Woolly Mammoth - Teacher Materials

Unit 6	Biology

The Curriculum and Instruction Department at New Visions for Public Schools develops free, full-course materials for all areas of high school science, math, ELA, and social studies, for use across our network of 80 New York City schools and beyond.

Unit 6 Woolly Mammoth

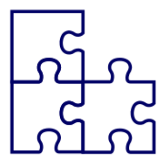
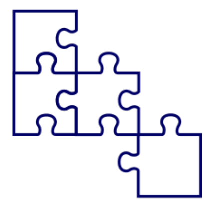
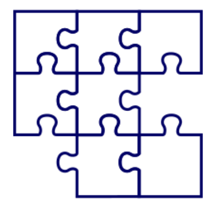
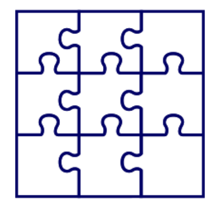
Ecology and Human Impact

Performance Expectations
HS-LS2-7, HS-LS4-6, HS-LS2-2, HS-LS2-5, HS-LS2-6

Time
27-33 days

What caused the woolly mammoth to go extinct? Should we bring the woolly mammoth back?

How can we develop claims about the extinction of species long ago, based on findings in current ecosystems affected by human actions? Human population growth, globalization, and industrialization are having profound impacts on the long term health and stability of ecosystems, permanently altering the products of billions of years of evolutionary history on planet Earth. After raising questions about the extinction of the woolly mammoth, students investigate how humans have altered ecosystems and what actions may be taken to preserve biodiversity. Students create models throughout the unit and utilize simulations to gain a deeper understanding of large scale geological and biological processes through a set of case studies that highlight the decline of three key species. Finally, students use their learning to evaluate several claims about causes for the extinction of the woolly mammoth, and evaluate a scientific argument about whether we should invest resources in bringing the mammoth back from extinction as a solution to human-caused biodiversity loss.

Unit Opening	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Anchor Phenomenon	→	**5E Lessons connect learning to the performance task**		→	**Performance Task**
					
What is the story of woolly mammoth extinction? What types of information do we need to know in order to evaluate the cause of a species' extinction?	*Why are there more tuskless elephants now than in the past?*	*How can we understand the causes and potential impacts of climate change?*	*How do all of the components of an ecosystem interact to provide resiliency against a disturbance?*	*How can we evaluate solutions to human-caused biodiversity loss?*	*How can we evaluate the argument that bringing back the woolly mammoth from extinction is a viable solution to biodiversity loss?*

Unit Introduction

How do we make science education meaningful and relevant to our students? High school biology courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help all students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through evaluating claims using evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

Evaluating solutions to real-word problems is an essential 21st century skill, and through this unit students deepen their understanding of the importance of engaging with problems and argumentation in science. This unit builds intentionally on earlier units in terms of problem-solving and arguing from evidence. Students first generated a scientific argument in Unit 2, Humans vs Bacteria, and then designed solutions to complex real-life problems in Unit 3, Evolution of Sick Humans. In Unit 5, Food for All, students are considering different local innovations that may serve as solutions to the lack of healthy and fresh foods in many communities. In this unit, students are evaluating a potential solution to human-caused biodiversity loss through the de-extinction of extinct organisms such as the woolly mammoth.

This unit was also intentionally designed to build on earlier units that engaged students in the development, use, and revision of models. Students are first introduced to the development and use of models in the first unit of this course, Marathon Runner. The use of models is woven throughout every unit of the course, especially in Unit 3, in which students use models to represent why some people are unable to digest dairy products in adulthood.

The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to figure out why woolly mammoths went extinct by evaluating claims and evidence, and if we should bring back organisms from extinction in order to address biodiversity loss. In this unit, students are introduced to several case studies of key stone species that are under threat due to human disturbances. Students apply what they learned about endangered organisms, such as elephants, to explaining the possible causes of the extinction of the woolly mammoth and to consider the ecological implications of the reintroduction of extinct megafauna.

As the final unit in the course, students have multiple opportunities to revisit and review important disciplinary core ideas. For example, students are encouraged to apply what they learned about feedback mechanisms and dynamic equilibrium in the human body from Unit 1, Marathon Runner to the complex interactions within an ecosystem to maintain stability. Natural selection from Unit 2 is reviewed in this unit, as students figure out that selective pressure from human hunting has dramatically changed elephant populations. Students make new connections about the use of biotechnology and genetic diversity in this unit based on their understanding of genetics and reproduction in Units 3 and 4. Finally, students use their understanding of photosynthesis from unit 5, Food for All, to generate a model of the carbon cycle as they consider the implications of human-caused climate change.

