i>You have 22 tokens representing different numbers of wildebeest. Why do you have that many tokens?</i>	There are about 1.3 million wildebeest, so the tokens add up to 1.3 million. There are 12 individual tokens plus 6 small groups (18 wildebeest), plus 4 herds (325,000) gives us just over 1.3 million wildebeest in the herd.
<i>You are putting your lions in these yellow areas. Why is this part of the game?</i>	Lions live in territories and cannot live outside of their territories.
<i>You have different types of tokens for spotted hyenas as well. Why do we have these different tokens?</i>	Hyena may hunt in small groups but live in clans with 55-75 individuals.

Individual students complete *Connected Behaviors*. While seated in their small groups, ask students to individually complete the *Connected Behaviors* related to the *Initial Conditions* on their handout in Table 1. Each agent should end up with at least two connected behaviors that explain an initial condition. Encourage students to share what they are identifying about their agent with others in the group who are all investigating different agents.

5 · MAKE SENSE OF THE GAME RULES

13 min

MATERIALS: *Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena*

 **Identify the behaviors that explain the rules.** Display **slide H**. Direct students to the *Rule* column of their table. Ask them to review the rules, refer back to the *Agent Background*, and identify the connected behaviors that the rule is based on. They should summarize and/or paraphrase ideas from the *Agent Background* in the *Connected Behavior* column of the table. Encourage them to discuss in their small groups as you circulate around the room and answer questions.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

how students are [reading their informational text to obtain information and paraphrasing](#) (SEP: 8.1). See *Meet Your Agent Key* for guidance on specific student responses.

What to do:

Support students as they work in their small groups. If students are struggling with classifying the type of behaviors or how they could be connected to the rule, review the example that the class completed together. Ask them to circle, underline, or highlight text in the *Agent Background* that is relevant to the initial condition or rule. Then support them in paraphrasing what is in the text by asking, *How can you say that in your own or simpler words?* Collect *Meet Your Wildebeest*, *Meet Your Lion*, or *Meet Your Hyena* and review using *Meet Your Agent Key* to provide feedback.

Provide written feedback to students. Press students to connect the rules of the game to the behaviors by using questions such as:

- Why does the game have more wildebeest tokens than lions or spotted hyenas?
- What is the significance of the lines that each agent stays within?
- Why do the wildebeest tokens have to be touching?

Building toward 7.A. [Read informational text to obtain and communicate information about how the rules of the game are designed to model behavior](#) in the *Serengeti system*. (SEP: 8.1; DCI: LS2.D.1; CCC: 4.1)

6 · NAVIGATE

5 min

MATERIALS: science notebook, *Meet Your Wildebeest*, *Meet Your Lion*, *Meet Your Hyena*

Small-group discussion. Display slide I. Say, *In your small groups, discuss what question you think the game can help us answer. Write your question down in your notebook so you can refer back to it later.*

End of day 1

7 · NAVIGATE

5 min

MATERIALS: science notebook, *Meet Your Wildebeest*, *Meet Your Lion*, *Meet Your Hyena*

Turn and Talk. Display slide J. Have students share the prediction they wrote down in the previous lesson.

Suggested prompt

What did we figure out yesterday?

Sample student response

We can use a game like a model to figure out how the migration affects predators.

We can use what we know about how the agents interact in the Serengeti to make rules in the game.

Suggested prompt	Sample student response
What question did you suggest as our investigation question?	How do predators and prey interact? What happens when different-sized groups of predators and prey interact?

Decide on an investigation question as a class. Call on a few pairs to share their investigation question. Record their ideas in a public space such as the whiteboard. Ask the class to notice similarities between the questions and come to a consensus on a single question. If students need additional guidance, point them back to the initial conditions and rules in *Meet Your Wildebeest*, *Meet Your Lion* and *Meet Your Hyena* to recall what kinds of questions the game will be able to answer. Student questions should relate to predators and prey and how they interact with each other.

8 · SET UP SERENGETI BOARD GAME

7 min

MATERIALS: *Game Data Collection*, *General Game Instructions*, Serengeti Board Game, game tokens, cards, dice (colors A and B), *Example Community Agreements*

Review Community Agreements that will support game play. Say, *Let's check in on our community agreements. Which agreement do you think would help us be most successful in our game play today?* Display **slide K** and listen to students' ideas. Review *Example Community Agreements* with the class if students need additional support.

Demonstrate the setup of the Serengeti Board Game. Display **slide L**. If you have an extra game board, you may want to set it up in a central location in the room to show students an example. If you have a document camera, you can project the initial game setup and demonstrate how to move tokens. Let students know that each group will have a game board, a set of tokens, a set of cards, and general game instructions. Show <https://www.youtube.com/watch?v=6-ooaGNlSk&list=PLSLDxqPb5NQmn2o4Z6bgFkQsqplvedyro&index=24> for additional guidance.

Review the instructions for the Serengeti Board Game. Display **slide M**. Review *General Game Instructions* for additional guidance.

Review the data collection procedure. Distribute *Game Data Collection* to each student. Display **slide N**. Ask students to record the investigation question at the top of the handout and make sure they circle the name of their agent. They should pay attention to what two tokens are interacting, who was successful in the interaction, and how many individuals were gained or lost. At the end of the turn, after they have taken an event card and added any additional gain or loss, they should total their population change.

ALTERNATE ACTIVITY

At your discretion, if students are interested in seeing a lioness hunt a wildebeest, please see <https://youtu.be/gyWd43fZ4Vc>.

9 · PLAY SERENGETI BOARD GAME

28 min

MATERIALS: *Game Data Collection*, Serengeti Board Game, game tokens, cards, dice (colors A and B), *General Game Instructions*, *Agent-Based Modeling*

Small groups organize the Serengeti Board Game. Organize students into the same small groups of 3-5 that they were in on day 1. Display **slide O**. Ask students to set up their game boards according to the *General Game Instructions* depending on their agent.

Support student game play. As students begin to play the game, circulate and make yourself available to ask and answer questions to support their thinking. Make sure that when they are done playing the game they know how to organize their materials and where to store them before moving on to the exit ticket.

10 · NAVIGATE

5 min

MATERIALS: loose leaf paper



Students complete an exit ticket. Display slide P, and ask students, *What data will you collect to help you answer your investigation question?*

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Data about how many individuals survive and/or die during predator/prey interactions. (SEP: 2.6; CCC: 4.4)
- Data about how many individuals survive and/or die during predator/prey interactions AND the group size of each agent. (SEP: 2.6; DCI: LS2.D.1; CCC: 4.4)

What to do:

As you navigate into Day 3, pair students who identified group size with those that did not. Ask them to review the data they identified. Encourage them to think about what will determine which agent is successful in interactions.

If students' data and investigation questions are not a good fit, ask them to revise their investigation question to one that they can answer with the data they have.

Building toward 7B. Use a model that simulates interactions in the Serengeti system to generate data to support explanations about group behavior. (SEP: 2.6; DCI: LS2.D.1; CCC: 4.4)

End of day 2

11 · NAVIGATE

5 min

MATERIALS: science notebook

Turn and Talk. Ask students to share their answers to the question from the exit ticket with a neighbor. Display slide Q. Call on a volunteer to answer the prompts below.

Suggested prompts	Sample student responses	Follow-up questions
<i>What was your main takeaway from playing the game?</i>	When predators hunted in groups, they were more successful. When the wildebeest were in groups, they were less likely to get eaten.	<i>What explains the outcomes in the predator-prey interactions?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>How will the data you collected help you answer your investigation question?</i>	We have the size of the group we circled and who was successful. We wrote down how many survived or were killed.	<i>What data did you collect as you played the game?</i>
<i>How can we make sense of this data?</i>	We need to organize it somehow. We could make a graph or a data table. We could write an algorithm.	<i>How have we made sense of data we collected in previous lessons?</i> <i>How could an algorithm help us make sense of this relationship?</i>

12 · DATA ANALYSIS, PART 1

20 min

MATERIALS: *Game Data Collection, Data Analysis, Meet Your Wildebeest, Meet Your Lion, Meet Your Hyena*

Support students in their analysis of data from game play. Say, *It sounds like you are ready to organize your data to look for patterns in your evidence.* Ask students to take out *Game Data Collection*, and pass out *Data Analysis* to each student. Organize students into the same small groups they played the game with. Display **slide R** and review with students how to use their data table from game play to complete the table in question 1.

Support students in developing algorithms in words. While students are still seated with their small groups, ask them to turn their attention to **slide S**. Remind students that they worked with algorithms in Lesson 5 when they developed a carrying capacity model. Say, *Remember that our game is an agent-based model with rules based on numbers that a computer could understand. We can use the same kinds of algorithms we used in Lesson 5 to make sense of this data.* Review the example on the slide and ask students to complete the algorithms in words for their agent.*



Develop a system model using inputs and outputs. Display **slide T**. Review the sample model with students and ask them to draw a model in their science notebooks using their agent. Students who had wildebeest can start with the wildebeest small group, and students who had predators can start either with an individual or with a small group.

When students are ready, display **slide U** and review numeric algorithms.

* ATTENDING TO EQUITY

The examples are built to have students focus on their agent. They can build out two examples for their agent (wildebeest in small groups and herds; lions and hyenas as individuals or small groups). The example has students aggregate all interactions between individual wildebeest and predators and does not account for individual and small-group predators. Adding these groups to the algorithm and model is the next step for students who are ready for an additional challenge. See *Extension Multiple Agents*.

Not all students will be ready to write numeric algorithms. Consider pairing up students who are working on written algorithms and those that are working on numeric. They will have different data but can support each other in structuring the algorithm and placing the correct evidence. Students working on written algorithms can also work on developing system models that include the percentages for the outcomes.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Algorithmic representation of interactions between 2 agents. (SEP: 5.2)
- Explanations using algorithms as evidence that group behavior increases survival for a single agent. (SEP: 5.2, DCI: LS2.D.1)
- Algorithms as evidence of a pattern, across all three agents, of group behavior increasing survival. (SEP: 5.2, DCI: LS2.D.1, CCC: 1.4)

What to do:

Collect student work and provide written feedback. Focus on the following for each group of students:

- For students developing algorithms in words:
 - Point them back to their data table, where they find the data they need to calculate % success. Use an example algorithm, such as the one below, to get them started:
 - If an individual, YOUR AGENT, interacts with ANOTHER AGENT, then YOUR AGENT is successful XX % of the time.
- For students developing numeric algorithms:
 - Use the following example and ask them to convert the underlined portions to numeric representations.
 - If an individual wildebeest interacts with any predator, then the wildebeest is successful 29% of the time.
- For students developing numeric algorithms accounting for group size for two agents:
 - Focus student attention on the difference they see when they disaggregate the predator or prey. In the sample data in slide R, the wildebeest was successful 29% of the time. Ask students to figure out the percentage when the predator is alone versus in a group to recognize the pattern of the benefit of group behavior across species.

Provide all students with an opportunity to revise their responses in written form or verbally. They will have additional opportunities to develop their use of mathematical and computational thinking in Lesson 8.

Building toward 7C. Use an algorithmic representation to support explanations about how group behavior increases survival by identifying patterns in mathematical representations. (SEP: 5.2, DCI: LS2.D.1, CCC: 1.4)

13 · BUILDING UNDERSTANDINGS DISCUSSION

15 min

MATERIALS: science notebook, *Data Analysis*, *Meet Your Wildebeest*, *Meet Your Lion*, *Meet Your Hyena*

Lead students in a Building Understandings Discussion. Display slide V. Organize students into a Scientists Circle with their notebooks, packets, and all of their notes to support them in sharing their ideas and figuring out new ideas together.*

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence. Your role during the discussion is to invite students to share conclusions and claims and to push them to support their conclusions and claims with evidence. Helpful prompts during these kinds of discussions include:

- What can we conclude?

Suggested prompt	Sample student response
<i>What accounted for differences in the outcomes during interactions between predators and prey?</i>	If the lions or spotted hyenas were alone, then they were less successful hunting. If the wildebeest was alone, it was more likely to die. Bigger groups of wildebeest were more likely to be successful and avoid one being killed. Groups or predators were more successful at getting prey.
<i>When an agent was successful, how could their success impact the rest of the group?</i>	If a wildebeest survived it would stay with the group and then help protect the rest of the herd. If a lion or a hyena was successful and got food it would bring it back to the group and they would all eat and that helps them survive.
<i>Did evidence from other agents' algorithms support similar or different conclusions?</i>	Similar. Groups helped predators get prey and avoid predators. Groups helped everyone survive.
<i>What kinds of limitations did you discover in the model?</i>	We wrote the algorithms for all the different token sizes we had, but we did not look at how the outcome changed based on the size of the other agent's group. Lions and hyenas eat other things besides wildebeest. We know that some wildebeest die of starvation and disease, and that was not in the model. The wildebeest move around the Serengeti, but there is no way to change it if there is a drought or food is not available for some reason.

- How did you arrive at that conclusion?
- What's your evidence?
- Does any group have evidence to support Group A's claim?
- What data do we have that challenges Group B's claim?

KEY IDEAS

Purpose of this discussion: To summarize evidence that supports group behavior as the explanation for different outcomes in predator-prey interactions.

Listen for ideas such as:

- Wildebeest survived more when they were in groups during interactions with lions and spotted hyenas.
- Lions and hyenas were more often successful when they hunted in groups compared to when they hunted alone.

Update personal glossaries. Say, *What I hear you saying is that for both the predators and the prey, being part of a group helped increase their success in interactions, which increases their survival. Scientists call this group behavior. Let's co-construct a definition and record it in our personal glossaries.* Display slide W.

ADDITIONAL GUIDANCE

As a class, co-construct the definition of *group behavior* based on data that was collected in the Serengeti Board Game. The class definition will vary from this sample definition: *groups of an organism that work together to increase their survival and the survival of their relatives.* Encourage students to include pictures, symbols, and/or words in their definition.

14 · NAVIGATE

5 min

MATERIALS: science notebook

Turn and Talk. Display slide X. Say, *We have figured out so much about the interactions between wildebeest, lions, and spotted hyenas. Remember that in our unit, we have been trying to figure out how ecosystems work. What additional questions do you have about this system? How could we investigate those components?* Call on a few pairs to share their ideas. Listen for students to bring up additional biotic and abiotic components of the system and their interactions that we do not yet understand.

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Students use information from a reading, summarized from scientific literature, and data from their own investigations to answer questions about predator and prey interaction in the Serengeti.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively. (HS-LS2-1)

Students develop algorithms in words and numerals to reason about their data and how it provides evidence to answer their questions.

LESSON 8: What other components of the Serengeti system interact with the migration?

PREVIOUS LESSON *We decided to investigate the role of predators in the migration. We read about the behaviors of wildebeest and their predators and related them to rules in an agent-based modeling game. We played the game and analyzed our data to figure out that group behaviors increase survival for predators and prey. We realized our model is limited because we only investigated a few components, and we wondered how we can include more of the components.*

THIS LESSON

INVESTIGATION

2 days



Mathis Jrdl, Unsplash

We decide to investigate other components of the Serengeti ecosystem. We gather information about eight different organisms and their interactions to develop a model that includes mechanisms and mathematical representations of relationships. We use our models to predict outcomes of disturbances and figure out that biodiversity can support resilience in the system. We update our Progress Trackers and the DQB and complete an exit ticket to show what we have learned.

NEXT LESSON *We will investigate human interests in the Serengeti ecosystem and add new interactions to our models. We will investigate a proposal to build a road in the Serengeti. We will evaluate road proposals and make a recommendation. Next, we want to apply our understanding to other systems.*

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

8.A Use a mathematical representation to model the interactions between components connected to wildebeest migration in the Serengeti ecosystem. (SEP: 5.2; DCI: LS2.C.1; CCC: 4.4)

8.B Develop and test a complex model for how ecosystems are resilient and the numbers and types of organisms relatively constant (stable) in response to disturbance (change). (SEP: 2.5; DCI: LS2.C.1; CCC: 7.1)

WHAT STUDENTS WILL FIGURE OUT

- Many components of the ecosystem connect to the wildebeest migration.
- The mechanism of their interactions includes predator/prey, group behavior, and competition.
- The wildebeest is a keystone species, and their migration supports biodiversity across the entire Serengeti.
- Biodiversity leads to greater stability within the ecosystem because with more species, a drop in population size of one species can be balanced by an increase in the population of another.
- Biodiversity contributes to ecosystem resilience when a disturbance occurs.

Lesson 8 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Ask students to recall what they figured out last lesson and what questions they still have.	A	
2	20 min		INVESTIGATE OTHER COMPONENTS AND INTERACTIONS IN THE SERENGETI ECOSYSTEM Support small groups investigating the different organisms and their interactions from the cards.	B-D	<i>Serengeti Component Interactions</i> , one organism from <i>Serengeti Component Articles</i>
3	15 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT MECHANISMS IN THE SERENGETI Move to a Scientists Circle. Lead a Building Understandings Discussion to determine the mechanisms responsible for interactions in the Serengeti ecosystem.	E-F	<i>Serengeti Component Interactions</i> one organism from <i>Serengeti Component Articles</i> , https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAj19QV007O84EX25BiN%2Ffile.json
4	5 min		NAVIGATE Map the computational model back to the real Serengeti.	G	
End of day 1					
5	3 min		NAVIGATE Support students in making predictions about changes in the Serengeti.	H	
6	12 min		USE A COMPUTATIONAL MODEL TO TEST PREDICTIONS ABOUT WHAT HAPPENS IN THE SERENGETI Give students time to develop questions that can be tested using the model, then test them.	I-J	modified by class period https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json , <i>Computational Model Instructions</i> , internet-connected devices, <i>Testing Predictions</i>
7	12 min		CONSENSUS DISCUSSION ABOUT HOW BIODIVERSITY SUPPORTS THE WILDEBEEST MIGRATION AND RESILIENCE IN THE SERENGETI Facilitate a Consensus Discussion about the mechanisms behind resilience in the Serengeti ecosystem.	K-L	modified by class period https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json
8	8 min		UPDATE PROGRESS TRACKERS Support students in updating their Progress Trackers.	M	<i>Progress Tracker</i> , <i>Conservation Profile Organizer</i>
9	7 min		FACILITATE INDIVIDUAL STUDENT EXIT TICKETS Give students time to complete an exit ticket.	N	https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7INSxO9dbYeJfU55LOI39g/copy

Part	Duration		Summary	Slide	Materials
10	3 min		NAVIGATE: RETURN TO THE DQB Have students work in pairs to evaluate what questions the class has answered from the DQB. Review and share the questions that students think we have answered.	O	Driving Question Board, sticky notes, markers

End of day 2

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Serengeti Component Interactions</i> - one organism from <i>Serengeti Component Articles</i> <i>Serengeti Component Interactions</i> one organism from <i>Serengeti Component Articles</i> <i>Progress Tracker</i> <i>Conservation Profile Organizer</i> https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7INSxO9dbYeJWheJfU55LOI39g/copy	- modified by class period https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json <i>Computational Model Instructions</i> - internet-connected devices <i>Testing Predictions</i>	https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAJ19QVO07O84EX25BiN%2Ffile.json - modified by class period https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json - Driving Question Board - sticky notes - markers

Materials preparation (35 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.
Make sure the classroom community agreements (from Lesson 1) are accessible.

Prepare to use SageModeler by experimenting with the template you and the students will manipulate: <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAJ19QVO07O84EX25BiN%2Ffile.json>.

Add to this computational model template as a class on day 1 to develop something similar to <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json>.

Before day 2, add rain, fire, and disease to the consensus model before sharing with students. On day 2 you will share a copy of your class's version of <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json> with student small groups to manipulate and create something like <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FInardyOXAY8QxDbPFzAo%2Ffile.json>.

Prior to class, determine how you will organize jigsaw groups for *Serengeti Component Articles*. Each student will need one card. The *Serengeti Component Articles* are designed to include one card of each of the 8 different organisms. If you do not have access to a unit kit, divide your class by 8 to determine how many copies of *Serengeti Component Articles* you will need. For example, if your class has 32 students, you will need 4 copies of *Serengeti Component Articles*. If your situation allows, you can print individual copies for each student to write on or print a class set to be reused through all classes and have students take notes in their science notebooks.

If needed, reserve 8 internet-connected devices for day 2 of the lesson, where students work in (at least) 8 small groups to use a computational model of the Serengeti ecosystem for their selected component. You can find a template for your whole-class model at <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAJ19QVO07O84EX25BiN%2Ffile.json>.

For the exit ticket, make a copy of <https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7INSxO9dbYeJWheJfU55LOI39g/copy> and make the link to your local copy of the form accessible to students. *Exit Ticket Guidance* for additional guidance.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

This lesson is designed to coherently build ideas related to the following disciplinary core idea: **LS2.C.1: A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.**

In addition to learning from prior lessons, students draw on a middle school level understanding of **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**

- *Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*
- *Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems.*

Students engage in the high school element of the science practice **Practice 5 Using Mathematics and Computational Thinking: Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.** Students progress in their understanding of this practice by using mathematical representations of individual components to create computational models for many components, interactions, and mechanisms within the Serengeti ecosystem.

Students use high school elements of the crosscutting concepts **Systems and System Models and Stability and Change.** In this lesson, students work with different scales of the Serengeti ecosystem by testing how changes to the system affect individual components and the system overall.

This lesson helps students build their understanding of **Systems and System Models and Stability and Change** by expanding the system they have investigated in previous lessons to include a greater number of components.

In this lesson, students co-construct definitions for *mechanism*, *keystone species*, *disturbance*, *biodiversity*, and *resilience*. This lesson provides opportunities for students to co-construct and record the definitions they build together in their personal glossaries and additional support for teachers if students are unfamiliar with these terms.

Where We Are NOT Going

This lesson does not explore the human impact or disturbances on the Serengeti ecosystem. Human impacts will be explored in Lesson 9.

While this lesson does address group behaviors, predator/prey interactions, competition, and the flow of matter, students are not tracking the flow of energy and matter in this system. This lesson and unit specifically address the interactions between abiotic and biotic components in the Serengeti system and introduces the mechanisms that explain those interactions. *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)* will specifically address the flow of matter and energy in ecosystems and will build evidence for mechanisms at the molecular level.

LEARNING PLAN for LESSON 8

1 · NAVIGATE

5 min

MATERIALS: science notebook

Review what we figured out last class and where we want to go next. Display **slide A**. Ask students to turn and talk to a classmate to discuss what we figured out last class and what we decided to work on next. Have partners give a visual cue (e.g., stand up, raise their hand, etc.) when they are ready. Call on a few pairs of students to share their thoughts. If students seem stuck, have them revisit their science notebooks.

Suggested prompt	Sample student response
<i>What did we figure out in our last lesson?</i>	We figured out that group behaviors increase survival for both wildebeest and their predators.
<i>What did we want to investigate next?</i>	We wanted to know about what is happening with other components of the Serengeti system.
<i>What might we want to know about those other components and how they could be interacting with the Serengeti system?</i>	Habitat, food, or prey Predators or competitors Organism size Population sizes or number of organisms Grouping or mating behaviors
<i>How did we think we could investigate those ideas?</i>	We wanted data from the interactions from the actual Serengeti. We thought that the Serengeti is very complex/has a lot of components, so maybe we could use something like a computer simulation to help us connect them.
<i>Why did we want to investigate those ideas?</i>	We have already figured out a lot about the wildebeest migration, grass, lions, African wild dogs, and spotted hyena but want to know what is happening with other components/organisms. We have figured out about how drought and disease can affect populations, but we are curious how other disturbances might affect populations.
<i>Say, That sounds important! After last class, I took some of your suggestions and found some data on the organisms in the Serengeti you were interested in learning more about. Let's take some time to get to know them better!</i>	

2 · INVESTIGATE OTHER COMPONENTS AND INTERACTIONS IN THE SERENGETI ECOSYSTEM

20 min

MATERIALS: science notebook, *Serengeti Component Interactions*, one organism from *Serengeti Component Articles*

Assign students to read articles. Display **slide B**. Assign each student to one of eight groups and distribute the corresponding *Serengeti Component Articles* to each student. * Ask them to read their assigned article individually and then respond to the slide's prompt on a blank piece of paper in their science notebooks. * These articles are short, so give students about 5 minutes for this task.

Serengeti Component Articles

- | | |
|----------------------|----------------|
| 1. Dung beetles | 5. Grasshopper |
| 2. Thomson's gazelle | 6. Acacia |
| 3. Kori bustard | 7. Giraffes |
| 4. Zebra | 8. Cheetah |

ALTERNATE ACTIVITY

If students are interested in other organisms, you can consider using the article template for the existing species to be particular to the organisms mentioned by your students. However, when doing so, ensure that the majority of your chosen organisms have a connection to the wildebeest migration to help us answer our lesson question with the computational model.

Prepare to work in groups. Display **slide C**. Ask all the students who will read article 1 to sit together at table 1, all the students who read article 2 to sit together at table 2, and so on. In a class of 30, for example, you would have 8 article groups of 3-4 students each. Explain to students that they will work in 8 groups to read different articles about various components of the system.



Arrange students in eight groups. Display **slide D**. Distribute *Serengeti Component Interactions*. Ask students to work together in their groups to share a notice and a wonder from their article. Then ask students to spend 10 minutes discussing and answering the prompts on *Serengeti Component Interactions*, with their group. Remind them to make sure each person answers the questions in language that makes sense to them so they are ready to share with the whole class during discussion. Give students about 10 minutes for this sensemaking activity.

* ATTENDING TO EQUITY

The *Serengeti Component Articles* are written at different reading levels and vary in length. You may wish to allow students to select readings based on interest before dividing them into groups. Or, at your discretion, count students into random groups 1-8, or assign them into intentional, mixed-ability reading groups with the students who need more reading support along with students who do not need the extra support. Articles 1 and 2 are the most complex, followed by article 7. Articles 3-6 and 8 are the most accessible to all reading levels. See *UDL Reading Supports* for additional support.

* ATTENDING TO EQUITY

Supporting emergent multilinguals:

Encourage students to record their ideas using linguistic (e.g., written words) and/or nonlinguistic modes (e.g., photographs, drawings, tables, graphs, mathematical equations, measurements). This is especially important for emergent multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of scientific phenomena. Have students use the literacy strategies in place in your school, such as close reading, graphic organizers, read aloud, or partner reading.

ADDITIONAL GUIDANCE

To assist students with *Serengeti Component Interactions*, refer back to the scaffolds from Lesson 4 about mathematical relationships in graphs, positive, negative, stronger and weaker. See **slide EE** (from Lesson 4).

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: See *Serengeti Component Interactions*.

- Students should **make claims** that:
 - are supported by use of the mathematical representations used to create the computational model. (SEP: 5.2)
 - describe the key interactions and mechanisms in the system to predict the behavior of components in the system (CCC: 4.4)
 - identify complex sets of interactions within the Serengeti ecosystem for different types of organisms. (DCI: LS2.C.1)

What to do: Support students as they work in their small groups. If students are struggling with identifying the interactions between components, refer students back to their articles. Push students to identify particular information from their article that mentions interactions. If students struggle to create a graph (mathematical representations) or if/then statement, refer back to the thinking they did in Lessons 4 and 5. Additionally, ask questions that will get students to think about the mechanism for what might be causing those interactions, such as *Why do you think that is happening?* or *What evidence is in the articles or previous lessons that would make you think that these two components interact in this way?*

Allow students to use *Serengeti Component Interactions* for the following Building Understandings Discussion and give them a chance to revise their responses as needed. Then collect it at the end of the day. See *Serengeti Component Interactions* for further guidance. Provide written feedback that will help students focus on the stability of the system to set them up for testing those ideas on day 2.

Building toward 8.A Use a mathematical representation to model the interactions between components connected to wildebeest migration in the Serengeti ecosystem. (SEP: 5.2; DCI: LS2.C.1; CCC: 4.4)

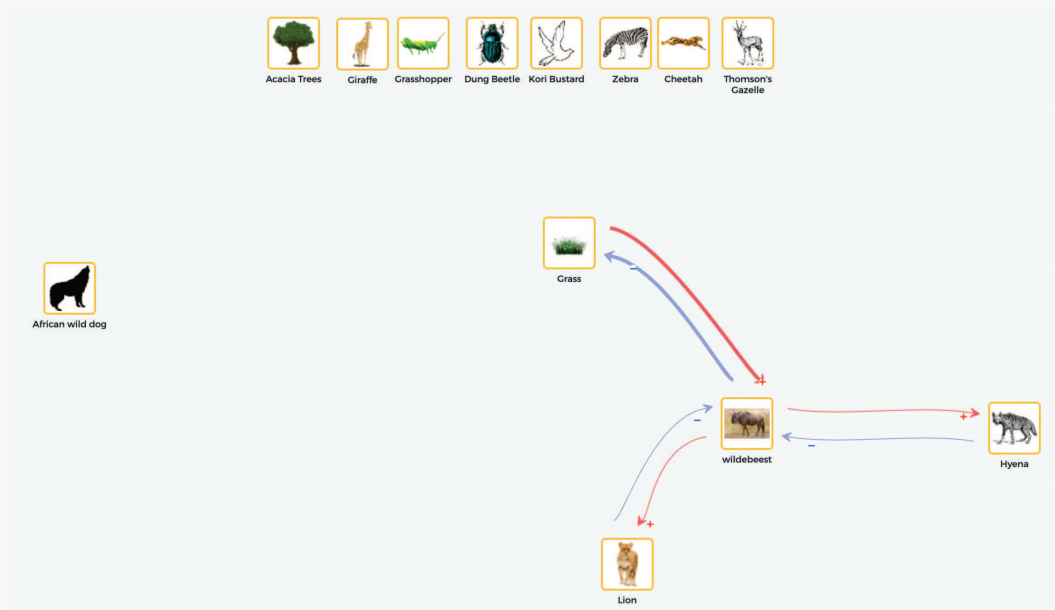
3 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT MECHANISMS IN THE SERENGETI

15 min

MATERIALS: *Serengeti Component Interactions* one organism from *Serengeti Component Articles*, <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAJ19QVO07O84EX25BiN%2Ffile.json>

Develop a model for the Serengeti as a class using SageModeler. Display slide E. Organize students into a Scientists Circle with their science notebooks to support them in sharing their ideas and figuring out new ideas together. Say, *As I walked around, I noticed your groups making many connections between components and interactions in the Serengeti. One of your ideas was that there is so much going on in the Serengeti that we might need something like a computer simulation to help us. I have a tool we can use called SageModeler that will let us build a model of all the components and interactions in the Serengeti that we investigated. We can use everything you figured out about your components in your articles to develop a class model for explaining what is happening in the Serengeti and input it into a computer!*

Here is the sample starting template for SageModeler:



KEY IDEAS

Purpose of this discussion:

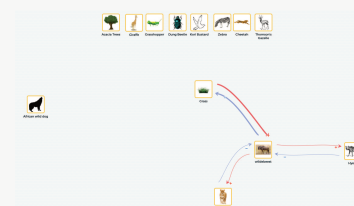
1. Identify the mechanisms behind interactions between components in the Serengeti ecosystem.
2. Facilitate student identification of wildebeest as a keystone species for the Serengeti.
3. Establish the Serengeti system in the computational model as stable.

Listen for ideas such as:

- Wildebeest have a higher number of interactions with other Serengeti ecosystem components.
- There are many mechanisms behind interactions in the Serengeti.

Teacher instructions for using SageModeler to develop a computational model:

Open the SageModeler link and make a copy for the current period/section. Display this on your projected screen for the class to see.



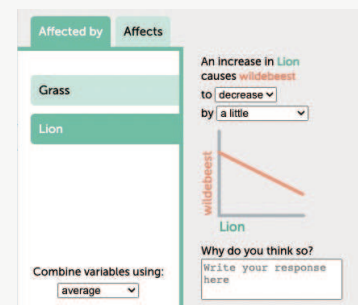
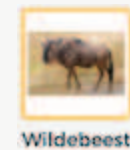
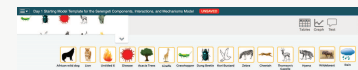
All of the components from the articles or prior investigations should be pre-populated on the template. You will be able to manipulate these as the class develops the model. On day 1, we are focusing on the living components. Non-living components such as fire and rain will be added on day 2.

To demonstrate interactions between organisms and to demonstrate how to build the model, ask the class to nominate a component they are already familiar with, such as wildebeest, grass, disease, wild dog, hyena, or lion.

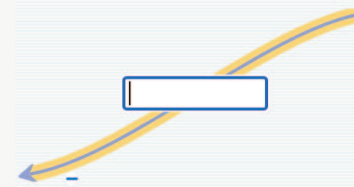
Briefly explain that you can add an arrow to connect components.

Double click on the component's icon to reveal the graph for the effect of that component's interactions on other components and the effects of other components on the original component. For example, you could explore the wildebeest population's effect on grass populations or the effect of the lion population on the wildebeest population. Show students you can also fill in the box asking Why do you think so? based on evidence and reasoning from earlier investigations.

Explain that once you fill in the increase, decrease, or vary by a lot, a little, more, or less, the arrow will change color and weight and use a plus or minus to represent the interaction.



Demonstrate that you can click on the arrowhead two times and a text box will appear on the arrow-line. Ask students to explain what we cannot see about the connection between two components. For example, students might say the wildebeest affects the grass a lot because it migrates to eat it all year round.



Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

See *SageModeler Introduction* for additional information on SageModeler.

Update personal glossaries. As students start to explain the interactions between components in the Serengeti ecosystem, pause them and point out that scientists call these explanations *mechanisms*. In addition to components and interactions, we will be adding mechanisms when we develop models in our class. If it comes up here, pause to give students a moment to add *mechanism* to their personal glossaries, or do it at the end of the discussion.

Say, Wait, I think I hear you doing more now than just explaining the interaction. You are getting into why these things are happening beyond just that they are. You are explaining how they are happening or what the cause is of these interactions. Scientists call this the mechanism behind the interaction.

ADDITIONAL GUIDANCE

As a class, co-construct the definition of *mechanism*. The class definition may be similar to some of the examples below or a combination:

Mechanism:

- *how things happen (the process)*
- *description of the cause of the relationship*
- *how a cause brings about an effect in a system*

Encourage students to include pictures, symbols, and/or words in their definition.

Add the new components, interactions, and mechanisms to the model for explaining the stability of the Serengeti. Continue to project the modified <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FhAJ19QV007O84EX25BiN%2Ffile.json> for the selected class period.

Teacher instructions for adding new components, interactions, and mechanisms in SageModeler:

All of the components from the articles or prior investigations and Serengeti Component Articles should be pre-populated at the top of the template. You will be able to manipulate these as the class develops the model. Invite groups to share their component and how it could be added to the model. Ask each group to explain the interactions for their component.

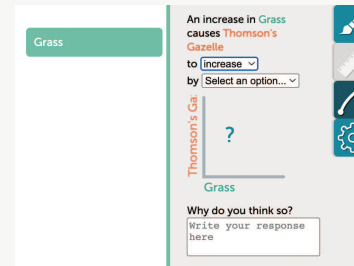
Groups will share what they made sense of on their Serengeti Component Interactions handout with the class to add their individual components. To add in new components, grab the icon for that component and drag it into the model.



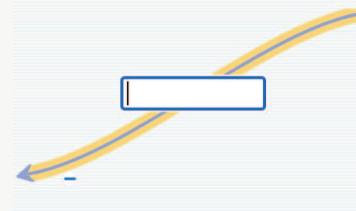
Next, ask the class to identify a second component in which the previous component interacts (such as Thomson's gazelle and grass). Use what the group says to add an arrow for the interaction. To do so, click on the little white curved arrow and drag it to the component affected by the component just added. The arrowhead should point towards the component that is affected. Ask students to tell you which way to connect arrows (going toward or away) for their component.



Double click on the component's icon to reveal the graph for the effect of that component's interactions. Ask students to tell you how a change in one component population affects the other component population.



Then ask the class to use words to describe the mechanism behind those interactions. To do so, click on the arrowhead two times and a text box will appear on the arrow-line.

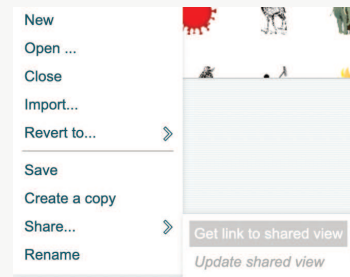


Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

Repeat the steps 2-5 for each group's component.

After you have added each component, ask the class to share noticings and wonderings about the system using the prompts below.

Make sure to save the copy of the modified template for each class so they can access it in small groups on the following day. You will need to save it and then share it so others can modify the model. Under share, click update shared view and then you can get the link to shared view for day 2.



Suggested prompt

Sample student response

Suggested prompt	Sample student response
<i>What do you notice about the components and interactions in our model?</i>	Answers will vary based on component. Listen for ideas like: There are lots of prey like gazelle, baby animals, etc. There are lots of predators like lions, hyenas, and cheetahs. There is a lot of competition, especially for grass, between wildebeest, grasshoppers, gazelle, and zebra. The wildebeest are surrounded by a bunch of arrows. Some components, like the acacia tree and the giraffe have very few arrows.
<i>Can you say more about what the arrows represent?</i>	Arrows represent the interaction between different components. Arrows can be plus or minus. The weight of the arrow can change based on a lot or a little interaction.
<i>Can you give an example?</i>	Answers will vary based on component. Listen for ideas like: One arrow represents the lion interacting with the wildebeest. The arrow points toward the wildebeest with a negative sign because if the population of lions increases, the population of wildebeest decreases. The line is not heavy because lions only affect wildebeest a little.
<i>What explanation do you have for why that interaction happens the way that it does?</i>	The lions eat the wildebeest sometimes. We figured out in Lesson 7 that the lions do not have a big effect because of the group behavior of the wildebeest, their individual size, and the size of the herd.

Suggested prompt	Sample student response
Can you say more about other interactions in the system?	Answers will vary. Another arrow represents the giraffes eating the acacia tree. The dung beetle eats the wildebeest poop, so if the wildebeest increases, the dung beetle increases a lot. There is competition for grass from the gazelle, wildebeest, zebra, and grasshopper. If one of them changes, the other might change too. The dung beetles make better soil with the dung from wildebeest and other animals. It seems like there are a lot of limiting factors in the Serengeti, such as the amount of dung made by wildebeest being a limiting factor for dung beetle survival.
Can you tell me the why behind what is happening? (such as why do the lions only affect the zebra a little?) Are there other places where we can explain the mechanism or why behind what is happening?	The zebra are more protected from predators because they migrate with the wildebeest, so those predators do not affect their populations a lot.
Earlier you said that different components had different numbers of arrows/connections? Who has the most connections in the system?	Wildebeest!
What does it mean that they have so many interactions?	They must mean wildebeest are really important in the system. That must mean they are connected to a lot of components. It is important that the wildebeest is stable because if the wildebeest is stable, then the other components will be stable as well.
Why then might it be so important to protect the wildebeest migration?	The reason to protect the wildebeest is more than just the wildebeest because they are connected to many other components. We need to keep the wildebeest migration protected because it has bigger implications for the system. But we are still not quite sure what those are.

Update personal glossaries. Display slide F. Students will likely identify that the wildebeest plays a more central role in the ecosystem than other organisms. Say, *What I hear you saying is that the wildebeest seem to be playing a central role in the Serengeti ecosystem because they have a lot of connections to many of the components in the system. Scientists call this a keystone species. Let's co-construct a definition and record it in our personal glossaries.* Students will also likely indicate that there are many different kinds of organisms in the ecosystem. Now is a good time to name *biodiversity* and add this to the personal glossaries as well.

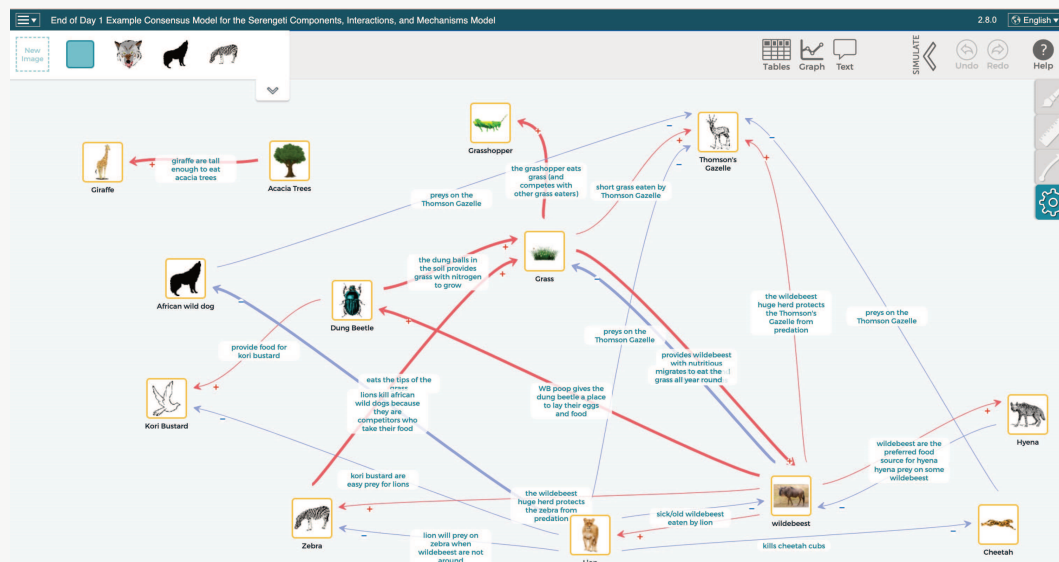
ADDITIONAL GUIDANCE

As a class, co-construct the definition of *keystone species* based on the class consensus model of interactions in the Serengeti. The class definition will vary from this sample definition: *an organism that is connected to a lot of other organisms in the system.*

Biodiversity is a definition that is part of the NGSS middle school grade band (MS LS2.C). Draw on students' prior understandings of biodiversity as well as their experiences in this unit to come to consensus on a definition. Definitions will vary but may be similar to: *the variety of species found in a particular place (e.g. planet Earth, the Serengeti etc.).*

Encourage students to include pictures, symbols, and/or words in their definition.

See one example below of a modified template for after day 1 Serengeti Ecosystem Components, Interactions, and Mechanisms. Or see <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json>. You will create a similar model to this for each of your sections and then share it with small groups on day 2.



Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

Say, We should celebrate that we have built this model of components, interactions, and mechanisms to explain how parts of the Serengeti ecosystem work.

4 · NAVIGATE

5 min

MATERIALS: science notebook

Support partner discussions to reflect on limitations of the computational model. Display slide G. Say, *You have investigated a lot of interactions and mechanisms between the living components of the Serengeti. Turn and talk with a partner about the questions on the slide.*

Suggested prompts	Sample student responses	Follow-up questions
<i>We have made models before with components and interactions, but this model is mathematical. What features made it mathematical?</i>	We added the direction and strength of the relationship/interaction. We modeled each interaction with a graph that shows how populations of two components change together.	<i>How did we add the idea of quantity to our models?</i>
<i>We can use models to explain AND predict. What has our model helped us explain so far?</i>	How the Serengeti ecosystem works. How all the different living things affect each other.	<i>Do you think this system is stable?</i>
<i>What can our model help us predict?</i>	We could add rain, fire, and disease to SageModeler and connect them to the other components they interact with in the system. We could see how the system changes when something happens like a drought or disease.	<i>What are the kinds of things that are likely to happen in the system that are not in our model?</i> <i>What is missing from the model?</i>

Collect *Serengeti Component Interactions* and if time allows provide feedback before day 2. See *Serengeti Component Interactions* for sample student responses.

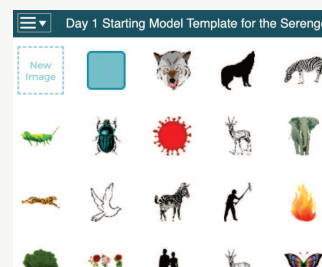
End of day 1

5 · NAVIGATE

3 min

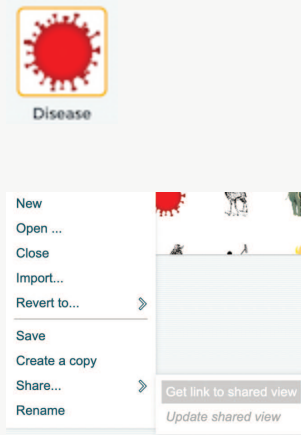
MATERIALS: science notebook

Before class, make sure you add fire, rain, and disease to the modified SageModel for each section.



Click on the image for each disturbance and drag it to the empty space on the model. Label the disturbance with rain, disease, or fire.

Make sure to save and share the model before class so student groups have a link that is easy to access.



Add disturbance to personal glossaries. Display slide H. Say, *Yesterday you all said that we could use our models to help us predict what would happen if something changed in the system. Scientists call these kinds of changes disturbances. Let's take a minute to co-construct a definition for our personal glossaries.*

ADDITIONAL GUIDANCE

As a class, co-construct the definition of *disturbance*.

Disturbance: living or nonliving changes that can affect an ecosystem

The class definitions will vary from these sample definitions but may be similar. Encourage students to include pictures, symbols, and/or words in their definition.

Make predictions about changes to the Serengeti ecosystem. Ask students to turn and talk about what we wanted to figure out on day 1, using the prompt on the slide, *Say, You talked about questions our model could help us answer and outcomes it could help us predict. What kind of disturbance can we add to our model? What will happen to the components if we add a disturbance?* Have students pick a disturbance mentioned on day 1 – rain, fire, or disease – and make their predictions of how that disturbance would affect the components in the system.

As students are sharing, walk around the room and listen to their predictions. As you are listening, ask questions to help them narrow their predictions down to something they can actually test using the disturbances and other components in the model.

6 · USE A COMPUTATIONAL MODEL TO TEST PREDICTIONS ABOUT WHAT HAPPENS IN THE SERENGETI

12 min

MATERIALS: science notebook, modified by class period <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8aI%2Ffile.js> on, *Computational Model Instructions*, internet-connected devices, *Testing Predictions*

Set up the task. Display slide I. Distribute *Testing Predictions* to each student. Take a minute or two for a few pairs to share their prediction (an increase or decrease in their component due to the disturbance) in an *If _____ then _____ because _____* format and write it down in their science notebooks. For example: *If the rain goes up, then the wildebeest population goes up because the rain makes more grass and*

* ATTENDING TO EQUITY

wildebeest eat grass.

Say, *If we think of a change that could be made, we can represent that by increasing or decreasing a disturbance. Then our model should be able to tell us not only how much that disturbance will affect another component but also other components in the system. We want to test our predictions that can give us somewhat quantitative answers.*

After this time, take a minute or two for a few pairs to share the prediction they plan to test (an increase or decrease in their component) and write it down in their science notebooks. Then say, *Let's test them using our model.* If time allows, groups moving at a faster speed can test more than one prediction.

Test predictions. Display slide J. Remind students how we can change the model using SageModeler. Distribute *Computational Model Instructions*. Demonstrate how to put SageModeler in simulate mode and how to move the sliders to increase or decrease the disturbance. Make sure that students have access to the modified by class period <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json> version from day 1, with fire, rain, and disease added as components.

Organize students into their small groups from day 1. Make sure you have enough internet-connected devices for each of the 8 groups to have at least one device to test their predictions, or consider having students work in pairs if enough devices are available. Share the modified link to that section's modified <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json>. Give students a few minutes to test their predictions for their component and wildebeest with partners and record their results in their notebooks. Walk around the room and support students in answering the questions on *Testing Predictions*.*

Prior to convening in the Scientists Circle, students work independently and in small groups to preview their predictions and look for ideas about affecting one component vs. many components/the whole system. Recruit a student who participates less frequently in whole-group conversations to share an idea they heard in their small-group conversation. You can quietly let the student you want to call on know about your intent in advance so they can think through their response ahead of time or let you know that they do not feel comfortable sharing. For example, you might say, *When we move to the Scientists Circle, I would like to ask you to share this idea you heard in your small group about the effect caused by the change to the system. Would you be willing to go public with this really productive idea?*

7 · CONSENSUS DISCUSSION ABOUT HOW BIODIVERSITY SUPPORTS THE WILDEBEEST MIGRATION AND RESILIENCE IN THE SERENGETI

12 min

MATERIALS: science notebook, modified by class period <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FMeWrQxm3KhvkTD5nj8al%2Ffile.json>



Discuss predictions and the effects on components and the system. Display slide K. Organize students into a Scientists Circle with their science notebooks and all of their notes to support them in sharing their ideas and figuring out new ideas together. Have a few pairs share their results from using the model, using the prompts on the slide to guide their responses. Remind students to cite specifically what they used to support their claims. *

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

A Consensus Discussion is different from other kinds of discussions because the purpose of the discussion is to converge on one idea or more ideas that the whole class agrees upon. In this discussion, your classroom community is pressing toward a common (class-level) explanation, model, or model representation. During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Helpful prompts include:

- What ideas are we in agreement about?
- Would anyone have put this point a different way?
- Who feels like their idea is not quite represented here?
- Are there still places where we disagree? Can we clarify these?

KEY IDEAS

Purpose of this discussion: to establish the importance of wildebeest for supporting biodiversity and resilience in the Serengeti ecosystem.

Listen for ideas such as:

- Wildebeest are important in the system because they have so many connections.
- One component might be affected by the disturbance a lot, but overall the system stays the same because there are so many connections.
- Resilience happens in the system because the system is biodiverse.

Suggested prompt

What was the prediction your group tested?

Sample student response

Answers will vary.

Suggested prompt	Sample student response
How were your predictions for what would happen similar or different for your component compared to the wildebeest compared to other components?	When the disturbance changed our component, it only affected some of the components. When the disturbance changed the wildebeest, it changed many of the components/system.
Why do you think that happened?	For example, since there are so many prey for the _____, if one of their prey decreases, then they can eat something else. Also, because the wildebeest have more than one predator, if that predator decreases, another one will have more to eat. The dung beetles could use other animal dung instead of wildebeest dung if the wildebeest decreased a little. Since there is so much competition for grass but the zebra, wildebeest, and gazelle all eat different parts, they are able to survive.

Listen for students to establish the need for biodiversity to create a resilient ecosystem in the Serengeti. Say, *What I hear you saying is that because there are so many different organisms and types of organisms, like the range of predator species and a range of prey species, together this results in a stable community resistant to change or disturbances on the whole system? Do you agree or disagree?* Ask students to give a thumbs up or thumbs down (or somewhere in the middle). Then use the prompts below to continue the conversation by asking why students agreed or disagreed.

Update personal glossaries. As they come up during the discussion, note and co-construct the meaning and importance of keystone species, biodiversity, and resilience in the system. If it is not natural to add them during the discussion, pause at the end of the discussion to update personal glossaries. Display **slide L**.

ADDITIONAL GUIDANCE

As a class, encounter or revisit the definition of biodiversity from middle school. In *OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*, students built out that the number of components in a system refers to the system's biodiversity when comparing rainforest ecosystems to oil palm farms. In addition, students developed ideas about how the numbers and different types of populations in an ecosystem are related to the system's biodiversity. If your students did not experience *Palm Oil Unit* or another middle school ecosystems unit, consider taking time to fully co-construct a definition for biodiversity here.

The class definitions will vary from these sample definitions but may be similar to: *all of the different kinds of living things in an area and that it was important to have a variety of living things.* Encourage students to include pictures, symbols, and/or words in their definition.

Revisit migration and have students summarize key takeaways we came to consensus on during the discussion. Use the prompts below as a guide.

Suggested prompt	Sample student response
<i>Why is the Serengeti ecosystem resistant to these disturbances?</i>	All of these animals are a little different and have different needs and behaviors, which allows them to all survive together, which creates stability for the ecosystem, even though there are changes.
<i>Think back to Lessons 4 and 5. We saw that wildebeest had access to grass year round in the Serengeti and that the population stabilized at 1.3 million wildebeest. What if there was no rain anywhere in the Serengeti?</i>	The wildebeest population would go way down. If the wildebeest went all the way down, the hyena would go down, the dung beetle would go down, which means the kori bustards would go down. The lions might go down a little too since the kori bustard are easy for them to eat. Many components in the system would be affected, but some would be okay.
<i>Can someone summarize why then it is so important to protect the wildebeest migration?</i>	There is a lot of biodiversity in the Serengeti, so it is less likely that a change to one component will affect everyone. Now we have all these connected species. If you mess with wildebeest, you mess with everybody. Changing some components has unequal effects. So if we protect the migration, we protect everybody. If you figure out who is connected to what, then you know that you are going to get more bang for your buck protecting one species vs. another.

Update personal glossaries. Say, *You all just described ideas about how the ecosystem can be resistant to disturbances. Scientists call this resilience. Pause to give students an opportunity to co-construct this definition and add it to their personal glossaries. Then give students an opportunity to revise their definition for keystone species.*

ADDITIONAL GUIDANCE

As a class, co-construct the definition of *resilience*.

Resilience: ecosystems have many overlapping layers that protect them from changing completely when a change/disturbance happens. The system remains similar even when a couple of components may change.

As a class, co-construct a revised definition of *keystone species*.

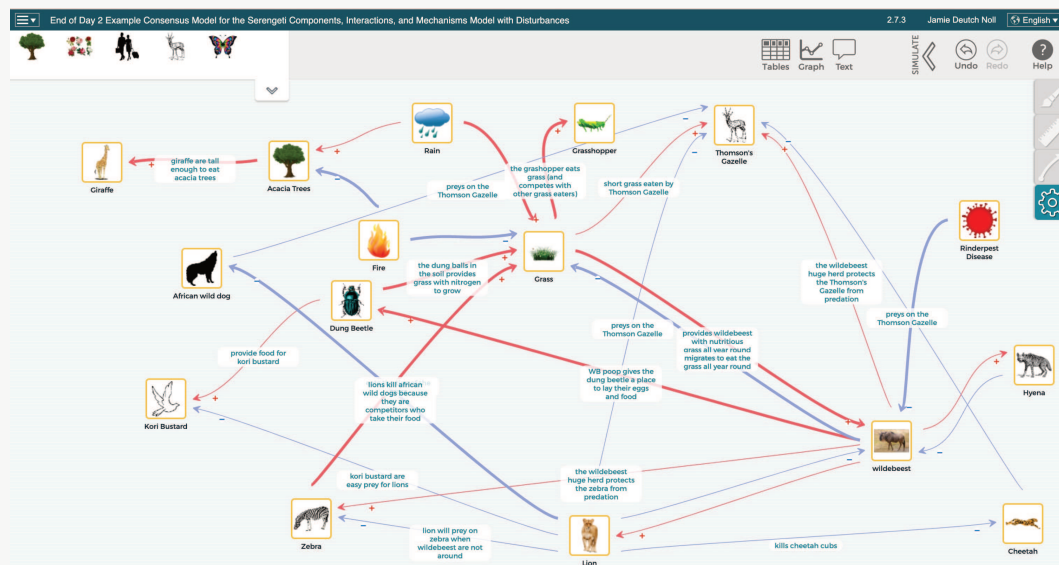
Keystone species: an organism that helps hold the system together and without it the ecosystem would look very different. If the keystone changes, then many other components of the system change as well.

The class definitions will vary from these sample definitions but may be similar. Encourage students to include pictures, symbols, and/or words in their definition.

ALTERNATE ACTIVITY

Extension: If students become curious during the Consensus Discussion about current efforts to monitor the health of the wildebeest or Serengeti ecosystem as a whole, tell them that they can contribute to these efforts through a citizen science project called Snapshot Serengeti. Through looking at pictures and identifying organisms, they can help scientists keep count of just how many organisms there are in the ecosystem. The link to this project is: <https://www.snapshotserengeti.org/>.

See one example below of a modified template for the after day 2 Consensus Model for Serengeti Ecosystem Components, Interactions, and Mechanisms. Or go to <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FInardyOXAY8QxDbPFzAo%2Ffile.json>



Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

8 • UPDATE PROGRESS TRACKERS

8 min

MATERIALS: *Progress Tracker*, *Conservation Profile Organizer*

Complete Progress Trackers. Have students move into their conservation profile groups from Lesson 1 and take out *Progress Tracker*. Remind them that each time they use the tracker, they should first fill in the lesson number and the question or topic they are writing about.

Ask them to turn and talk about the questions in the column that describes what they learned about the Serengeti.

Next, ask students to get out *Conservation Profile Organizer*. Display **slide M** and talk through the types of questions students should be able to answer about their profile. Provide time for students to read through their notebooks and look through earlier models and investigations. They should answer what they can in column 2. Anything they cannot find should be written as a question or note for further investigation in column 3. Walk around as students are working on columns 2 and 3 and ask questions like the one below to prompt student thinking.

One possible representation of a completed Progress Tracker is shown below.

	What did I figure out about the Serengeti?	What in my profile connects to ideas we figured out about the Serengeti?	What information do I need/questions do I have about how to protect ecosystems?
Lesson 8 What happens to the rest of the ecosystem?	Wildebeest are a keystone species in the Serengeti because their population is important to many other components. The Serengeti is biodiverse because there are so many species in the Serengeti that need different things to survive or parts of things. The ecosystem is resilient to disturbances (like drought, fire, or disease) because of that biodiversity.	Everglades: Alligators might be a keystone species because they seem to be connected to many other components in the system. I am not sure how resilient the Everglades are since it seems like water is important here, and I am not sure how resilient the system would be if the water amount or quality went down. Saguaro: The saguaro cactus is probably the keystone species. If it is gone, then a lot of organisms might lose their homes. Protecting the cactus probably makes the system more biodiverse and more resilient. Hoh: The salmon are really important in the river, and they affect a lot of other organisms. Protecting them makes the system more resilient. Lake Michigan: Quagga mussels and other invasive species disturb the ecosystem. They may make it unstable and make the fish population less stable.	How are humans impacting the Serengeti? If we are trying to protect biodiversity because it makes ecosystems more resilient, what impact are humans having? How are humans impacting our conservation profile? I wonder if _____ is the keystone species in my conservation profile.

9 • FACILITATE INDIVIDUAL STUDENT EXIT TICKETS

7 min

MATERIALS: <https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7INSx09dbYeJWhEjFU55LOl39g/copy>



Administer an individual exit ticket. Display slide N. Say, *We figured out some pretty important things about this system and how the components, interactions, and mechanisms are important to the biodiversity and resilience of the system that supports wildebeest migration. You have lots of questions about what this means for Serengeti National Park and your conservation profiles. Before we investigate further, you will*

complete an exit ticket that will give you a chance to show the progress you have made on the ideas that we have developed. Give students time to complete a copy of <https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7INSx09dbYejWheJfU55LOl39g/copy>. There is also a key for this exit ticket: *L8 Electronic Exit Ticket Key*.

ADDITIONAL GUIDANCE

See *Exit Ticket Guidance* for instructions on how to make the electronic exit ticket.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *L8 Electronic Exit Ticket Key* for guidance.

What to do: See *L8 Electronic Exit Ticket Key* for guidance.

Building toward 8.B.2 Develop and test a complex model for how ecosystems are resilient and the numbers and types of organisms relatively constant (stable) in response to disturbance (change). (SEP: 2.5; DCI: LS2.C.1; CCC: 7.1)

10 · NAVIGATE: RETURN TO THE DQB

3 min

MATERIALS: science notebook, Driving Question Board, sticky notes, markers

Navigate to the next lesson. Celebrate all the progress we have made to help us understand the components, interactions, and mechanisms that make the Serengeti a diverse and resilient ecosystem. Display **slide O** and have the DQB visible.

- What questions have we already answered?
- What questions do we still need to answer?

Give students some alone time to think about the two prompts before turning and talking with a partner. Circulate and listen for students to ask questions such as:

- *How are humans impacting the Serengeti?*
- *Does the park actually work?*
- *If we are trying to protect biodiversity because it makes ecosystems more resilient, what impact are humans having?*
- *Does the Serengeti protect biodiversity and resilience so it can protect the migration?*
- *How are humans impacting our conservation profile?*

Say, *I heard many of you discussing questions about humans and their impact on the Serengeti. Let's spend some time next class investigating those questions about humans and the system.*

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.RST.11-12.2

Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Students read articles about components of the Serengeti ecosystem using a jigsaw structure before summarizing the interactions in their articles for their peers when adding their component to the class model.

CCSS.ELA-LITERACY.RST.9-10.7: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Students integrate information from *Serengeti Component Articles* into graphs and if/then statements. Later in the lesson, students use those graphs to create a computation model to explain interactions and mechanisms in the Serengeti ecosystem.

CCSS.ELA-LITERACY.RST.9-10.8

Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-LS2-6)

Students develop claims, evidence, and reasoning about the effect of disturbance on the Serengeti ecosystem.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively. (HS-LS2-2)

Students develop mathematical representations using computer-based models that include direction, magnitude, and graphical representation of relationships.

CCSS.MATH.PRACTICE.MP4 Model with mathematics. (HS-LS2-2)

Students use mathematical representations of the interactions between components of the Serengeti ecosystem to develop a dynamic computational model of the system.

LESSON 9: How do humans interact with the Serengeti ecosystem?

PREVIOUS LESSON

We decided to investigate other components of the Serengeti ecosystem. We gathered information about eight different organisms and their interactions and developed a model that included mechanisms and mathematical representations of relationships. We used our models to predict outcomes of disturbances and figured out that biodiversity can support resilience in the system. We updated our Progress Trackers and the DQB and completed an exit ticket to show what we learned.

THIS LESSON

INVESTIGATION

3 days



Data Source: Sinclair, A. R. E. (2021). A place like no other : Discovering the secrets of serengeti. Princeton University Press.

We decide to explore how different human interest holders interact with the Serengeti ecosystem. We hear about different human interactions from Dr. Simon Mduma, and we add them to our model. We use our model to evaluate the Serengeti conservation plan and decide that it was successful in achieving its goals. We wonder what will happen in the future and investigate a proposal to build a road in the Serengeti. We evaluate three separate road proposals and make a recommendation. We decide to apply our understanding to other systems.

NEXT LESSON

We will look at more ecosystems by returning to our conservation profiles from Lesson 1. We will evaluate the conservation plans in those systems, present our findings to the class, and build an understanding about what it means for conservation to be successful and how we can use what we learned to protect more lands and waters.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

9.A Use a model based on evidence to explain how the plan to establish the Serengeti National Park contributed to the stability of the ecosystem. (SEP: 2.3; DCI: ESS 3.C.1; CCC: 7.1)

9.B Evaluate competing road proposals to determine how such human activity could impact the Serengeti ecosystem over short and long periods of time (SEP: 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC 7.1)

WHAT STUDENTS WILL FIGURE OUT

- Creating the park protected the wildebeest migration and the stability of the system.
- The whole system is more stable because the wildebeest are connected to so many things and protecting them protects biodiversity.
- Some interest holders benefit, but others are harmed, and not all human connections in the system are stable.
- Successful conservation that supports a stable ecosystem also involves relationships between the conservation managers and the broader community.
- There are numerous short- and long-term consequences that interest holders need to consider when making conservation decisions.

Lesson 9 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Revisit what we figured out and identify limitations of our current consensus model.	A-C	class consensus model from Lesson 8
2	5 min		CONSIDER HUMAN INTERACTIONS Identify human components and interactions to add to our model.	D	
3	8 min		EXPLORE HUMAN INTERACTIONS IN THE SERENGETI Revisit and explore human interactions in the Serengeti with Dr. Mduma	E-F	students' completed <i>Graphic Organizer</i> , https://youtu.be/V3E7_ozVrcY
4	15 min		REVISE CLASS CONSENSUS MODELS Support students in revising their class model from Lesson 8.	G	printed copy of class consensus model from Lesson 8
5	8 min		EVALUATE THE SERENGETI CONSERVATION PLAN Reintroduce students to the Serengeti conservation plan.	H-K	<i>Conservation Plan Evaluation</i> , complete <i>Graphic Organizer</i>
6	4 min		NAVIGATE: EXIT TICKET Facilitate an exit ticket.	K	
End of day 1					
7	5 min		NAVIGATE Introduce students to the case of a proposed road through the Serengeti.	L-M	individual consensus model, <i>Conservation Plan Evaluation</i> , class consensus model from Lesson 8
8	8 min		EXPLORE THE ROAD Introduce additional information about the road and support sensemaking.	N	<i>Interest Holder Cards</i>
9	13 min		EXPLORE DIFFERENT PROPOSALS FOR ROAD Organize students into small groups to make sense of road proposals.	Q-S	<i>Road Proposal Organizer</i> , <i>Road Proposal Cards</i>
10	16 min		EVALUATE DIFFERENT PROPOSALS FOR ROAD Facilitate students in evaluating the different road proposals in small groups.	T	completed <i>Road Proposal Organizer</i> , <i>Road Proposal Evaluation</i> , <i>Road Proposal Cards</i>
11	3 min		NAVIGATE Review what we figured out today and discuss next steps.	U	
End of day 2					
12	5 min		NAVIGATE Facilitate a whole-class discussion to summarize what we figured out about the road proposal.	V	

Part	Duration		Summary	Slide	Materials
13	10 min		REVIEW FEEDBACK Support students as they review individual feedback.	W	completed <i>Road Proposal Evaluation</i>
14	25 min		INDIVIDUAL ASSESSMENT Administer an individual student assessment.	X	<i>Individual Assessment</i>
15	5 min		NAVIGATE Ask students to stop and jot about how what they learned applies to other ecosystems.	Y	

End of day 3

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • students' completed <i>Graphic Organizer</i> • printed copy of class consensus model from Lesson 8 • <i>Conservation Plan Evaluation</i> • complete <i>Graphic Organizer</i> • individual consensus model • <i>Road Proposal Organizer</i> • completed <i>Road Proposal Organizer</i> • <i>Road Proposal Evaluation</i> • completed <i>Road Proposal Evaluation</i> • <i>Individual Assessment</i>	• <i>Interest Holder Cards</i> • <i>Road Proposal Cards</i>	• class consensus model from Lesson 8 • https://youtu.be/V3E7_ozVrcY • <i>Road Proposal Cards</i>

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so that they can be added to students' notebooks.

Print a copy of the class consensus model from SageModeler in Lesson 8 for each student.

Before day 2, organize the following:

Interest Holder Cards by making enough copies for each pair of students to have a set of cards.

Road Proposal Cards by making enough copies so that each group has a different card and there are enough cards for each individual student to have a copy.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

On day 1, students continue to develop their modeling practice by using a model (Conservation Evaluation Tool) to explain how the establishment of the Serengeti National Park contributed to stability in the ecosystem (CCC: 7.1). They continue to build on the understanding of HS-ESS3.C.1: *The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources* developed in Lesson 1, where they explored conservation profiles. Here students build on their understanding as they evaluate the establishment of the park using the ideas they figured out about ecosystems (e.g., biodiversity in Lesson 8).

On day 2, students use a new element of SEP 6 *constructing explanations* as they ~~design~~, *evaluate, and/or refine* a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

Students build on their use of crosscutting concept 7.1: *Systems can be designed for greater or lesser stability*. They used this element in Lesson 2 when they considered how the Serengeti National Park was established. Here they consider how a road in Tanzania could be designed to support greater or lower ecosystem stability.

Students develop understanding of DCI HS-ETS1.B.1 *When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts* for the first time in the high school program. Here they build on a middle school use of MS-ETS1.B *There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem*. They also build new understanding of HS LS2.C.2 *Moreover, anthropogenic changes (induced by human activity) 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*. Students first built an understanding of this DCI in Lesson 2, when they were introduced to the creation of the Serengeti National Park.

This lesson uses resources from Ethical Deliberation and Decision-Making in Socio-Ecological Systems Framework. For more information see http://learninginplaces.org/wp-content/uploads/2020/08/framework_socioecological-decisionmaking.pdf.

Students revisit the definitions they recorded in their personal glossaries for *criteria* and *nature-culture relations* and revise as needed.

Where We Are NOT Going

This lesson does not address the climate change portion of DCI: HS LS2.C.2. This anthropogenic change will be addressed in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

The road proposals do not give students an opportunity to explore invasive species, pollution, and overexploitation in meaningful ways. However, the conservation profiles explored in L1 and L10 address these aspects of anthropogenic change in different systems.

DCI: HS LS2.C.2 also calls out *the survival of some species*. While this lesson and unit introduce the idea of population change, elimination of species from some systems, and endangered species in the Serengeti and systems in the conservation profiles, they do not address extinction. Extinction will be addressed in *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes? (Speciation Unit)*.

LEARNING PLAN for LESSON 9

1 · NAVIGATE

5 min

MATERIALS: science notebook, class consensus model from Lesson 8

Revisit what we figured out in the previous lesson. Display **slide A**, showing an example of a consensus model using SageModeler. If your classroom model is different, refer to the model your students developed during Lesson 8.

Turn and Talk. Have students open their science notebooks, take two minutes to discuss with a partner what they figured out during the last class, and share the questions they still had at the end of the last lesson.

Write-Pair-Share. Display **slide B**. Say, *Let's think about our unit question, How do ecosystems work, and how can understanding them help us protect them? How can we use the unit question to identify what we still need to figure out and what our consensus model is missing. Take one minute to jot down your ideas about what our model is currently missing, or what does our model currently not account for?* Then have students share their ideas with a partner for one to two minutes.

Whole-class discussion. Display **slide C** and use the following prompts to facilitate a whole-class discussion.

Suggested prompts	Sample student responses	Follow-up questions
<i>What is our model currently missing if we are trying to answer the question: How do ecosystems work?</i>	Humans. We have not seen how the interactions between the animals in the Serengeti are affecting humans or are affected by humans. Our model does not show what and how decisions are made that could impact what happens in or outside of the Serengeti. Interactions outside of Serengeti National Park. We know humans protected the park, but that was a long time ago. How else do humans interact?	<i>Let's take stock of what is in our system and what is not.</i> <i>What component is missing that has a lot of interactions with the other components?</i>
<i>What else do we need to understand if we are trying to answer the question: How can understanding ecosystems help us protect them?</i>	We need to understand more about the humans involved in the protection of the park. We need to know who exactly protects the park and how they do it.	<i>Who protects ecosystems?</i> <i>How are they protected?</i>

2 · CONSIDER HUMAN INTERACTIONS

5 min

MATERIALS: science notebook

Brainstorm initial ideas about human interactions with the Serengeti. Say, *It sounds like we need to add humans and their interactions. Let's start by brainstorming some of the ways you think humans interact with components of the Serengeti.* Display **slide D** and give students a moment to stop and jot ideas in their notebooks using the questions on the slide as a guide. Call on a few students to share their ideas with the whole class.

ADDITIONAL GUIDANCE

Support students in using these personal examples to draw connections to the Serengeti. Students might share some of the following interactions:

- Keeping things like mold or insects and other pests out of where they live.
- Keeping predators away from their livestock or pets.
- Visiting protected spaces for recreation.
- Working and even sometimes living in a protected space.

Help students make connections between their experiences and experiences people living, working, or visiting the Serengeti might have.

3 · EXPLORE HUMAN INTERACTIONS IN THE SERENGETI

8 min

MATERIALS: science notebook, students' completed *Graphic Organizer*, https://youtu.be/V3E7_ozVrcY

Reintroduce Dr. Simon Mduma. Say, *Those are some great initial ideas you came up with. We can use our own experiences of interacting with protected spaces to help us understand how humans interact with the Serengeti.* Remind students that in Lessons 2 and 3 we heard from a scientist who has lived and worked in Tanzania and in the Serengeti. Let students know that he shared some information about human interests. Display **slide E**. Have students make a T-chart in their science notebooks to identify different interest holders and consider their different goals and values in preparation for hearing from Dr. Mduma.

ADDITIONAL GUIDANCE

Remind students that in Lesson 2 they heard about the views and interests of different groups of people. In this lesson, we are using the term *interest holders* instead of *stakeholders*, which has roots in colonialism and may be offensive to some individuals or groups. Feel free to use terminology that you and your students are comfortable with. Examples include, *rights holders* or *interested parties*. Pause to give students a moment to enter the term in their personal glossaries as a word or definition we encounter.

Watch a video of Dr. Simon Mduma. Say, *I am going to share another part of the interview with Dr. Simon Mduma.* Play https://youtu.be/V3E7_ozVrcY from **slide E**. Instruct students to notice and keep track of the different interest holders and their interactions in the park on their T-chart.

Generate a list of interest holders and interactions as a class. Display **slide F**. Ask students to share what they recorded in their science notebooks and make a public class record on chart paper or the whiteboard. Prompt students to add additional interest holders that they think may interact with the system. Encourage them to use additional resources in their science notebooks such as *Graphic Organizer*, and *A Brief History of the Serengeti*. See an example below:

Interest Holder	Interactions
<i>People living near the park boundaries</i>	<i>Poaching (illegally hunting) wildebeest to eat or sell to nearby towns.</i>
<i>Dr. Simon Mduma and other researchers</i>	<i>Protecting the wildebeest and the ecosystem. Studying the ecosystem.</i>
<i>Conservation groups/Park management</i>	<i>Educate and build relationships with surrounding communities.</i>
<i>Local tribes</i>	<i>Live around the park and keep cattle, which might eat grass and use habitat that other wild animals would otherwise use.</i>
<i>Tourists</i>	<i>They drive through and take pictures. Some of them probably have no impact, but some of them might harm it by littering or disturbing the animals.</i>

4 • REVISE CLASS CONSENSUS MODELS

15 min

MATERIALS: printed copy of class consensus model from Lesson 8

Individually revise the class consensus model by adding human interactions. Display slide G. Distribute a print copy of the class consensus model to each student. Organize students into small groups of 3-4 and ask them to revise the consensus model by adding humans and their interactions. *

* ATTENDING TO EQUITY

Universal Design for Learning: Give students the option of using SageModeler to revise the consensus model. Allowing students to express their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas.

5 • EVALUATE THE SERENGETI CONSERVATION PLAN

8 min

MATERIALS: science notebook, *Conservation Plan Evaluation*, complete *Graphic Organizer*

Revisit nature-culture relationships. Display slide H. Say, *Remember in Lesson 2, we encountered the term nature-culture relationships. Look in your personal glossaries to remind yourself of what we discussed.* Ask students to find their completed *Graphic Organizer* from Lesson 2 in their science notebooks. Ask students to use their models, *Graphic Organizer*, and what they heard from Dr. Mduma to think about which model best represents the Serengeti today. Listen to and accept all answers. Students may choose one of the two images or may propose an image that looks different from either example, which may represent an intermediate relationship.

Revisit the Serengeti conservation plan. Say, *Now that we have added to our understanding of how the Serengeti works by considering humans, we can use what we have learned to understand how humans decided to protect it.* Remind students that they heard about conservation plans in Lesson 2 when they learned about the creation of the Serengeti National Park. Use the prompts below to lead a discussion about the success of the conservation plan in the Serengeti.

Suggested prompts	Sample student responses	Follow-up questions
What was the conservation plan in the Serengeti?	Making the park. Protecting the migration.	Look back in your science notebook at what we figured out in Lesson 2. Look at Graphic Organizer and https://docs.google.com/presentation/d/1OEpkHOqu3MGfndVqpFvaGDOEaovsTAMZgbKL3HZ_mEO/edit?usp=share_link .
What data do we have that can support claims about the stability of the wildebeest population over time?	The wildebeest migration is still happening. We know the ecosystem is still pretty healthy. We have the carrying capacity data that shows it has been around 1.3 million for many years.	What data did we investigate? How does the wildebeest population compare to its carrying capacity? How are other organisms impacted by the wildebeest population?
What do you think the various interest holders would say?	Some of them would say yes, but others might say no. If they lost their land and had to move, they might say no. If they benefited from the tourist industry, they might say yes.	What about families that lost their homes or lost access to grazing land or the ability to hunt? What about the people who work in the park or benefit from the tourist industry? How do you think their interests and/or beliefs may have changed over time?
How can we use all of this information to evaluate the plan?	We could look at data. We could ask more people.	

ADDITIONAL GUIDANCE

If students need a reminder of how a *conservation plan* is defined, ask them to return to their personal glossaries to reread and/or revise their definition. Their definition may look like this: *a plan to conserve a natural place, ecosystem, and/or organism that details how it will be protected with goals and outcomes.* Encourage students to add their definitions in their personal glossaries as a definition we encounter.

Introduce the Conservation Evaluation Tool. Display slide I and say, *I have a tool that I think can help us look more critically at the success of the conservation plan.* Introduce the Conservation Evaluation Tool and talk through each of the steps in the diagram.

- Who is making these decisions?
- What are the goals and actions?
- What are the outcomes?
- What is the impact on ecosystem stability and resilience?
- What is the impact on interest holders?

Evaluate the conservation plan for the Serengeti in pairs. Distribute *Conservation Plan Evaluation* to each student. Ask students to turn and talk to a partner and answer the questions on the handout.

Lead a class discussion to share ideas about the Serengeti conservation plan. Display slide J and use the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>What were the goals of the conservation plan to establish the Serengeti National Park?</i>	To create a park to protect the migration. To protect large herds of animals from hunting. To provide a place for the Maasai to live.	<i>What did we hear about in Lesson 2?</i> <i>What have we been investigating in our unit?</i>
<i>What plans were put in place to support the goal(s)?</i>	People cannot live inside the park, and their activities in the park are restricted. There is no hunting in the park. There are park rangers and others who manage/enforce the rules.	<i>Who lives and/or works in the park?</i> <i>What kind of activities happen in the park?</i> <i>Who makes sure the rules get followed?</i>
<i>Who made the decisions that determined the conservation plan?</i>	Western scientists. The colonial government. Europeans. The Maasai protested the original boundaries.	<i>Did everyone agree on the original plan?</i>
<i>What data can help us understand if the goals were met?</i>	We have the data on the wildebeest population. We know about some of the other organisms that live in the park.	<i>What did we investigate to help us understand the migration?</i>
<i>How did the conservation plan impact the stability and resilience of the ecosystem?</i>	It protected the wildebeest and that helped protect a lot of other components.	<i>How did protecting the wildebeest migration affect other components of the system?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>How did the conservation plan impact interest holders?</i>	Some people, like the Maasai, had to leave the park after living there for a long time. Some people lost a place to hunt. Tourists gained a place to visit. Some people made money off the tourists. People who wanted to protect animals were happy.	<i>Who benefited from the plan?</i> <i>Who was harmed by the plan?</i>

Students revise responses. Give students a few moments to individually revise their responses on *Conservation Plan Evaluation* before collecting it.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Use a model (the conservation evaluation tool) to explain the following evidence (SEP 2.3)

- Creating the park protected the wildebeest migration and protected stability of the system. (DCI: ESS 3.C.1; CCC 7.1)
- The whole system is more stable because the wildebeest are connected to so many things and protecting them protects biodiversity. (DCI: ESS 3.C.1; CCC 7.1)
- Some interest holders benefit, but others are harmed, and not all human connections in the system are stable. (DCI: ESS 3.C.1; CCC 7.1)
- Successful conservation that supports a stable ecosystem also involves relationships between the conservation managers and the broader community. (DCI: ESS 3.C.1; CCC 7.1)

What to do: Collect *Conservation Plan Evaluation*. Provide written feedback with a focus on questions 5 and 6 using *Conservation Plan Key* as a guide. Provide an opportunity for students to revise their thinking and resubmit their responses either verbally or in writing.

Point them to their consensus model and use the following prompts:

- What did the park protect?
- How did that protection contribute to stability in the ecosystem?
- How were different interest holders impacted?

Building toward 9.A Use a model based on evidence to explain how the plan to establish the Serengeti National Park contributed to the stability of the ecosystem. (SEP: 2.3; DCI: ESS 3.C.1; CCC: 7.1)

6 • NAVIGATE: EXIT TICKET

4 min

MATERIALS: science notebook

Introduce an exit ticket. Display slide K and ask students to take out a half sheet of paper from their science notebooks. Say, *We spent some time thinking about why the conservation plan was successful. Will it be successful forever? What kinds of disturbances might it face in the future? How will the ecosystem respond to future disturbances?* Give students several minutes to complete and turn in their exit tickets.

End of day 1

7 • NAVIGATE

5 min

MATERIALS: science notebook, individual consensus model, *Conservation Plan Evaluation*, class consensus model from Lesson 8

Connect to students' ideas. Say, *In looking through your exit tickets, you all identified some really interesting ideas that could present a challenge to the conservation plan in the Serengeti.* Share a few student ideas from the exit tickets or ask a few students to share their ideas.

Introduce a new challenge. Say, *I came across a case that presented a challenge to the conservation plan in the Serengeti and involved a lot of the different interest holders you identified in our last class.* Display **slide L** and introduce students to the proposed road in the Serengeti. *The road would be paved, 50 kilometers long (about 30 miles), and would connect existing roads on the east and west sides of the park.*

Turn and talk about the road. Display **slide M**. Ask students to turn and talk to a partner using the prompts on the slide. Encourage students to use their models of the Serengeti ecosystem. Then ask a few pairs to share what they came up with.

Lead a whole-class discussion. Use the following prompts as a guide:

Suggested prompt	Sample student response
<i>What ideas do you have about the impact the road will have on the system?</i>	It will probably be really harmful. It could disrupt the migration.
<i>How would the road affect the wildebeest carrying capacity?</i>	It would probably be lower if the wildebeest cannot cross the road because then they cannot get the grass that is on the other side.
<i>How would it affect biodiversity and resilience in the system?</i>	If the wildebeest population goes down, a lot of other organisms' populations will go down. The biodiversity will probably be lower. The system might not be as resilient to changes in the future.

8 • EXPLORE THE ROAD

8 min

MATERIALS: science notebook, *Interest Holder Cards*

Introduce further exploration of the road. Say, *You all had a lot of great initial ideas about how the road could impact the ecosystem. I found a short video that describes a little more about the road and provides perspectives from different human interest holders. Since we do not know much about human interests in the area, I thought this would be a good place to start. In your science notebooks, make a three-column chart to help you organize what you notice and wonder about the different interest holders.* Display **slide N** and give students a moment to create a chart in their notebooks. Then display **slide O** and play <https://www.youtube.com/watch?v=ApPa9IBwh8M>.

Whole-class discussion about the road. Display **slide P** and call on a few students to share what they noticed in the video.

Suggested prompt	Sample student responses	
What else did you learn about the road proposal?	There are some people who really want the road because it would make their lives better.	
What interest holder was highlighted in the video, and what was their perspective on the road, or what were their wants and needs related to the road?	People who live in the villages want access to health care and education.	

Explore interest holder cards with a partner. Ask students to turn and talk to a partner and distribute *Interest Holder Cards* to each pair. Ask them to use the cards to explore the perspectives of the different interest holders more in depth and continue to add to the chart in their science notebooks.

9 · EXPLORE DIFFERENT PROPOSALS FOR ROAD

13 min

MATERIALS: *Road Proposal Organizer*, *Road Proposal Cards*

Introduce alternative road proposals. *We made a lot of progress toward understanding the Serengeti ecosystem and the perspectives of different interest holders and what their positions might be on a road in the Serengeti. There is actually a proposal with three different options that has been written about. Let's take a look at these different options.* Display **slide Q** and point out the three different locations for the proposed road.

Small groups explore the proposals for the road organized by criteria. Distribute *Road Proposal Organizer* to each student. Display **slide R** and review with students how they will organize the ideas about the road. Organize students into groups of 3-5. Distribute one card from *Road Proposal Cards* to each student. Students in the same group should all have the same card.

ADDITIONAL GUIDANCE

Students likely added criteria to their personal glossaries in Lesson 2. Take a moment here to revisit those definitions to see if they need to be revised to use in the context of the road proposals. A sample definition may look like: *a standard for judging something*.

ADDITIONAL GUIDANCE

If you or your students are interested in learning more about the road proposals, the data found on *Road Proposal Cards* was adapted from the following resource:

Hopcraft, J.G.C., Bigurube, G., Lembeli, J.D., Borner, M. (2015). Balancing Conservation with National Development: A Socio-Economic Case Study of the Alternatives to the Serengeti Road. *PLOS ONE*, 10(7): e0130577.



Rearrange students into new groups to share findings. Organize students into mixed groups of four so that each group has a representative of each criteria. Display **slide S**, which suggests a protocol students might follow for sharing and learning from each other. Give students about 5 minutes to share with their groups.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- The Eyasi route is most likely to **best meet the criteria** of the **cost and travel time**. (SEP 6.5; DCI: ETS1.B.1)
- The Mbulu route is most likely to **best meet the criteria** of **economic development and social services**. (SEP 6.5; DCI: ETS1.B.1)

What to do:

Circulate around the room as students work in small groups and complete *Road Proposal Organizer*. Use the feedback prompts on *Road Proposal Organizer Key* to support student thinking about each of the criteria.