The embedded group learning routines and formative assessments found in each of the Biology units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior to high school, or if three-dimensional teaching and learning is brand new to them (or to the teacher!). This unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 6, the overall question on if we should bring back the charismatic woolly mammoth is intended to motivate student engagement across the unit. It is our intention that from the students' perspective, there is a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop four coherent learning sequences within Unit 6. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question about why the mammoths went extinct, and if we should bring them back. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 6.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in *A Framework for K-12 Science Education* and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (four in this unit) • Presented in the Engage phase of each 5E

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else's experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Solving Problems

One of the major NGSS shifts is integrating engineering into science instruction. Defining problems and developing and optimizing solutions are critical components of engaging in addressing significant global and social problems within an NGSS-designed high school science course. After being presented with the unit anchor phenomena, students are naturally inclined to want to do something about it - and thus students' investigations across a unit are also motivated by the desire to solve the related problem. This engineering thread is intertwined with the anchor phenomenon as the science figured out is useful in arguing for a causal explanation of the phenomenon *and* figuring out a solution.

Storyline and Pacing Guide

Unit Opening				
	What is the story of woolly mammoth extinction? What types of information do we need to know in order to evaluate the cause of a species' extinction?	**Performance Expectations**	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 2 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. ● Why don't we see woolly mammoths today? ● What role did early humans play in causing the extinction of the woolly mammoth? ● How did climate change impact the ecosystem of the woolly mammoth? ● What can we learn about the woolly mammoth extinction event that can help us conserve	Students begin the unit by reviewing a series of visual texts and a video about woolly mammoth extinction, then discussing trends in those graphics. Through this discussion, students "tell the story" of this anchor phenomenon and ask questions related to figuring out what happened to cause the woolly mammoth to become extinct and what they might investigate.	*These ideas are revisited throughout the unit storyline.* ● Woolly mammoths, relatives of today's elephants, are extinct. ● There may be many contributing factors that led to their extinction, including climate change and human exploitation. ● We can use ideas surfaced about the extinction of the woolly mammoth to think about why other species are endangered and how we could conserve

Student Questions	What Students Do	Student Ideas
biodiversity today? • Should we consider using biotechnology to bring the woolly mammoth back from extinction as a solution to biodiversity loss?		them. • Some people think it would be a great idea to bring back the woolly mammoth as a solution to reverse human caused climate change and biodiversity loss.

During the Driving Question Board routine, student questions related to humans possibly hunting mammoths to extinction will surface. Once a category related to these questions has been articulated, let students know that over the next sequences of lessons they will be investigating this question to figure out how overhunting may impact organisms and if there is evidence that connects humans to the extinction of the woolly mammoth.

Tuskless Elephants 5E	Why are there more tuskless elephants now than in the past?	**Performance Expectations** HS-LS4-6, HS-LS2-7	**Investigative Phenomenon** Some elephant populations have more tuskless elephants than has typically been normal.	**Time** 6-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why are the number of tuskless elephants increasing in some populations? • How do human activities such as hunting impact biodiversity? • How can we use the causes behind environmental concerns and biodiversity loss to develop effective solutions? • What types of solutions to environmental and conservation concerns are possible? • How can we design, test, and evaluate solutions for reducing the impacts of human activities on the environment and biodiversity?	Students begin this instructional sequence by engaging with a graph that represents data on the changes in the percentage of tuskless elephants in Gorongosa National Park in Mozambique. In order to investigate the reasons behind this phenomenon, students did deeper into the data to better understand why there has been an increase in tuskless elephants in some populations. This activity leads to questions about how human activities are impacting biodiversity in general and how we may design solutions to mitigate negative impacts on elephants and other endangered organisms. Finally, students use evidence collected throughout the 5E sequence to evaluate a claim about how humans may have over hunted the woolly mammoths, contributing to their extinction.	*Students figure out these ideas in this 5E sequence.* • Pressure from poaching has contributed to the trait of tusklessness increasing • Elephants play an important role in the ecosystem by engineering the environment for other organisms • Human activities such as habitat destruction and hunting cause negative impacts to biodiversity and ecosystems. • Understanding the root causes of environmental problems and biodiversity loss facilitates the development of solutions. • Many organisms are under threat due to unsustainable harvesting by humans. • There are many types of solutions available--technological, social, political, and individual actions • Solutions to environmental and conservation concerns must consider the scale of impact, social and economic impacts, and tradeoffs

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about the ecosystem, food web, or habitats of the woolly mammoth. Tell students that in the next sequence of lessons, they will investigate the role organisms play in maintaining ecosystem resilience.

Coral Bleaching 5E	How can we understand the causes and potential impacts of climate change?	**Performance Expectations** HS-LS2-5, HS-LS2-2	**Investigative Phenomenon** Coral reefs are ejecting their symbiotic algae, a phenomenon called coral bleaching.	**Time** 7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. ● How did climate change impact the woolly mammoths? How did it impact other organisms still alive today? ● What is the greenhouse effect and how does it relate to climate change? ● How will climate change impact biodiversity? ● How do the current changes in climate compare to past changes in Earth's history? ● How do human activities, such as habitat destruction, work alongside climate change to accelerate the loss of biodiversity?	Students begin this instructional sequence by considering a case study on coral bleaching. Questions about this phenomenon lead students into exploring how factors such as warming sea temperatures impact keystone species, such as coral. Students explore the enhanced greenhouse effect through a hands-on simulation in order to surface the role of humans in modern climate change. Students use complex texts and peer discussion to better understand how human induced climate change is impacting ecosystems at different scales.	*Students figure out these ideas in this 5E sequence.* ● Human activity, including burning fossil fuels, increases the amount of carbon in the atmosphere. ● Current climate change is happening at a faster rate than what has been observed in the past, and many organisms may not be able to adapt to deal with these changes in time. ● There is evidence that climate change is impacting species in many ways: shifting their ranges, changing behaviors, and placing stress on vulnerable organisms. ● Greenhouse gasses, such as carbon dioxide, trap heat in the atmosphere. This is the greenhouse effect. ● Increasing atmospheric greenhouse gasses, such as carbon dioxide, trap heat and increases the Earth's temperature -- which in turn changes climate. ● Climate change will have many impacts including shifting climate zones, increasing sea level, and destroying habitats -- these impacts will have a negative impact on biodiversity ● There are a variety of human activities that are negatively impacting ecosystems and species. These activities usually exacerbate stress ecosystems face due to climate change (e.g. habitat destruction may limit migration to cooler regions).

Have students identify which categories/questions they have not addressed yet. One question category should relate to the role the woolly mammoth played in its environment, if the mammoth went extinct because of change in its ecosystem (e.g. loss of a predator), and how to evaluate impacts to the current environment if we reintroduce the mammoth. Tell students that in the next sequence of lessons, they will investigate the role organisms, like the mammoth, play in the stability of ecosystems.

Kelp Forest 5E	How do all of the components of an ecosystem interact to provide resiliency against a disturbance?	**Performance Expectations** HS-LS2-2, HS-LS2-6	**Investigative Phenomenon** Kelp forests and urchin barrens are two stable ecosystems that can be found in the same location. How is that possible?	**Time** 6-7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • How is the carrying capacity of an ecosystem dependent on the biotic and abiotic factors of that system? • How do keystone species contribute to the overall biodiversity and stability of an ecosystem? • How do all of the components of an ecosystem interact to provide resiliency against disturbance? • How do ecosystems recover from both natural and human-caused disturbances? • How can our knowledge of keystone species, ecosystem functioning and resiliency help us be strategic in conservation decisions and in our questions around the de-extinction of the woolly mammoth?	Students begin this instructional sequence by considering a case study on kelp forests and urchin barren ecosystems. Students engage with a map and data set to generate initial claims about the stability of these two ecosystems. Students then generate a model to further investigate how disturbances (both small and extreme) impact ecosystems. Students use their ecosystem models, and a complex text to better understand the roles of keystone species, biodiversity, and the interactions between biotic and abiotic factors, in maintaining stable and resilient ecosystems. Finally, students evaluate claims, evidence, and reasoning on an argument that one ecosystem is more stable or resilient than another.	*Students figure out these ideas in this 5E sequence.* • Complex interactions within an ecosystem serve to maintain stability in population numbers and types of organisms over time • Stable ecosystems can generally recover from modest biological and physical disturbances • Extreme fluctuations in populations or other disturbances can change an ecosystem • Resilient ecosystems are generally biodiverse, have sufficient resources, complex relationships between organisms and between organisms and the environment. • Ecosystems have many different component systems that are interdependent. • Resilient ecosystems are more likely to fully recover from disturbances.