Building toward 9.B.1 Evaluate competing road proposals to determine how **such human activity could impact the Serengeti ecosystem over short and long periods of time** (SEP 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC 7.1)

10 · EVALUATE DIFFERENT PROPOSALS FOR ROAD

16 min

MATERIALS: completed *Road Proposal Organizer*, *Road Proposal Evaluation*, *Road Proposal Cards*



Small groups evaluate road proposals. Display slide T. Say, *Now you have had a chance to investigate evidence and hear about all three road proposals. You will choose one proposal to evaluate, and then you will explain your evaluation.* Assign students to small groups of 2-3 based on the proposal they chose to evaluate. Distribute a copy of *Road Proposal Evaluation* to each student and explain that they will work through the questions together to prepare for an individual assessment on day 3. Organize the students into their small groups. As students work on their evaluations, circulate around the room to support student thinking.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- The **Serengeti road option** has the potential to **disrupt the ecosystem in the short and long term** and harm human interest holders. (LS2.C.2 & ETS1.B.1; CCC 7.1)
- **Interest holders** will **prioritize criteria** in various ways. (SEP 6.5; ETS1.B.1)
- Some options may **better meet the greatest number of interest holder needs in the short and long term**. (SEP 6.5; ETS1.B.1; CCC 7.1)

What to do:

Circulate around the room as students work in small groups and complete *Road Proposal Evaluation*. Use *Group Assessment Key* to support student thinking. Focus on items 3, 4, and 5. Collect student work and provide individual feedback in advance of the assessment on day 3.

Building toward 9.B.2 Evaluate competing road proposals to determine how **such human activity could impact the Serengeti ecosystem over short and long periods of time** (SEP 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC 7.1)

11 · NAVIGATE

3 min

MATERIALS: science notebook

Stop and Jot. Display slide U. Ask students to stop and jot in their science notebooks to reflect on what we figured out today and what the next steps are in putting together what we know about ecosystem impacts with what we just figured out about interest holder impacts. Let them know that on day 3 they will complete an individual evaluation based on all the work they did on days 1 and 2.

End of day 2

12 · NAVIGATE

5 min

MATERIALS: None

Whole-class discussion to summarize the road proposal. Display **slide V**. Ask students to turn and talk about the question on the slide. Then call on a few students to share.

13 · REVIEW FEEDBACK

10 min

MATERIALS: completed *Road Proposal Evaluation*

Students individually review feedback on *Road Proposal Evaluation*. Display **slide W**. Hand back *Road Proposal Evaluation*. Remind students that they will have an opportunity to revise their ideas in an individual assessment and that they should take time now to plan for their revision.

Plan for revision. Give students a few minutes to review feedback, ask questions, jot down notes, and get organized to engage in an individual assessment.

14 · INDIVIDUAL ASSESSMENT

25 min

MATERIALS: *Individual Assessment*

Students engage in individual assessment. Distribute *Individual Assessment* to each student. Display **slide X** and review the expectations with students. Provide them with about 25 minutes to complete their individual explanations and collect them when complete.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- A specific road option is selected to **evaluate**. (SEP: 6.5)
- Evidence of the **impact of the road** in the **short/long term** on both the **ecosystem** is explained, **including the wildebeest migration and the broader ecosystem**. (SEP: 6.5; DCI: LS2.C.2; C,CC: 7.1)
- Evidence of the impact on human **interest holders** in the **short/long term by criteria** is explained. (SEP: 6.5; ETS1.B.1; CCC: 7.1)

What to do:

Collect *Individual Assessment* from each student. Use *Explanation Key* to evaluate and provide feedback. Encourage students to use the feedback they receive on this assessment to support the evaluation they will complete in Lesson 10.

Building toward 9.B.2 Evaluate competing road proposals to determine how **such human activity could impact the Serengeti ecosystem over short and long periods of time**. (SEP: 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC: 7.1)

MATERIALS: science notebook

Reflect on next steps. Say, *While parts of the Serengeti ecosystem have been protected for over 70 years, how and what is protected can change as the components of the local and global systems change.* Ask students to stop and jot in their science notebooks using the prompts on **slide Y**.

Additional Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-10.7

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.9-10.1

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

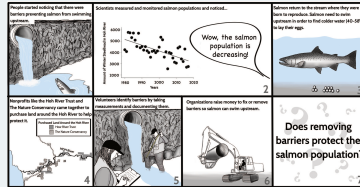
LESSON 10: How do we evaluate if a conservation effort is working?

PREVIOUS LESSON We decided to explore how different human interest holders interact with the Serengeti ecosystem. We heard about different human interactions from Dr. Simon Mduma, and we added them to our model. We used our model to evaluate the Serengeti conservation plan and decided that it was successful in achieving its goals. We wondered what will happen in the future and investigated a proposal to build a road in the Serengeti. We evaluated three separate road proposals and made a recommendation. We decided to apply our understanding to other systems.

THIS LESSON

PUTTING PIECES TOGETHER

3 days



We decide to look at more ecosystems and return to our conservation profiles from Lesson 1. We evaluate the conservation plans in those systems by considering the impact the plan would have on organisms, the ecosystem overall, and other interest holders. We present our findings to the class and build understanding about what it means for conservation to be successful and how we can use what we learned to protect more lands and waters.

NEXT LESSON We will complete a transfer task to demonstrate how what we figured out throughout the unit about how ecosystems work and how understanding them can help us protect them.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

10.A Evaluate a conservation plan by using evidence and reasoning about stability and change from complex interactions in the ecosystem. (SEP: 6.5; DCI: LS2.C.1; CCC: 7.1)

WHAT STUDENTS WILL FIGURE OUT

- There are different strategies to reach the goal of the conservation plan that vary in their outcomes.
- Scientists evaluate if conservation plans are effective by looking at ecosystem interactions, individual organisms populations over time, and ecosystem resilience.
- Conservation success relies on the plan's goals being met while supporting ecosystem resilience and minimizing any negative impacts on interest holders.
- Interest holders have different goals, and the criteria by which they judge success may be different from the overall plan.
- We can learn how to protect more places in the future by conservation happening now.

Lesson 10 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Ask students to recall what they made progress on and what they still need to know.	A	
2	12 min		REVISIT CONSERVATION PLANS FROM PROFILES Reorient students to their conservation profiles from Lesson 1.	B-C	Lesson 1 initial models and/or <i>Conservation Profile Models</i>
3	10 min		INVESTIGATE CONSERVATION PLANS IN EACH PROFILE Facilitate small-group sensemaking about conservation plans.	D-E	<i>Evaluating Conservation Plans, Conservation Plan Storyboards, completed Progress Tracker</i>
4	17 min		ANALYZE ADDITIONAL DATA FROM CONSERVATION PROFILES Provide students with additional data related to their conservation profile.	F-K	<i>Evaluating Conservation Plans, Everglades Data Packet, Great Lakes Data Packet, Hoh River Data Packet, or Saguaro Data Packet</i>
5	3 min		NAVIGATE Guide students in answering reflection questions to determine next steps.	L	
<i>End of day 1</i>					
6	3 min		NAVIGATE Reflect on the use of the Conservation Evaluation Tool so far.	M	
7	12 min		SHARE AND COMBINE IMPACT MAPS INTO A GROUP DISPLAY Create a display to combine impact boxes that highlights the short-term and long-term effects of the conservation plan.	N	<i>Evaluating Conservation Plans</i> , chart paper or whiteboard
8	8 min		EVALUATE THE CONSERVATION PLAN Reflect on the conservation plan's impact on the ecosystem and interest holders to evaluate its success.	O	<i>Evaluating Conservation Plans</i> , Group Impact Map
9	19 min		PREPARE AND PRESENT CONSERVATION PLANS AND EVALUATIONS Present data displays and take notes about the similarities and differences between conservation plans and students' evaluation of them.	P-Q	<i>Conservation Presentation Notes</i> , Group impact map
10	3 min		NAVIGATE Reflect on the different conservation presentations.	R	<i>Conservation Presentation Notes</i>
<i>End of day 2</i>					
11	5 min		NAVIGATE Reflect on how the different conservation presentations can help us understand future conservation plans.	S	<i>Conservation Presentation Notes</i>

Part	Duration		Summary	Slide	Materials
12	22 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT CONSERVATION NOW AND IN THE FUTURE Facilitate a Building Understandings Discussion about evaluating a conservation plan and determining its success.	T	
13	13 min		EVALUATE DRIVING QUESTION BOARD (DQB) QUESTIONS Evaluate our list of questions in pairs and determine ones we think we have made progress on. Indicate those questions on our DQB and move into the Scientists Circle.	U-V	<i>Reviewing our DQB, Driving Question Board (DQB)</i>
14	5 min		NAVIGATE Return to the 30 by 30 Initiative to individually consider how conservation plans are created.	W	

End of day 3

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials	• <i>Evaluating Conservation Plans</i> • <i>Conservation Plan Storyboards</i> • completed <i>Progress Tracker</i> • <i>Everglades Data Packet</i> • <i>Great Lakes Data Packet</i> • <i>Hoh River Data Packet</i> • or <i>Saguaro Data Packet</i> • science notebooks • <i>Conservation Presentation Notes</i> • <i>Reviewing our DQB</i>	• Lesson 1 initial models and/or <i>Conservation Profile Models</i> • chart paper or whiteboard • Group Impact Map • Group impact map	• Driving Question Board (DQB)

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so that they can be added to students' notebooks.

Make the initial models students made of their conservation profile systems in Lesson 1 available or make copies of *Conservation Profile Models* for each group.

Make sure you have at least one copy per group of *Conservation Plan Storyboards*. If you do not have a kit, print in color and laminate.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build on what they figured out in Lessons 8-9 about ecosystem stability and resilience to evaluate conservation plans for the different conservation profiles they were introduced to in Lesson 1.

This lesson addresses **HS-LS2.C.1**: *A complex set of interactions within an ecosystem can keep its number and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient) as opposed to becoming a very different ecosystem. Extreme fluctuation in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.*

In addition to learning from prior lessons, students draw on a middle school level understanding of **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**

- *Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*
- *Organisms, and populations of organisms, are dependent on their environmental interactions, both with other living things and with nonliving factors.*

In Lesson 9, students were introduced to SEP 6.5: ~~design~~, evaluate, ~~and/or refine~~ a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations, and they continue to build on this practice here as they evaluate conservation plans in the profiles they were introduced to in Lesson 1.

As they have in many lessons in the unit, students continue to develop their use of the crosscutting concept *stability and change*. In this lesson, students evaluate the success of a conservation plan based on its impacts on bringing stability to the ecosystem and supporting ecosystem resilience.

Where We Are NOT Going

While this lesson focuses on changes in the ecosystem and conservation plans that restore or protect the system, students do not see examples that result in a permanent change to the system. Examples of ecosystems changing more dramatically will be explored in both *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects?* (Urbanization Unit) and *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes?* (Speciation Unit).

LEARNING PLAN for LESSON 10

1 · NAVIGATE

3 min

MATERIALS: None

Reflect on our unit questions. Display **slide A**. Say, *At the end of our last lesson, we revisited our unit questions: How do ecosystems work, and how can understanding them help us protect them?* Use the prompts below to facilitate a whole-class discussion.

Suggested prompt	Sample student response
<i>What did we decide we made good progress on?</i>	We know a lot about how ecosystems work from studying the Serengeti. We know that the conservation plan to make the Serengeti National Park was successful in achieving its goals because it protected the migration and made the ecosystem resilient.
<i>What do we still need to know?</i>	We need to see how conservation plans work in other places so we know how to protect more lands and waters.

2 · REVISIT CONSERVATION PLANS FROM PROFILES

12 min

MATERIALS: Lesson 1 initial models and/or *Conservation Profile Models*

Return to conservation profiles to learn more. Say, *You all suggested that we need to look at other systems. What other systems did investigate at the start of the unit?* Listen for students to recall the conservation profiles from Lesson 1. If they have difficulty recalling, show them the images on **slide B**.

Return to the initial models from the conservation profiles in Lesson 1. Say, *Let's go back to our conservation profiles to remember what they were all about.* Display **slide B** and organize students into their conservation profile groups from Lesson 1. Return the initial models they developed. If student initial models are not available, pass out a copy of *Conservation Profile Models*.

Small groups answer questions about their models. Display **slide C** and ask small groups to discuss the questions on the slide. Call on a few student groups to share their answers.

Suggested prompt	Sample student response
<i>What does this model help us explain?</i>	How the components in the ecosystem interact. How humans have protected it.

Suggested prompt	Sample student response
<i>Does it help us answer our unit question: How do ecosystems work and how can understanding them help us protect them?</i>	The interactions in the model tell us some parts of how it works. We probably need more information about the interactions to know how to protect the system.
<i>How is this ecosystem being protected?</i>	Humans made national parks (Saguaro and Everglades). Humans tried to keep invasive species out of Lake Michigan. Humans put together areas of land and water to protect the Hoh River for salmon.
<i>To respond to the 30 by 30 Initiative, we need to know if the conservation plan was successful so we can think about protecting more lands and waters. How will we know the conservation plan was successful?</i>	We need to know more about the conservation plan and what it was. We need to know the goals and actions of the plan.
<i>Say, It sounds like we know a little bit about how these systems work and how humans are protecting them, but we do not know much about conservation plans. I have some additional information to share with you.</i>	

3 · INVESTIGATE CONSERVATION PLANS IN EACH PROFILE

10 min

MATERIALS: *Evaluating Conservation Plans, Conservation Plan Storyboards, completed Progress Tracker*

Introduce new information about conservation plans and update models. Display **slide D** and distribute the appropriate *Conservation Plan Storyboards* to each group. Let students know that while each of the systems they investigated in their profiles could have multiple conservation plans, we are going to focus on a single plan from each conservation profile today. Give students a few minutes to make sense of the conservation plan for their profile. Ask them to add additional components and interactions from the conservation plan to their models.

Begin evaluating the conservation plan. Display **slide E** and distribute *Evaluating Conservation Plans* to each student. Introduce them to the Conservation Evaluation Tool on the slide. Then ask them to answer the questions on part A of the handout. Circulate around the room as students are working and look for students to identify the goals and actions of the conservation plan.

Review the Progress Tracker with your group. Say, *Investigating the Serengeti gave you a lot of tools for figuring out how ecosystems work. Remember, we kept track of what we wanted to know about our conservation profiles throughout the unit. Take out your Progress Tracker. Talk with your group about what data your group said they wanted to collect from the conservation profiles and complete the additional questions in part B of Evaluating Conservation Plans.*

4 · ANALYZE ADDITIONAL DATA FROM CONSERVATION PROFILES

17 min

MATERIALS: *Evaluating Conservation Plans, Everglades Data Packet, Great Lakes Data Packet, Hoh River Data Packet, or Saguaro Data Packet*

Introduce new data related to the conservation profiles. Say, *You all have a lot of great ideas about what data we might need to have in order to answer questions about the success of the conservation plans in your systems. I have some data that I think might help.* Display **slide F**. Distribute a copy of *Everglades Data Packet* *, *Great Lakes Data Packet*, *Hoh River Data Packet*, or *Saguaro Data Packet* to each student, corresponding with

*** ATTENDING TO EQUITY**

their conservation profile. Have students skim the data packets to get an idea of the kind of data available to them. Have students review the kind of data they identified in Part B of *Evaluating Conservation Plans* to see how it aligns.

Supporting students reading below grade level: For students who read below grade level investigating the Everglades, the <https://youtu.be/aUR7iegp7ew> serves as a companion resource to *Everglades Data Packet*. The audio and captioned text in the video describe much of the content included in the written text, and will support comprehension and deeper understanding.

ADDITIONAL GUIDANCE

Remind students that the data we have is not always the data we wish we had. When we were investigating the Serengeti, we wanted to know about grass and had data about rain. Students will have to make sense of the data they have to figure out which of their questions it can help them answer.

Discuss how to sort through the data and organize it. Say, *We have a lot of data to sort through in our data packets that we think will help us figure out if these conservation plans are working. Let's briefly discuss what we need from these data packets and how to organize this data to help us evaluate these conservation plans.* Display **slide G**. Facilitate a discussion with the class using the prompts below as a guide.

Suggested prompt	Sample student response
Look back at the Conservation Evaluation Tool on slide E . How will the data from the data packet connect to the tool?	We need to find data to help us understand if the conservation goals are being met. We need to use the information to identify how the conservation plan is affecting the rest of an ecosystem and other interest holders.
In the next section of the Conservation Evaluation Tool, we keep track of the outcome of the conservation plan and its impacts. What did we do to keep track of impacts in Lesson 9?	We modeled them with boxes and arrows. We mapped them out.

Share a tool to help students organize their impacts. Say, *It sounds like we were able to make sense of the impacts by mapping them out. Let's try that here. I have a template to help you map out your impacts in part C on Evaluating Conservation Plans. This template uses the Conservation Evaluation Tool as a guide to help you to organize and make sense of the data.* Display **slide H** and review how students will use the template to map out their impacts.

Plan for successful collaboration in groups. Say, *Now we have a better idea of how we are going to organize the data, but there is still a lot of data to sort through and make sense of. To do this efficiently, you will need to work effectively as a group. Let's take a moment to discuss how to do this. We need to make sure everyone in your group can make a meaningful contribution to this work.*

Review community agreements that will support collaboration. Say, *Let's check in on our community agreements. Which agreement do you think would help us be most successful in our data analysis and evaluation today?* Display **slide I** and listen for students' ideas. Review *Example Community Agreements* with the class if students need additional support. *How will you be sure everyone gets to contribute?*

Elicit responses such as the following:

- Everyone in the group could be assigned to either look for data about interest holders or impacts on the ecosystem.
- Everyone in the group is assigned a different part of the data to look at in order to connect it to the questions from our Progress Tracker.
- The group needs to discuss the data to find consensus about what the data is saying about the impact of the conservation plan.

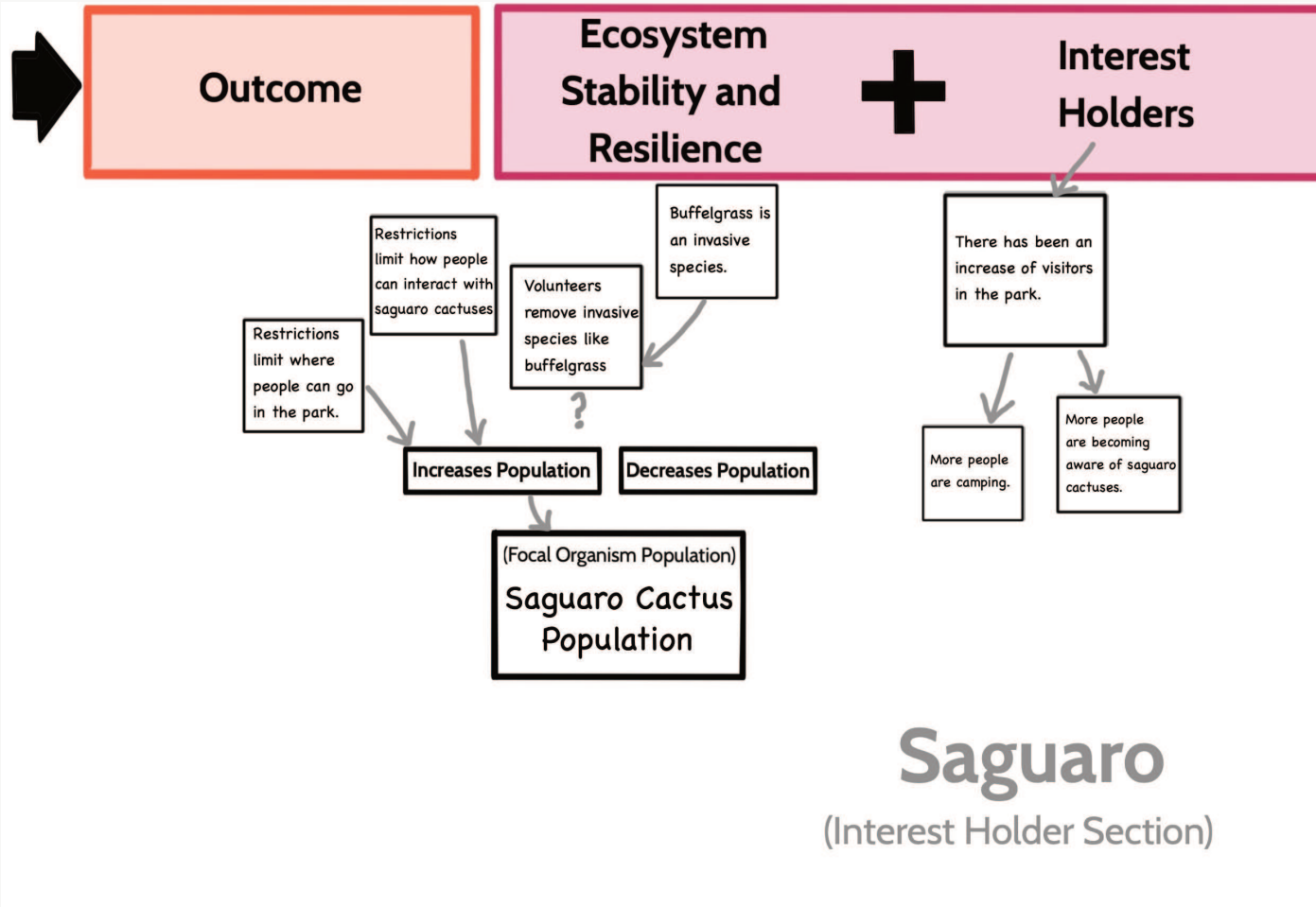


Analyze data from conservation profiles by individually mapping out impacts. Display **slide J**. Allow groups to divide up the work so that each student is working on organizing data from their profile's data packet into part C of *Evaluating Conservation Plans*. The data packet is organized into five sections: Conservation Motivation, Interest Holders, Focal Organism Data, Interactions, and Future Concerns. Have students use the following directions to record the conservation plan's impacts on the ecosystem and interest holders.

- First, write the name of the focal organism population in the corresponding box on the *Conservation Evaluation Tool* template.
- Add any components from your Lesson 1 model and your data packet that interact with the focal organism.

- Using the information from your section(s), map out the impacts that increase or decrease the focal organism's population.
- Add other impacts under the *Interest Holder* heading to show how the plan, area, and/or organism impacts different interest holders.
- After all the impact boxes have been drawn, use a highlighter (or other method) to show which impact boxes are a part of the conservation plan.

The following is an example diagram from the Saguaro conservation profile only using the interest holders section from that data packet. Display **slide K** to show students an example of what this could look like.



ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Interactions between the focal organism and other components of the system. (LS2.C.1)
- Components/interactions include evidence of the conservation plan put in place by humans to change or stabilize a population. (SEP 6.5, CCC 7.1, LS2.C.1)
- Arrows that indicate how the components are impacted. (+/-). (CCC 7.1, LS2.C.1)
- Arrows that indicate how the focal population increases or decreases. (CCC 7.1, LS2.C.1)

What to do: If students struggle to map impacts, then encourage them to look back at their Lesson 1 model to see how the focal organisms from the conservation plans connect to other organisms in the ecosystem. Prompt students to think about what happens as the population of the focal organism changes and how it will affect the other organisms they are connected to. Point them back to the section of *Everglades Data Packet*, *Great Lakes Data Packet*, *Hoh River Data Packet*, or *Saguaro Data Packet* that they were assigned and ask them to circle or highlight the information that is missing from their map.

Building toward 10.A.1 Evaluate a conservation plan by using evidence and reasoning about stability and change from complex interactions in the ecosystem. (SEP 6.5, CCC 7.1, LS2.C.1)

5 · NAVIGATE

3 min

MATERIALS: science notebooks

Reflect on where we are and where we are going. Say, *We made some great progress in sorting through a lot of data that helped us use what we learned in the Serengeti to understand our conservation profiles.* Display **slide L** and ask students to respond to the questions on the slide in their science notebooks.

End of day 1

6 · NAVIGATE

3 min

MATERIALS: None

Turn and talk about the Conservation Evaluation Tool. Ask students to turn and talk with a partner to share how the class has used the Conservation Evaluation Tool so far and discuss what we need to do next in our group in order to evaluate the conservation plan. Display **slide M**. Call on a few students to share their ideas. Listen for students to share ideas for sharing the impacts they mapped out to organize their data.

7 · SHARE AND COMBINE IMPACT MAPS INTO A GROUP DISPLAY

12 min

MATERIALS: *Evaluating Conservation Plans*, chart paper or whiteboard

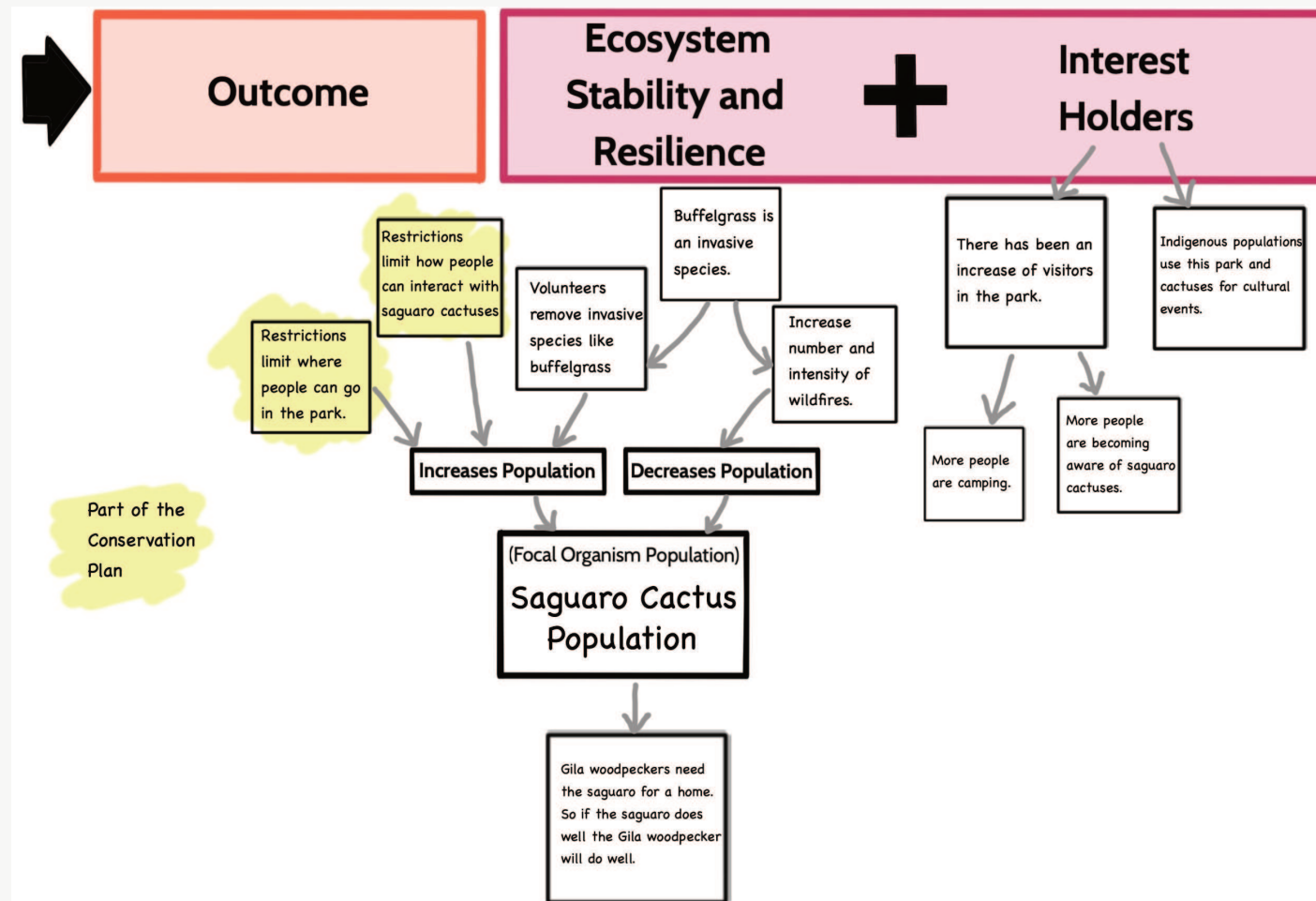
Explain how to create a group display. Say, *Each of you have made some connections between the data in your data packet and the impact it will have on the ecosystem and the interest holders. Now let's put that together with what the rest of your group figured out.* Direct students to share their impact map and create a larger group display on chart paper or a whiteboard to share with the rest of the class.

Construct a group display about the impacts of the conservation plan. Display **slide N**. Have students work together to share their individual impact boxes in order to create a combined display using directions given in part C of *Evaluating Conservation Plans*.

- First, come together with your group and give everyone time to share their map.
- Look for anything you all have in common to add to the group map first.
- Then add anything unique to each group member's map.
- Make sure to include all arrows and +/- signs to show the relationship.
- Finally, use a highlighter to show which impact boxes are a part of the conservation plan.

Encourage students to use the data from the data packet AND what they figured out about ecosystems from their investigation of the Serengeti. Once students have completed their display, have them circle the corresponding box in which data shows whether the focal organism's population is increasing and/or decreasing.

An example display of combined impact boxes for the Saguaro conservation profile can be seen in the following image.



8 · EVALUATE THE CONSERVATION PLAN

8 min

MATERIALS: *Evaluating Conservation Plans*, Group Impact Map

Individually reflect on the impact of the conservation plan. Say, *You all worked really hard creating a display of your impact map, but we still need to evaluate these plans to see if they are successful.. Ask, How do we define success?* Listen for students to share ideas about the conservation plan meeting its goal. If students have trouble defining success here, remind them of how we judged success in the Serengeti conservation plan or draw on their everyday experiences with success.

Reorient student to *Evaluating Conservation Plans*. Display slide O. *To help us think about how effective each conservation plan is, we should return to the Conservation Evaluation Tool.* Direct students to part D on *Evaluating Conservation Plans*. Have students work individually to use their group's display to help them answer the questions in part D on *Evaluating Conservation Plans*.

9 · PREPARE AND PRESENT CONSERVATION PLANS AND EVALUATIONS

19 min

MATERIALS: *Conservation Presentation Notes*, Group impact map

Prepare for group presentations. Display slide P. Have students prepare for their presentations by reviewing their displays. Students should divide the presentation into three main sections and make a plan for which group members will present each section:

1. Briefly describe the conservation profile system.
2. Discuss the conservation plan.
3. Discuss the group's evaluation of this plan, focusing on the impacts to the ecosystem and interest holders.



Small groups present their work to the class. Display slide Q. Distribute *Conservation Presentation Notes* to each student and ask students to keep track of what they hear from their classmates on the handout.

Revisit the classroom agreements to help students prepare for being respectful as each group shares. As each group shares their presentation, periodically remind students to record notes on *Conservation Presentation Notes*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Interactions between the focal organism and other components of the system. (LS2.C.1)
- Components/interactions include evidence of the conservation plan put in place by humans to change or stabilize a population. (SEP 6.5, CCC 7.1, LS2.C.1)
- Arrows that indicate how the components are impacted. (+/-). (CCC 7.1, LS2.C.1)
- Arrows that indicate how the focal population increases or decreases. (CCC 7.1, LS2.C.1)
- Evaluation of whether or not the conservation plan was successful based on evidence and criteria. (SEP 6.5)

What to do: As students present their impact maps, use the following questions:

- What interactions impacted the focal species?
- How has the system changed or stayed the same?
- What do you think will happen to it in the future?
- What evidence supports your evaluation of success?
- Would all interest holders agree? Why or why not?

Building toward 10.A.2 Evaluate a conservation plan by using evidence and reasoning about stability and change from complex interactions in the ecosystem. (SEP 6.5, CCC 7.1, LS2.C.1)

10 · NAVIGATE

3 min

MATERIALS: *Conservation Presentation Notes*, science notebooks

Reflect on conservation evaluation presentations. Display **slide R** and ask students to independently reflect on the different presentations by answering the questions on the slide in their science notebooks.

End of day 2

11 · NAVIGATE

5 min

MATERIALS: *Conservation Presentation Notes*, science notebooks

Set a purpose for today's work. Display **slide S**. As students enter the classroom, have students review the last two questions on *Conservation Presentation Notes*. Use a prompt similar to the ones below to set the purpose of today's work.

Suggested prompt	Sample student response
<i>How can what we heard in the presentations support our thinking about the 30 by 30 Initiative?</i>	It can give us ideas for how to protect places. Some things are common among all conservation plans; some are specific to an individual plan.
<i>How might these conservation strategies help us protect more lands and waters?</i>	We have some ideas about what works and how different people are impacted that we can learn from for the future.

12 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT CONSERVATION NOW AND IN THE FUTURE

22 min

MATERIALS: None



Lead a Building Understandings Discussion about conservation now and in the future. Display **slide T**. Have students bring their copy of *Conservation Presentation Notes* to a Scientists Circle. Have the group impact maps available around the room for students to refer to. Use prompts such as those that follow to facilitate the discussion. *

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Be explicit with students about your role in this discussion, which is to press students for evidence and examples when they discuss evaluating conservation plans. Tell students explicitly, *My role in this discussion is to press for evidence and examples. You might hear me ask, "Where did you see that?" It is my job to push us as a class to articulate the evidence we have to support our ideas.*

Suggested prompts	Sample student responses	Follow-up questions
<i>What similarities did you find as you listened to the presentations and as you took notes about these different conservation plans?</i>	We saw that all the conservation plans had an initial problem that was caused by humans. All the conservation plans were trying to protect an organism and/or places in order to protect the greater ecosystem. All of the conservation strategies required humans to take actions to minimize other negative human impacts on organisms and/or the ecosystem.	<i>What were they trying to protect?</i> <i>How did they enact protection?</i> <i>How did protecting one species help the whole system?</i>
<i>How were the conservation plans different from each other?</i>	Most plans were trying to increase species (manatee, saguaro, salmon). Lake Michigan was trying to decrease an invasive species (mussels). Two of the plans were national parks, the Hoh River was a plan that put together lots of pieces of land, and Lake Michigan had to deal with a lot of different interest holders.	<i>How was Lake Michigan different from the other systems?</i>
<i>How did you determine if the plan was successful?</i>	We looked at focal organism population data; if they increased, they were meeting goals (except Lake Michigan) Many of the conservation plans were trying to help save native organism populations.	<i>What did data about one population tell you about the system?</i>
<i>Humans are important parts of ecosystems. How did human interest holders interact with the systems?</i>	Humans caused problems (boats, blocking the river, bringing in invasive species). Humans also did something to conserve through the plans.	<i>When did we explore this in the previous lesson as we looked at the proposed road going through Serengeti National Park?</i>
<i>What criteria were important to humans?</i>	Answers will vary. In the Hoh River some people wanted to log, but others wanted to preserve land. Some people prioritize nature; others prioritize economic gain.	<i>Did all the human interest holders have the same values?</i> <i>What criteria would different interest holders use to evaluate the conservation plans?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>All the conservation plans we looked at have been in action for a while. How does knowing about all these plans help us protect new lands and waters?</i>	We know that good conservation plans support ecosystem stability and resilience. If we understand the various interactions of the ecosystem and use data to identify the area of concern, then we can use that knowledge to create a conservation plan.	<i>What should we do with all this information?</i> <i>How can we apply it to the 30 by 30 Initiative?</i>

KEY IDEAS

Purpose of this discussion: There are three goals for this discussion: 1) to describe that there are varying plans for conservation that are based on the specific threats to an ecosystem, 2) to show the complexity of conservation, and 3) to demonstrate that conservation success relies on the stability and resilience of an ecosystem.

Listen for these ideas:

- Conservation plans are typically based on trends of organism population data and on prior conservation successes.
- There are different conservation strategies that vary in their outcomes on the goal of the conservation plan.
- Whether a conservation plan is successful or not is difficult to determine because there are a lot of factors to take into consideration.
- Scientists evaluate the effectiveness of conservation plans by looking at ecosystem interactions, individual organism populations over time, and ecosystem resilience.
- Scientists also look at the impact a conservation plan has on local people.
- Sometimes in order to achieve goals, interest holders have to make trade-offs and give up something that matters to them.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Similarities and differences in conservation profiles.
- Evaluation of success for the profiles based on evidence of interactions, stability, or change. (SEP 6.5, CCC 7.1; LS2.C.1)
- Inclusion of human interactions, priorities, and criteria for conservation decisions. (SEP 6.5)
- Knowing all of this can help us understand how to protect spaces in the future. By supporting ecosystem stability and resilience, humans are minimizing negative human changes. (CCC 7.1, LS2.C.1)

What to do: Use the follow-up prompts to support student thinking. If students struggle to answer some of the prompts, have them stop and jot their answers, talk to a partner, and then share an idea the pair discussed.

Building toward 10.A.3 Evaluate a conservation plan by using evidence and reasoning about stability and change from complex interactions in the ecosystem. (SEP 6.5, CCC 7.1, LS2.C.1)

13 · EVALUATE DRIVING QUESTION BOARD (DQB) QUESTIONS

13 min

MATERIALS: Reviewing our DQB, Driving Question Board (DQB)

Work in pairs to evaluate what questions the class has answered from the DQB. Display slide U. Say, *Wow, we have figured out a lot about ecosystems and conservation from the Serengeti and each of our conservation profiles. Let's return to the questions we had from earlier in our unit and see what we can now answer.* Provide each student with a copy of *Reviewing our DQB* that you created to contain all the student questions from the DQB. Have students work with partners to mark how they think the class has answered the questions:

- We did not answer this question or any part of it yet: ○ or ?
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+

Mark questions on the DQB individually. Display slide V. Ask individual students to come to the DQB and mark questions that the class has answered in whole or in part through our investigations. Have as many students as possible participate until all the questions that the class has answered have been marked. Ask students to share evidence that we have answered the questions as each one is checked off. At the end, you may ask students to summarize which groups of questions have and have not been answered. Thank students again for all their hard work on this unit and celebrate just how much we have figured out through our efforts. *

* ATTENDING TO EQUITY

Revisiting the Driving Question Board is important for students to see that their questions are valued and recognized. While not all questions will have been addressed, this activity helps students see the hard work they have done to answer many of their own questions. Many of the remaining unanswered questions will be addressed in future units.

14 · NAVIGATE

5 min

MATERIALS: None

Lead a whole-class discussion about next steps. Say, *Let's celebrate the progress we made in figuring out how ecosystems work and how understanding them helps us protect them. Some of the questions we still were not able to answer were about the 30 by 30 Initiative and how we add new protected spaces. How can we apply everything we figured out about ecosystems and conservation to protecting new spaces?* Display slide W and ask students to answer the question on the slide.

Introduce the next lesson's transfer task. Say, *Next time you will have a chance to demonstrate what you have figured out about ecosystems and conservation and apply it to a new conservation plan that supports the 30 by 30 Initiative.*

**ADDITIONAL
GUIDANCE**

If students need a reminder, summarize what they learned about the 30 by 30 Initiative in Lesson 1: that in 2021, the US Office of the President issued an executive order setting a goal of conserving 30% of land and water in the United States by 2030. This is a movement happening in the US and beyond. Currently, at least 95 other countries have committed to this goal as well.

Additional Lesson 10 Teacher Guidance

**SUPPORTING
STUDENTS IN
MAKING
CONNECTIONS IN
ELA**

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

Students read about a specific conservation plan from their conservation profile. Students will look at the data from a data packet to use as evidence to evaluate if the conservation plan is successful.

LESSON 11: Can we use everything we have figured out about ecosystems and conservation to expand conservation to new lands and waters?

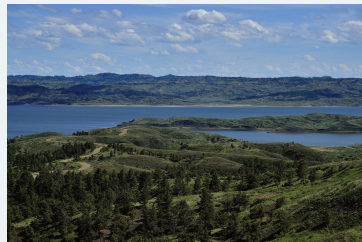
PREVIOUS LESSON

We decided to look at more ecosystems and returned to our conservation profiles from Lesson 1. We evaluated the conservation plans in those systems by considering the impact the plan would have on organisms, the ecosystem overall, and other interest holders. We presented our findings to the class and built an understanding about what it means for conservation to be successful and how we can use what we learned to protect more lands and waters.

THIS LESSON

PUTTING PIECES TOGETHER

1 day



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We complete a transfer task about the American Prairie Reserve to demonstrate what we figured out throughout the unit about how ecosystems work and how understanding them can help us protect them.

NEXT LESSON

There is no next lesson.

BUILDING TOWARD NGSS

HS-LS2-1, HS-LS2-2, HS-LS2-6,
HS-LS2-7*, HS-LS2-8, HS-ESS3-3,
HS-ETS1-3†



WHAT STUDENTS WILL DO

11.A Evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity. (SEP:6.5; DCI: LS2.C.2, LS4.D.2, ETS1.B.1; CCC: 7.1)

WHAT STUDENTS WILL FIGURE OUT

- Human-caused changes can cause disruptions that change an ecosystem.
- Some changes have greater or lesser effects and impact the stability of the system.
- A change to a keystone species can affect the biodiversity of the system.
- Humans consider many criteria when making decisions about conserving or using the natural world.

Lesson 11 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	8 min		NAVIGATE Students review progress tracker and notes in preparation for the transfer task.	A	<i>Progress Tracker</i>
2	35 min		COMPLETE A TRANSFER TASK Orient students to the transfer task and administer.	B	<i>Prairie Transfer Task</i>
3	2 min		NAVIGATE Celebrate student accomplishments.	C	

End of day 1

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Progress Tracker</i> • <i>Prairie Transfer Task</i>		

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole punch all handouts so that they can be added to students' notebooks.

Lesson 11 • Where We Are Going and NOT Going

This lesson is the culminating lesson in the unit. Students complete a transfer task to apply what they have figured out about ecosystems to elements of HS-LS2-7.

Students use the science practice *constructing explanations* to ~~Design, evaluate, and/or refine~~ a solution to a complex real-world problem, based on scientific knowledge, ~~student-generated sources of evidence~~, prioritized criteria, and trade-off considerations.

The scientific knowledge that they consider includes ways in which humans have interacted with the prairie ecosystem and they use the following DCI elements in their explanations:

LS2.C.2 Moreover, anthropogenic changes (induced by human activity) 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.

LS4.D.2 Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through ~~overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change~~. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Students also use elements of the crosscutting concept, *stability and change* in their explanations as they consider the long and short term implications of the decline and potential reestablishment of the American bison in the US.

LEARNING PLAN for LESSON 11

1 · NAVIGATE

8 min

MATERIALS: science notebook, *Progress Tracker*

Review science notebook and Progress Tracker. Show slide A. Say, *We have figured out a lot of great science ideas in this unit about ecosystems and how we protect them. Today, you will have a chance to look at how we expand conservation to new lands and waters to support the 30 by 30 Initiative.* Ask students to review *Progress Tracker* and any additional materials they wish in their science notebooks.