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about the use of biotechnology to bring extinct organisms back from extinction, including the ethical and scientific concerns of de-extinction.

Passenger Pigeon 5E

How can we evaluate solutions to human-caused biodiversity loss?

Performance Expectations
HS-LS2-7, HS-LS2-6

Investigative Phenomenon
Ecosystem loss and organism extinction are critical problems. An organization argues that bringing the passenger pigeon back from extinction will restore ecosystems. Do they have a valid argument to justify de-extinction?

Time
5-6 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. ● What solutions exist for ecosystem collapse? ● Why would scientists and others want to bring back the passenger pigeon? ● What role did humans play in the demise of the passenger pigeon? ● What role did it play in the ecosystem? How did it interact with other components of the ecosystem? ● How would reintroducing it to its habitat impact ecosystem stability and functioning? ● How can we evaluate scientific arguments and/or solutions to problems? ● How can the story of the passenger pigeon help us better understand if we should bring back the woolly mammoth?	Students begin this instructional sequence by learning about the extinction of the passenger pigeon and its relationship to ecosystem instability. Students engage with historical descriptions of the pigeon in order to generate models that represent the role they played in their ecosystem in order to better understand how a solution of de-extinction could benefit this problem, allowing them to critique an argument on bringing them back. Finally, students consider counterclaims and evidence presented in a counter argument that outlines the perspective of some scientists and conservationists that argue de-extinction is not the best solution to biodiversity loss and human impacts on the environment. **Extension** Students may have questions and/or be very interested in the biotechnology tools that scientists are using or developing (like CRISPR) to bring back extinct organisms like the passenger pigeon and the woolly mammoth. Although genetics are not a part of the Unit 6 Performance Expectations, engaging with the concepts of modern genetic engineering is a great way to review **LS3.A Heredity: Inheritance and Variation of Traits**, from Unit 3 and Unit 4. Provide students with HHMI's activity, Building a Paper Model of CRISPR-Cas9	*Students figure out these ideas in this 5E sequence.* ● Human over-exploitation of the passenger pigeon drove it to extinction over a short time scale ● The loss of the passenger pigeon had negative consequences on the environment, biodiversity, and led to the loss of the cultural and inspirational values held by humans ● Passenger pigeons had an important role in engineering their environment by maintaining the composition of the forest ecosystem, creating disturbances, and limiting other species through competition ● De-extinction could play a role in supporting ecosystem health by restoring ecosystem engineer species

Student Questions	What Students Do	Student Ideas
	, or use the diagrams depicting the revival of the passenger pigeon, Passenger Pigeon Project to investigate how scientists plan on using biotechnology bring organisms back from extinction.	

Students have had opportunities to evaluate arguments on the de-extinction of organisms, including examining new evidence and counter-arguments. In the final task, they will apply their learning to revise their woolly mammoth extinction models and create the final argument evaluation.

Unit Closing	How can we evaluate the argument that bringing back the woolly mammoth from extinction is a viable solution to biodiversity loss?	**Performance Expectations** HS-LS2-6, HS-LS2-7	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 1-3 days

Student Questions	What Students Do	Student Ideas
These questions are addressed in the performance task. • What were the causes behind the extinction of the woolly mammoth? • Should we use resources to bring back the mammoth as a way to address human caused biodiversity loss? • How might the reintroduction of the woolly mammoth address human-caused climate change? • What are some of the challenges, including the possible disruption of ecosystems, in bringing extinct organisms back?	Students revisit and revise their earlier work generating an extinction model and evaluating an argument. **Extension** At the end of the performance task, students can engage in a Socratic Seminar to discuss their critique of the argument on bringing the woolly mammoth back as a solution to biodiversity loss.	*These ideas were developed throughout the unit storyline.* • Complex interactions maintain stable ecosystems • Resilient ecosystems are able to return to their original state after modest biological or human caused disturbances • Extreme fluctuations in populations or major physical disturbances can disrupt ecosystem stability • Humans are causing disruptions to ecosystem stability and biodiversity loss through a variety of actions including habitat destruction and over-hunting • Human caused climate change is a disruption of the carbon cycle due to combustion of fossil fuels and other activities • Humans depend on ecosystem functioning and biodiversity for many reasons including recreational and aesthetics • Solutions to human caused disruptions should evaluated

Based on all of the evidence and scientific reasoning generated in this unit, students generate a model that represents the causes behind the extinction of the woolly mammoth and evaluate the argument that bringing back the woolly mammoth is a viable solution to the human-caused loss of biodiversity.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

HS-LS2-7 * **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.**
Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.
Assessment Boundary: None

In NYS the following has been added to the clarification statement: Examples of solutions could include simulations, product development, technological innovations, and/or legislation.