2 · COMPLETE A TRANSFER TASK

35 min

MATERIALS: *Prairie Transfer Task*

Orient students to the American Prairie Transfer Task. Display slide B. Distribute *Prairie Transfer Task* and give students a few minutes to read over the scenario and ask clarifying questions. Consider allowing your students to use their completed *Progress Trackers* to support them as they complete the transfer task.



Administer the task. Give students the rest of the period to complete the task, then collect assessments before students leave.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: After students complete *Prairie Transfer Task*, use *Prairie Task Key* to evaluate their responses.

What to do: Provide feedback using *Prairie Task Key* as guidance.

Building toward 11.A Evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity. (SEP:6.5; DCI: LS2.C.2, LS4.D.2, ETS1.B.1; CCC: 7.1)

3 · NAVIGATE

2 min

MATERIALS: None

Close the unit. Display slide C. Congratulate students on all that they have figured out throughout the unit about how ecosystems work and how understanding them can help us protect them.



Unit B.1 Teacher Reference Materials

ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial Models Driving Question Board	Pre-Assessment The student work in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Hearing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit. The initial model developed on day 2 of Lesson 1 is a good opportunity to pre-assess student understanding of how students define and identify the important components and interactions of the system they investigate in their Conservation Profiles. The Driving Question Board is another opportunity for pre-assessment. Reinforce that students should generate open-ended questions, such as how and why questions, and post them to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway.
Lesson 2	Scavenger Hunt Notes <i>Obtaining and Communicating Information Self-Assessment</i> Graphic Organizer Graphic Organizer Scavenger Hunt Key Driving Question Board	Formative At the end of day 1 students complete an exit ticket that summarizes what they learned about the formation of Serengeti National Park from the scavenger hunt on <i>Scavenger Hunt Notes</i>. This allows the teacher to assess individual students' ability to summarize information concisely and accurately. It also allows the teacher to group students who will work together using complementary information on day 2. Formative + Student Self-Assessment Students complete <i>Obtaining and Communicating Information Self-Assessment</i> on day 2 to reflect on their ability to record what they learned from the scavenger hunt and share that information with their peers when they worked together to complete <i>Graphic Organizer</i>. This allows students to reflect on their progress in SEP 8: <i>obtaining, evaluating and communicating information</i>. Formative This Driving Question Board check-in allows students to see if they have answered any of their initial questions and then add questions about the Serengeti ecosystem function, in particular the migrating wildebeest that were introduced in this lesson. These serve as motivation for further investigations in the unit.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 3	<i>Analyzing Wildebeest Data Cards</i> <i>Data Cards Patterns Key</i>	Formative On day 1 students record patterns in part three on <i>Analyzing Wildebeest Data Cards</i> as they analyze the wildebeest data cards. This allows teachers to assess individual student's ability to communicate patterns that they observed and to be able to distinguish which patterns could be used as evidence to explain the wildebeest migration. On day 2 groups of students share their data displays that highlight the patterns and lack of patterns their group observed as they analyzed the wildebeest data cards. This allows teachers to assess each group's ability to identify patterns and to distinguish which patterns and lack of patterns could be used as evidence to explain the wildebeest migration. On day 3 the class will develop the classroom consensus model to explain the wildebeest migration. Students should be able to connect the patterns and lack of patterns they observed to the different ideas the class originally thought could be responsible for the wildebeest migration. Students should be able to articulate that disease and predation are unlikely to be causing the wildebeest migration because of the lack of patterns in the data and that food is likely to be the cause of the wildebeest migration based on the patterns observed.
Lesson 5	<i>Serengeti Kinesthetic Model</i> <i>Serengeti Kinesthetic Model Key</i> <i>Wildebeest Population Data</i> <i>Serengeti Kinesthetic Model Key</i> <i>Lesson 5 Exit Ticket (Electronic Exit Ticket)</i> <i>L5 Electronic Exit Ticket Key</i>	Formative Students collect and make sense of data from a kinesthetic model for the interactions between wildebeest and grass in the Serengeti, in numbers, graphical representations, and words. Collecting <i>Serengeti Kinesthetic Model</i> at the end of day 1 allows for teachers to provide feedback before examining historical data on day 2. Formative Students analyze rates of change over different time periods for historical wildebeest population data from the Serengeti to build the idea of a relatively stable carrying capacity. Formative + Summative + Community Building The first Electronic Exit Ticket allows relatively quick individual assessment of students on a key LLPE. Teachers can quickly check students' understanding of rate of change to see if more practice is necessary, but students also have an opportunity here to reflect on how food affects population size and engage with metacognitive questions around their own lives, how they used science and engineering practices and crosscutting concepts in sensemaking, and the value of their classmates in supporting their learning.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 6	<i>African Wild Dog Transfer Task</i> <i>Transfer Task Key</i> <i>Peer Rubric</i> Driving Question Board	Formative + Summative Mid Unit Transfer Task This mid-unit transfer task uses the novel phenomenon of the relocation of African wild dogs to a new conservation area to protect them as a way to assess student understanding of limiting factors and how to determine carrying capacity. It assesses HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. Formative + Self-assessment The teacher facilitates a debrief of the first portion of the transfer task. Students discuss what is necessary to prepare for a transfer task and how to write quality scientific explanations for selected questions. This allows students to reflect on their answers to the first part of the task and consider how to write more complete answers. This also allows the teacher to gauge readiness to complete the remainder of the task. Community Building + Self-assessment Students complete an exit ticket reflecting on their ability to collaborate equitably towards the completion of the first portion of the transfer task. Peer Feedback Students use <i>Peer Rubric</i> to assess peer responses to the final transfer task question. The rubric assesses 3D learning towards HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. After receiving peer feedback, students revise their original answers before turning their responses in to the teacher for formal evaluation. Formative This second Driving Question Board check-in allows students to clear additional questions from the first lesson set and add questions pertaining to the role of predators in the Serengeti ecosystem. These questions set students up for their activities in lesson 7.
Lesson 7	<i>Meet Your Wildebeest</i> <i>Meet Your Lion</i> <i>Meet Your Hyena</i> <i>Meet Your Agent Key</i> <i>Data Analysis</i> <i>Data Analysis Key</i>	Formative Students complete the Connected Behaviors column connecting the rules for game play in the Rules column based on the information in the Agent Background about the agent that they will be representing in the agent-based model (Table 2). When the teacher reviews them and provides written feedback, they will be able to see if the students are connecting the animal's behaviors to the rules as the algorithms that are governing how the model works. Formative Students complete the <i>Data Analysis</i> to analyze the data that they generated from the agent-based model. Students then move on to create algorithms in words that explain the data about agent interactions collected during the game. The final step is for students to convert the algorithms in words into algorithms with numbers that computers are more likely to understand. Collecting these documents will help teachers see the ideas that students have at each step to help support writing their algorithms and push their thinking from what they figured out in Lesson 5. There is a tiered feedback approach depending on student responses.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 8	<i>Serengeti Component Interactions</i> <i>Serengeti Component Interactions</i> Driving Question Board <i>Lesson 8 Exit Ticket (Electronic Exit Ticket)</i> <i>L8 Electronic Exit Ticket Key</i>	Formative This assessment opportunity aids students in applying the ideas they developed earlier in the unit to a develop a model of a more complex ecosystem components, interactions, and mechanisms in the Serengeti that could be affected by disturbance. Formative This Driving Question Board check-in provides students a chance to answer questions related to complex interactions in ecosystems, while also aiding navigation into Lesson Set 3 by reminding them that many of our unanswered questions related to Serengeti National Park and their conservation profiles. Formative + Summative + Community Building This second and final Electronic Exit ticket focuses on how ecosystems are resilient in response to a disturbance which students will use again in Lessons 9, 10 and 11. It also provides an opportunity for students to share their thinking about various models developed from data and predictions, tie the concepts of biodiversity, disturbance, and resilience to their conservation profiles, and reflect on the role of stability and change in their sensemaking. Finally, students again celebrate how they have helped the class make progress.
Lesson 9	<i>Conservation Plan Evaluation</i> <i>Conservation Plan Key</i> <i>Road Proposal Evaluation</i> <i>Road Proposal Organizer Key</i> <i>Individual Assessment Explanation Key</i>	Formative Students use a model (Conservation Evaluation Tool) to evaluate the conservation plan in the Serengeti and identify the impacts for the system including the human interest holders. Formative This assessment opportunity asks students to evaluate three different road proposals using the resources from the Leaning in Places Ethical Decision Making Tool. Formative This individual assessment opportunity asks students to construct a three dimensional explanation of their road proposal evaluation.
Lesson 10	<i>Evaluating Conservation Plans</i> <i>Conservation Evaluation Key</i> Driving Question Board <i>Reviewing our DQB</i>	Formative This assessment opportunity asks students to evaluate a conservation plan by using the data from their conservation profile as evidence to determine the impact the plan would have on organisms, the overall ecosystem and other interest holders. Formative + Summative The final Driving Question Board check-in allows students to celebrate everything they have figured out in the unit. Students can also identify questions that were not answered in this unit, which might be addressed in later units or courses, or can serve as areas of independent research. Finally, this Driving Question Board check-in acts as a review of the units' ideas before students engage with the final transfer task.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 11	<i>Prairie Transfer Task</i> <i>Prairie Task Key</i>	Summative End-of-Unit Transfer Task This end of unit transfer task engages students with the novel phenomenon of The American Prairie Preserve, which can be explained using ideas from the unit. It assesses students on HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. This task is robust and will take approximately 30-45 minutes. The ideas, crosscutting concepts, and practices students engage with as part of completing this assessment can be found at the top of the Scoring Guidance (key). Please use scoring that works for your class and your requirements. We strongly recommend that you encourage students to use their notebooks as a resource for completing all assessments.
After each lesson	Lesson Performance Expectation Assessment Guidance	Formative Assessment Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in several lessons	<i>Progress Tracker</i>	Formative and Student Self-Assessment The Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena. They help to figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Trackers reflects their own thinking at that particular moment in time. In this way, the Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Trackers are meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative “grade” other than for completion. Students add or revisit their progress trackers in Lessons 2, 5, 6, 8, and 10.
Any time after discussion	Teacher Background Information	Self-Assessment This resource is available in the <i>OpenSciEd Teacher Handbook: High School Science</i>. The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small-group discussions can be more productive. Opportunities for individual self-assessment and reflection outside of this tool may be found in the electronic exit tickets in Lessons 5 and 8 as well as in Lessons 2 and 6.

When	Assessment and Scoring Guidance	Purpose of Assessment
Peer Assessment	Teacher Background Information	Peer-Assessment This resource is available in the <i>OpenSciEd Teacher Handbook: High School Science</i> and should be used as needed. Facilitating students to give each other feedback is very valuable for their three-dimensional learning. Additionally, peer feedback can support teachers in managing the time-intensive demands of individualized feedback. We suggest that peer review happen at least two times per unit. Peer feedback is most useful when there are complex and diverse ideas visible in student work. That is, peer feedback works best when not all work is the same. Student models and explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work. Rather, peer feedback will be more valuable to students if they have time to revise after receiving peer feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback. Recommendations for moments in which to use the peer assessment tool may be found in Lessons 2, 6, and 9.

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to **Science and Engineering Practice(s)**, alignment to **Cross-Cutting Concept(s)**, and alignment to the **Disciplinary Core Ideas**.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
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Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	1.A Obtain information about how and why humans manage natural resources and communicate it as conservation criteria established to stabilize parts of the system. (SEP 8.1; DCI ESS 3.C.1; CCC 7.1) 1.B Develop a model based on evidence of an ecosystem that illustrates relationships between living and nonliving components and how they have changed over time as a result of human interactions. (SEP 2.3; DCI ESS 3.C.1; CCC 7.1) 1.C Ask questions to clarify or seek information about what causes humans to protect ecosystem functioning and productivity and what the effects of the protection are. (SEP 1.1; DCI LS 4.D.2; CCC 2.2)	1.A When to check for understanding: On day 1, when students brainstorm criteria for conservation based on information found in <i>30 by 30 Initiative</i>. What to look for/listen for in the moment: - Varied motivations for humans to protect places, lands, and waters to stabilize the system, such as (DCI: ESS 3.C.1; CCC: 7.1): - natural beauty - recreation - ecosystem services - biodiversity - endangered/threatened species - cultural significance 1.B When to check for understanding: When students develop their initial models on day 2. What to look for/listen for in the moment: - Models include evidence of components and interactions from conservation profiles (SEP: 2.3; DCI: ESS 3.C.1). - Models include interactions between human and non-human components that illustrate changes over time (SEP: 2.3; DCI: ESS 3.C.1; CCC: 7.1). 1.C When to check for understanding: When students develop the Driving Question Board on day 3. What to look for/listen for in the moment: Questions to clarify and seek information about (SEP: 1.1): - causes or motivations of conservation (DCI: 4.D.2) - targets of conservation - effects of the conservation on stability and change (CCC: 2.2) of: - living and nonliving components of the ecosystem (DCI: 4.D.2) - interactions (DCI: 4.D.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	2.A Integrate information presented in different formats about the factors that prompted humans to create the Serengeti National Park and how the protected area boundaries changed or stayed the same. (SEP 8.2; DCI: LS2.C.2; CCC: 7.1) 2.B Develop a model based on evidence to explain how the Serengeti National Park system was designed for the stability of the migrating populations as valuable to humans in various ways. (SEP 2.3; DCI: ESS 3.C.1; CCC: 7.4)	2.A When to check for understanding: On day 1, during the scavenger hunt when students integrate information from <i>Scavenger Hunt Notes</i> with new information they learn from the information stations (SEP 8.2) What look/listen for in the moment: • Serengeti National Park (SNP) was created to protect the movement of huge herds of animals. (DCI: LS2.C.2; CCC: 7.1) • SNP protected animal populations from disappearing due to overhunting. (DCI: LS2.C.2; CCC: 7.1) • People disagreed about the role humans play in the Serengeti ecosystem. (DCI: LS2.C.2; CCC: 7.1) • People disagreed about what part of the ecosystem to protect, and boundaries changed over time. (DCI: LS2.C.2; CCC: 7.1) 2.B When to check for understanding: On day 2 during the Scientists Circle. What look/listen for in the moment: Students will develop a consensus model and explanation using evidence (SEP 2.3) to explain the following: • SNP was created to protect the migration route for huge herds of wildebeest, zebra, and Thomson's gazelles. (DCI: ESS 3.C.1; CCC: 7.4) • Show the wildebeest migration route on the base map. • SNP and the reserve system were created to protect a large diversity of animals. (DCI: ESS 3.C.1; CCC: 7.4) • The SNP does not protect the full migration route. (DCI: ESS 3.C.1; CCC: 7.4) • The British and Europeans often made decisions without including people in Tanzania/Tanganyika, which may not protect the ecosystem. (DCI: ESS 3.C.1; CCC: 7.4) • Reserves protect the animals but also allow people to live, hunt, and graze livestock. (DCI: ESS 3.C.1; CCC: 7.4) • The SNP protects the animals and excludes humans from living in or taking resources from the area. (DCI: ESS 3.C.1; CCC: 7.4) • Question why wildebeest migrate, especially if it is dangerous. (CCC: 7.4)
Lesson 3	3.A Communicate information about patterns in factors that affect wildebeest migration. (SEP: 8.5; DCI: LS2.A.1; CCC: 1.5) 3.B Develop a model of wildebeest migration using patterns found in empirical evidence about factors such as predation and food availability. (SEP: 2.3; DCI: LS2.A.1; CCC: 1.5)	3.A.1 When to check for understanding: On day 1 when students analyze wildebeest data cards and record patterns in <i>Analyzing Wildebeest Data Cards</i> and on day 2 (3.A.2) when they present their data displays to the class. What to look for/listen for in the moment: Visit each group to assess how they communicate (SEP 8.5) about patterns in (CCC: 1.5): • Bone marrow health showing that wildebeest killed by predators have slightly better bone marrow health than wildebeest that did not die from predators. (DCI: LS2.A.1) • Live wildebeest have a higher percentage of fat in their bone marrow than dead wildebeest. (DCI: LS2.A.1) • June and July were the only months where anthrax was found in the population. (DCI: LS2.A.1) • There was no difference of anthrax infection percentages between living and dead wildebeest. (DCI: LS2.A.1) • In some months/locations there were bigger differences between living and dead wildebeest's bone marrow fat (June–October) than other months (May). (DCI: LS2.A.1) 3.B When to check for understanding: On day 2 when the class develops a consensus model. What to look for/listen for in the moment: • An absence of patterns in the data to show that there is no evidence to connect predation and disease to migration. (SEP: 2.3; CCC: 1.5; DCI: LS2.A.1) • Patterns in the data to use as evidence to model the connection between food and migration. (SEP: 2.3; CCC: 1.5; DCI: LS2.A.1)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	4.A Analyze data using CODAP to determine how seasonal changes in rainfall limit food availability in the Serengeti. (SEP 4.1; DCI: LS2.A.1; CCC: 7.1) 4.B Use mathematical representations of empirical evidence related to rainfall and wildebeest location to support claims about the cause of the migration. (SEP: 5.2; DCI: LS2.A.1; CCC: 2.1) 4.C Revise a model to include new evidence about factors that affect wildebeest survival to illustrate the patterns and relationships and limits of resources that the wildebeest migration depends on. (SEP 2.3; DCI: LS2.A.1; CCC 3.1)	4.A When to check for understanding: When students complete an exit ticket at the end of day 1. What to look for/listen for in the moment: Evidence to support the following claims (SEP 4.1): - There is a wet season and a dry season that repeat each year with the most rain around April and the least around July. More rain means more grass and vice versa. (DCI LS2.A.1; CCC 7.1) - There is no evidence to support this claim. - The pattern was similar for all three regions, but the rainfall amounts were always slightly higher for the north in each month, so there should be more grass there all year long. (DCI LS2.A.1; CCC 7.1) 4.B When to check for understanding: When students complete an exit ticket at the end of day 2. What to look for/listen for in the moment: Evidence to support or contradict the following claims, drawing on patterns identified from mathematical representations (SEP 5.2; CCC 2.1): - The scatter plot for the south region shows a positive relationship between annual rainfall and wildebeest occupancy, so this claim is supported by the data. Students do NOT need to use the word positive, but look for the conceptual recognition of the upward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1) - The scatter plot for the west and north regions shows a negative relationship between annual rainfall and wildebeest occupancy, so this claim is not supported by the data. Students do NOT need to use the word negative, but look for the conceptual recognition of the downward trend in the data. (SEP 5.2; DCI LS2.A.1; CCC 2.1) - When comparing the scatter plots for all three regions, we can see that the wildebeest are spending more time in the west and in the south based on the higher values for wildebeest percentage occupancy. (SEP 5.2; DCI LS2.A.1; CCC 2.1) 4.C When to check for understanding: When the class revises the consensus model at the end of day 3. What to look for/listen for in the moment: Model revisions that include the following evidence: (SEP 2.3) - Wildebeest are in the south during the wet season, even though that is not where the most rain is. (DCI LS2.A.1; CCC 3.1) - Wildebeest give birth in the south during the wet season, and that is where the best, most nutritious food is due to the richest soil and also where they can see their predators. (DCI LS2.A.1; CCC 3.1) - The wildebeest move on to the west when the wet season is ending in search of other grass. (DCI LS2.A.1; CCC 3.1) - During the dry season, the soil in the west is drier, making it easier for the wildebeest to walk through and making the grass more nutritious during that time. (DCI LS2.A.1; CCC 3.1) - The north has the most rain, but it has less nutritious grass, so the wildebeest only go there in the dry season, when there is no food in the south. (DCI LS2.A.1; CCC 3.1) - The Mara River is in the north, which provides water year round. (DCI LS2.A.1; CCC 3.1) - Looking at small-scale relationships can help us understand the pattern of migration at the scale of the Serengeti ecosystem. (CCC 3.1)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 5	5.A Develop and use a kinesthetic and mathematical model to generate evidence to explain how grass is a limiting factor that affects carrying capacity of wildebeest populations within the conditions of the Serengeti ecosystem. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3) 5.B Use mathematical representations of data to quantify rates of population change over time to support explanations about the effect of limiting factors on population size. (SEP: 5.2; DCI: LS2.A.1; CCC: 7.2)	5.A.1 When to check for understanding: On day 1, when students complete the Making Sense questions on <i>Serengeti Kinesthetic Model</i>. In addition, you can listen to student thinking in the navigation that directly follows. What to look for/listen for in the moment (Part 1): • Graphs that model an increase in population that levels off and is replaced by a cycle of ups and down around an average. (SEP: 2.4) • Availability of grass and competition for food allowed for growth and then limited the wildebeest population in the Serengeti. (CCC 4.3, DCI: LS2.A.1) • When the population was increasing, wildebeest got enough food to survive and reproduce. (SEP: 2.4, DCI: LS2.A.1) • When the population was decreasing, there was not enough food for the number of wildebeest, and some died. (SEP: 2.4, DCI: LS2.A.1) 5.A.2 When to check for understanding: On day 1 when students develop an algorithm. What to look for/listen for in the moment (Part 2): • Algorithms that include if-then statements about the relationship between wildebeest, grass, and wildebeest population growth. (SEP: 2.4; CCC 4.3; DCI: LS2.A.1) • An explanation using evidence from the algorithm or graph to explain the relationship between wildebeest, grass, and wildebeest population growth. (SEP: 2.4; DCI: LS2.A.1; CCC 4.3) 5.B.1 When to check for understanding: On day 2, when students complete <i>Wildebeest Population Data</i>. In addition, you can listen to student thinking in the Building Understandings Discussion that directly follows. What to look for/listen for in the moment: See <i>Wildebeest Population Data Key</i> for guidance on student responses. 5.B.2 When to check for understanding: On day 2 when students complete an <i>Electronic Exit Ticket</i>. What to look for/listen for in the moment: See <i>L5 Electronic Exit Ticket Key</i> for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	6.A Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. (SEP: 5.2; DCI: LS2.A.1; CCC 3.1)	6.A When to check for understanding: On day 1 as pairs of students complete <i>African Wild Dog Transfer Task</i>. Students should be engaging with the graphs and data tables to explain (SEP 5.2); • Space, prey biomass, and lions are limiting factors for African wild dogs. (DCI LS2.A) • How each limiting factor can be used to determine carrying capacity. (DCI LS2.A) • Carrying capacity cannot be determined in only three years. (DCI LS2.A; CCC 3.1) What to do: Collect one completed transfer task from each pair. Review the task before it is returned on day 2 in order to provide feedback that indicates where more detail is needed. Use <i>Transfer Task Key</i> as a guide. For example ask, <i>What is the smallest amount of space a pack requires according to the graph?, Is this a positive or negative relationship? or What evidence does the graph provide to determine carrying capacity?</i> If students need more support in developing their ideas before completing the individual assessment item on day 2, take some additional time prior to the individual assessment to review the answers to this first part of the task as a class and perhaps revisit the connections of each question to supporting documents from previous tasks. 6.B When to check for understanding: On day 2 during peer assessment and revision of the transfer task, students will revise responses to demonstrate engagement with the graphs and data tables to explain (SEP 5.2) • Create a graphical representation of population changes in African wild dogs over 10 years. (SEP 6.2; DCI LS2.A; CCC 3.1) • Describe the minimum space and prey biomass requirements for African wild dogs. (DCI LS2.A) • Describe how each limiting factor is used to determine carrying capacity for the National Park. (DCI LS2.A) • Liwonde National Park can support one pack of 11-12 African wild dogs. (DCI LS2.A) • It is necessary to scale up this project dozens to hundred of times over to greatly increase the population of African wild dogs. (DCI LS2.A; CCC 3.1) What to do: Prompt students to: • Check off items in the Organized Understanding column of the rubric. • Revisit <i>Wildebeest Population Data</i>, which explains why populations fluctuate annually, what causes them to reach carrying capacity, and how many years it takes to reach. • Reexamine figure 3 and examine the units on the graph to determine the minimum territory size one pack needs. • Reexamine figure 4 and examine the units on the graph to determine the minimum amount of prey biomass one pack needs. • Compare the data provided in table B from Liwonde with figures 3 and 4 from South Africa. • Consider if one limiting factor seems more important than another. • Ask how knowing that lions are below carrying capacity might impact wild dogs. • Consider how the lion population might change over time and how that would impact the carrying capacity of wild dogs (Extending). • Consider what human interactions could raise or lower the carrying capacity of African wild dogs (Extending).

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 7	7A. Read informational text to obtain and communicate information about how the rules of the game are designed to model behavior in the Serengeti system. (SEP: 8.1; DCI: LS2.D.1; CCC: 4.1) 7B. Use a model to predict interactions in the Serengeti system to generate data to support explanations about group behavior. (SEP: 2.6; DCI: LS2.D.1; CCC: 4.4) 7C. Use an algorithmic representation to support explanations about how group behavior increases survival by identifying patterns in mathematical representations. (SEP: 5.2, DCI: LS2.D.1, CCC: 1.4)	7.A When to check for understanding: On Day 1, when students complete Table 2 in <i>Meet Your Wildebeest</i>, <i>Meet Your Lion</i>, or <i>Meet Your Hyena</i>. What to look for/listen for in the moment: Use <i>Meet Your Agent Key</i> for sample responses. 7B. When to check for understanding: On Day 2, when students complete an exit ticket. What to look for/listen for in the moment: Evidence from student data includes: (SEP: 2.6) • Data about how many individuals survive and/or die during predator/prey interactions. (SEP: 2.6; CCC: 4.4) • Data about how many individuals survive and/or die during predator/prey interactions AND the group size of each agent. (SEP: 2.6; DCI: LS2.D.1; CCC: 4.4) 7.C When to check for understanding: On Day 3 when students develop algorithms. What to look for/listen for in the moment: • Algorithmic representation of interactions between 2 agents. (SEP: 5.2) • Explanations using algorithms as evidence that group behavior increases survival for a single agent. (SEP: 5.2, DCI: LS2.D.1) • Algorithms as evidence of a pattern, across all three agents, of group behavior increasing survival. (SEP: 5.2, DCI: LS2.D.1, CCC: 1.4)
Lesson 8	8.A Use a mathematical representation to model the interactions between components connected to wildebeest migration in the Serengeti ecosystem. (SEP: 5.2; DCI: LS2.C.1; CCC: 4.4) 8.B Develop and test a complex model for how ecosystems are resilient and the numbers and types of organisms relatively constant (stable) in response to disturbance (change). (SEP: 2.5; DCI: LS2.C.1; CCC: 7.1)	8.A When to check for understanding: On day 1, when students are working in their groups on <i>Serengeti Component Interactions</i>. Additionally, you can listen for ideas shared orally during the day 1 Building Understandings Discussion. What to look for/listen for in the moment: Students should make claims that: • are supported by use of the mathematical representations used to create the computational model, (SEP: 5.2) • describe the key interactions and mechanisms in the system to predict the behavior of components in the system (CCC: 4.4) • identify complex sets of interactions within the Serengeti ecosystem for different types of organisms. (CCC: 4.4; DCI: LS2.C.1) 8.B When to check for understanding: On day 2, when students submit an electronic exit ticket. If you would like an additional formative moment before the exit ticket, listen in on discussions as students use the computational model in small groups and during the Consensus Discussion. What to look for/listen for in the moment: See <i>L8 Electronic Exit Ticket Key</i>.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 9	9.A Use a model based on evidence to explain how the plan to establish the Serengeti National Park contributed to the stability of the ecosystem. (SEP: 2.3; DCI: ESS 3.C.1; CCC: 7.1) 9.B Evaluate competing road proposals to determine how such human activity could impact the Serengeti ecosystem over short and long periods of time (SEP: 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC 7.1)	9.A When to check for understanding: On day 1, when students complete <i>Conservation Plan Evaluation</i> What to look for/listen for in the moment: Students use a model (the conservation evaluation tool) to explain the following evidence (SEP 2.3) • Creating the park protected the wildebeest migration and stability of the system. (ESS: 3.C.1; CCC 7.1) • The whole system is more stable because the wildebeest are connected to so many things and protecting them protects biodiversity. (ESS 3.C.1; CCC 7.1) • Some interest holders benefit, but others are harmed, and not all human connections in the system are stable. (ESS: 3.C.1; CCC 7.1) • Successful conservation that supports a stable ecosystem also involves relationships between the conservation managers and the broader community. (DCI: ESS 3.C.1; CCC 7.1) 9.B.1 When to check for understanding: On day 2, when students complete <i>Road Proposal Organizer</i> in small groups. What to look for/listen for in the moment: • The Eyasi route is most likely to best meet the criteria of the cost and travel time. (SEP 6.5; DCI:ETS1.B.1; CCC 7.1) • The Mbulu route is most likely to best meet the criteria of economic development and social services.(SEP 6.5; DCI: ETS1.B.1; CCC 7.1) See <i>Road Proposal Organizer Key</i> for additional guidance. 9.B.2 When to check for understanding: On day 2, when students complete <i>Road Proposal Evaluation</i> in small groups. What to look for/listen for in the moment: • The Serengeti road option has the potential to disrupt the ecosystem in the short and long term and harm human interest holders. (DCI: LS2.C.2 & ETS1.B.1 ; CCC 7.1) • Interest holders will prioritize criteria in various ways. (SEP 6.5; DCI: ETS1.B.1) • Some options may better meet the greatest number of interest holder needs in the short and long term. (SEP 6.5; DCI: ETS1.B.1 ; CCC 7.1) See <i>Group Assessment Key</i> for more guidance.

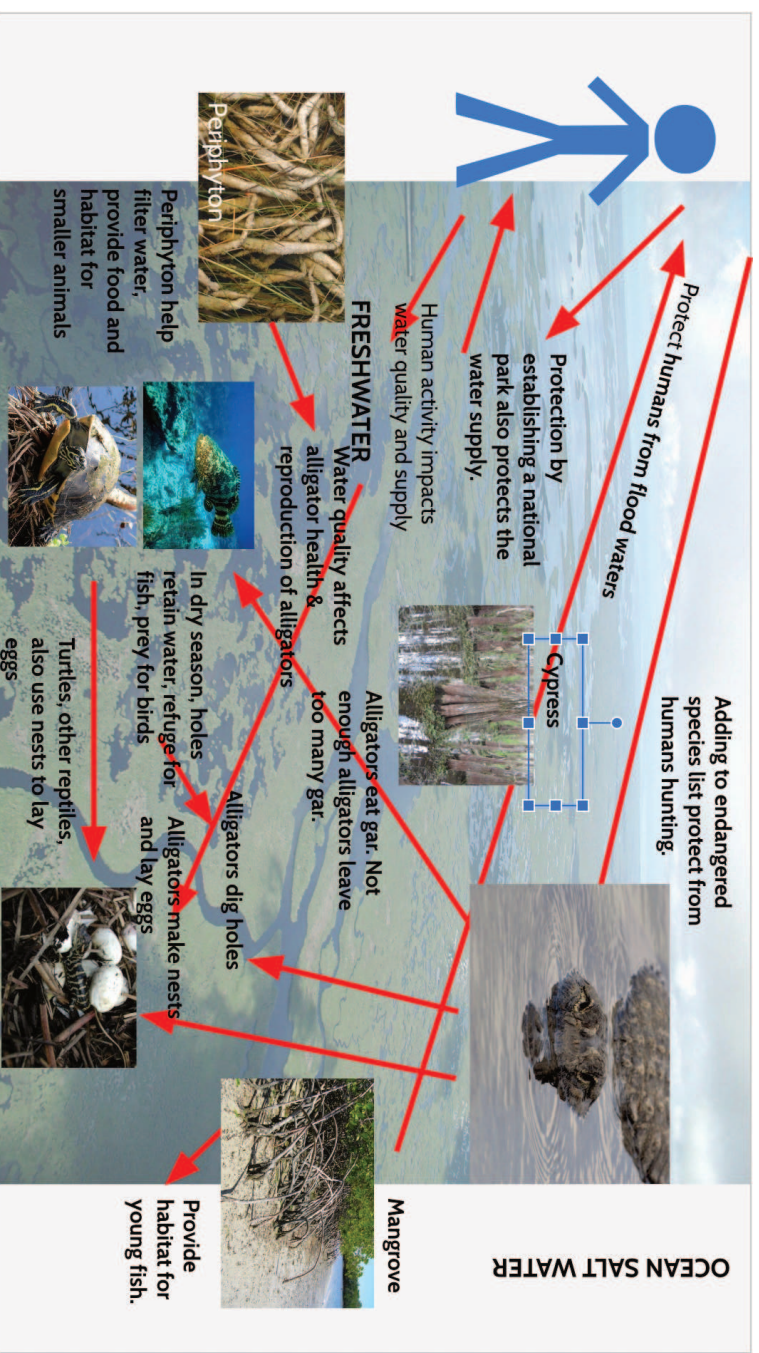
Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	10.A Evaluate a conservation plan by using evidence and reasoning about stability and change from complex interactions in the ecosystem. (SEP: 6.5; DCI: LS2.C.1; CCC: 7.1)	10.A When to check for understanding: On day 1, as students complete part C on <i>Evaluating Conservation Plans</i>. What to look for/listen for in the moment (Part 1): • Interactions between the focal organism and other components of the system. (LS2.C.1) • Components/interactions include evidence of the conservation plan put in place by humans to change or stabilize a population. (SEP 6.5, CCC 7.1, LS2.C.1) • Arrows that indicate how the components are impacted (+/-). (CCC 7.1, LS2.C.1) • Arrows that indicate how the focal population increases or decreases. (CCC 7.1, LS2.C.1) On day 2, when students present their impact maps. What to look for/listen for in the moment (Part 2): • Interactions between the focal organism and other components of the system. (LS2.C.1) • Components/interactions include evidence of the conservation plan put in place by humans to change or stabilize a population. (SEP 6.5, CCC 7.1, LS2.C.1) • Arrows that indicate how the components are impacted (+/-). (CCC 7.1, LS2.C.1) • Arrows that indicate how the focal population increases or decreases. (CCC 7.1, LS2.C.1) • Evaluation of whether or not the conservation plan was successful based on evidence and criteria.(SEP 6.5) On day 3 during the Building Understanding Discussion. What to look for/listen for in the moment (Part 3): • Similarities and differences in conservation profiles. • Evaluation of success for the profiles based on evidence of interactions, stability, or change. (SEP 6.5, CCC 7.1; LS2.C.1) • Inclusion of human interactions, priorities, and criteria for conservation decisions.(SEP 6.5) • Knowing all of this can help us understand how to protect spaces in the future. By supporting ecosystem stability and resilience, humans are minimizing negative human changes. (CCC 7.1, LS2.C.1)
Lesson 11	11.A Evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity. (SEP:6.5; DCI: LS2.C.2, LS4.D.2, ETS1.B.1; CCC: 7.1)	11.A When to check for understanding: On day 1, when students complete <i>Prairie Transfer Task</i>. What to look for/listen for in the moment: See <i>Prairie Task Key</i>.



Lesson-Specific Teacher Materials

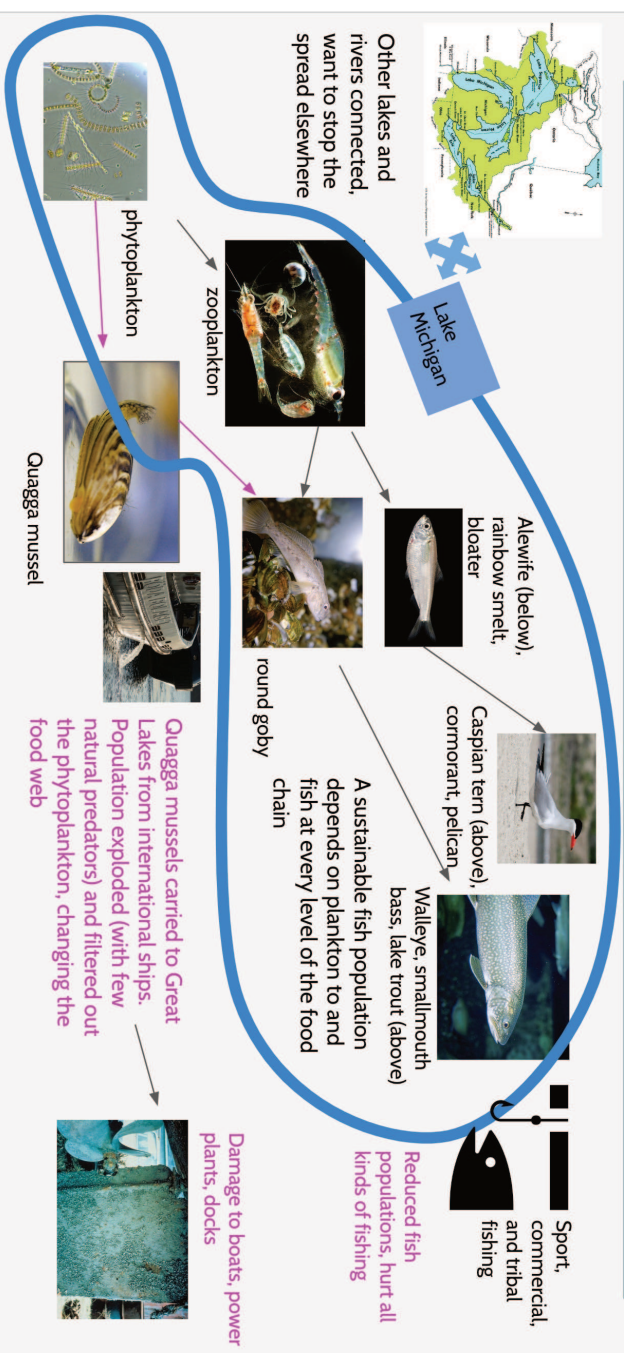
Conservation Profile Models

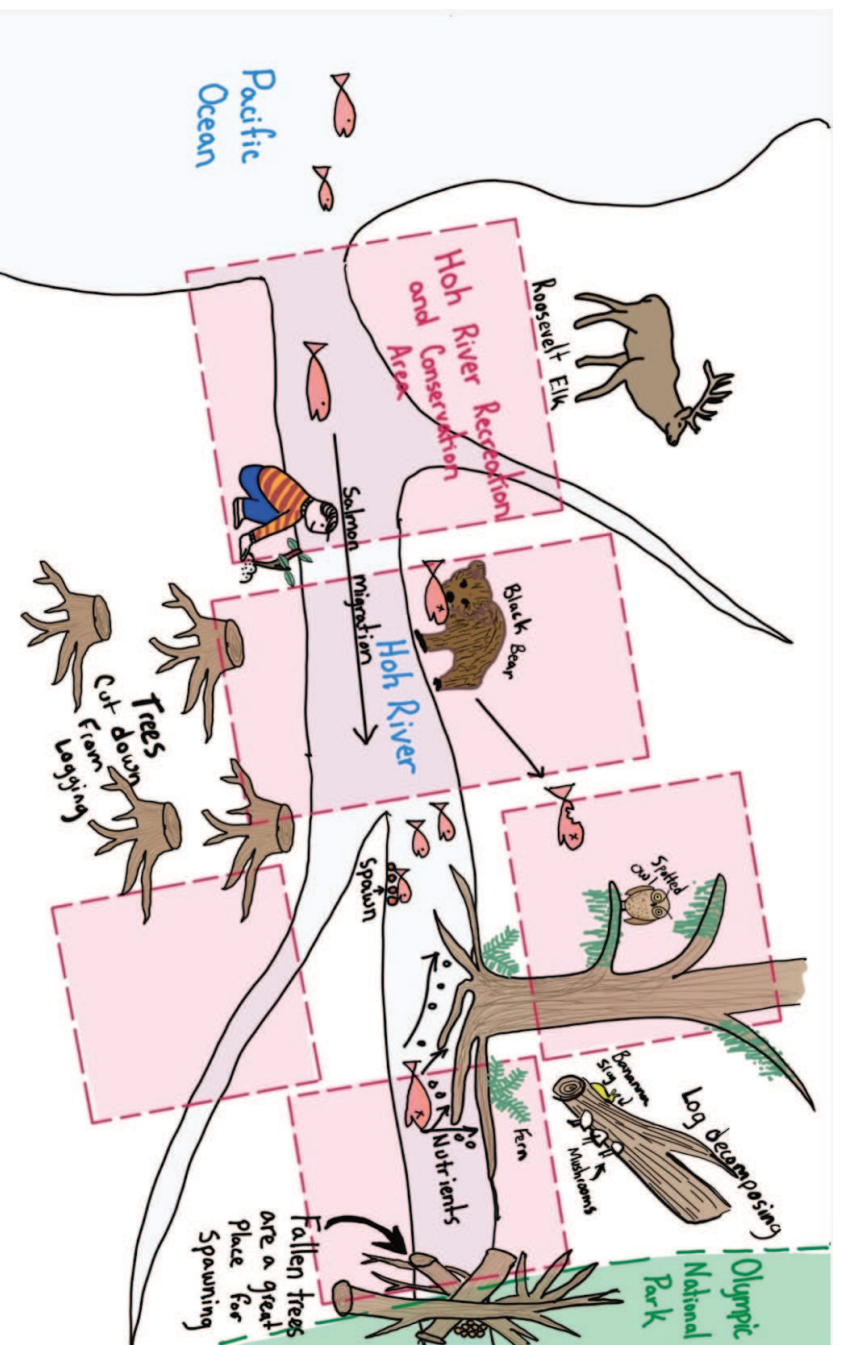
Everglades



National Park Service

Great Lakes





Saguaro



Example Community Agreements

Respectful Our classroom is a safe space to share.	• We provide one another with support and encouragement. • We share our time to talk. We do this by giving others time to think and share. • We critique the <i>ideas</i> we are working with but not the <i>people</i> we are working with.
Equitable Everyone's participation and ideas are valuable.	• We monitor our own time spent talking. • We encourage others' voices that we have not heard yet. • We recognize and value that people think, share, and represent their ideas in different ways.
Committed to Our Community We learn together.	• We come prepared to work toward a common goal. • We share our own thinking to help us all learn. • We listen carefully and ask questions to help us understand everyone's ideas. • We speak clearly and loud enough so that everyone can hear.
Moving Our Science Thinking Forward We work together to figure things out.	• We use and build on others' ideas. • We use evidence to support our ideas, ask for evidence from others, and suggest ways to get additional evidence. • We are open to changing our minds. • We challenge ourselves to think in new ways.

Lesson 1 Teacher Reference

Supporting Questioning

- 1. What is the question you are working on?
- 2. What is the purpose of your question?
Here are some reasons why people ask questions in science:
We do not fully understand how the phenomenon (or a part of the phenomenon) works.
We have a disagreement (in our model or with someone's explanation or argument).
We need to test an idea we have.
Other reason: _____
- 3. Is your question close-ended or open-ended? Circle one. close-ended (Complete step 4.) open-ended (Skip to step 5.)

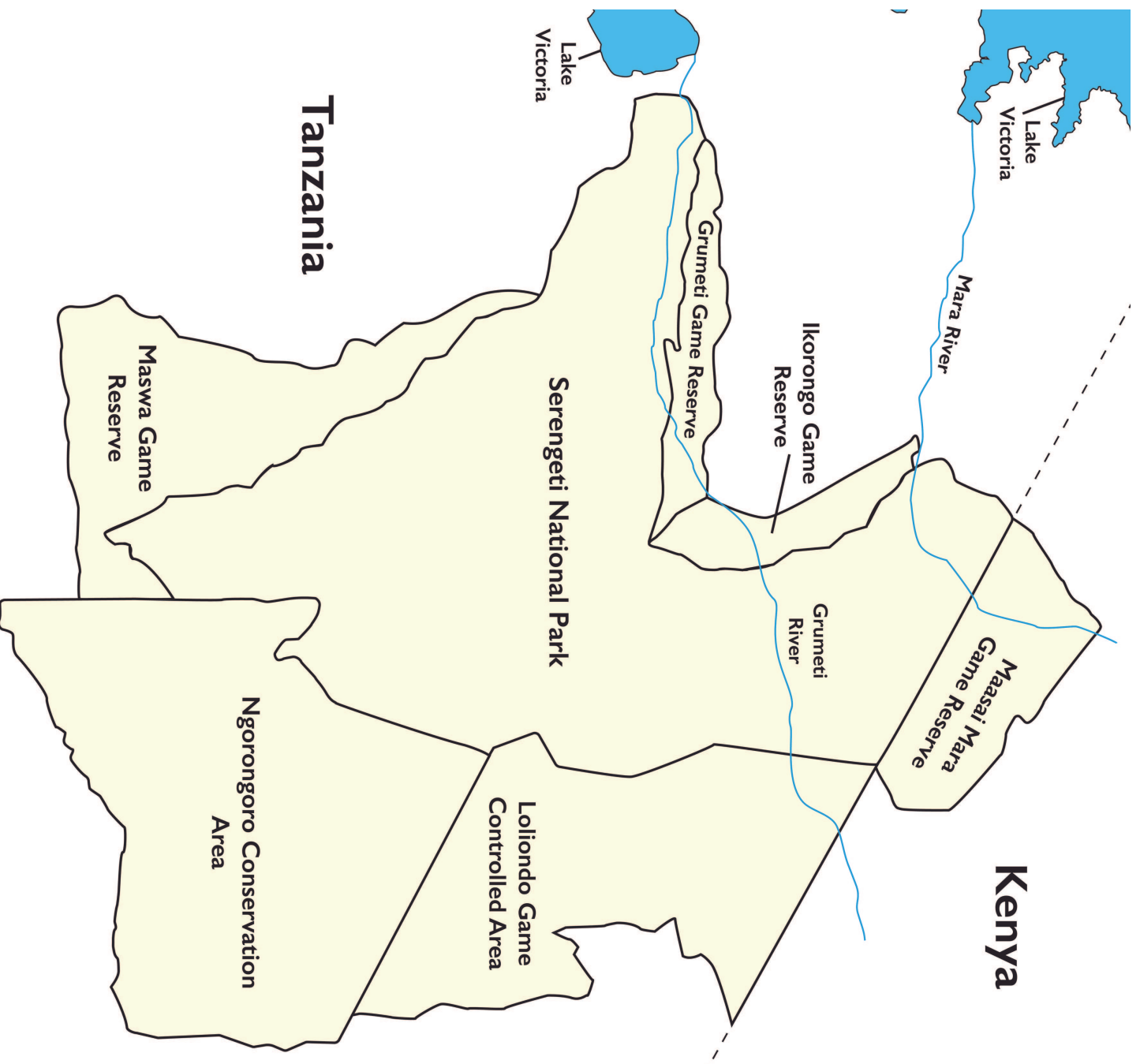
Close-ended and open-ended questions: Questions that can be answered with “yes” or “no” or with a single word are close-ended questions. Asking open-ended questions gives you space to figure out more things. Scientific questions are open-ended questions.

- 4. Revise your question to make it an open-ended question. Think about what you want to explain about the phenomenon.
Try using one of these question stems:
How does ... ?
Why does ... ?
What happens when ... ?
What happens if ... ?
What is the difference between _____ and _____ ?
Write your revised question:
- 5. What information or data do you need to answer your question?

- 6. How would this information or data help you achieve the purpose you circled in step 2?
Provide feedback to another student using the table below.

Criteria	Yes or no?	Feedback and/or suggested revision
Is the question open-ended?		
Does the information or data in step 5 help answer the question?		
Does the question help the student achieve their purpose for asking the question?		

Lesson 2 Teacher Reference
Serengeti Map



Data Source: Sinclair, A. R. E. (2021). A place like no other: Discovering the secrets of serengeti. Princeton University Press.

Name: _____

Date: _____

Lesson 2: Answer Key 2

Graphic Organizer Scavenger Hunt Key

Why did people decide to protect the Serengeti? How did they decide what to protect?

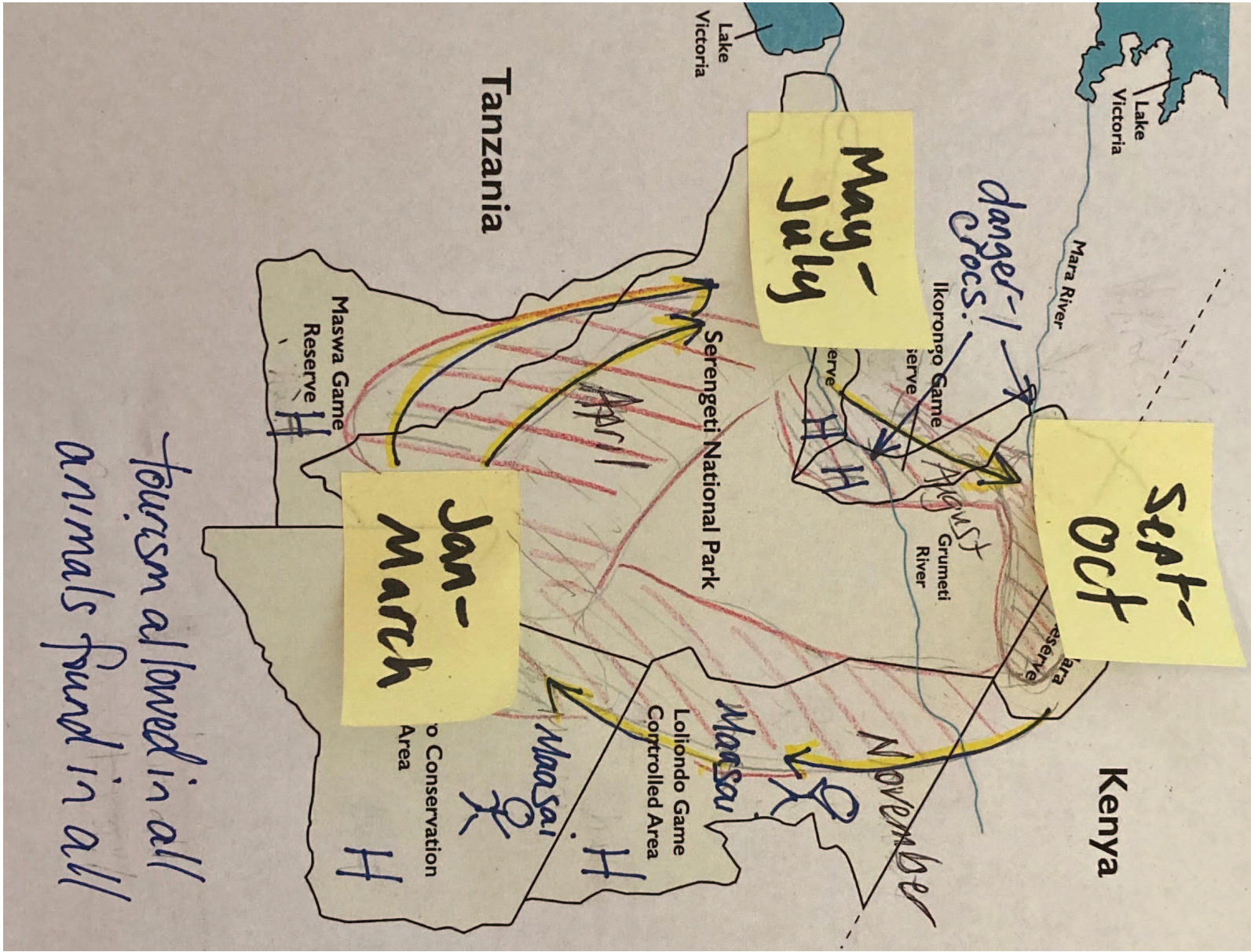
Use the Graphic Organizer to record your response. Use the map to note important locations.

	Noticings	Wonderings
System • <i>What places, lands, and waters are included?</i> • <i>What is outside the system?</i>	• <i>The Serengeti ecosystem is in Tanzania and Kenya.</i> • <i>Lake Victoria is to the west, Great Rift Valley to the east and south.</i> • <i>There are two rivers (shown) running through it, the Grumeti and Mara.</i>	• <i>Why doesn't the park go all the way to Lake Victoria?</i> • <i>Why do wildebeest leave the protected areas?</i>
Components • <i>What species and other kinds of living and nonliving things are found in the ecosystem?</i> • <i>What behaviors do they exhibit (roles, actions, decisions).</i>	• <i>There are grasslands, savanna and woodland.</i> • <i>High biodiversity: wildebeest, zebra, ostriches, elephants, acacia, leopards, ants, butterflies, etc.</i> • <i>Wildebeest migrate every year and travel 650 km!</i> • <i>Crocodiles eat wildebeest when they cross the river.</i> • <i>Lions eat wildebeest.</i> • <i>Acacia trees protect ants and vice versa.</i> • <i>Wildebeest eat grass.</i>	• <i>Why do wildebeest migrate?</i>
Interactions • <i>What are human relationships to these species and kinds?</i>	• <i>Maasai, Nara, and others used to live in SNP and were part of the ecosystem.</i> • <i>People hunt animals for food and sport and grazed cattle on the land.</i> • <i>Tourists visit the ecosystem.</i> • <i>Researchers investigate the ecosystem.</i> • <i>People do not live in SNP but can live in Game Controlled Reserve Areas, NCA.</i>	• <i>Are humans part of the Serengeti ecosystem? If so, what should they be able to do there?</i>

Decision-Making • How have the lands, waters, species, and kinds in the area been affected by human activity and human decision-making, and how are they being affected now? • What decisions were made about the land? • Who made those decisions and why? • What motivated humans to make those decisions?	• Before SNP was formed, Europeans over-hunted lions and other animals, which threatened animals with extinction. • Europeans decided to create SNP and other reserve areas. • The Reserves were created when they learned where the wildebeest migration goes. • NCA and Loliondo were created to give land back to the Maasai people. • Some African people were involved in decision-making about the park, but many were excluded, especially early on. • People did not agree about whether humans are part of the Serengeti ecosystem and if local Tanzanians should be able to continue living in the park and using the resources as they always had.	• What happens to the wildebeest when they are outside of SNP? Are they hunted? Are they safe? • Will they change the boundaries of the park again to better protect the wildebeest? • How do the local people feel about the park?
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Please note questions from this framework were adapted from: *Learning in Places Collaborative (2022). Framework: Complex Socio-Ecological Systems*. Bothell, Seattle, WA & Evanston, IL: Learning in Places. Please see <http://learninginplaces.org/frameworks/complex-socio-ecological-systems-framework/> for further information and guidance.

Full version of image provided in teacher guide. H-areas that allow hunting. Stick figures represent places people can live.



Tourism allowed in all
animals found in all

Data and Sources

Scientists collect a lot of different data when studying organisms in the field, and not all of it is useful to their research. This data by itself does not have meaning. Scientists must make sense of the data by first organizing the data, analyzing it by looking for patterns, and then interpreting the patterns they observe. The data students are observing came from several different research studies. While students will have to sift through data in order to find meaningful patterns that can be used to explain wildebeest migration, data has been intentionally selected to help highlight these patterns. If you or your students have more questions about the data, or the larger data sets this lesson uses, the following information should help.

Data Selection

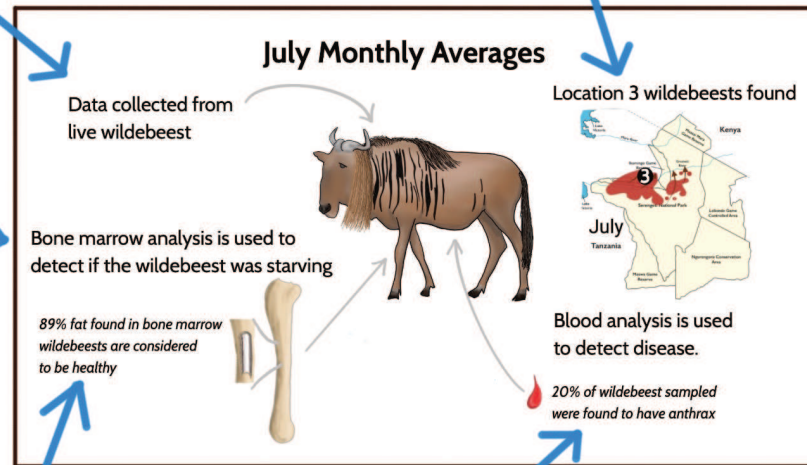
For the purposes of the activity, students are only engaging with data from male wildebeest. Dr. Mduma collected data for both male and female wildebeest. The data for female wildebeest is a little more complex to analyze because some females in the population are caring for calves (their offspring). The patterns of bone marrow nutrition still show similar results, but the data also shows an additional nutritional difference between male and female wildebeest. (E., S. A. R., 2021) Since these females are providing nutrition for themselves and their offspring, it makes the data a little more complex to analyze, and therefore this data was not included on *Wildebeest Data Cards*.

Sources for Data Cards

Mduma, S. A., Sinclair, A. R., & Hilborn, R. (1999). Food regulates the Serengeti Wildebeest: A 40-year record. *Journal of Animal Ecology*, 68(6), 1101–1122.
<https://doi.org/10.1046/j.1365-2656.1999.00352.x>

Tombazzi, G. (n.d.). Maps and satellite images of Serengeti National Park. African World Heritage Sites. Retrieved September 6, 2022, from https://www.africanworldheritagesites.org/assets/files/Maps_and_Satellite_Images_of_Serengeti_National_Park.pdf

E., S. A. R., & Beyers, R. (2021). The Discovery of Food Regulation. In *A place like no other: Discovering the secrets of Serengeti* (pp. 44–58). essay, Princeton University Press.



Sinclair, A. R., & Arcese, P. (1995). Population consequences of predation-sensitive foraging: The Serengeti Wildebeest. *Ecology*, 76(3), 882–891.
<https://doi.org/10.2307/1939353>

Lembo, T., Hampson, K., Auty, H., Beesley, C. A., Bessell, P., Packer, C., Halliday, J., Fyumagwa, R., Hoare, R., Ernest, E., Mentzel, C., Mlengeya, T., Stamey, K., Wilkins, P. P., & Cleaveland, S. (2011). Serologic surveillance of anthrax in the Serengeti Ecosystem, Tanzania, 1996–2009. *Emerging Infectious Diseases*, 17(3), 387–394.
<https://doi.org/10.3201/eid1703.101290>

Anthrax data:

The anthrax data used on *Wildebeest Data Cards* is from a year with an anthrax outbreak. Research has shown that anthrax is not passed from individual to individual but rather by certain soil conditions at certain times of the year. (Lembo, 2011)

Data conclusions:

The bone marrow data is the data that provides the strongest evidence for what is causing wildebeest migration.

If predation were the main factor, we would expect the wildebeest dying from predation to have no difference in overall health when compared to the live population. This is not the case. As students will notice, the wildebeest dying from predation were less nutritionally healthy than those that were living (Sinclair, 1995).

If food were the main factor, we would expect to see wildebeest dying both by predation and non-predation to have similar bone marrow, but it would be worse than live wildebeest bone marrow. This is what the data shows and is what we hope students notice in the data cards.

References

- Sinclair, A. R., & Beyers, R. (2021). The Discovery of Food Regulation. In *A place like no other: Discovering the secrets of Serengeti* (pp. 44–58). essay, Princeton University Press.
- Hampson, K., Lembo, T., Bessell, P., Auty, H., Packer, C., Halliday, J., Beesley, C. A., Fyumagwa, R., Hoare, R., Ernest, E., Mentzel, C., Metzger, K. L., Mlengeya, T., Stamey, K., Roberts, K., Wilkins, P. P., & Cleaveland, S. (2011). Predictability of anthrax infection in the Serengeti, Tanzania. *Journal of Applied Ecology*, 48(6), 1333–1344. <https://doi.org/10.1111/j.1365-2664.2011.02030.x>
- Lembo, T., Hampson, K., Auty, H., Beesley, C. A., Bessell, P., Packer, C., Halliday, J., Fyumagwa, R., Hoare, R., Ernest, E., Mentzel, C., Mlengeya, T., Stamey, K., Wilkins, P. P., & Cleaveland, S. (2011). Serologic surveillance of anthrax in the Serengeti Ecosystem, Tanzania, 1996–2009. *Emerging Infectious Diseases*, 17(3), 387–394. <https://doi.org/10.3201/eid1703.101290>
- Mduma, S. A., Sinclair, A. R., & Hilborn, R. (1999). Food regulates the Serengeti Wildebeest: A 40-year record. *Journal of Animal Ecology*, 68(6), 1101–1122. <https://doi.org/10.1046/j.1365-2656.1999.00352.x>
- Sinclair, A. R., & Arcese, P. (1995). Population consequences of predation-sensitive foraging: The Serengeti Wildebeest. *Ecology*, 76(3), 882–891. <https://doi.org/10.2307/1939353>
- Tombazzi, G. (n.d.). *Maps and satellite images of Serengeti National Park*. African World Heritage Sites. Retrieved September 6, 2022, from https://www.africanworldheritagesites.org/assets/files/Maps_and_Satellite_Images_of_Serengeti_National_Park.pdf

Data Cards Patterns Key

As the class identifies different ways to organize and sort the data cards, it should be noted that some ways to sort the cards are easier than others. The more groups/piles of cards, the more challenging and difficult this task is. Be sure to assign students to groups strategically, and also assign groups to sort the data cards so that students will be successful in identifying the key patterns. The following table highlights the patterns students should be able to observe based on how they are assigned to sort the cards.

Way to sort:	Patterns/Summary	
Predators/dead not predators/ living	Predators 54-75% bone marrow Dead Not Predators 23-90% bone marrow Living 73-95% bone marrow	The living wildebeest are healthier. Wildebeest that were killed by predators were not nutritionally healthy. Dead wildebeest not killed by predators had a big range but the lowest health.
Nutritional health	Healthy (9): 9 total cards. 6/9 living 2/9 killed by predators. 1/9 killed by other causes. 3/9 were from May, 1 each from the other months. Nutritionally Stressed (6) No living 4 predators 2 other causes dead No May, June--Oct 3/6 20% anthrax Nutritionally Starved (3) Dead not predation July-Aug-Sept 1=20% anthrax	Living wildebeest are mostly nutritionally healthy. They are all healthy in May. None of the dead wildebeest were healthy. The stressed and starved were all dead. Wildebeest are stressed/starved other months than May.
Anthrax	There were 6 cards in the 20% anthrax category all from June and July. In the 0% anthrax category, there were 3 from each month: May, Aug-Oct (12 total).	A small number (20%) of all kinds of wildebeest have anthrax in June and July in the same location. They don't get it any other time/place.

Month	May 75-90% bone marrow 0% anthrax All in same location June 60-92% bone marrow All in same location July 31-89% bone marrow All in same location August 23-73% bone marrow All in same location Sept 31-76% bone marrow All in same location October 54-77% bone marrow All in same location	Nutritional health seems to be better in the spring and worse in the fall. In each month live wildebeest have better health than dead wildebeest.
Location	1 75-90% bone marrow 0% anthrax All in May 2 60-92% bone marrow All June 3 31-89% bone marrow All July 4 23-73% bone marrow All August 5 31-76% bone marrow All September 6 54-77% bone marrow All October	Nutritional health seems to be better in location 1 and worse at location 6. In each location live wildebeest have better health than dead wildebeest.

If students are struggling to recognize these patterns, the following table provides some additional prompts that a teacher could use to help provide feedback.

Way to sort	Patterns in Data	Suggested Prompts to Support Student Thinking
Predators/dead not predators/living	The only patterns we observed between wildebeest killed by predators and those not killed by predators had to do with food. Wildebeest killed by predators have slightly better bone marrow health than wildebeest that did not die from predators.	What do you notice is similar between these piles? What did you notice is different between these piles? Was there any pattern with anthrax? What did you notice about the nutritional health between the piles?

Nutritional health	Live wildebeest have a higher percentage of fat in their bone marrow than dead wildebeest.	What do you notice is similar between these piles? What did you notice is different between these piles? Considering only nutritional health, was there any difference between living and nonliving wildebeest? Explain.
Anthrax	June and July were the only months where anthrax was found in the population. There was no difference of anthrax infection percentages between living and dead wildebeest.	What did you notice that was similar between all the cards that had anthrax? What was different about the cards that had anthrax? What was similar between all the cards that did not have anthrax? What was different between all the cards that did not have anthrax? Considering only anthrax, was there any difference between living and nonliving wildebeest? Explain.
Month	In some months there were bigger differences between living and dead wildebeest's bone marrow fat (June-October) than other months (May).	Looking at each pile individually, what do you notice is similar between the living and dead wildebeest? Looking at each pile individually, what do you notice is different between the living and the dead wildebeest? What is similar in the patterns you observed between the piles? What is different, or what lack of patterns did you observe between the piles?
Location	In some locations there were bigger differences between living and dead wildebeest's bone marrow fat (locations 2-6) than other months (location 1).	Looking at each pile individually, what do you notice is similar between the living and dead wildebeest? Looking at each pile individually, what do you notice is different between the living and the dead wildebeest? What is similar in the patterns you observed between the piles? What is different, or what lack of patterns did you observe between the piles?

Enlaces de CODAP/formularios Google

Enlace al archivo CODAP para Excursión de data Parte 1:
<https://www.openscienced.org/general/dataexcursion1/>

Enlace al archivo CODAP para Excursión de data Parte 2:
<https://www.openscienced.org/general/dataexcursion2/>

Formulario de Google para recopilar los gráficos que los estudiantes crean en CODAP:
https://docs.google.com/forms/d/1ikjBSMgDT1xrw4Zi2fratMXMD5AojI3qA_0Y39kckjs/copy

CODAP/Google Form Links

Link to CODAP file for Data Excursion Part 1:

<https://www.openscienced.org/general/dataexcursion1/>

Link to CODAP file for Data Excursion Part 2:

<https://www.openscienced.org/general/dataexcursion2/>

Google form for collecting the graphs students create in CODAP:

https://docs.google.com/forms/d/1lkjBSMgDT1xrW4Zi2fratMXMD5AoJ3qA_OY39kckjs/copy

Exit Ticket Guidance

What are Electronic Exit Tickets?

These are short **formative** assessments that occur 2-3 times per unit, in between other assessments. They include items to check for understanding of lesson-level PEs, to make connections between content and students' lives, and to elicit information about their experiences and to help students reflect on their own progress in focal SEPs and CCCs. **They are built in Google Forms, but can be ported to any survey software.**

How to create Electronic Exit Tickets

In *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*, the two Electronic Exit Tickets in this unit are found:

- at the end of Lesson 5 (**slide S**);
- and at the end of Lesson 8 (**slide N**).

Select the link for the Electronic Exit Ticket that corresponds with the lesson you are teaching.

<https://docs.google.com/forms/d/12Petr5L51VuOuM9rJ6xHlQBI8FCatMF2kZC5zrNyw1M/copy>

<https://docs.google.com/forms/d/1CmuK41jTigco1xCLG7lNSxO9dbYeJfU55LOl39g/copy>

Spanish versions are available here:

<https://docs.google.com/forms/d/1341osz8cut7HJ6cY-6znmvPGtMDL4Cd6dJpWMdnnLDs/copy>

https://docs.google.com/forms/d/17U9mflZqLPp3E1uxoDpFQqsTmISDbj_GHE6Gq51lyB8/copy

Attending to Equity

Some students may benefit from completing the Electronic Exit Tickets on a printed version. Complete the steps below to create a copy of the Electronic Exit Ticket. Once you have created a copy in your own Google Drive, click on the 3 dots in the upper right side of the form next to the SEND button. This should give you an option to print a paper copy of the Electronic Exit Ticket.

When you select the link, it will ask you to make a copy in your own Google Drive.

Copy document

Would you like to make a copy of **Family and Friends MRE Survey**?

Make a copy



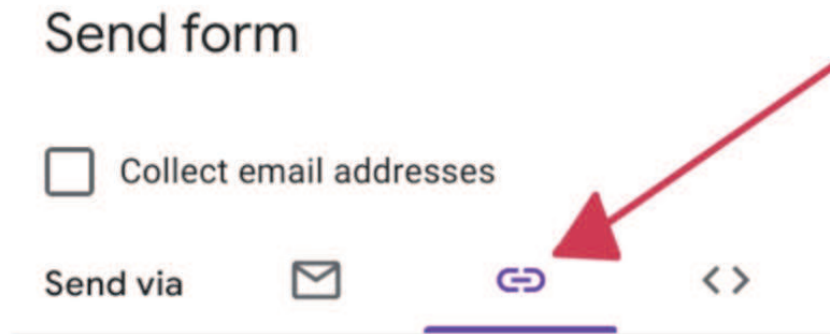
The student survey will open in your own Google Drive.



Select the “Send” button in the upper right corner to get a link to give to students.



In the “Send via” panel select the middle icon in order to choose to send the survey via a link.



Copy the link it provides you or select the “Shorten URL” box then copy the link. This second option creates a link that will be easier for students to type.

Link

<https://forms.gle/9YFjGS5FQhY3P7VR6>

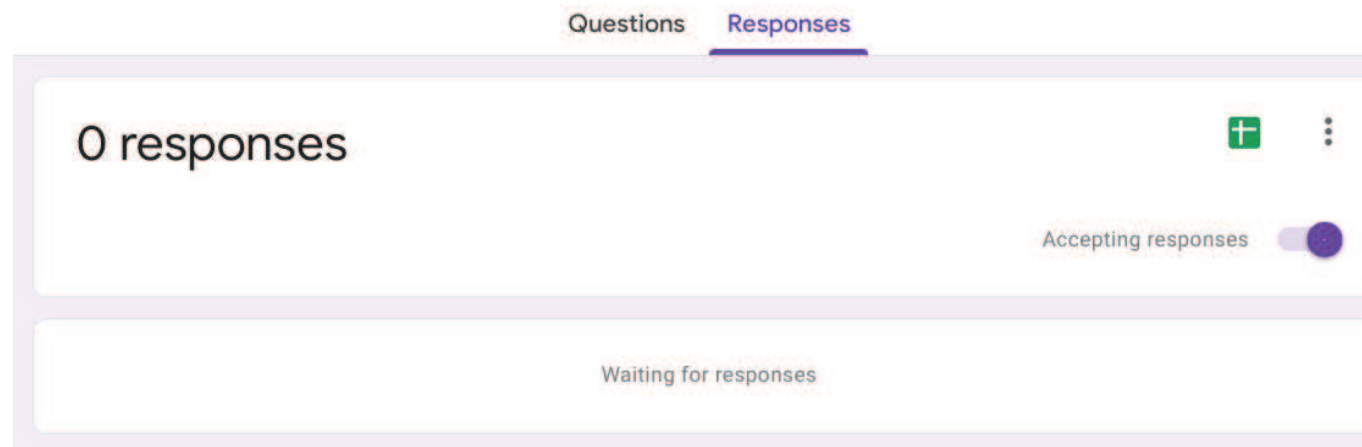
☒ Shorten URL

Press Ctrl+C to copy

Cancel

Copy

Once people submit responses they will show up in your Google Form under "Responses". Google will automatically provide you with some visualizations of these responses.



If you want to see the data in a spreadsheet format, click the sheet icon to create a Google Sheet of your data. It will automatically populate when people respond to the survey.

For each survey, you will need to repeat the process above. You can choose to make a copy of the survey for each of your classes or choose to have one survey for all your classes.

Serengeti Kinesthetic Model Key

Data Collection

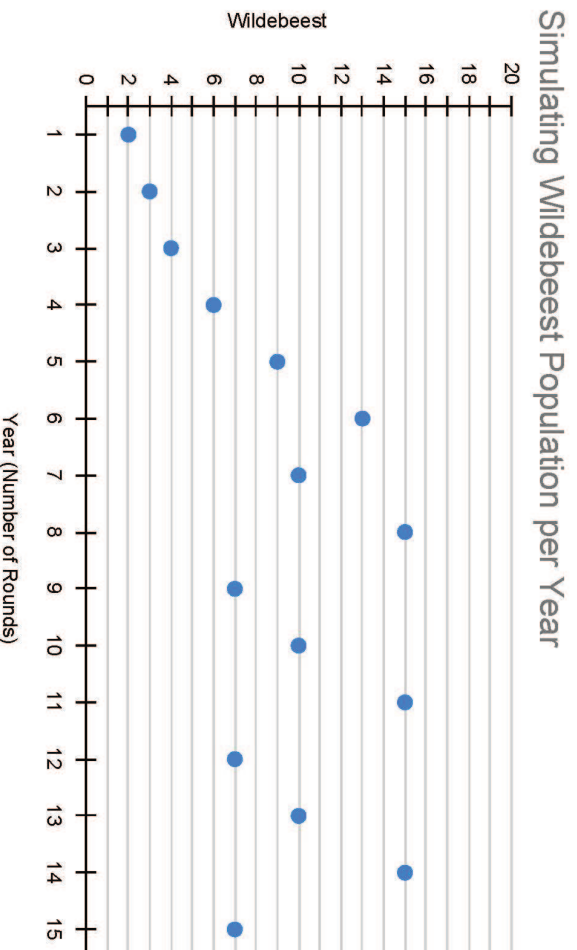
When you are the observer, record the changes in the wildebeest population for each year on the table below.

Since wildebeest need a partner to reproduce, round 1 begins with 2 offspring. At the end of each round, every 2 surviving wildebeest will reproduce. To simplify, you can multiply the number of surviving offspring by .5 and round down to determine how many wildebeest to add.

Year (number of rounds)	Starting Wildebeest	Surviving Wildebeest	Offspring	Grass
1	2	2	1	18
2	3	3	1	17
3	4	4	2	16
4	6	6	3	14
5	9	9	4	11
6	13	7	3	7
7	10	10	5	10
8	15	5	2	5
9	7	7	3	13
10	10	10	5	10
11	15	5	2	5
12	7	7	3	13
13	10	10	5	10
14	15	5	2	5
15	7	7	3	13

Data Analysis

Use the blank graph below to create a representation of your data. Be sure to label the axes and title.



Making Sense

1. Describe what happened to the wildebeest population during the simulation. Include any patterns you see.

Wildebeest population increased a lot for 6 years, then it went down slightly before going up again and down again in a repeating pattern, but never all the way down.

2. Explain what was happening when there were increases in the wildebeest population during the simulation.

Wildebeest increased when there was more grass than wildebeest. Since there was more than enough grass, more wildebeest could survive, and there could be more wildebeest being born than dying because there was plenty to eat.

3. Explain what was happening when there were decreases in the wildebeest population during the simulation.

Wildebeest decreased when there were a lot of wildebeest and too little grass. Since there were so many wildebeest, there was not enough grass for all of them due to competition, so there were more wildebeest dying than surviving and being born.

Making Sense: Part 2

Algorithms are another way that we can use mathematical representations to make sense of patterns. Review the algorithm below that describes what happens when the number of wildebeest is **less than** the number of grass.

If the number of wildebeest is less than the number of grass, then all of the wildebeest survive and 50% of them reproduce.

4. Write an algorithm that describes what happens when the number of wildebeest is **greater than** the number of grass.

[Example in words](#)

If the number of wildebeest is more than the number of grass, **then** not all of the wildebeest survive and only 50% of the survivors reproduce.

Example in Words Alternative

If you multiply the starting wildebeest times half, then you get the offspring number (as long as there is enough grass), as long as you round down because there is no such thing as a partial wildebeest that can survive. The grass is equal to the total number of participants minus the number of starting wildebeest for the next round.

Example using numbers/symbols

N = total number of student participants

Surviving Wildebeest = W

grass = G

S = Starting wildebeest for next round

$W*.5 = S$ (as long as $S \geq G$)

$G = N - S$

If $G \leq S$, then $W = G$

Example using Arrows

Wildebeest ↑ Grass ↓

Grass ↓ Wildebeest ↓

Wildebeest ↓ Grass ↑

Grass ↑ Wildebeest ↑

Wildebeest ↑ Grass ↓

Example using fill in the blank

Word bank: Increase, decrease, stays the same

If the wildebeest population _____, then the grass _____.

If the grass _____, then the wildebeest population _____.

If the wildebeest population _____, then the grass _____.

5. Use evidence from the algorithm and/or the graph to explain the relationship between amount of grass and wildebeest population.

For example, in year 8: There were 15 starting wildebeest but only 5 survived because there was only 5 grass. This meant only 2 babies were born.

So the next year (year 9) there were now 7 starting wildebeest (5 surviving and 2 babies), so that year all 7 survived because there was 7 grass and there were 3 babies born.

So in year 10, there were now 10 wildebeest starting (7 surviving and 3 babies), and there was 10 grass so all wildebeest survived and 5 babies were born.

So in year 11, there were now 15 starting wildebeest (10 surviving and 5 babies), and there was 5 grass, which meant only 5 survived and only made 2 babies, which meant in year 12 there would only be 7 starting wildebeest.

Wildebeest Population Data Key

Data Analysis



Data adapted from Hopcraft et al. Data Source: Hopcraft, G. et al. (2015)

Making Sense of Actual Wildebeest Population Data

1. Describe how the historical data compares to the data you collected during the simulation.

The actual data for wildebeest populations looked very similar to the data we collected in the simulation. Both sets of data increased rapidly at first and then reached a high point. In the next few years, the population stayed relatively the same with small fluctuations up and down. Except in the actual data there was in 1993, the wildebeest population went down rapidly but then returned quickly to about 1.3 million.

2. Before 1961, a disease called rinderpest was killing many of the animals in the Serengeti. The disease spread from domestic cattle to wild animals like wildebeest and buffalo. In the early 1960s, the cattle began being vaccinated against rinderpest. By 2011, rinderpest was considered to be completely eliminated.

a. Use this information, what you figured out during the *Kinesthetic Model: Simulating the Serengeti*, and the graph above to explain what happened to the wildebeest population between 1961 and 1977.

1961-77: The wildebeest population started around 250,000 and rose to 1.5 million. Since there was no more rinderpest and lots of grass, there was no competition, which resulted in many more wildebeest.

b. Calculate the rate of change for the wildebeest population during this time period.

$$\text{Average Rate of Change} = \frac{\text{change in } Y / \text{change in } X}$$

$$Y = \text{difference in } Y \text{ values for wildebeest}$$

$$X = \text{number of years for that time period}$$

$$Y_1 = 263,362$$

$$Y_2 = 1,400,000$$

$$X_1 = 1961$$

$$x_2=1977$$

Δy = change from y_2 to y_1 = 1,400,000-263,362 = +1,136,638 wildebeest

Δx = number of years= 1961 to 1977= 16 years

Average Rate of Change= $\Delta y/\Delta x$ = 1,136,638/16= +71,039 wildebeest per year

3. Look at the wildebeest population from 1977-1978.

a. Describe what happened to the wildebeest population between 1977 and 1978.

There were too many wildebeest for the amount of grass, which increased competition for grass, and some wildebeest died when there was not enough food.

b. Calculate the rate of change for the wildebeest population during this time period.

$$y_1=1,400,000$$

$$y_2=1,248,934$$

$$x_1=1977$$

$$x_2=1978$$

Δy =change from y_2 to y_1 = 1,248,934-1,400,000 =-151,066 wildebeest

Δx = number of years= 1977 to 1978= 1 year

Average Rate of Change= $\Delta y/\Delta x$ = -151,066/1= -151,066 wildebeest per year

4. Look at the wildebeest population from 1978 and 2004.

a. Describe what happened to the wildebeest population between 1978 and 2004.

The wildebeest population went up and down in a kind of cycle. When the population was lower, there was a lot of food and the population increased, but then there were too many wildebeest and some of them died. The number of wildebeest went up and down around a similar number

b. Calculate the rate of change for the wildebeest population during this time period.

$$y_1=1,248,934$$

$$y_2=1,361,548$$

$$x_1=1978$$

$$x_2=2012$$

$\Delta y=y_2-y_1$ = 1,361,548 to 1,248,934= 112,614 wildebeest

Δx = number of years= 1978 to 2004 = 34 years

Average Rate of Change= $\Delta y/\Delta x$ = 112,614/34= 3,312 wildebeest per year

5. Organize your rate of change calculations in the table below and use evidence and what you know about limiting factors to support an explanation for the rate of change during that time period.

Time Period	Rate of Change	Explanation
1961-1977	+71,039	The population was low because it had been limited by disease, so grass was not a limiting factor. All the wildebeest survived to reproduce, and the population increased.
1977-1978	-151,066	The population decreased by around 150,000 in one year. There were too many wildebeest and not enough food. There was competition for food, and if they didn't get enough food, they died. The population was limited by food.
1978-2004	+3312	After 1977 the population increased and decreased by relatively small amounts. Except for the big decrease during the drought in 1993-1994. The population went back up to what it was before the drought where the population was stable for the amount of grass. Some wildebeest died and some were born but overall there was not a very big change.

6. What do the rates of change tell you about the effect of limiting factors on the wildebeest population during these three different time periods?

When the rate of change is positive the limiting factors are not negatively affecting the population. When it is negative, they are. The bigger the number the more they are affected.

7. In 1993, a severe drought occurred in the Serengeti.

a. What happened to the wildebeest population during the drought? Use evidence from the graph to support your answer.

The wildebeest population dropped suddenly by about 200,000 in one year. This is the biggest drop we see at any point in the graph.

b. Make a prediction about the rate of change between 1993 and 1994 based on the graph.
+200,000

c. Wildebeest population data was not available for 1995-1998. Explain evidence from the graph about if and when the drought ended.

The wildebeest population appears to have reached 1.3 million by 1998, so the drought must have ended at least 1 year before that in 1997, but it could have ended as early as 1994.

8. If conditions in the Serengeti remain relatively constant, what do you predict would happen to the wildebeest population in the next 20 years?

The population will continue to fluctuate around a carrying capacity of 1.3 million as long as there are no huge disturbances (like the disease or major drought) or new limiting factors introduced into the system.

References

Hopcraft, G., Holdo, R., Mwangomo, E., Mduma, S., Thirgood, S., Borner, M., Fryxell, H., & Sinclair, A. R. (2015). Why are wildebeest the most abundant herbivores in the Serengeti ecosystem? In Sinclair, A., Metzger, K., Mduma, S. & Fryxell, J (Eds.) *Serengeti IV: Sustaining biodiversity in a coupled human–natural system*. 125–174. University of Chicago Press.

Year	Wildebeest Population
1961	263362
1963	356124
1965	439124
1966	
1967	483292
1971	692777
1972	773014
1977	1400000
1978	1248934
1980	1337979
1982	1208711
1984	1337879
1986	1146340
1991	1221783
1994	917204
1999	1296944
2000	1245222
2003	1183966
2006	1239164
2009	1272233
2012	1361548

Data from Hopcraft et. al. (2015).

Lesson 5: Answer Key 3

L5 Electronic Exit Ticket Key

5.B Use mathematical representations of data to quantify rates of population change over time to support explanations about the effect of limiting factors on population size. (SEP: 5.2; CCC 7.2; DCI: LS2.A.1)

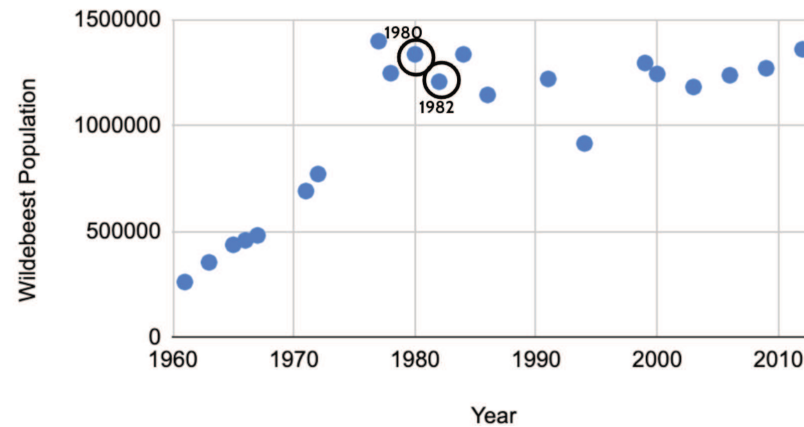
Where these elements are addressed in this assessment.	5.2 Using Mathematics and Computational Thinking Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.	LS2.A: Interdependent Relationships in Ecosystems Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	7.2 Stability and Change Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
Q1	X	X	
Q2		X	X
Q3			
Q4	X		X
Q5	X		
Q6			X

Question 1

Look at the graph: Which of the following describes a possible **explanation** of the change in **population** between 1980 to 1982?

- The population decreased from 1980 to 1982 because there were more wildebeest competing for a limited supply of food.
- The population increased from 1980 to 1982 because there were few wildebeest competing for an unlimited supply of food.
- The population increased from 1980 to 1982 because there were more wildebeest competing for a limited supply of food,
- The population decreased from 1980 to 1982 because there were few wildebeest competing for an unlimited supply of food.