HS-LS4-6 * **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.**
Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
Assessment Boundary: None

This PE is not included in the NYSSLS.

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.**
Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.
Assessment Boundary: Assessment is limited to provided data.

HS-LS2-5 **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.**
Clarification Statement: Examples of models could include simulations and mathematical models.
Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.

In NYS the PE and clarification statement have been edited as follows: Develop a model to illustrate the role of various processes in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations, diagrams, and mathematical models of the carbon cycle (photosynthesis, respiration, decomposition, and combustion].

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.**

Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Examples of changes in ecosystem conditions could include ecological succession, modest biological or physical changes, such as moderate hunting or seasonal floods; and extreme changes, such as volcanic eruption or sea level rise.

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

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Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school biology, Unit 6 focuses primarily on ideas related to ecosystem stability, human impact on the environment, and the carbon cycle as it relates to human-caused climate change. These ideas fall mostly within Core Idea LS2 of the NGSS/NYSSLS Ecosystem Dynamics, Functioning. This unit also reinforces the SEP of Engaging in Argument from Evidence and the SEP of Developing and Using Models. That is not to say that students will not engage in other SEPs throughout the lessons; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! Similarly, the foregrounded CCC for this unit is Stability and Change, which fits well with our selected DCI. As students deepen their understanding of the content to understand how and why human actions are impacting ecosystems and biodiversity, they learn how to use multiple lines of evidence to make causal claims and evaluate arguments. Scaffolding across the unit supports students' three-dimensional learning and will help shift classrooms to become more NGSS-aligned spaces.

Three Dimensions in Unit 6

This chart is a high-level summary of the standards for Unit 6. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence	ETS1.B Developing Possible Solutions	Cause and Effect

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions	LS2.A Interdependent Relationships in Ecosystems LS2.B Cycles of Matter and Energy Transfer in Ecosystems LS2.C Ecosystem Dynamics, Functioning, and Resilience LS4.C Adaptation LS4.D Biodiversity and Humans	Scale, Proportion, and Quantity Systems and Systems Models Stability and Change

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Science and Engineering Practices from Middle School

Developing and Using Models
- Students in middle school have previous experience using and developing models, based on evidence, to illustrate relationships and to make predictions about a phenomena. This unit builds on this practice, providing students with multiple opportunities to use, develop, and revise models based on evidence to represent complex systems and relationships between components of the system or between systems.

Construction Explanations and Designing Solutions
- Students in middle school have previous experience constructing or implementing a solution based on criteria and tradeoffs. This unit builds on this practice prompting students to design, evaluate, and refine a solution to a complex real-world problem.

Engaging in Argument from Evidence
- In middle school, students have previous experience constructing arguments supported by evidence and reasoning, as well as evaluating competing design solutions. This unit builds on the practice of Engaging in Argument from Evidence through evaluating the strengths and weaknesses of a scientific argument. Students have the opportunity to identify and evaluate the claims, evidence, and reasoning of a presented solution.

Disciplinary Core Ideas from Middle School

LS2.C Ecosystem Dynamics, Functioning, and Resilience

- In middle school, students learn that ecosystems are dynamic and that changes in an ecosystem result in changes in populations. In high school, they examine the idea of resilience and how ecosystems can shift and change based on disturbances; becoming a different ecosystem. In this unit, students engage in multiple opportunities to closely examine how ecosystems work, and the conditions that can contribute to resilience, or the ability of an ecosystem to bounce back after a disturbance.

Crosscutting Concepts from Middle School

Stability and Change

This unit builds on the following aspects of Stability and Change in middle school.

- Students in middle school learn that we can examine the forces that change the stability of systems over time. This unit builds on this understanding by engaging students in multiple opportunities to use the concept of stability of change to better understand and explain how ecosystems function.

Scale, Proportion, and Quantity

This unit builds on the following aspects of Scale, Proportion, and Quantity in middle school.