Wildebeest Population vs. Year



TUBS, CC BY-SA 3.0

Correct response:

The population **decreased from 1980 to 1982** because there were more wildebeest **competing for a limited supply of food**.

Rationale for correct response: The population decreased during this time period. The main limiting factor affecting wildebeest population growth.

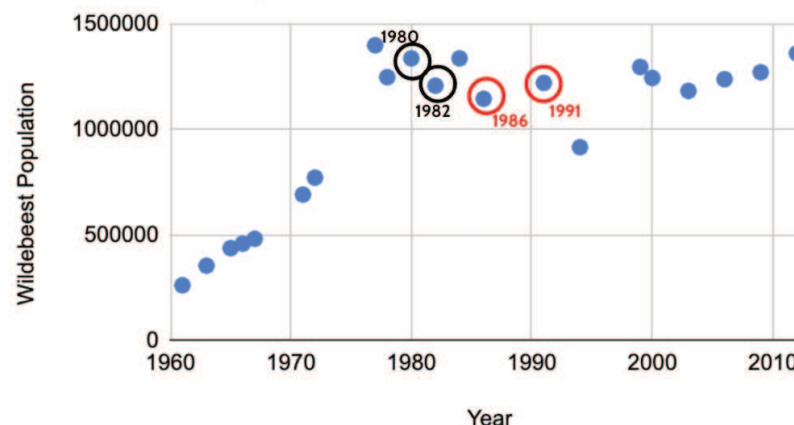
What to do: Point students to the graph and ask them to determine if the population change was positive or negative. Ask them to imagine a line between the points and consider if the slope would be positive or negative. Then ask them to consider whether a population decrease is more likely to be associated with more or less food.

Question 2

Based on the **rates of change**, In which time period 1980-1982 or 1986-1991 was there more likely to have been a **drought**?

- 1980-1982 because the rate of change was more negative and more wildebeest were dying.
- 1984-1986 because the rate of change was more negative and more wildebeest were dying.
- 1980-1982 because the rate of change was less negative and more wildebeest were dying.
- 1984-1986 because the rate of change was less negative and more wildebeest were dying.

Wildebeest Population vs. Year



Data Source: Hopcraft, G. et al. (2015)

Correct response:

1980-1982 because the **rate of change was more negative** and **more wildebeest were dying**.

Rationale: The rate of change from 1980 to 1982 is negative and from 1986-1991 it is positive. This indicates that more wildebeest are dying from 1980-1982. Since rain limits food and food limits wildebeest this is the most likely explanation.

What to do: Point students to the graph and ask them to determine if the population change was positive or negative for each time period. Ask them to imagine a line between the points and consider if the slope would be positive or negative. Then ask them to consider how rain affects food and how food affects wildebeest.

Question 3

How did what we figured out today help you better understand your conservation profile?

What to look for in response:

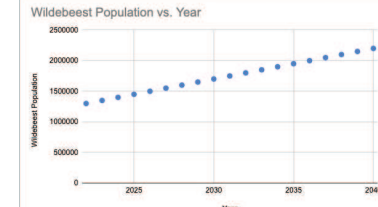
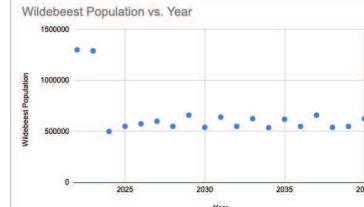
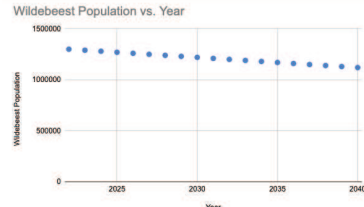
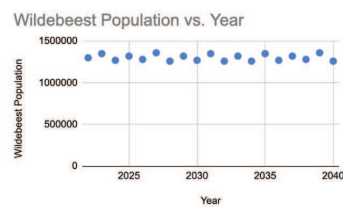
Accept all responses. Validating these responses engages students in activating the **relevance** and **interest** in these issues, which can motivate future questions.

What to do:

Encourage students to think back to their conservation profile and the information they collected on *Progress Tracker* and in their *Conservation Profile Organizer* for ideas.

Question 4

Scientists have established the carrying capacity of wildebeest at 1.3 million in the Serengeti ecosystem. They predict that the population will fluctuate around this number if **conditions in the ecosystem stay the same**. Which of the following **graphs represents the most likely outcome for the wildebeest** if the total area of the park decreased and all other components of the system stayed the same?

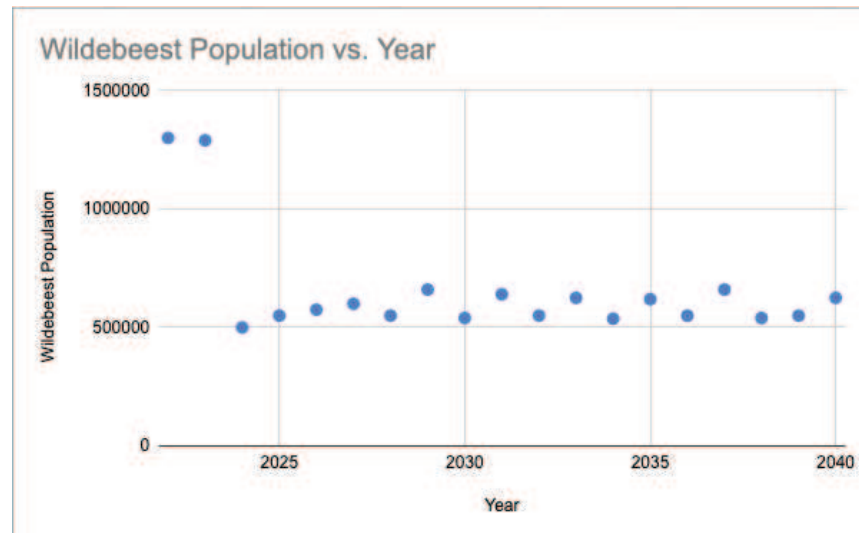


Correct response:

Rationale: This **mathematical representation (graph)** shows that following a disturbance such as reduced habitat area, the population would respond with an initial **very negative rate of change**. If all other conditions stayed the same, the population would stabilize around a new, lower, carrying capacity.

What to do:

This prompt is intended to help students think about why their work in Lesson 5 will be important, and should only be a completion grade. Student responses here can help you prepare for supporting student thinking in Lesson 9 when students reason about the consequences of a road for the wildebeest population.



Question 5

How did **mathematics and computational thinking** help you make sense of the carrying capacity of the wildebeest population?

What to look for in response: *Note: These could be different for each student.*

- Students should **identify which model was most useful to them**.
- They should identify the **aspects of the model that led to it being most useful**. Students may mention how the chosen model illustrates illustrated carrying capacity more clearly or how one model helped explain another.

What to do:

Encourage students to think about how **mathematical and algorithmic models** like this are relevant to their work as scientists and in their daily lives.

Question 6

How did the **use of rates of change** help you explain the lesson question: How does food affect the population size?

What to look for in response:

- Students should mention that observing **rates of change** in the wildebeest population corresponded with food availability.

What to do:

If students are having difficulty answering, you may rephrase **"rates of change"** with other common names, such as change over time, or slope.

Question 7

Name one student who helped you learn today. What did they do?

What to look for in response:

- Students identify another student that helped them.
- Students articulate how that student helped them.

What to do: Depending on student responses, it may be beneficial to revisit the Community Agreements.

- If many students do not name another student, spend time revisiting the Community Agreements to ensure that students are using the agreements as they work together to make progress on figuring out science and engineering ideas.
- If many students do not explain what the other student did to help them, revisiting the Community Agreements may encourage students to think about what specific agreement the classmate was adhering to that caused them to be helpful.

Transfer Task Scaffold

If students are inexperienced with Transfer Tasks, the structure below can be used as a scaffold as they learn how to engage with this type of assessment. The assessment is administered over two days instead of one to provide additional time for support.

Day 1

1. Introduce Transfer Tasks. Explain that the purpose of a Transfer Task is to apply what students learned to a new situation. Say, "Because this may be your first time completing a Transfer Task, you will work with a partner to complete the first portion of the task. You will also be able to use all of your notes, models, and readings to help answer the questions. Tomorrow, you will use everything you do today to complete the last part of the task on your own."
2. Read the background information as a class. Read through the introductory information together and review any media (images/videos) included with the introduction.
3. Facilitate a discussion about the task scenario. Check for understanding about the scenario from students after they read. Answer any clarifying questions they have.

4. Organize materials. Provide time for students to organize their materials and pull out items from their science notebook that could be helpful for completing the task, including the Progress Tracker, and handouts from previous lessons. Suggest that students pay attention to which items are most useful for answering questions during the task and how they provide support.
5. Revisit community agreements. Before students move into pairs, revisit the agreements your class developed for group work – for example, our commitment to an equitable classroom community where everyone's participation and ideas are valuable – and discuss productive ways to complete the Transfer Task together. It is important to involve both partners in writing all answers rather than dividing up the questions between them because the Transfer Task is a story that builds. Before writing an answer, they should discuss their strategy or intention with their partner. They might assign one person to read and one person to write. The person who reads could also be sure to reread the question once the answer is "complete" to make sure they answered all portions of the question and supported the answer as appropriate.

6. Complete the first questions of the Transfer Task in pairs. Organize students into pairs to complete the task. Remind them that they should write answers on their own copy of the task, but will only turn in one. Collect one copy of each assessment from each pair to return on day 2. Skim each pair's answers using the Transfer Task Key and provide feedback based on suggestions provided. Use the answer key to determine which items assess all three elements. These items may provide more powerful feedback opportunities.

7. Assess students' reaction to the Transfer Task. Students should remain seated with their Transfer Task partners with the one remaining copy of the Transfer Task shared between them. Ask students to hold up the number of fingers that matches how they feel in relation to the scale provided to quickly tell you how they felt after completing the first part of the Transfer Task. Make a note to yourself about their reactions and use this to guide the amount of encouragement or validation you need to provide students during the strategy conversation.

8. Debrief the Transfer Task. Say, "Remember this is an introduction to successfully completing Transfer Tasks. Let's look at a question together and talk about how you used what you figured out in the unit to answer the question. Facilitate a conversation about the connections students recognized between this task and activities from previous lessons and the resources they accessed to assist them in writing their answers. Remind students that they will complete the Transfer Task tomorrow individually. Encourage them to organize their science notebooks so they have what they need readily available."

9. Complete exit ticket about collaboration. Distribute one sticky note or piece of scrap paper to each student. Ask them to answer the questions related to how well student partners collaborated together and to bring you the exit ticket as they leave.

Day 2

10. Prepare for the Transfer Task. Return the Transfer Task to students as they confer with their partners from day 1 about the strategies they used yesterday to complete the task.

11. Revise and review Transfer Task feedback. Explain that the goal last class was for them to learn about the expectations for a Transfer Task. They completed the first set of questions with a partner to learn strategies from one another to successfully respond to questions. If you provide feedback, let them know where to look and whether or not you would like them to revise your responses. Hand out the individual portion of the Transfer Task to all students, read through the question together, and answer any clarifying questions. Facilitate a brief discussion of the resources they will need to answer the questions.
12. Students complete Transfer Task individually. Give students time to complete the Transfer Task. They should hold onto their answers when they finish.
13. Facilitate peer assessment of Transfer Task. Remind students that the Transfer Task may be a new type of assessment for them. The goal last class was for them to learn about the expectations for a Transfer Task. They completed the first questions with a partner to learn strategies from one another to successfully respond to questions. Hand out Peer Rubric and explain that this is the same rubric you will use to evaluate their answers. Direct students to trade responses with their partners and use the rubric to review the strengths of the response and places where more detail is needed. Walk students through the rubric, pointing out the column headings and the list of expectations for a thorough response in the Organized Understanding column. Point out the Suggestions for improvement. Note that peer rubrics have been developed for B.1 Lesson 6, C.1 Lesson 7, and P.1 Lesson 6. Use these rubrics as guides to develop peer rubrics for other lessons.
14. Facilitate a Peer Review. Explain the steps of the peer review. Provide students with 5 minutes to quietly review their partner's task and fill out the rubric. Then provide one minute for each student to explain their suggestions to their partner.
15. Revise the task. Provide 6 minutes for students to work independently to incorporate the peer feedback into a revision of their original answer. Collect both the Transfer Task and the peer rubric from each student. Evaluate using the Transfer Task Key.
16. Collect student feedback on giving and receiving feedback. Hand out one sticky note or scrap paper to each student and ask them to rate how comfortable they were giving and receiving feedback. Match their self-score to what you see on the peer rubrics they turn in with the Transfer Task. Use their responses to guide future opportunities for discussion when you use peer feedback as described in the previous guidance callout.

Transfer Task Key

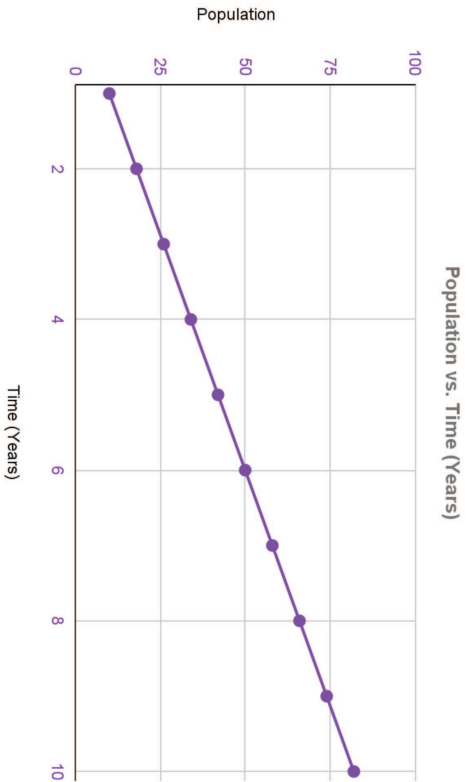
HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

3D Elements	Question #							
	1	2	3	4	5	6	7	8
Using mathematics and computational thinking. Use mathematical and/or computational representations of phenomena or design solutions to support explanations.		X		X	X	X	X	X
Interdependent Relationships in Ecosystems. Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	X	X	X	X	X	X	X	X
Scale, proportion and quantity. The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.		X						X

How do African wild dog pack populations change over time?

To understand more about African wild dogs, scientists need to know how often they reproduce to understand how populations might change over time. African wild dogs live in packs of 7-15. One female dog of the pack gives birth to one *litter* every year. A *litter* is the group of young animals born to an animal at one time. The average number of pups per litter is 8.

1. Sketch a graph that shows what you predict should happen to a single pack of wild dogs over 10 years if there were enough resources for all the dogs to survive and the death rate was very low. *Sketch your graph, assuming the population started at 10.*



2. The graph below shows the population of one pack of wild dogs in Kruger National Park in South Africa, where the dogs have been protected and studied.

a) How does this graph compare to the graph you drew in your response to question 1?

- Answers will vary. Likely linear vs. rising and falling pattern.

b) What are the likely reasons for the ups and downs in the population at some times of the year?

- Include explanation for increase such as pups born, dogs migrating into pack from another place.
- Include explanation for decrease such as dogs being killed by predators, disease, old age, seasonal starvation.

c) Do you have enough information to know whether or not this wild dog pack is at carrying capacity in Kruger National Park? Why or why not?

- Notice rise and fall pattern is regular and stable.
- No, not enough time has passed to know if this will be the pattern long term.

3. Recall that carrying capacity is affected by limiting factors. Identify potential limiting factors that scientists could investigate to understand the carrying capacity of African wild dogs.

Limiting Factor	Predicted Effect on African Wild Dog Population
<i>Amount of land available</i>	<i>Wild dogs need space to hunt, find shelter, and provide the resources they need to survive.</i>
Predators in the area	If there are too many predators, then too many wild dogs might be eaten, and they won't survive. If there are not enough predators, there may be too many dogs in packs for the amount of prey.
Prey availability	If there is not enough prey, then the wild dogs won't have enough to eat. If there is too much prey, then there might not be enough land for the wild dogs to make their den, or home.
Diseases	Diseases can harm the wild dogs and possibly kill them off.
Human interactions	If there are too many human interactions, the dogs might get diseases from humans or even their dogs. If humans are building or living in the areas where wild dogs are, then their habitats might be affected, and they won't have enough land to roam. They might be hunted or trapped.
Climate	If the climate is too hot or too cold for the wild dogs, they may not survive.
Wild dog characteristics (e.g., behavior, reproduction details)	Knowing how they behave might be related to where they choose to live, how they hunt, and how they reproduce. The number of new babies born and when they are born might be needed to know how fast the population can grow and when new babies will be seen so they can be supported if needed.

Does the size of the dog's territory determine how many African wild dogs can live there?

African wild dogs are known to hunt and roam over large areas of land called territories. Scientists wondered how territory size could limit pack size. They wanted to use this information to figure out how many dogs the new reserve in Malawi could support. The graph below shows the data they collected comparing pack size to territory size.

4. While scientists did not establish a clear relationship between territory size and pack size, they determined that there is a minimum territory size required to establish a new pack. Use evidence from the graph to propose a minimum territory size for the reserve in Malawi.

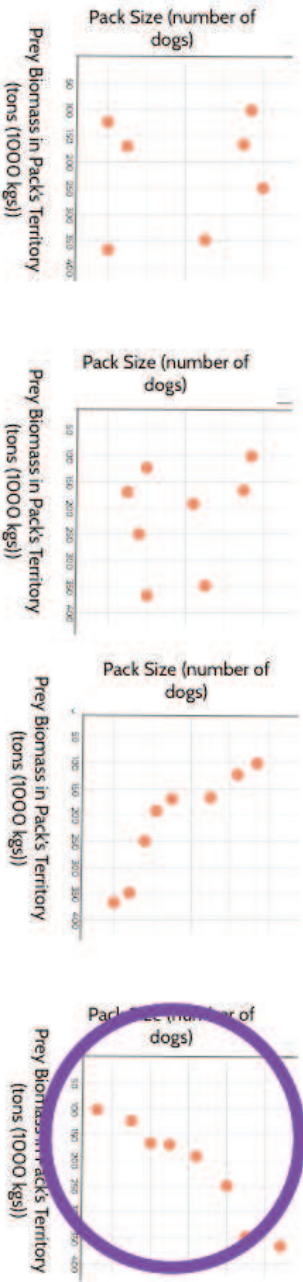
- At least 350 km² is the smallest amount required for any pack on the graph.

Does the amount of prey in the habitat determine how many African wild dogs can live there?

African wild dogs' main prey are impala and kudu.

5. Scientists wondered if the amount of prey in the territory could limit the size of the pack. The graphs below show pack size and prey biomass, a measure of how much food is available. If prey biomass is a limiting factor for African wild dog pack size, which graph represents the relationship?

a) Circle your choice:



Images generated using CODAP (<https://codap.concord.org/>), developed at the Concord Consortium.

- b) Explain your thinking.
- It is a positive relationship. As the amount of prey rises, more dogs will be able to eat, so the pack will get bigger.
6. In South Africa, scientists observed the following relationship between prey biomass and dog pack size.
- a) Using this graph, explain what relationship, if any, you see between prey biomass and pack size?
- The relationship is somewhat positive. As biomass rises, pack size rises, but it is not clear that there is a strong relationship. It is not a straight line.
 - The biggest pack has the biggest territory, but smaller packs are scattered around the graph more. A pack of six has a bigger territory than a pack of 8 and 10.
- b) In the reserve in Malawi, how much prey biomass should there be to establish a new pack?
- At least 100 tons.

Does the presence of predators in the territory determine where African wild dogs live?

7. Like wild dogs, lions also prey on kudu and impala. You would expect to find both lions and wild dogs living in the same habitats. However, lions will kill wild dogs they encounter. In South Africa. Scientists investigated the relationship between lions and wild dogs by looking at habitat preferences (Table X). Scientists ranked each animal's preferred habitats from 1 to 6, with one being the more favored and six being the least.

Table A.

Habitat Type	Wild dogs' ranking (1 = most preferred)	Lions' ranking (1 = most preferred)
A	2	6
B	3	4
C	4	2
D	5	3
E	6	1
F	1	5

Data adapted from Mills and Gorman, 1997

a) Write a claim about the effect of lions on where wild dogs live. Use evidence from the table to support your claim and give a reason.

Claim	Wild dogs and lions prefer different habitats.
-------	--

Pattern in Data That Supports my Claim

The highest-ranked wild dog habitats were least preferred by lions.

Reason

Wild dogs do not prefer areas that lions prefer because lions prey on them and compete for food with them.

b) In the new National Park in Malawi, how could scientists use the habitat preference data as they planned to bring wild dogs there?

They should make sure that there is enough space where wild dogs and lions do not overlap.

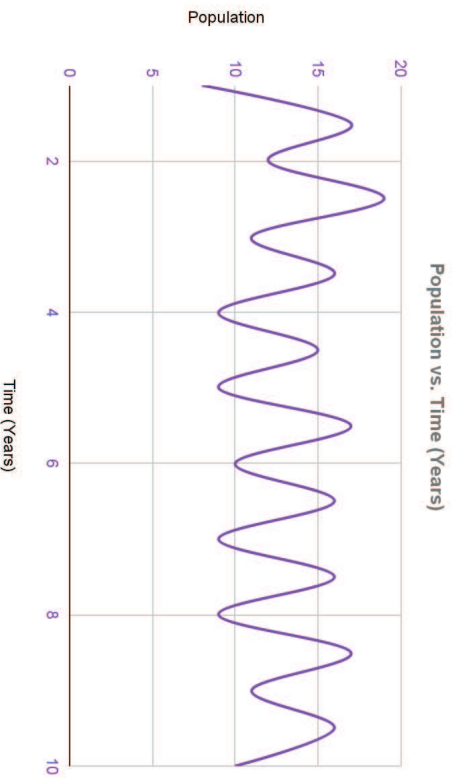
They should make sure there is enough of habitat type F and A, which are the dogs top two preferences and E and C, which lions prefer, so the two predators go to different habitats in the park and lions do not kill dogs.

8. In 2021, scientists moved 8 African wild dogs to Liwonde National Park in Malawi. Several months after they arrived, a litter of 9 pups was born. Use the information below about Liwonde National Park to answer the questions below.

Liwonde National Park	
Area	548 km ²
Prey	In 2015, there was approximately 106 tons of biomass of impala with an increasing population. Several other species of antelope, including kudu, are present in the park.
Predator	In 2018, there were 17 lions in the park. The lion population is below carrying capacity.

a) Sketch a graph of what you think will happen to the African wild dog population over the next ten years if moving the dogs to Liwonde National Park is successful.

Sample answer:



b) Use data from this task as evidence to explain your graph. Identify the estimated carrying capacity of this pack. Include the concepts of carrying capacity and limiting factors (space, food, and predation) in your explanation.

Sample answer:

We chose a carrying capacity of 11-12 animals.

Evidence:

- Dogs have enough space when 8 animals are introduced (need at least 350 km² and Liwonde has 548 km²).
- Space may become a limiting factor when the pack reaches 11 animals according to Figure 3.
- They have enough food, (need 100 tons, have 106 tons of impala, and there are other prey animals in the park for more food). There could be 200 tons of food, which could support more than 10 animals according to Figure 4. We are not certain that food is a limiting factor for wild dogs from Figure 4.
- Around 8 pups will be born each year, so the curve rises by 7-9 each year, but they will not all survive due to disease, predation, or starvation.
- The lion population is below carrying capacity, so there is less predation and competition. Lions should be less of a limiting factor in Liwonde than in South Africa because there are fewer lions around that might kill the dogs.

- If there are fewer lions, this could justify a population with a higher carrying capacity than ones in South Africa. Less competition means more prey.
- Extending: concern that lion population will increase over time and cause competition and predation, resulting in lower carrying capacity for dog population.

c) To date, the reintroduction of the African wild dogs to Liwonde National Park is seen as a success story. Many people would like to replicate this project at the scale of the African continent and reestablish wild dog populations in the countries they used to live in. What recommendations would you make to help them accomplish this?

- Recommend replication of the Liwonde National Park effort throughout the wild dogs' former range in Africa.
- Make sure minimum size prey needs are met and that there are not too many lions.
- Extending: work with people who live in the areas where reintroduction may occur to reduce conflicts and increase success.
- Extending: make sure there is money and people power to do the reintroduction.

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	Graph rises at the beginning and levels off but does not consider appropriate scale. Lists relevant ideas: • Limiting factors (food, prey, predators) • Carrying capacity • Time Understands that when birth rates exceed death rates for a population, the size of the population will increase. Explains that the population may level off over time. Recommends more reserves.	Graph includes at least four of the bullets listed in organized understanding. Describes how graph shape connects to one or two, but not all, limiting factors and carrying capacity. Connects some, but not all, limiting factors to carrying capacity. Uses evidence from at least three, but not all, relevant data sources to support the explanation. Explains that the population may not reach carrying capacity right away. Recommends a large number of reserves but does not consider where.	Graph includes: • Starting pack size of 8. • Increase of 9 to 17 in year 1. • Goes up and down every year by about the same amount. • Carrying capacity is between 10 and 15 dogs. • Appropriate scale on axes (y axis to approximately 20 animals, x axis ends at 10 years). Optional: Pack size could increase for approximately 1-3 years before reaching carrying capacity. Describes how graph shape connects to limiting factors and carrying capacity. • How does space limit? • How does prey limit? • How do predators limit? Connects <u>all</u> limiting factors to estimate of carrying capacity. • Available space • Prey biomass • Lions/predation Uses all relevant evidence from the task to justify carrying capacity. • Figure 3 (territory size) • Figure 4 (prey biomass) • Area of Liwonde • Prey biomass of Liwonde • Litter size Explains that the population may take 5-10 years to reach carrying capacity. Discusses the need for a large number of reserves in the African wild dogs former range to increase overall population.

Feedback/What to Do	To revise toward <i>Linking</i> :	To revise toward <i>Organizing</i> :	To revise toward <i>Extending</i> :
	- Suggest discussion of missing limiting factors. - Suggest inclusion of data from specific figures to support carrying capacity.	- Suggest discussion of missing limiting factors. - Suggest inclusion of data from specific figures to support carrying capacity.	- Why might the carrying capacity change for the dogs over time? - How are humans connected to carrying capacity? - What unknowns impact your answer? - How could different groups of people impact the ability to carry out your plan in Africa?

Ideas for Instruction	Foundational Understanding	Linked Understanding	Organized Understanding
	- Support students in identifying limiting factors. - Review relationships between limiting factors and population size in graphs. - Ask questions about the scale of the changes to the population.	- Review how food was connected to carrying capacity in Lesson 5. - Refer back to wildebeest population graphs and ask questions about the factors that affected the population during different time periods. - Review the scale of the change in the population of wildebeest over time.	Ask students to predict what future changes the wild dog population might face and how the population might respond.

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Agent-Based Modeling

About the Serengeti Board Game

In this unit, students use a board game to explore the relationships between predators and prey in the Serengeti National Park ecosystem with the goal of understanding how group behaviors support the survival of species and how computational modeling can support scientists in making sense of complex systems.

Connections to Computer Science Concepts

This board game is designed to engage students in computational modeling concepts without using a computer or coding. The game rules are like a computer algorithm. They use computational logic like if/then statements to guide the gameplay. For example, “If a lion token is touching a wildebeest token, then the lions can hunt.” When students create or revise game rules, they should be encouraged to use specific and precise descriptions that are more easily understood by machines or computers (Caeli & Yadav 2020). For example, “Lion tokens can move up to 2 spaces within the boundaries of their territory” is a better instruction for a computer than, “Lions can move anywhere.” Being specific and imagining how a computer would interpret these rules better prepares students to engage with computer science.

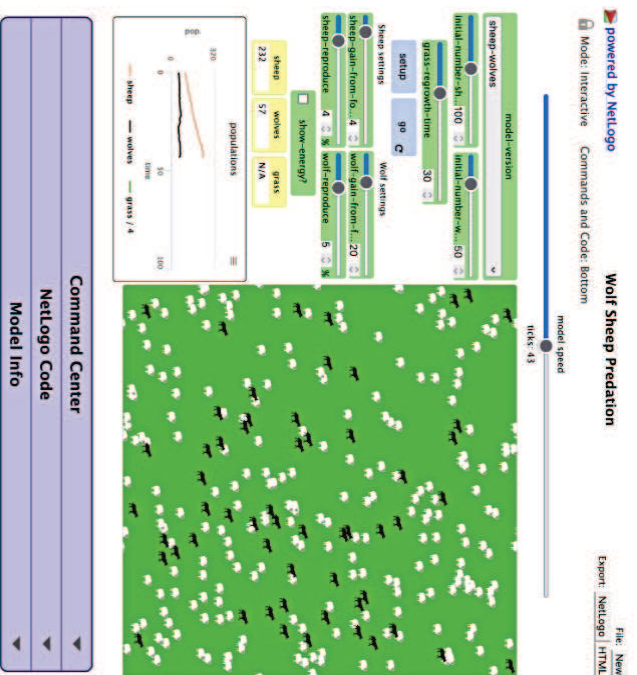
Agent-Based Modeling

The Serengeti Board Game is an example of an agent-based model. *Agent-based models* are a type of computational simulation that has been found to help learners understand how large, complex systems work (Wilensky & Reisman, 2010). Scientists use these types of models to understand complex systems and to simulate the consequences or outcomes of changes to a system, e.g., the impact that a conservation approach will have on an ecosystem.

This game is designed to build on previous research, which finds that tabletop board games can act as an “unplugged” (does not require a computer) form of agent-based modeling that can guide students in understanding the computational practices and concepts that underlie computational agent-based models while still supporting students in exploring and making sense of complex systems (Horn et al., 2012).

Agent-based models include agents, an environment, and rules. *Agents* can be any entity in a system (blood cells, sheep, particles of gas, etc.). *Environments* are the places where these agents interact (blood vessels, a pasture, the atmosphere, etc.). *Rules* control each agent’s behavior and tell the agent how to interact with other agents and the environment. Another characteristic of agent-based models is that they have boundaries. They often take place in a specific time frame, e.g., one year, and in a specific place, whether it is a real place like the Serengeti National Park or an imagined space like a rectangular container that holds gas particles.

Agent-based models are not intended to be fully accurate simulations of scientific phenomena. Modelers make “deliberate simplifications” or abstractions to focus on investigating a specific question they have about a system (Bodine et al., 2020). Simplifications might look like including only a few agents in a model or creating rules that are not completely accurate depictions of what happens in real life because the information needed to make an accurate rule is missing. For example, the Serengeti Board Game doesn’t represent all of the organisms in the ecosystem because we are focusing on the relationships between a few key animals: wildebeest, lions, and spotted hyenas. Including all of the agents in the ecosystem would be overwhelming for the modeler and would distract from the goal of understanding the relationship between predators and prey.



Agent-based models are different from models like flowcharts because they are **dynamic and interactive** and can **simulate change over time**. Typically agent-based models run on a computer in specialized programming environments like NetLogo <https://ccl.northwestern.edu/netlogo/>. Computers are great at representing dynamic models because of their ability to quickly calculate and visualize complex information. Additionally, a code-based model allows students to quickly make changes to the rules of the agents or the parameters of the environment and to easily observe the effects of those changes over time.

Connections to NGSS Practice 5: Using Mathematics and Computational Thinking

When students work with agent-based models, they are engaging in the practice, “**using mathematics and computational thinking**,” which requires students to “engage in computational thinking” create “sequences of steps called algorithms,” and to use and create “simulations of natural and designed systems.”

Lesson 7C specifically targets SEP 5.1 –“Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.” by asking students to create new rules for the game. When students create new rules, they are revising the way the Serengeti simulation works.

Lessons 7A and 7B target SEP 5.2 – “Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations” by asking students to use their gameplay data to reflect on predictions they made about the interactions between predators and prey in the Serengeti ecosystem.

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Tarjetas de evento

Una leona mata a un ñu que tenía problemas para seguir el ritmo de la manada porque estaba viejo y enfermo. **Retire 1 ficha de ñu individual del tablero de juego.**



Muhammad Mahdi Kairim, GNU 1.2

Un pequeño grupo de hienas manchadas mata a una cría de ñu que era demasiado lenta para seguir el ritmo del resto de la manada. **Retire una ficha de ñu individual del tablero de juego.**



Muhammad Mahdi Kairim, GNU 1.2

Un pequeño grupo de ñus pastando en un área donde los pastos son cortos y les permiten detectar fácilmente a los depredadores. **Mueve una de las fichas de ñu de u grupo pequeño hasta 3 espacios de distancia de una ficha de depredador.**



Muhammad Mahdi Karim, GNU 1.2

Un pequeño grupo de ñus nota que se acerca un depredador y muestra comportamientos agresivos como pisotear el suelo. Ahuyentan con éxito al depredador. **Elija una ficha de hiena manchada o león que esté cerca de una de las fichas de ñu de su grupo pequeño y muévela hasta 2 espacios lejos de su ficha de ñu. La ficha de depredador debe permanecer dentro su territorio.**



Muhammad Mahdi Karim, GNU 1.2

Se está produciendo una sequía y las fuentes de agua se están secando, por lo que es más probable que los depredadores y las presas entren en contacto. Mueve una de tus fichas de hiena un espacio más cerca de una ficha de ñu. Si puedes colocarlo junto a una ficha de ñu, usa las reglas de caza.



Photo by Marcus Löfvenberg on Unsplash

Un cachorro de hiena manchada no sobrevive. Retire una de las fichas de hiena individuales del tablero de juego.



Photo by Marcus Löfvenberg on Unsplash

Un pequeño grupo de hienas manchadas viaja para buscar comida. **Puedes mover una de las fichas de hiena de tu grupo pequeño hasta 6 espacios de su territorio sólo durante esta ronda.** Si puedes colocarlo junto a una ficha de ñu, **usa las reglas de caza.** En la próxima ronda, tu ficha de hiena debe regresar a su territorio original.



Photo by Marcus Löfvenberg on Unsplash

Un pequeño grupo de hienas manchadas sale a cazar y captura con éxito un ñu recién nacido que estaba aislado de la manada. **Retire 1 ficha de ñu individual del tablero de juego.**



Photo by Marcus Löfvenberg on Unsplash

Un cachorro de hiena manchada nace y sobrevive a pesar de la alta probabilidad de que muera durante el nacimiento. **Añade una ficha de hiena individual a cualquiera de tus territorios.**



Photo by Marcus Löffvenberg on Unsplash

Un deslizamiento de tierra obliga a un clan de hienas manchadas a abandonar su territorio. **Retira una ficha del clan de hienas del tablero de juego.** Ahora ninguna de las fichas individuales o de grupos pequeños restantes dentro del territorio del que retiraste la ficha puede cazar.



Photo by Marcus Löffvenberg on Unsplash

Una inundación obliga a una manada de leones a abandonar su territorio. Retira una ficha de clan de la manada de leones del tablero de juego. Ahora ninguna de las fichas individuales o de grupos pequeños restantes dentro del territorio del que retiraste la ficha puede cazar.	 Graphic made by MostafaElTurkey36 on Pixabay
Una sequía provoca que las fuentes de agua se sequen, por lo que es más probable que los depredadores y las presas entren en contacto. Mueve una de tus fichas de león un espacio más cerca de una ficha de ñu. Si puedes colocarlo junto a una ficha de ñu, usa las reglas de caza.	 Graphic made by MostafaElTurkey36 on Pixabay

Un pequeño grupo de leonas acecha y derriba con éxito a un ñu adulto que fue separado de la manada. **Retire una ficha de ñu individual del tablero de juego.**



Graphic made by MostafaElTurkey36 on Pixabay

Un león muere al intentar acabar con un ñu que se defendió. **Retire una ficha de león individual del tablero de juego.**



Graphic made by MostafaElTurkey36 on Pixabay

Varías leonas dan a luz a sus cachorros. **Agrega una ficha de león de grupo pequeño a cualquiera de tus territorios.**



Graphic made by MostafaElTurkey36 on Pixabay

Un pequeño grupo de leones utiliza el paisaje cubierto de hierba para esconderse mientras acechan y se acercan sigilosamente a algunos ñus. **Mueve una de las fichas de león de tu grupo pequeño 1 espacio más cerca de una ficha de ñu. Si puedes colocar tu ficha junto a una ficha de ñu, usa las reglas de caza.**



Graphic made by MostafaElTurkey36 on Pixabay

Event Cards

A lioness kills a wildebeest that was having trouble keeping up with the herd because it was old and sick. **Remove 1 individual wildebeest token from the gameboard.**



Muhammad Mahdi Ka'im, GNU 1.2

A small group of spotted hyenas kill a young wildebeest calf that was too slow to keep up with the rest of the herd. **Remove one individual wildebeest token from the gameboard.**



Muhammad Mahdi Ka'im, GNU 1.2

A small group of wildebeest grazing in an area where the grasses are short and allow them to easily spot predators. **Move one of your small group wildebeest tokens up to 3 spaces away from a predator token.**



Muhammad Mahdi Ka'im, GNU 1.2

A small group of wildebeest notice a predator approaching, and they display aggressive behaviors like stomping on the ground. They successfully scare away the predator. **Pick one spotted hyena or lion token that is near one of your small group wildebeest tokens and move it up to 2 spaces away from your wildebeest token. The predator token must stay within its territory.**



Muhammad Mahdi Ka'im, GNU 1.2

A spotted hyena cub does not survive. Remove one of the individual hyena tokens from the gameboard.



Photo by Marcus Löfvenberg on Unsplash

A small group of spotted hyenas commute to find food. You can move one of your small group hyena tokens up to 6 spaces away from its territory for this round only. If you are able to place it next to a wildebeest token, use the hunting rules. Next round, your hyena token needs to return to its original territory.



Photo by Marcus Löfvenberg on Unsplash

A spotted hyena cub is born and survives despite the high chance that they would die during birth. **Add an individual hyena token to any one of your territories.**

Photo by Marcus Löfvenberg on Unsplash



A landslide forces a spotted hyena clan to leave their territory. **Remove one hyena clan token from the gameboard.** Now none of the remaining individual or small group tokens within the territory you removed the token from can hunt.

Photo by Marcus Löfvenberg on Unsplash



A small group of spotted hyenas go for a hunt and successfully capture a newborn wildebeest that was isolated from the herd. Remove 1 individual wildebeest token from the gameboard.



Photo by Marcus Löfvenberg on Unsplash

A small group of lionesses successfully stalk and take down an adult wildebeest that was separated from the herd. Remove one individual wildebeest token from the gameboard.



Graphic made by MostafaElTurkey36 on Pixabay

A flood forces a lion pride to leave their territory.
Remove one lion pride clan token from the gameboard. Now none of the remaining individual or small group tokens within the territory you removed the token from can hunt.



Graphic made by MostafaElTurkey36 on Pixabay

A drought results in water sources drying up, so predators and prey are more likely to come into contact. **Move one of your lion tokens one space closer to a wildebeest token.** If you are able to place it next to a wildebeest token, use the hunting rules.



Graphic made by MostafaElTurkey36 on Pixabay

A flood forces a lion pride to leave their territory. **Remove one lion pride clan token from the gameboard.** Now none of the remaining individual or small group tokens within the territory you removed the token from can hunt.



Graphic made by MostafaElTurkey36 on Pixabay

A drought results in water sources drying up, so predators and prey are more likely to come into contact. **Move one of your lion tokens one space closer to a wildebeest token.** If you are able to place it next to a wildebeest token, **use the hunting rules.**



Graphic made by MostafaElTurkey36 on Pixabay

Several lionesses give birth to cubs. Add one small group lion token to any one of your territories.



Graphic made by MostafaEl Turkey36 on Pixabay

A small group of lions use the grassy landscape to hide as they stalk and sneak up on some wildebeest. Move one of your small group lion tokens 1 space closer to a wildebeest token. If you are able to place your token next to a wildebeest token, use the hunting rules.

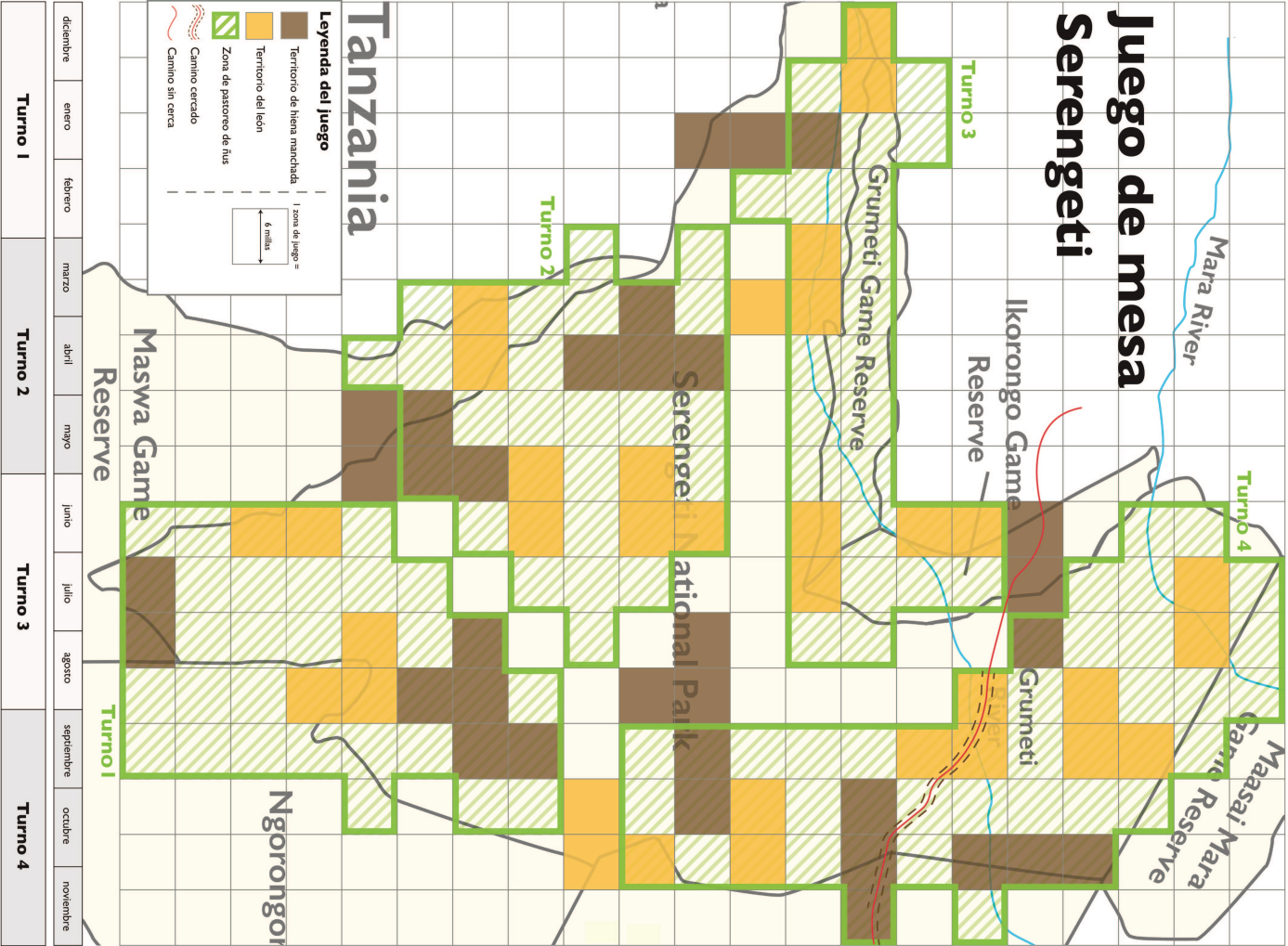


Graphic made by MostafaEl Turkey36 on Pixabay

A lion dies while trying to take down a wildebeest that defended itself. **Remove one individual lion token from the game board.**

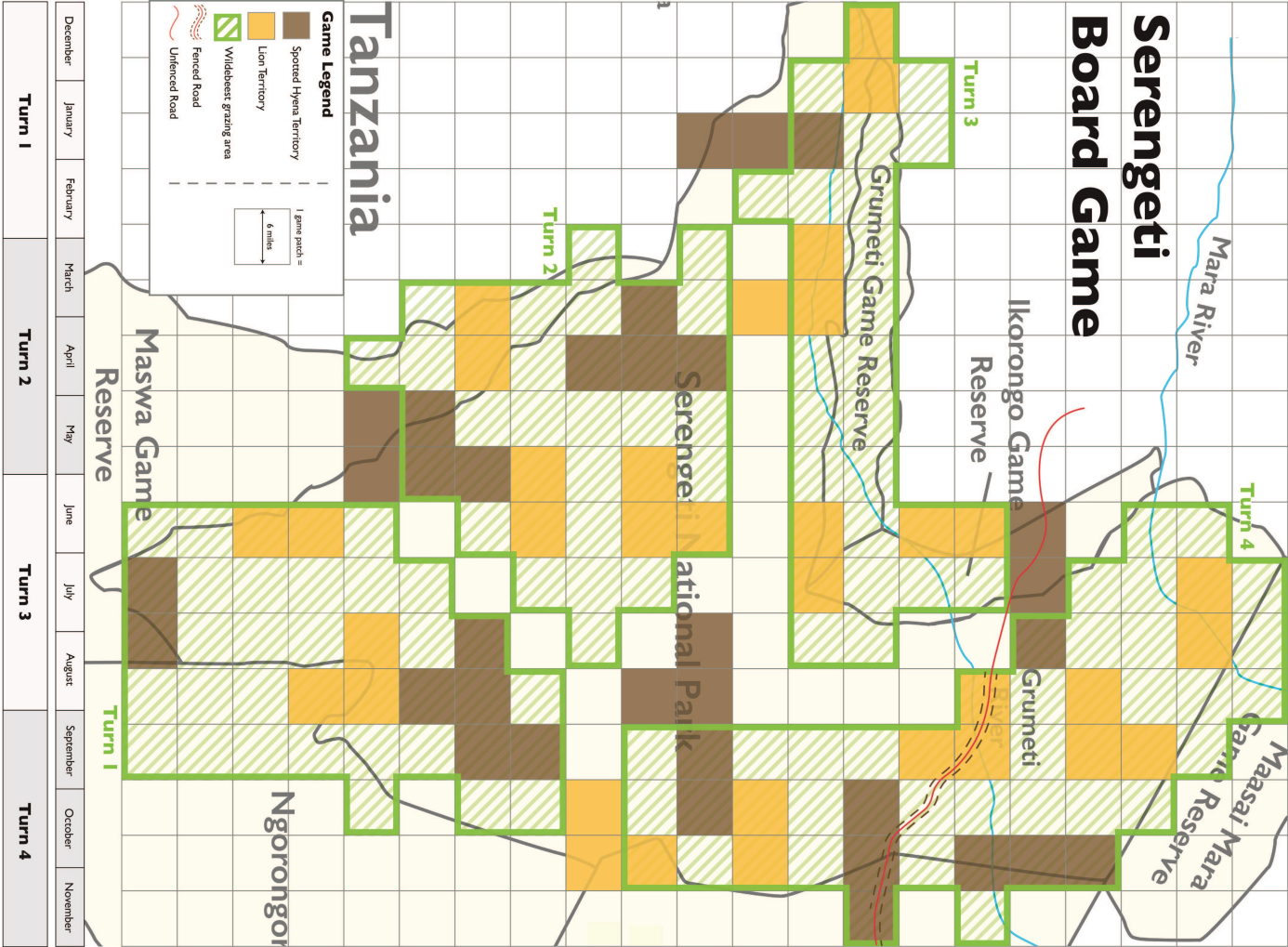


Graphic made by MostafaEl Turkey36 on Pixabay



Lesson 7 Teacher Reference

Serengeti Game Board



Data Analysis Key

Part 1

1. Analyze your data.

a) Use your game play data to complete the table below.

Who was your agent? _____

Group Size*	Number of Interactions	Number of Successful Interactions	% of Time Successful
Individual	7	2	29
Small Group	6	4	67
Herd (Skip for lion or hyena)	7	5	71

*Sample data for wildebeest

Hint: To calculate % success , divide the number of successful interactions by the number of interactions.

b) What does it mean for your agent to be successful?
Wildebeest: Survive encounters with predators.

Lions/spotted hyena: Kill a wildebeest to get food.

c) How did group size contribute to success?
Wildebeest: When the wildebeest were in a small group, they were more likely to survive than when they were alone. They were the most likely to survive when they were with the herd.

Lions/spotted hyena: When they were in a small group, they were more likely to be successful at killing a wildebeest.

2. Develop algorithms to help explain patterns in data.

a) Write an if/then statement based on each of the rows in your data table..

For example:

Group Size	Number of Interactions	Number of Successful Interactions	% of Time Successful
Individual	7	2	$2/7 \times 100 = 29\%$

Group Size	Algorithm in Words
Individual	If the wildebeest are alone and they interact with a predator, they are successful 29% of the time. OR If the wildebeest are alone and they interact with a predator, they are unsuccessful 71% of the time.

Group Size	Algorithm in Words
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Individual	If the wildebeest are alone and they interact with any kind of predator, they are successful 29% of the time.
Small Group	If the wildebeest are in a small group and they interact with any kind of predator, they are successful 67% of the time.
Herd (Skip for lion or hyena)	If the wildebeest are in a herd and they interact with any kind of predator, they are successful 71% of the time.

b) Write a NUMERIC if/then statement based on each of the rows in your data table..

For example:

Group Size	Number of Interactions	Number of Successful Interactions	% of Time Successful
Individual	7	2	29%

Group Size	Numeric Algorithm		
Individual	<i>If wildebeest (1) + predator then wildebeest= -0(.29)</i> OR <i>If wildebeest (1) + predator then wildebeest= -1(.71)</i>		

Group Size	Numeric Algorithm		
Individual	If wildebeest = 1 and predator = 1 and 2, then wildebeest 0(.29)		
Small Group	If wildebeest = 2 and predator = 1 and 2, then wildebeest 0(.67)		
Herd (Skip for lion or hyena)	If wildebeest => 2 and predator = 1 and 2, then wildebeest 0(.71)		

3. Talk to your group members. How do their algorithms compare to yours? *How do the algorithms for all three agents help you identify a pattern?*
Even though success is measured differently for different agents, they were all more successful when they were in a group than when they were alone. The algorithms make it clear that groups are more successful. This is repeated across agents which makes it a pattern.

4. Our game was designed to model interactions in the Serengeti system. How well did our design of the game support that goal? What recommendations would you make to revise the game system?
The game only showed what was happening inside the park, so maybe it could include the animals living outside the park.

The game only included wildebeest, lions and hyena, it could include some of the other species.

The game included grass but not rain, it could be revised to also include rain.

5. The data we collected predicts the behavior of the agents in the model. Our model made assumptions about the system that limit the value of our predictions. All models have limitations. In what ways do you think our model is limited? How do those limits affect the kinds of conclusions we can make? Use the example below to help you identify one assumption and limit.

Answers will vary.

Prediction	Assumption	Limit
Group behavior increases chances of survival for predators or prey.	We drew a line around the park and assumed that the agents outside the park boundaries did not impact our model.	There might be a lot more lions or hyena living outside the park that can travel in and interact with the wildebeest, we would not capture these interactions so the number of interactions might be lower.
	We only had wildebeest dying from lions and hyenas, they die from other causes.	The survival of the wildebeest population was higher than it would be in real life.
	Lions and hyenas eat other things, not just wildebeest.	If there were a lot of zebras or gazelle around the wildebeest might have survived differently.

Lesson 7: Answer Key 2

Meet Your Agent Key

Wildebeest

Table 1. Initial Conditions

Wildebeest	Initial Conditions	Connected Behaviors
 Muhammad Mahdi Karim, GNU 1.2	Look at the game board and notice the squares where tokens go. For each turn, there is an area outlined in green on the game board that shows where the most nutritious grasses are. The wildebeest must stay within these areas. It is okay for wildebeest tokens to be placed within lion or spotted hyena territories. Add 21 tokens to the game board, including: • 11 individual tokens • 6 small group tokens • 4 herd tokens	About 1.3 million wildebeest live in Serengeti National Park. There are far more wildebeest than lions or hyenas. This is why wildebeest starts the game with more tokens on the gameboard. Most wildebeest travel together in a large group. This is why the tokens must be touching. Sometimes small groups and individuals get separated from the herd. Wildebeest migrate in search of food, like nutritious grasses.

Instructions: Complete the *Connected Behavior* column based on information found in the *Agent Background*. Explain how each behavior connects to the rule.

Table 2. Game rules.

	Rule	Connected Behavior
Life Events	At the start of each turn you will draw one life event card. Follow the instructions on the card. If you gain or lose a token, record the outcome in your data table.	Event cards are based on animal behaviors

Move	At the start of each turn, you will move all of your tokens to the next turn's green outlined area. You will check your tokens to make sure all of the wildebeest tokens are touching another wildebeest token on at least one side. If not, you will move your tokens so they are touching.	Wildebeest eat grass. When they eat all of the grass in an area, they move on, following the rains first to the west and then to the north. They return to the short grass plains on an annual cycle. During the migration, wildebeest can travel up to 4.3 miles/day in search of the best and most plentiful grass they can find along their route. Wildebeest move in large groups called herds, and during the migration, the whole wildebeest population moves together.
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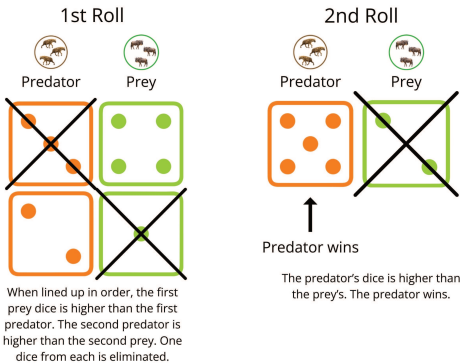
**Interact with
Predators**

When a predator attacks, you will engage with them by rolling 1-3 dice, depending on the token being attacked.

- a. Herd = 3 dice
- b. Small group = 2 dice
- c. Individual = 1 die

You will roll your dice and line up your dice from highest to lowest. Whoever is attacking you will also be rolling dice. Compare the highest die you each rolled. Then compare the next two highest dice and the next (if you have them). If your number is higher, you will roll that die again. If your number is lower, you take that die away. If you tie, you both can roll that die again. You keep rolling until one person runs out of dice.

Sample Hunt 1



When you lose, you will remove a token with an **INDIVIDUAL WILDEBEEST** from the board. If you run out of **INDIVIDUAL** wildebeest, replace a small group with 2 individuals on the game board.

Hunting and feeding behavior is based on the role of the dice and you roll more dice if you have more members of the group involved. Every time you roll the dice they have a chance to survive because they use behaviors to defend themselves.

Lions
Table 1. Initial conditions.

Initial Conditions	Connected Behaviors
--------------------	---------------------



MostafaElTurkey
36, Pixabay,
FreeStockPhoto
s.biz Collection

Look at the game board and notice the squares where tokens go. You will start by placing your pride tokens in the yellow lion territories. There can only be one pride token in each territory and every territory must have pride.

Then, you will place your individual and small group tokens. You can place individual and small group tokens in territories that contain a pride token. You can place as many small group and individual tokens in a territory as you want as long as there is room.

Add a total of 28 tokens to the game board, including:

- 7 individual tokens
- 7 small group tokens
- 14 pride tokens

Instructions: Complete the *Connected Behavior* column based on information found in the *Agent Background*. Explain how each behavior connects to the rule.

Table 2. Game rules.

	Rule	Connected Behavior
Life Events	At the start of each turn you will draw one life event card. Follow the instructions on the card. If you gain or lose a token, record the outcome in your data table.	Event cards are based on animal behaviors
Move	At the start of each turn, you will look at your tokens. For each individual or small group lion token, you may move the token 1 space in any direction within the token's territory. When a token is moved, try to place it next to a wildebeest token to give an opportunity to hunt. If your tokens are already in a good position, you can choose to keep them where they are.	Remember that wildebeest are lions' preferred food source. Prides typically stay in their territories. They don't travel long distances while hunting. Instead, they target nearby prey. They stalk their prey and pounce usually within 30 meters of their prey.

Hunt or Feed

Check your tokens. Are any of the small group or individual tokens in this turn's area touching a wildebeest token?

If so, your small group and individual lions will attack a wildebeest.

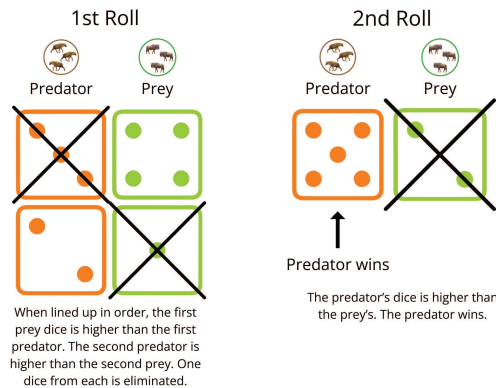
To attack, you will roll 1-2 dice, depending on the token you are attacking with:

- a. Small group = 2 dice
- b. Individual = 1 die

The wildebeest will roll 1-3 dice, depending on the type of token you are attacking.

You will roll your dice. You will compare the highest die you each rolled. If your number is higher, you keep that die to roll again. If your number is lower, you remove that die and do not roll it again. If you tie, you both can roll that die again. You will keep rolling until one person runs out of dice.

Sample Hunt 1



If you win, you get to eat! The wildebeest loses a token. If you lose, you do not eat, but you are unharmed and continue to play.

Hunting behavior is based on the role of the dice and you roll more dice if you have more members of the group involved.

Initial Conditions		Connected Behaviors
 Photo by Marcus Löfvenberg on Unsplash	Look at the game board and notice the squares where tokens go. You will start by placing your clan tokens in the brown spotted hyena territories. There can only be one clan token in each territory and each territory must have a clan. Then, you will place your individual and small group tokens. You can place individual and small group tokens in territories that contain a clan token. You can add as many small group and individual tokens to a territory as you would like as long as there is room in the territory. You will add a total of 22 tokens to the game board, including: • 8 individual tokens • 5 small group tokens • 9 clan tokens	

	Rule	Connected Behavior
Life Events	At the start of each turn you will draw one life event card. Follow the instructions on the card. If you gain or lose a token, record the outcome in your data table.	Event cards are based on animal behaviors
Move	At the start of each turn, you will look at your tokens. For each individual or small group hyena token, you may move the token 1 space in any direction within the token's territory. When a token is moved, try to place it next to a wildebeest token to give an opportunity to hunt. If your tokens are already in a good position, you can choose to keep them where they are. The spotted hyena tokens can not move outside of their territories unless an event card allows it.	Hyenas usually stay within their territories but can travel up to 16 miles per night outside of their territories in search of prey.

Hunt or Feed

You will check your tokens to see if any of the small group or individual tokens in this turn's area are touching a wildebeest token. If so, your small group and individual hyenas will attack the wildebeest.

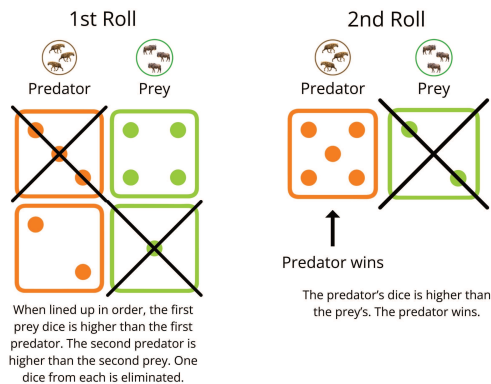
To attack, roll 1-2 dice, depending on the token you are attacking with:

- Small group = 2 dice
- Individual = 1 die

The wildebeest will roll 1-3 dice, depending on the type of token you are attacking.

Roll your dice. Compare the highest die you each rolled. If your number is higher, you keep that die to roll again. If your number is lower, you remove that die and do not roll it again. If you tie, you both can roll that die again. You keep rolling until one person runs out of dice.

Sample Hunt 1



If you win, you get to eat! The wildebeest loses a token. If you lose, you do not eat, but you are unharmed and continue to play.

If you win, you get to eat! The wildebeest loses a token. If you lose, you do not eat, but you are unharmed and continue to play.

Hunting behavior is based on the role of the dice and you roll more dice if you have more members of the group involved.

UDL Reading Supports

Universal Reading Supports for Jigsawed Readings

Engagement	Representation	Action & Expression
Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal-Directed
Recruit interest: Allow students to choose readings. Sustaining effort: Jigsaws are social, and all participants are treated as experts.	Perception: Electronic format supports screen reading; images support background knowledge. Language & Symbols: We pay attention to structure and text features. Comprehension: Students access key information relevant to the big question.	Physical action: Using computers optimizes access to translation/screen readers. Expression & Communication: The lesson encourages use of text features. Executive Function: Students have a distinct goal/purpose for reading and use handouts to organize ideas.

Here are some text structures and design features that benefit **all readers** in this lesson, and can be applied to other texts your students may encounter:

1. **Images:** There is a reason “a picture is worth a thousand words.” Images help readers engage with the text on a sensory level before the reading activity begins. An image that is closely related to the text’s main content can activate sensemaking that includes students’ previous experiences, cultural funds of knowledge, and their curiosity.
2. **Short sentences and paragraphs:** If a reader has to decode a lot of words in a sentence, it is hard to remember the concepts from previous parts of a sentence to string together. One way to alleviate this is with shorter sentences that maintain the meaning of an idea or paragraph.
3. **Titles, subtitles, and other section names:** Titles highlight the purpose of the text and “set the stage” for students to make conceptual connections to the text. Students can use their background knowledge and cultural funds of knowledge to connect with the reading right away.
4. **Language register:** Science articles can take on different registers of language depending on the audience and purpose. Articles written for youth may have more colloquial language, while articles written for professionals will have more highly specialized language. While specificity is important, it should not come at the expense of general comprehension for any audience. One general guideline is the 90% rule: If 1 in 10 words is unfamiliar to students, the reading or text is not easily comprehensible.

The Google versions of these articles are accessible to screen-reading technology and online translator services.

References

(2018). Universal Design for Learning Guidelines version 2.2. CAST. Retrieved December 14, 2022, from <https://udlguidelines.cast.org/>

SageModeler Introduction

Getting Started

SageModeler is a tool for creating models of phenomena. It allows you to take your current ideas about how something works and design a runnable simulation without needing to write equations or do traditional coding. By making it possible to map your ideas about a phenomenon to a working computational simulation, you can test, share, evaluate, and revise your model (and your understanding of the phenomenon).

SageModeler makes possible three different types of modeling: from the basic modeling of the structure of a system to the creation of static equilibrium or dynamic time-based models. In this lesson, you will focus on developing a dynamic computational model.

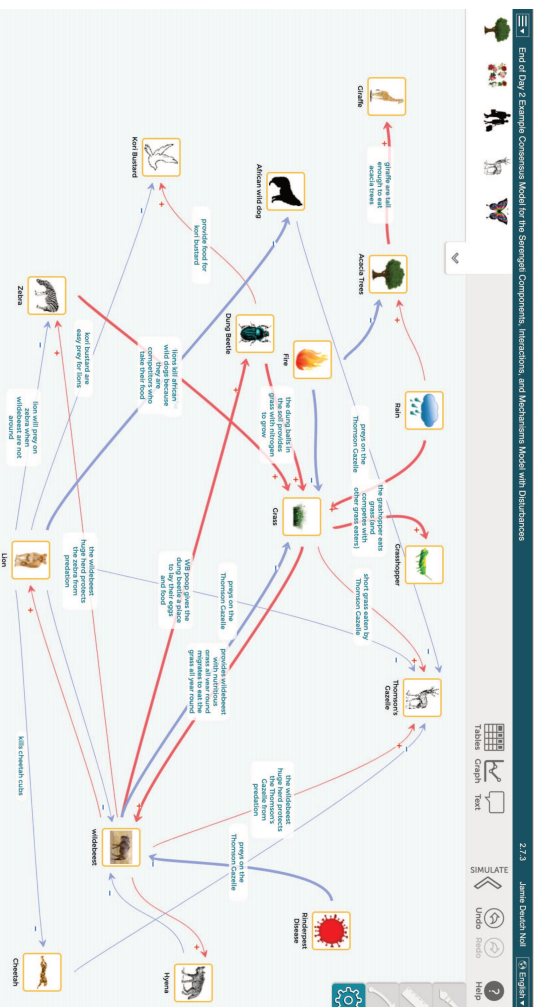
For more information on SageModeler, see:

- Watch this screencast: https://youtu.be/_qVE9OSG0k
- Read this for help getting started: <https://sagemodeler.concord.org/getting-started/index.html>
- See general examples of other models here: <https://sagemodeler.concord.org/example-models/index.html>

Guidance

1. If you are adding or allowing students to add any additional components to the ecosystem, make sure to filter image search to narrow the possible images for appropriateness.
2. You will use a template that makes a master copy for each section and then share a link for that particular section, which opens a new copy for each group to manipulate on day 2.

See one example below of a modified template for the after day 2 consensus model for: Serengeti Ecosystem Components, Interactions, and Mechanisms. Or go to <https://sagemodeler.concord.org/app/#shared=https%3A%2F%2Fcfm-shared.concord.org%2FInardYOXAV8QxDbPFzAo%2Ffile.json.1>



Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

References

SageModeler [Computer software]. (2020). Concord, MA: The Concord Consortium and the CREATE for STEM Institute at Michigan State University.

Serengeti Component Interactions

Part 2: Investigating Components and Interactions in the Serengeti

1. What component of the Serengeti ecosystem are you investigating?

Answers will vary based on component. Look for students to list one of the following:

- Dung beetles
- Thomson's gazelle
- Kori bustard
- Zebra
- Grasshopper
- Acacia
- Giraffes
- Cheetah

2. What other components of the system does your component interact with?

Answers will vary based on component.

Example for dung beetles:

- Wildebeest
- Grass

3. Identify the interactions between your component and other components of the system:

- a. Draw a line from your component to each component that your component connects to and your component interacts with in the Serengeti.
- b. How do the two components interact? If the population of your component changes, do you predict it will cause the population of the other component to change? If so, draw an arrow at the end of the line pointing toward the other component.
- c. Or would the population of your component change if the population of the other component changed? If so, draw an arrow pointing toward your component.
- d. Is the interaction positive or negative? Will the population increase (+) or decrease (-).
- e. What is the strength of those interactions in terms of a lot or a little? If the relationship is strong, make the line thicker. For example, *we know that the spotted hyena and the wildebeest interact. Hyena do not have a large impact on the wildebeest population, but wildebeest do have a big impact on lions.* See the example below:

Answers will vary based on component. Example for dung beetles:

+ wildebeest → + dung beetle

4. We have been investigating what happens to different components of the Serengeti ecosystem that are connected to wildebeest migration. Create an if/then statement for a possible interaction between your component and another component in the Serengeti. For example *If _____ (write the component) _____ (increases, decreases, or stays the same) then _____ (write another component) will _____ (increases, decreases, or stays the same).*

Answers will vary based on component. Example for dung beetles:

If wildebeest increase, then dung beetles will increase.

5. Take your if/then statement and turn it into a graphical representation. What would you predict a graph of your component's interactions with another component would look like? Recall (from Lesson 4) that a graph is a mathematical representation of a relationship between two variables. In this case, we have two populations that are changing together.
 - a. Sketch your graph below.

Answers will vary based on component.



6. Describe and explain the cause for the interaction you modeled in your graph. For the example in question 3, *The group behavior of the wildebeest and size of herd means that they are seldom alone, and so the predation threat is low.*

*Answers will vary based on component. Example for dung beetles:
Since dung beetles eat the leftover grass in the wildebeest dung (poop) and lay their eggs in it, then more wildebeest dung will mean more food and habitat for dung beetles to eat and lay their eggs, which means more dung beetles.*

L8 Electronic Exit Ticket Key

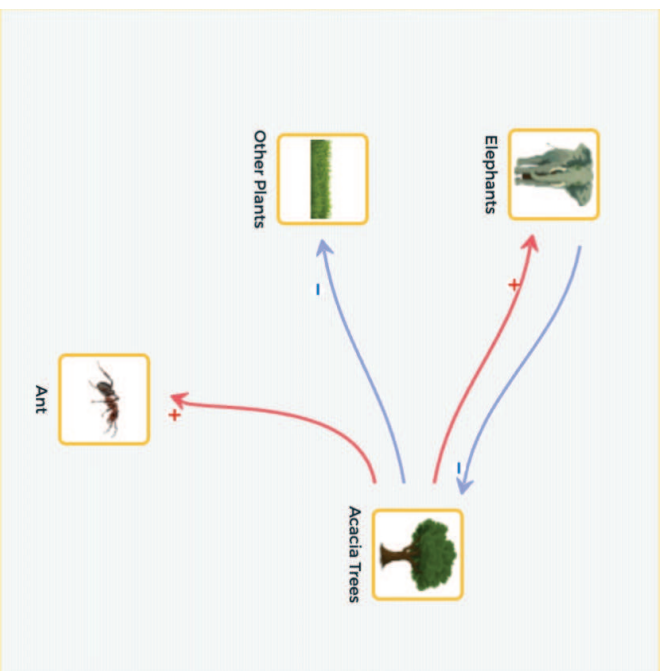
8.B-Develop and test a complex model for how ecosystems are resilient and the numbers and types of organisms relatively constant (stable) in response to disturbance (change). (SEP: 2.5; DCI: LS2.C.1; CCC: 7.1)

Where these elements are addressed in this assessment.	2.5 Developing and Using Models Develop a complex model that allows for manipulation and testing of a proposed process or system.	LS2.C.1 Ecosystem Dynamics, Functioning, and Resilience A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability	7.1 Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.
Q1	X	X	
Q2		X	X
Q3			
Q4	X		X
Q5	X		
Q6			X

Question 1

Examine the model below. Which statement best **explains how ecosystems are resilient in response to a disturbance?**

As part of the ivory trade, the African elephant was killed for its tusks. The population of African elephants decreased from 26 million in the 1800s to just 415,000 today. Based on this change to the elephant population, what do you predict would happen to the acacia trees, the ants, and other plants?



- The acacia trees would increase, the ants would increase, and the other plants would increase as well.
- **Acacia trees increase, ants increase, and grasses and other plants decrease.**
- Acacia trees decrease, ants increase, and grasses and other plants increase.
- The acacia trees increase, ants decrease, and grasses and other plants decrease.

Correct response: Elephants eat acacia trees, so a reduction in the elephant population could cause an increase in the acacia tree population. The ants feed on nectar made by the acacia tree, so an increase in the acacia tree population could cause an increase in the ant population. Lastly, as the acacia tree population increases, the grasses and smaller plants could get crowded out or outcompeted for sunlight, which could cause a decrease in those populations.

Rationale for correct response: Students should recall that impacts to the system are experienced differently by the organisms and the impact to their population numbers is based on their interactions with each component in the system.

What to do:

Remind students to think back to the models they developed in class. Ask students what they observed when the **availability of food changed with the wildebeest** and how the **results of the change affected the ecosystem**.

Question 2

Scientists have identified the elephant as a keystone species in the African savanna ecosystem. One reason is that the elephant digs holes to access groundwater that other organisms use as well. If the **elephant population declined**, what do you predict would happen to the **ecosystem over time**?

- The populations of animals that rely on water from elephants would increase. The ecosystem function would not change.
- The populations of animals that rely on water from elephants would increase. The ecosystem could function differently.
- The populations of animals that rely on water from elephants would decrease. The ecosystem function would not change.
- **The populations of animals that rely on water from elephants would decrease. The ecosystem could function differently.**

Correct response: If there was a decrease in the elephant population, then any of the organisms that benefit from the elephant would decrease as well.

Rationale: Students should recall that a keystone species has many different interactions with various components in the system. The presence of the keystone species and their activities provide food, shelter, and other benefits to these organisms that would no longer continue in the absence of the keystone species.

What to do: Remind students of the impact of the wildebeest on the African savanna. If there was a change in the number of wildebeests in the area, have students explain all of the different ways that the system would be affected.

Question 3

How did what we figured out today help you better understand your conservation profile?

What to look for in response:

Accept all responses. Validating these responses engages students in activating the **relevance** and **interest** in these issues, which can motivate future questions.

What to do:

Encourage students to think back to their conservation profile and the information they collected on *Progress Tracker* and in their *Conservation Profile Organizer* for ideas.

Question 4

What **component** would you need to add to the model to represent the interaction that **caused the elephant population to change**?

- Humans are the missing component that is impactful to the elephant population.
- Weather is the missing component that is impactful to the elephant population.
- African buffalo are the missing component that is impactful to the elephant population.
- None of the above

Correct response: The ivory trade was created and implemented by humans, so they are the missing components that are impactful to this elephant population. The ivory trade was the disturbance that created the change in the ecosystem.

Rationale: Students should recall that the ivory trade was created by a non-natural disturbance, so the presence of humans is missing from the model and is needed to understand what is happening to this ecosystem at this time.

What to do: Have students explain what the ivory trade is and relate that to the other components of the ecosystem. Ask them if there could be an ivory trade without humans.

Question 5

How did the **models we used in this lesson** help you explain the lesson question: What other components of the Serengeti system interact with the migration?

What to look for in response: *Note: These could be different for each student.*

- Students should identify which model was most useful to them.
- They should identify the aspects of the model that led to it being most useful. Students may mention how the chosen model illustrates how the organisms (like the lions, hyenas, and the grasses) are impacted by the migration.

What to do:

If students are struggling to articulate how one model helped them to explain the importance of the migration to the Serengeti system, spend some time discussing as a class the limitations of each of the models. These could be:

- Each of the different models has its own limitations due to the complexity of the system.
- The models are snapshots in time, and the system may have more overlap between transitions that may make patterns more difficult to see.
- The amount of data in the models may be insufficient.

Discussion of limitations of the models used in the lesson (and previous lessons) can help students identify which model may have provided more information to help explain the lesson question.

Question 6

How do the concepts of **stability and change** help you make sense of: What other components of the Serengeti system interact with the migration?

What to look for in response:

- Students should mention that observing changes in the populations of organisms prompted them to want to investigate the interactions between the components using a simulation.

What to do:

If students do not identify any changes in populations, prompt them to identify them (e.g., wildebeest, lions, and hyena). Tell them this is important to explain how the system is affected by the migration.

Question 7

Name one way you helped the class make progress on the lesson question today.

What to look for in response:

- Students identify how they helped another student or groups of students during the investigations.
- Students articulate how they contributed to helping the class achieve their goals for the lesson.

What to do: Depending on student responses, it may be beneficial to revisit the community agreements.

- If many students do not identify how they helped, spend time revisiting the community agreements to ensure that students are using the agreements as they work together to make progress on figuring out science and engineering ideas.
- If many students do articulate how they contributed, revisiting the community agreements may encourage students to think about what specific agreement they could adhere to be more helpful.

Explanation Key

9.B Evaluate competing road proposals to determine how such human activity could impact the Serengeti ecosystem over short and long periods of time (SEP: 6.5; DCI: LS2.C.2 & ETS1.B.1; CCC: 7.4)

3D Elements Addressed in this Assessment	
SEP	Design, evaluate, and analyze <u>refine</u> a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
DCI	Moreover, anthropogenic changes (induced by human activity) 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.
	When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts.
CCC	Systems can be designed for greater or lesser stability.

Instructions: Use evidence from the unit and the road proposal materials to explain which road you think is the best option for Tanzania.

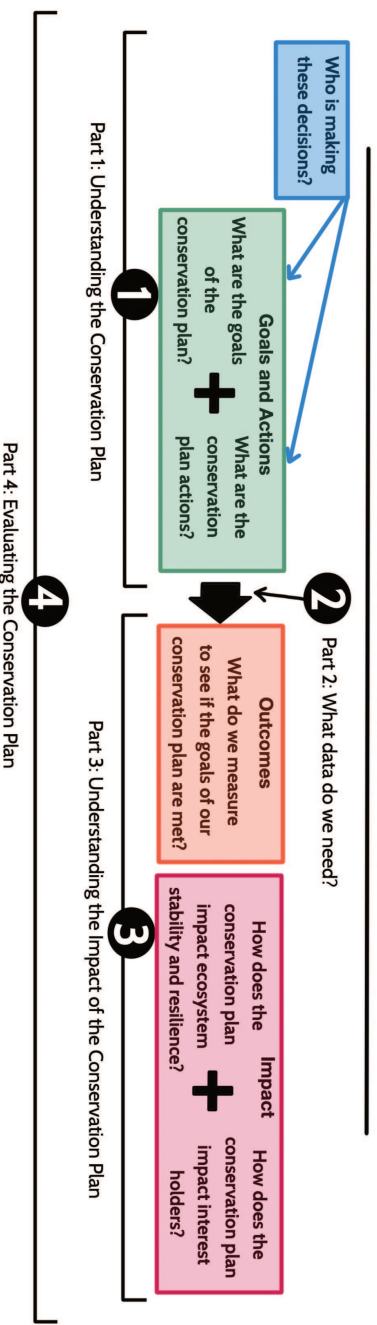
Gotta-Have-It Checklist	Ideas for Sentence Starters
Your recommendation.	The _____ road is the best option.
Impacts on the ecosystem supported with evidence for your recommended road (use evidence from investigations in previous lessons).	The impact on the (<u>ecosystem component</u>), would be _____. Evidence I have to support that is _____ and _____. The impact on the whole ecosystem would be _____. Evidence I have to support that is _____ and _____. These interest holders: _____ would be impacted in this way: _____. My evidence is _____.
Impacts on interest holder by criteria (choose at least two):	

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	In this explanation, look for: Students support their choice by identifying evidence of the impact on one or more components of the system (e.g., wildebeest), and whether they will be positively or negatively impacted. Students support their choice by identifying one or more specific criteria (cost/connection, travel time, economic development, social services) that are important to interest holders and whether they will be positively or negatively impacted.	In this explanation, look for: Students support their choice by identifying evidence of the impact on one or more components of the system (e.g., wildebeest), and how the stability will be impacted by changing interactions between components. Students support their choice by identifying one or more specific criteria (cost/connection, travel time, economic development, social services) that are important to interest holders and how they will be positively or negatively impacted.	In this explanation, look for: Students support their choice by using evidence of the impact on the carrying capacity of the wildebeest and the biodiversity, stability, or resilience of the ecosystem. Students support their choice by identifying two specific criteria (cost/connection, travel time, economic development, social services) that are important to interest holders and how it will provide long-term benefits.

Example	The South Eyasi road is the best option. It will not make the wildebeest population go down. It will also be good for economic development.	The South Eyasi road is the best option. It will not make the wildebeest population go down, so other populations they are connected to will also stay stable. The ecosystem will not be negatively impacted. It will also be good for economic development because there will be more opportunities for agriculture.	The South Eyasi road is the best option. The impact on the wildebeest and the ecosystem would be less than the road through the Serengeti because the road would not block the migration and would not reduce the amount of grass available to wildebeest in the dry season when there is little to eat. If the wildebeest population stayed stable, the rest of the system probably would too because they interact with a lot of organisms. The South Eyasi road is also good for the government because it is shorter than Mbula, and it has a lot of connections, so it will be less expensive. It also takes less time to travel, and it can be traveled on at night. The South Eyasi road is also good for reducing poverty because it connects agriculture so people can get and sell food. Mbula is slightly better for this criteria, but the other benefits outweigh this small drawback.
Feedback/ What to Do	<i>Linking:</i> Revisit the class model for the Serengeti ecosystem and ask students to consider how the flow of matter and energy changed at different temperatures. Support students in seeing why the South Eyasi is a good option. Ask students to revise their models after review.	<i>Organizing:</i> Review how carrying capacity affected the wildebeest in early lessons. Support students in seeing how the road would impact migration. Ask students to revise their models after review.	<i>Extending:</i> Ask students to imagine another model or phenomenon that functions like the Serengeti ecosystem. Ask students to predict how matter and energy flow in that system.

Conservation Plan Key

Conservation Evaluation Tool



Goals and Actions

1. What were the goals of the conservation plan to establish the Serengeti National Park?
2. What plans were put in place to support the goal(s)?

They protect the ecosystem without people living inside of most of it. Human activity is restricted inside the park. There is no hunting or agriculture use. There are some protected areas around the park that have some different rules about human activity.

Decision-Makers

3. Who made the decisions that determined the conservation plan?
- At the time, most of the decisions were made by the colonial government (Europeans) because Tanzania was not independent. When it became independent, they had more opportunities to make their own decisions.

Outcomes

4. What data have we already investigated that can help us understand if the goals were met?
- Data we looked at in Lesson 5 about the carrying capacity. We know that the wildebeest population has been stable for many years around its carrying capacity.

Impact

5. How did the conservation plan impact the stability and resilience of the ecosystem?
- We know that the predator populations rely on the wildebeest (Lesson 7) and many others too because they are keystone species, so we know that protecting the wildebeest has protected the biodiversity and resilience of the whole system (from Lesson 8).
6. How did the conservation plan impact interest holders?

The tourist industry, which is very important to the economy, depends on it, so that is beneficial for anyone interested in that.
 The scientific community benefits from all of the information.
 The people who used to live and/or make a living in and around the park may have been displaced, and their ability to provide for themselves and their families may have been harmed.

Name: _____

Date: _____

Lesson 9: Answer Key 2

Road Proposal Organizer Key

From which criteria are you evaluating the road proposals?	Why are these criteria important to consider?	Which road proposal seems to be the best option for these criteria?	Suggested Student Feedback
<i>Cost of the road and connections it would make.</i>	<i>The cost should not be greater than the economic gain it would bring to the area. The connection it makes should help people, especially people in poverty. The more connections it makes to roads that are already there, the less it will cost.</i>	<i>The South Mbulu route is probably going to be the most expensive to build because it is the longest.</i> <i>Even though the Serengeti route is the shortest, it does not have a lot of connections, so it will be expensive.</i> <i>The South Eyasi route is medium length with the most connections, so it will be cheaper.</i>	<i>Which road is the longest?</i> <i>Which road makes the most connections?</i> <i>How can you put those two pieces of information together?</i>
<i>Travel time.</i>	<i>The purpose for the road is to move goods between Lake Victoria and the Indian Ocean. Doing this as quickly as possible will bring the most economic benefit. If it takes longer, all the workers have to be paid more to move fewer goods.</i>	<i>The total travel time for the South Mbulu route is the longest. The total travel time for the Serengeti route is the shortest, but 151 km of it is in the park and cannot be traveled on at night so that would make it slower.</i> <i>The South Eyasi Route is best because it is a little shorter than South Mbulu and you can travel on it at night.</i>	<i>Which road will take the longest to travel?</i> <i>Which road will allow nighttime travel?</i> <i>Have you ever driven on a highway at night? Do you see a lot of big trucks then? Why would this matter?</i>
<i>Economic development.</i>	<i>The road could improve access to agriculture by buyers and sellers, so it needs to connect areas that have agriculture already. It could also connect new areas that do not have agriculture.</i>	<i>The Serengeti route does not have much agriculture on the route because people do not live in the park. Also, there is unlikely to be agriculture allowed in the park in the future, so it limits future growth options.</i> <i>The Mbulu route has slightly more agriculture, but it is almost equal to the Eyasi route, so there is not much difference for this criteria.</i>	<i>Which road is connected to the most agriculture?</i> <i>Will agriculture be allowed in the future in the Serengeti system?</i>

<i>Social services: healthcare and education.</i>	<i>It could improve people's lives by giving access to education and healthcare. Since more than half of Tanzanians do not have access to these things, this is really important.</i>	<i>The Serengeti route is not good because it does not connect to health care and it does not have a lot of people living around it.</i> <i>The Mbulu route has the most people living around it, including children, and would give the best access to healthcare. The Eyasi route is a good second choice.</i>	<i>Why should we be concerned about where children live?</i> <i>Where do the most children live?</i> <i>Which roads are near dense populations?</i> <i>Which roads will connect communities to healthcare?</i>
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Lesson 9: Answer Key 3

Group Assessment Key

Instructions: As a group, evaluate the road proposal of your choice. Consider how the ecosystem and different interest holders will be impacted. In addition to the resources from today's lesson, draw on the expertise of each group member and other resources you have developed throughout the unit. Use words, symbols, and/or drawings in your responses below.

1. How did the need to make the decision come to be?

Students should draw on their notes from the video and interest holder cards; possible responses include:

- The road would bring much needed social and economic development to Tanzania.
- The road would link Tanzania's coast to Lake Victoria and support economic development.

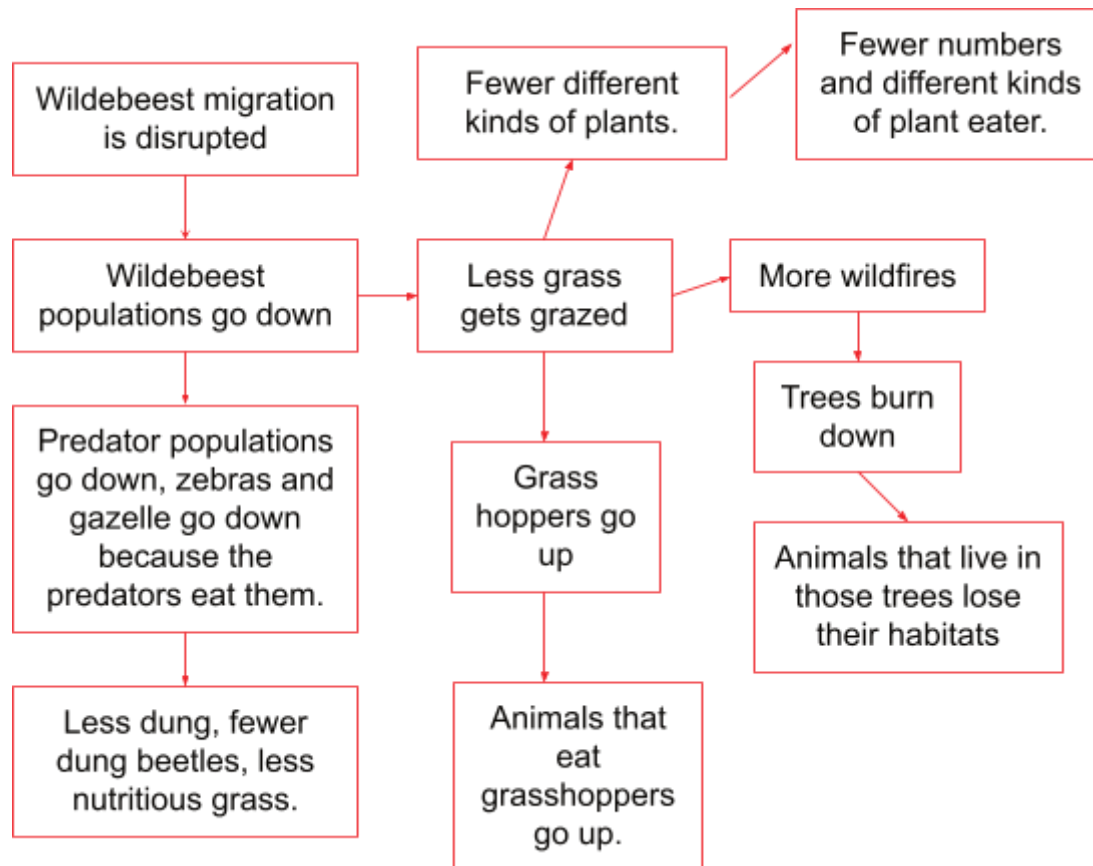
2. How do you think interest holders might prioritize criteria? Use *Road Proposal Organizer* and what you have learned in the unit so far to rank each criteria from 0 (not a priority) to 5 (high priority).

	Cost and connections	Travel time	Economic development: agriculture	Social services: healthcare and education	Protecting the ecosystem
Tourists					
Conservationists					
Elipkea Urio - youth leader					
Tanzanian government					
Maasai					
Bernard Kissui - research scientist					

3. How will the Serengeti ecosystem be impacted by this decision? Use words and/or pictures to predict impacts to the wildebeest migration and ecosystem. Consider which components will change and which will stay the same.

Possible responses include:

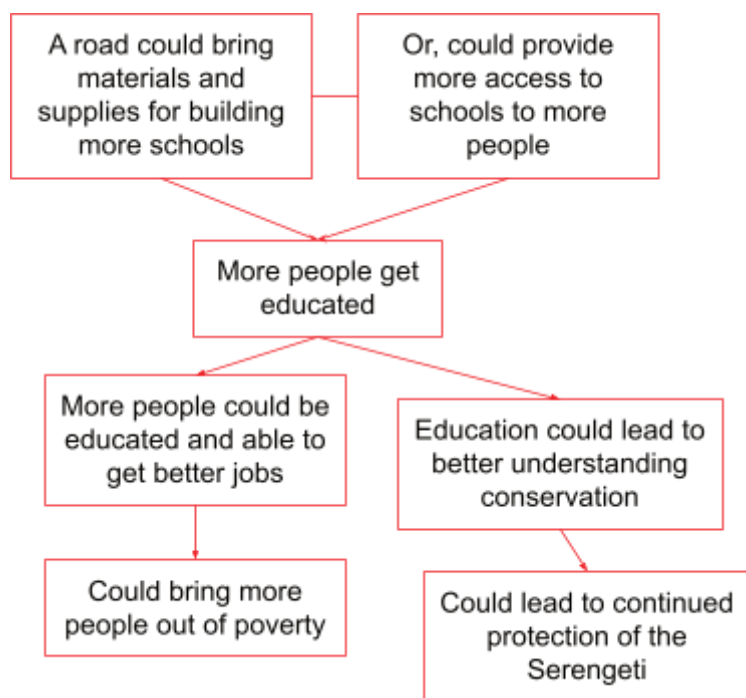
- The road could disrupt the wildebeest migration as they move north and then again when they try to move south. -> This could reduce the population of the wildebeest. -> This could lead to less grass being grazed. -> This could lead to more wildfires -> which could burn Acacia trees down -> which could affect the animals that rely on those trees for habitats or food.
- A reduction in the wildebeest population could also impact the predator-prey relationship with hyenas and lions; these predators might have to start going after other prey, like zebras and Thomson's gazelles.



4. How will the decision impact human interest holders? Use words and/or pictures to predict impacts to at least two different groups of interest holders.

Possible responses include:

- A road could bring materials and supplies for building more schools and/or could provide more access to schools to more people. -> This means that more people could get educated, particularly people living in rural areas. -> People might be able to get better jobs -> which could then bring more people out of poverty; if people get more educated, that could lead to a better understanding of conservation -> which could lead to continued protection of the Serengeti.
- If the Mbulu or Eyasi roads get built, these would lead to connecting more of the agriculture market. -> This could lead to Tanzania producing more food for its citizens. -> This could help reduce the number of children who are undernourished.



Ethical Decision Making

5. Based on the evidence above, which road proposal do you think meets the needs of the greatest number of interest holders?

Responses will likely vary, reflecting the complex nature of making decisions in the real world.

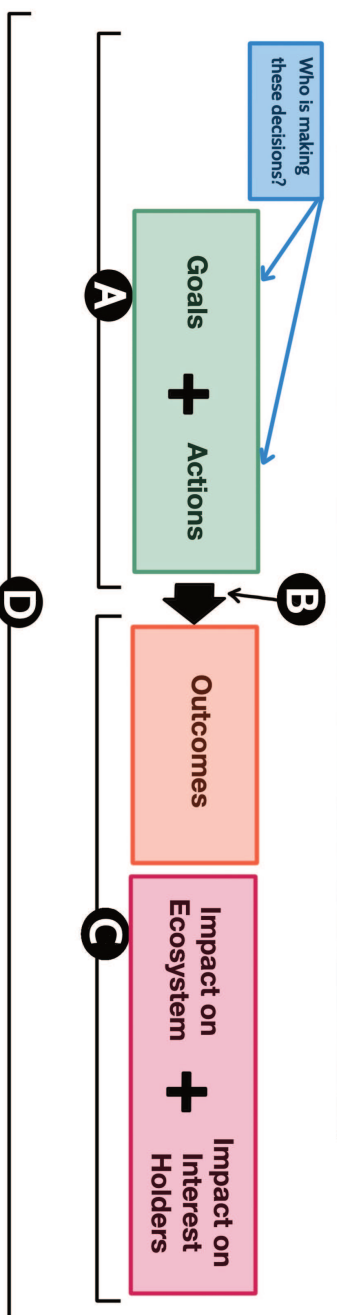
Name: _____

Date: _____

Lesson 10: Answer Key

Conservation Evaluation Key

Conservation Evaluation Tool



Part A: Understanding the Conservation Plan

Directions: Answer the following questions using the *Conservation Plan Storyboards* to gather evidence.

Question	Everglades	Great Lakes	Hoh River	Saguaro
1. What is the problem the conservation plan is trying to solve?	Manatees are being hurt and killed by watercraft.	People noticed new species being introduced to the Great Lakes.	Salmon populations declined, and they were unable to swim upstream to reproduce.	Saguaro cactus population declining.
2. Who is making the conservation decisions? What are their motivations?	Scientists, law enforcement, conservation groups.	Both the Canadian and US governments.	Local nonprofit organizations like the Hoh River Trust and Nature Conservancy.	The University of Arizona started the conservation, then the government made it a national park to protect the saguaro cactus because they became iconic for the area.
3. What are the goals of the conservation plan?	Create protection zones for manatees around the docks.	To monitor ballast water and reduce the amount of water being dumped into the Great Lakes.	To acquire land around the Hoh River and to fix/remove barriers.	To create restrictions to limit human interaction in order to protect the saguaro cactus.

4. What are the conservation plan's actions?	Law enforcement monitors for unsafe watercraft practices (speeding) in manatee areas.	To have boats dump their ballast water and flush tanks in different stations throughout the region.	To identify and remove barriers like culverts so salmon can swim upstream.	To limit how and where people can camp and where they can drive.
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Part B: What data is needed?

Directions: Using your Progress Tracker, answer the questions about the types of data your group would find useful to evaluate the conservation plan.

1. What types of data helped us evaluate the conservation plan to protect the wildebeest migration by creating Serengeti National Park?

When evaluating Serengeti National Park, we first needed to understand that the park's goal was to protect the wildebeest migration. We looked at how the wildebeest population changed over time. Then we had to look at the different ecosystem interactions to see how different organisms rely on each other. We used this information to model how changes in the wildebeest population would impact the rest of the Serengeti.

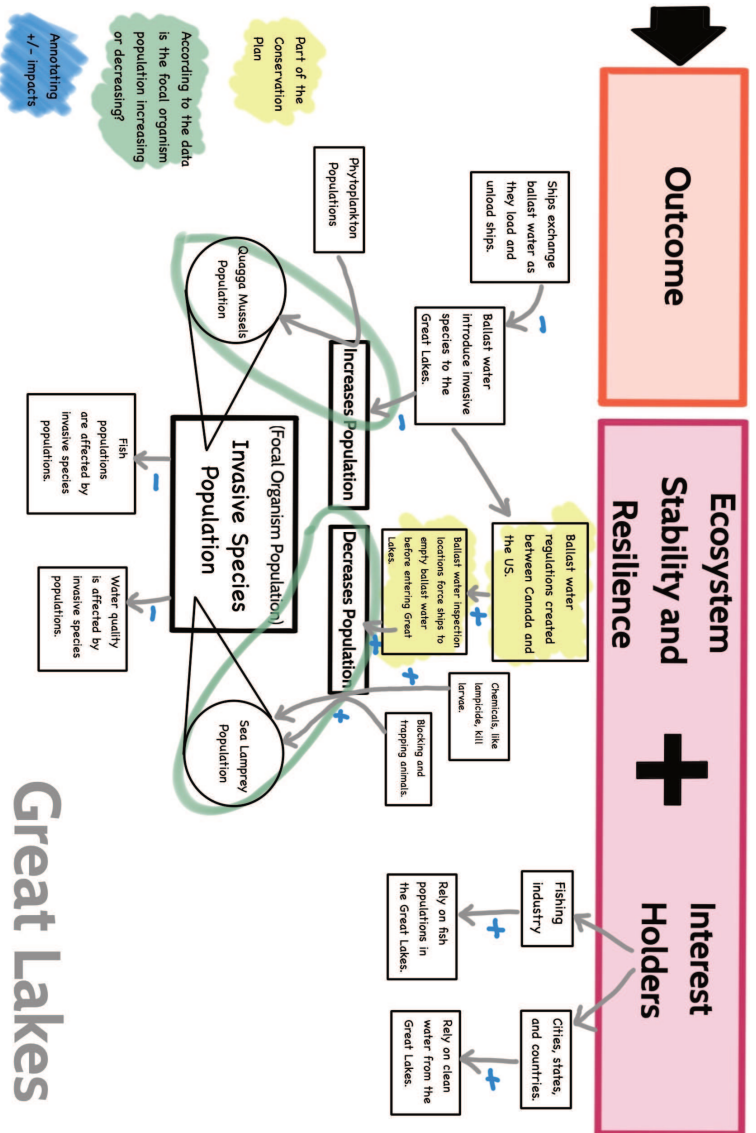
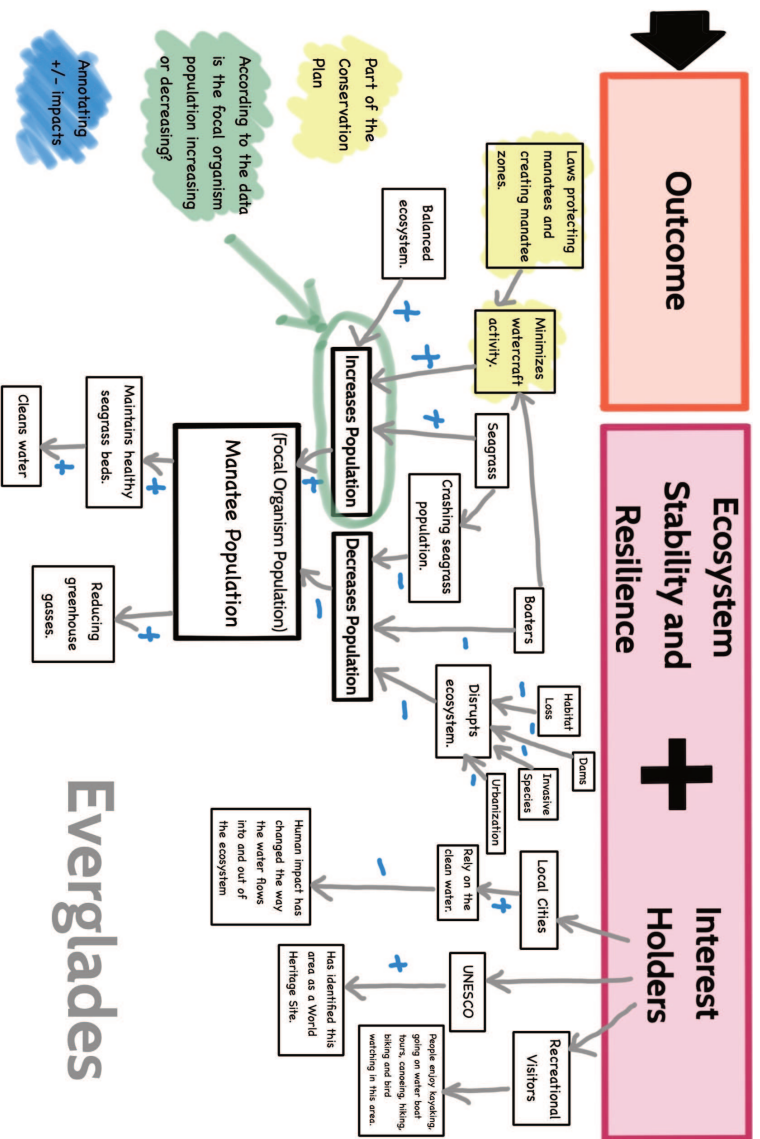
2. What types of data could help evaluate the specific conservation plan from your group's conservation profile?

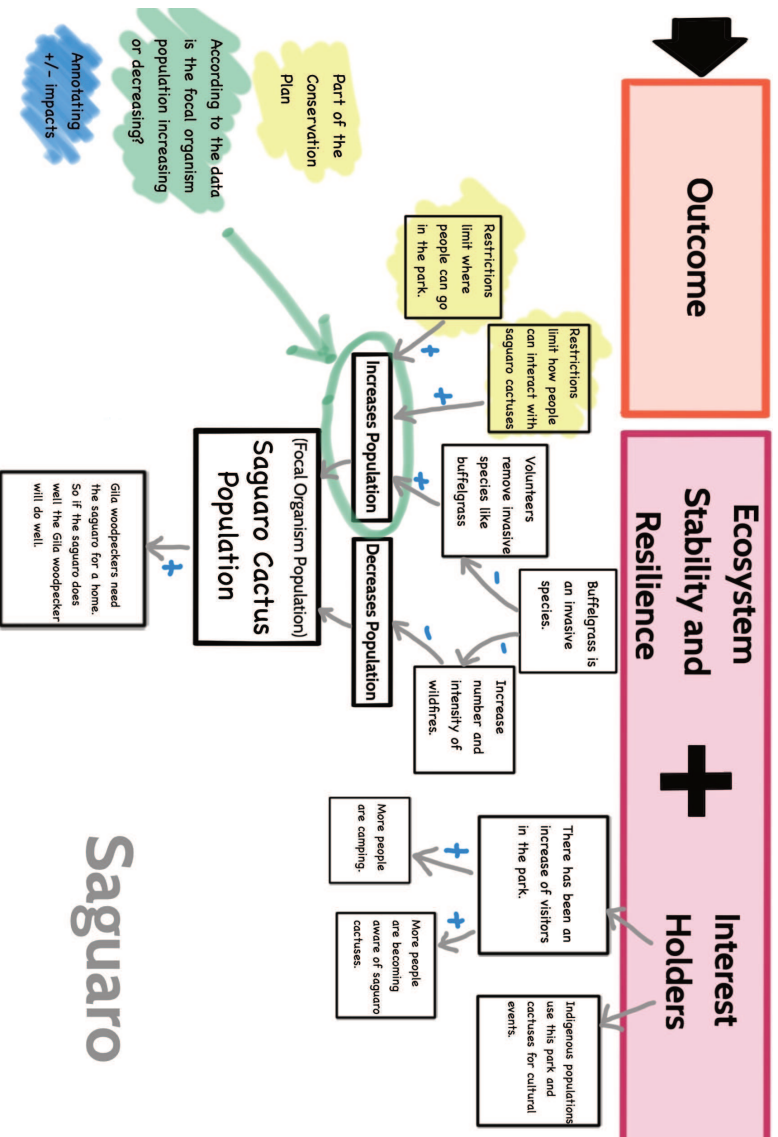
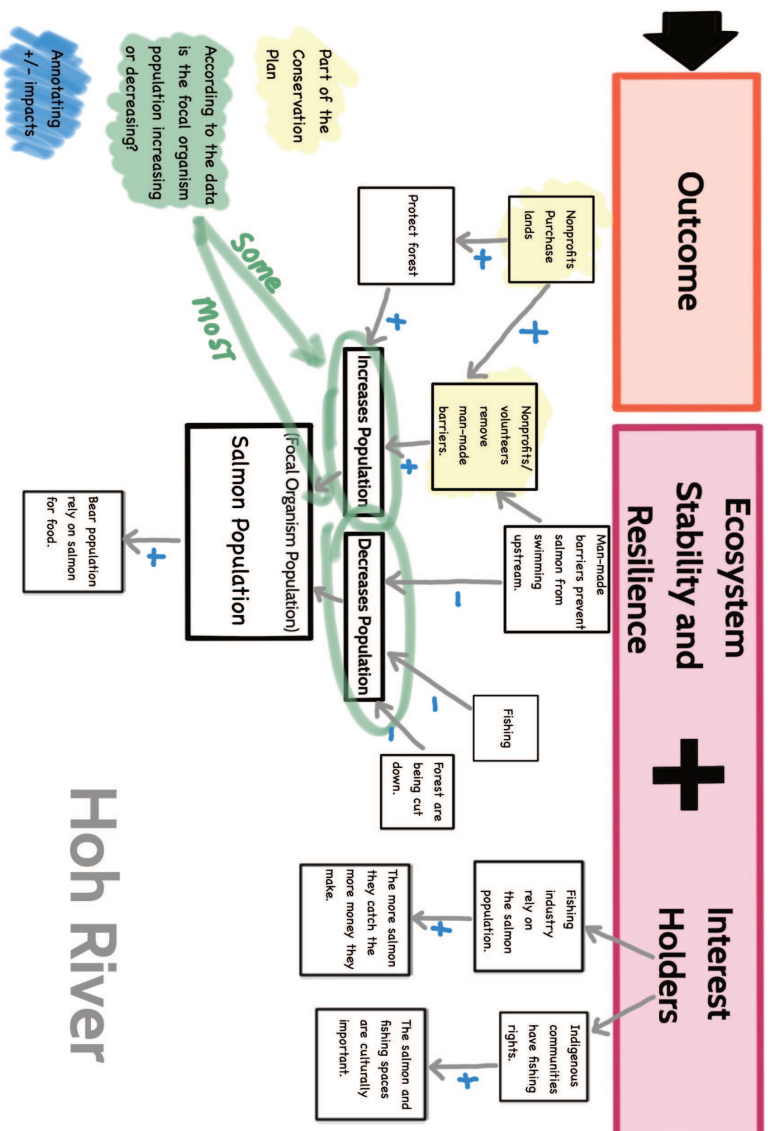
Everglades	Great Lakes	Hoh River	Saguaro
We need population data for manatees and maybe some information about the impact of this on other organisms.	We need information about recent population data for quagga mussels and other invasive species.	We need to look at current salmon population data.	We need to look at saguaro cactus population data today.

Part C: Understanding the Impact of the Conservation Plan

Directions: (1) Write the name of the focal organism population in the corresponding box on the conservation evaluation tool template. (2) Add any organisms from your Lesson 1 model that are affected by the focal organism. (3) Using the information from your section(s), draw under the Ecosystem Stability and Resilience heading different connected impact boxes that increase or decrease the focal organism's population. (4) Add other connected impact boxes under the Interest Holder heading to show how the plan, area, and/or organism impacts different interest holders. (5) After all the impact boxes have been drawn, use a highlighter to show which impact boxes are a part of the conservation plan.

1. What section(s) am I using to build the impact diagram?
Below are models that the whole group might create once they combine all their sections.





Part D: Evaluating the Conservation Plan

Directions: Answer the following questions using your groups combined annotated impact diagram to evaluate the conservation plan.

1. Does data show that the conservation goal was met? Explain.

Everglades	Great Lakes	Hoh River	Saguaro
Yes, there was evidence that the manatee population increased.	No, invasive species that are already in the Great Lakes are still a problem.	Not really. While some salmon species are doing better, most salmon species are still declining.	Yes, because there was evidence that the saguaro cactus population increased.

2. Would you describe this conservation plan as successful? Explain.

Everglades	Great Lakes	Hoh River	Saguaro
Yes, because the manatee population increased, and their recovery helps the rest of the ecosystem.	Not really. While the rate of introducing new invasive species has decreased, invasive species that are in the Great Lakes are increasing.	Not really. While some salmon species are doing better, most salmon species are still declining.	Yes, because the saguaro cactus population has increased, and their recovery helps the rest of the ecosystem.

3. How does the overall conservation plan impact the ecosystem's stability and resilience?

Everglades	Great Lakes	Hoh River	Saguaro
This conservation plan helps protect manatees that help manage seagrass beds, which are important for cleaning the water and as nurseries for fish.	This conservation plan tries to protect the ecosystem by limiting disruptions caused by invasive species.	This conservation plan tries to protect the ecosystem by making sure that salmon populations are able to have access to the entire Hoh River, providing food and nourishment to bears and trees.	The conservation plan protects Saguaro cactuses, which also provide food and shelter to a number of other organisms.

Lesson 11: Answer Key

Prairie Task Key

This task is aligned to NGSS PE HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

3D Elements Addressed in this Assessment				
SEPs	6.5 Construction Explanations and Designing Solutions Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.			
DCIs	LS2.C.2 Moreover, anthropogenic changes (induced by human activity) 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.	X	X	
	LS4.D.2 Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.	X	X	X
	ETS1.B.1 When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts.		X	X
CCCs	7.1 Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.	X	X	X

In North America, the prairie ecosystem used to exist across much of the United States from the Mississippi River to the Rocky Mountains. The prairie is composed of grasslands with few trees.

Great Plains Prairie Ecosystem (before white settlement) Prairie

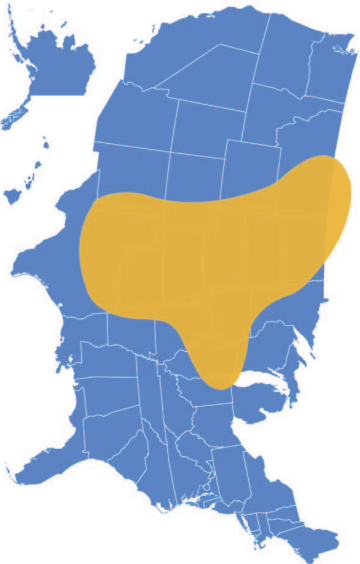


Figure 1. Historical range of prairie in the United States. Zntrip, GPL

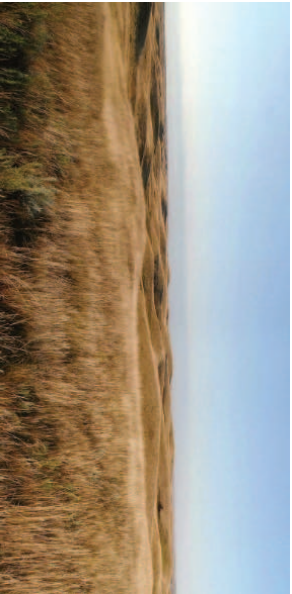


Figure 2. The North American Prairie. Rick Bohn, CC BY-NC-SA 2.0

Prairies have moderate rainfall and temperature and provide habitat for many birds, insects, mammals, reptiles, and plants. The Homestead Act of 1862 gave many Euro-Americans an opportunity to own land that was, until that point, the ancestral land of many Native American nations. The new landowners converted the land to agricultural use in farming or ranching. Today, most of the historical prairie has been converted to agriculture use for grazing livestock and growing crops.

The prairie ecosystem is a critical habitat for many organisms. It has fertile soil and provides filtration for water as it moves underground. It serves as the traditional homeland of several Native American nations, and the land provides for their physical and spiritual well-being. Early Euro-Americans who settled in the area engaged in trade with Native Americans and in cattle herding across the open expanse of the Great Plains. Agricultural development of the prairie ecosystem is a major economic activity that provides many jobs as well as food to many Americans. Today, the area also provides recreational opportunities open to many.

In this task, you will investigate:

- factors that affect biodiversity in the prairie.
- human interactions that cause changes in the ecosystem.
- solutions that take into consideration multiple criteria and/or constraints.

The American bison once freely roamed the North American prairie and had a population of about 60 million.

The graph below shows the estimated population of bison from 1800 to present, as well as major events that took place on the Great Plains during that time.



Figure 3. American Bison. Stephen Pribut, CC BY-SA 3.0

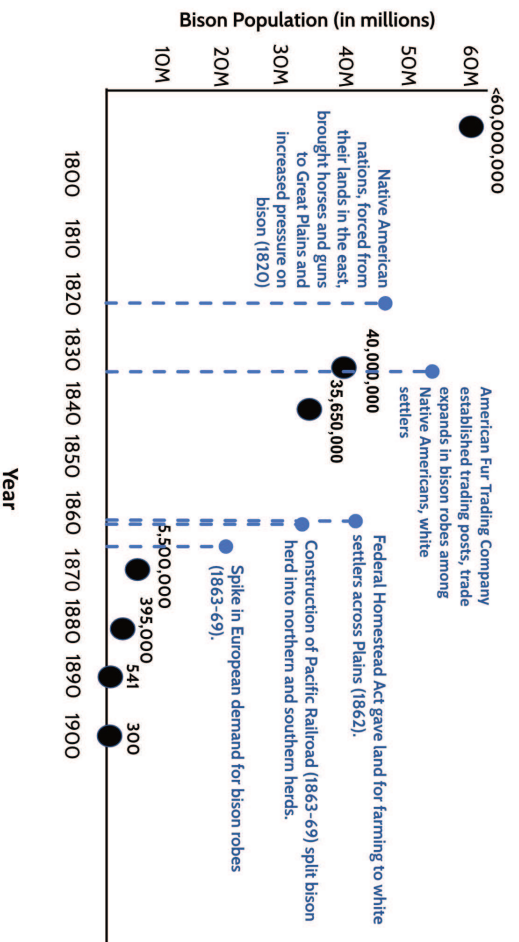


Figure 4. Bison population and key events 1800–1900. Data Source: National Park Service

1. Use your understanding of ecosystems and the graph above to answer the following questions.

A. How did the bison population change between 1800 and 1900?

The bison population decreased dramatically during that time, from above 40,000,000 to 300.

B. Based on the information presented in the graph, what are three ways that human activities may have impacted the bison population?

Native Americans needed bison for food and trade after being removed from their lands, reducing the size of the population.

Increased trade in bison robes led to more hunting.

Grazing and railroads reduced the land available to bison.

2. Scientists have identified the bison as a keystone species in the prairie ecosystem.

A. Review the ecosystem model below that shows some of the interactions in the prairie ecosystem before the bison were removed. **Remember that the red lines are positive relationships and the blue lines are negative relationships.** *For example, if the pronghorn population increases, the coyote population increases.* What do you predict happened to the system when the bison were removed?

If the bison were removed, then there would be more grass. If there were more grass, there would be fewer other kinds of plants. Then there would be fewer of the different kinds of organisms that eat those kinds of plants (elk, prairie dog, rabbits, birds). There would be fewer ferrets, owls and coyotes. There would be more pronghorn and more coyotes. The coyotes might stay the same because they would be affected positively and negatively.

B. Choose two interactions in the model below and explain how you think the components changed without the bison.

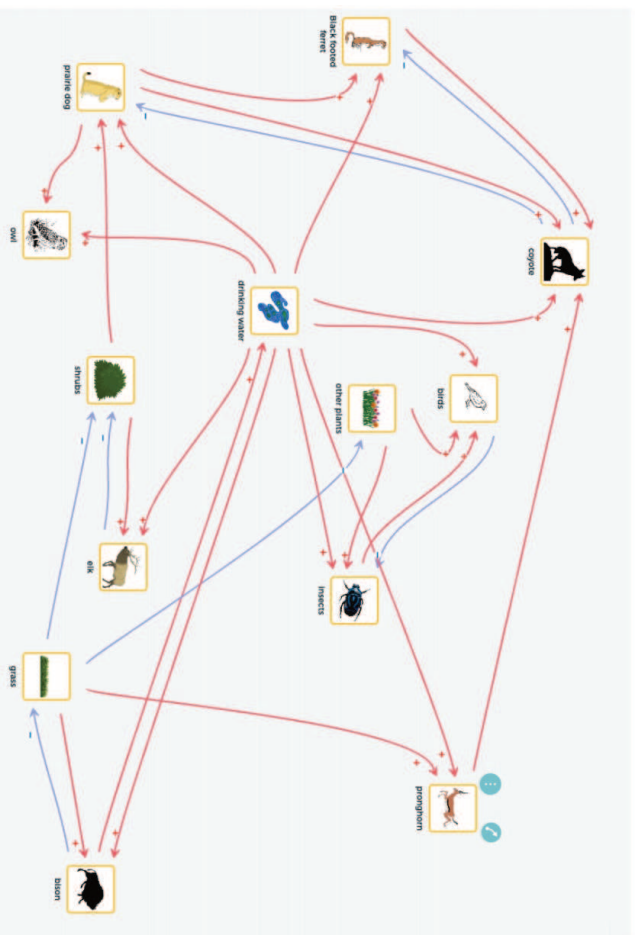


Figure 5. Model of the prairie ecosystem. Images generated using SageModeler (<https://sagemodeler.concord.org/>), developed at the Concord Consortium and Michigan State University.

1. If the bison were removed, there would be more grass, and more grass would mean fewer “other plants” and less for all the animals that eat them.
2. If the bison were removed, there would be fewer insects that live in the shrubs and flowers, so there would be fewer birds.
3. If the bison were removed, the soil wouldn’t get compacted and hold water. Less water would support fewer animals in the system. Fewer dead bison would make the plants less nutritious.
4. If the bison were removed, there would be fewer plants, and that would mean fewer prairie dogs and the animals that eat them (ferrets) and the animals that burrow in their holes.
3. Many scientists believe that maintaining and increasing biodiversity is an important part of conserving ecosystems. Since data from the 1800s is not readily available, scientists have investigated how bison affect biodiversity by studying similar areas in the prairie with and without bison. One group of scientists studied the kinds of plants present in areas with and without bison. The graph below highlights some of their findings. Forbs and shrubs are different kinds of plants.



Figure 6. Average cover of plant types with and without bison. Data Source: Elson & Hartnett (2017)

What do you notice about grass in areas with in and without bison?
There is less grass in areas with bison.

What could account for the difference?
Bison eat the grass.

What do you notice about other kinds of plants in areas with and without bison?
There are more types of plants in areas with bison.

What could account for the difference?
Less grass makes room for more of the other kinds of plants.

Based on the data, scientists predict that the biodiversity of herbivores (animals that eat plants) will be higher when bison are present. What reasoning would explain this prediction? Use data from the model and the graph to support your answer.

The data shows that there are more different kinds of plants. The model shows that many birds, insects, and mammals eat those plants. If there are more plants, the system can support more of the animals that eat them. If there are more different kinds of plants, there will be greater biodiversity.

4. A conservation plan called the American Prairie Reserve is an effort to preserve and restore American prairie in Montana. The goal is to bring together 3.2 million acres of land by working with public, private, and Indigenous interest holders. By adding additional protected lands, this conservation plan has the potential to contribute to the goals of the 30 by 30 Initiative.

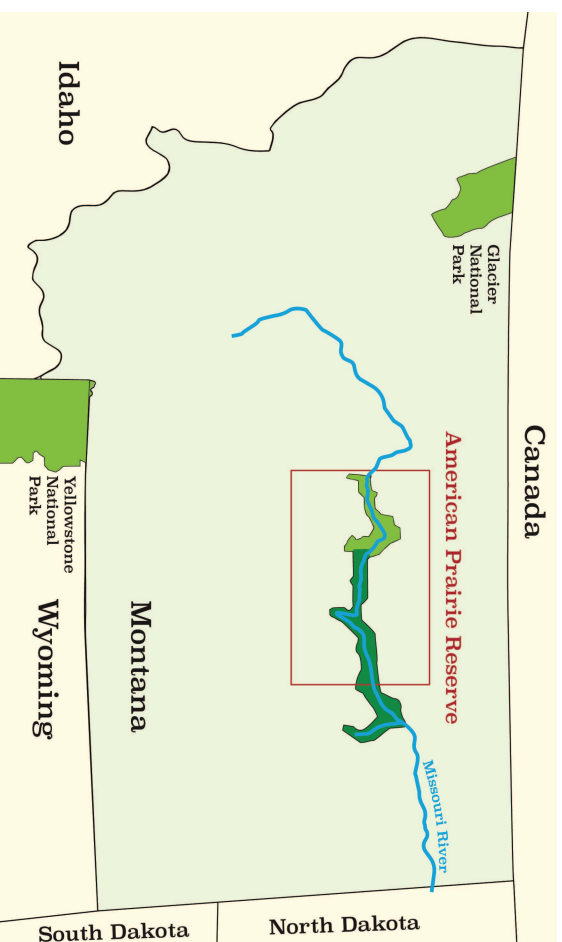


Figure 7. American Prairie Reserve map. Data Source: American Prairie Reserve

The figure (above) shows the American Prairie Reserve in Montana. The lands that the reserve wants to connect include the following:

- Land that has been leased or bought by the reserve
- Indian reservations
- National monuments
- National wildlife refuges
- Bureau of and management and other public land
- Private land

Some of the lands are connected to each other, while others are disconnected. When the reserve buys private land to connect lands, bison will graze on the public land. This can put them in competition with cattle. The law gives ranchers the right to allow cattle to feed and roam freely and graze on public lands.

Ranching has a long history in the area. Indigenous people in the area have a deep connection to bison, which provide and care for people through food, shelter, clothing, tools, and cultural teachings.

How might each of those interest holders – ranchers and Native Americans – view the priorities and strategies of the American Prairie Reserve?

	Priority(ies) Valued	Support or Opposition to Strategies
Ranchers	Value protecting area and the historic value of ranching as a part of the landscape.	Likely oppose the restriction on grazing lands, since this limits the number of cattle they can raise. Fencing removal might harm cattle as well, who are threatened by bison.
Native Americans	Value creating large enough areas to sustain bison.	Likely supports the strategy of removing fences to allow for more bison.
Residents and Tourists	Value the open space for fishing, wildlife, hunting. Residents value individual property rights.	Some who value nature might support the reserve. Some that value private ownership may oppose it.

5. Considering evidence from the model of the ecosystem and the priorities of different groups, how does the conservation plan--to buy private land and connect to private and public land--address the priorities of the different interest holder groups. What compromises (trade-offs) will they have to make if the plan moves forward?

	How does it address priorities?	What compromises will they have to make?
Ranchers	The bison will compete with the cattle, so it will not address their priorities to raise cattle to earn money.	They will have to give up some of the cattle grazing grass and money they earn for the bison increasing biodiversity and the health of the ecosystem.
Native Americans	The area will sustain bison and allow for cultural connection.	They may compromise cultural traditions to allow the ranchers to graze cattle.
Residents and Tourists	If addresses preserving nature for its beauty.	Residents might give up private land ownership
American Prairie Reserve	They will connect lands and add more space to the reserve.	They will compromise with the ranchers and have fewer bison so there can also be cattle.

Their solutions are likely to meet the shared priorities of Native Americans and the American Prairie Reserve for creating an area large enough to sustain a bison population and the shared priorities of ranchers and the foundation for preserving landscapes of historical value. However, the solution of limiting grazing is likely to not meet all the needs of the ranchers.

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	Identifies criteria for each interest holder. Considers one or more constraints. Includes short- or long-term outcomes. Sample student responses: Ranchers: Care about the grazing cattle for financial reasons. Native Americans: Care about cultural connections. Reserve: Care about making more land OR care about biodiversity/ecosystem resilience.	Identifies criteria for each interest holder and connects to their priorities. Considers one or more constraints and connects to the appropriate interest holder. Includes short- or long-term outcomes connected to interest holder priorities. Sample student responses: Ranchers: The bison will compete with the cattle. They will lose money from cattle sales OR there will be conflict between conservation and the ranchers. Native Americans: The area will sustain bison OR allow for cultural connection, which addresses some of their priorities. This may allow for future collaboration. Reserve: Their priority of adding more conservation land will be addressed. In the long term, this should increase biodiversity OR ecosystem resilience.	Identifies criteria for each interest holder and connects to their priorities. Consider a range of constraints such as cost, cultural connections, inspirational value, biodiversity, and/or system resilience and connects to the appropriate interest holder. Includes short- and long-term outcomes connected to interest holder priorities. Sample student responses: Ranchers: The bison will compete with the cattle, which will be in conflict with their priority of earning money from cattle sales. This could cause long-term conflict between conservation and the ranchers. Native Americans: The area will sustain bison and allow for cultural connection, which addresses some of their priorities. This may allow for future collaboration. Reserve: Their priority of adding more conservation land will be addressed. In the long term, this should increase biodiversity and ecosystem resilience.

Feedback/ What to Do	<i>To revise toward Linking:</i>	<i>To revise toward Organizing:</i>	<i>To revise toward Extending:</i>
	How will the new reserve land impact the ranchers' ability to make money?	What will happen if the ranchers are unhappy with the reserve?	How can the plan support improved relations between the reserve and the ranchers?

6. To meet the goals of the 30 by 30 Initiative to conserve more land and water, what recommendation would you make about whether or not connecting private and public land is a good solution?

Reserve:

Answers will vary by should be supported by evidence.

For example:

Yes it is a good solution my evidence

References

Anna Elson, David C. Hartnett "Bison Increase the Growth and Reproduction of Forbs in Tallgrass Prairie," The American Midland Naturalist, 178(2), 245–259, (1 October 2017).

Name: _____

Date: _____

Lesson 11: Answer Key 2

Progress Tracker Key

Driving Question
How do ecosystems work, and how can understanding them help us protect them?

	What did I figure out about the Serengeti?	What in my profile connects to ideas we figured out about the Serengeti?	What information do I need/ questions do I have about how to protect ecosystems?
Lesson 2 Why was the Serengeti protected?	The Serengeti is diverse. The park and reserves protect wildebeest on their migration. Conservation area boundaries changed because humans wanted to use the ecosystem for a variety of purposes. The park boundaries changed because the Maasai had been excluded from their land.	The Everglades is diverse and has endangered species, like the alligator, manatee, wood stork, and Florida panther. The Everglades was protected because it provides fresh drinking water to people.	Why do animals like the wildebeest migrate? What animals migrate in the Everglades? What happened to the Indigenous people who used to live in the Everglades?

Lesson 5 How does food affect the population size?	Wildebeest populations can have very large carrying capacities because food does not become a limiting factor when they migrate and make food available all year round.	Everglades: There are a certain number of alligators that the ecosystem can support. Due to human hunting and habitat destruction, the alligator population was below carrying capacity. Now it is protected, and the population has increased. Saguaro: Saguaro grow really slowly and need nurse trees for protection as they grow. Saguaro also needs to have rain to get big. Hoh: The conservation area protects the salmon migration. The river has a certain carrying capacity for salmon, but human factors reduce the number of salmon living there by adding dams etc. Lake Michigan: Quagga mussel population grew at a high rate after being introduced to Lake Michigan because they had a lot of phytoplankton to eat and few predators.	What (other) limiting factors exist in my profile? Are there other limiting factors for the wildebeest? What are the factors that affect carrying capacity in _____ system? What are the limiting factors for ____?
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Lesson 8 What happens to the rest of the ecosystem?	Wildebeest are a keystone species in the Serengeti because their population is important to many other components. The Serengeti is biodiverse because there are so many species in the Serengeti that need different things to survive or parts of things. The ecosystem is resilient to disturbances (like drought, fire, or disease) because of that biodiversity.	Everglades: Alligators might be a keystone species because they seem to be connected to many other components in the system. I am not sure how resilient the Everglades are since it seems like water is important here, and I am not sure how resilient the system would be if the water amount or quality went down. Saguaro: The saguaro cactus is probably the keystone species. If it is gone, then a lot of organisms might lose their homes. Protecting the cactus probably makes the system more biodiverse and more resilient. Hoh: The salmon are really important in the river, and they affect a lot of other organisms. Protecting them makes the system more resilient. Lake Michigan: Quagga mussels and other invasive species disturb the ecosystem. They may make it unstable and make the fish population less stable.	How are humans impacting the Serengeti? If we are trying to protect biodiversity because it makes ecosystems more resilient, what impact are humans having? How are humans impacting our conservation profile? I wonder if _____ is the keystone species in my conservation profile.
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