- Middle school students learn that proportional relationships are helpful in understanding phenomena and that models are useful in representing relationships at different scales. In this unit, students build on these ideas in order to consider how the concept of orders of magnitude can be supportive of understanding how models relate to one another at different scales. Students are developing and using models at different scales (from the individual level, to the ecosystem, to the ocean biome) to make sense of a phenomenon.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 6 targets a bundle of four PEs taken from the second core idea in high school life science (HS-LS), *Ecosystem Dynamics, Functioning, and Resilience*; those standards are HS-LS2-2, HS-LS2-5, HS-LS2-6, and HS-LS2-7. We have also included HS-LS4-6, as it relates to solutions designed to mitigate adverse impacts of human activity. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learning goals informed by the bundled PEs for the unit. All other evidence of learning related to the other dimensions/elements in the PEs can be found within the instructional sequences.

There are two primary foregrounded practices for this unit, the SEP of Engaging in Argument from Evidence and the SEP of Developing and Using Models. Providing students with claims to evaluate is a scaffold. Ideally students will generate their own claims for the performance task. Based on students' needs, teachers can move forward with all claims provided, can modify them to better align with student-generated claims, or use entirely student-generated claims, keeping in mind the other instructional goals for the unit. However, as this is the last unit of the course, there are much fewer scaffolds to support student use of the Science and Engineering Practices than found in earlier units.

The **Teacher Materials** for each 5E instructional sequence includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence. Each 5E addresses the integration of the three dimensions across the activities. Please keep in mind that

Explore/Explain phases in the matrix should be looked at together, as a continuous experience to assess the foregrounded three-dimensional learning goals across the two phases.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual days of instruction. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts are assessed throughout the unit:

	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E
Engaging in Argument from Evidence		✔	✔	✔
Developing and Using Models	✔	✔	✔	✔
Using Mathematics and Computational Thinking	✔	✔	✔	
Constructing Explanations and Designing Solutions	✔			
ETS1.B Developing Possible Solutions	✔			✔
LS2.A Interdependent Relationships in Ecosystems			✔	
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		✔		
LS2.C Ecosystem Dynamics, Functioning, and Resilience	✔	✔	✔	✔
LS4.C Adaptation	✔	✔		
LS4.D Biodiversity and Humans	✔	✔		✔

	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E
Cause and Effect	✔	✔	✔	
Scale, Proportion, and Quantity		✔	✔	
Systems and Systems Models	✔	✔	✔	
Stability and Change	✔	✔	✔	✔

At the end of the unit, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 6 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (Mathematics)

Standards for Mathematical Practice

MP2 Reason abstractly and quantitatively.	Mathematically proficient students make sense of the quantities and their relationships in problem situations. Students bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
MP3 Construct viable	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate

arguments and critique the reasoning of others.	them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.
MP4 Model with mathematics.	Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

Common Core State Standards (ELA/Literacy)

Speaking and Listening Standards

SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Reading Standards for Literacy in Science and Technical Subjects

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.
RST.9-10.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.
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.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects

WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
WHST.9-10.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 6

This unit is designed to be the sixth and final unit of the Biology course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student "gets it," with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it's a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units every year!

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Class Consensus Discussion		1	1	1	1	

	Unit Opening	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Consensus Building Share	1	2		1	1	
Domino Discover		2	3	3	2	
Idea Carousel			1	1		
Read-Generate-Sort-Solve			1		1	
Rumors		1	1			
Think-Talk-Open Exchange				1	1	

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Chunking Text			1		1	
Partner Reading			1			
Text Annotation	1	1			1	

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Tuskless Elephants 5E	Eco Ocean an Overfishing Simulation	https://www.ecoocean.de/play-online/	NA	NA

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Coral Bleaching 5E	Annenberg Learner Interactive Carbon Cycle Lab	https://test-learnermedia.pantheonsite.io/wp-content/interactive/envsci/carbon/carbon.html	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	Ice Age 2- Mammoths	https://www.youtube.com/watch?v=vlv5lqFYs1s&t=7s	NA	NA
Unit Opening	Amazing Life Mammoths of The Ice Age Discovery Documentary	https://www.youtube.com/watch?v=Pna2A8tKFfg	NA	NA
Tuskless Elephants 5E	The Great Elephant Census	https://www.biointeractive.org/classroom-resources/great-elephant-census	NA	NA
Tuskless Elephants 5E	Selection for Tuskless Elephants	https://www.biointeractive.org/classroom-resources/selection-tuskless-elephants	NA	NA
Tuskless Elephants 5E	Appetite for Destruction: Eating Bluefin Tuna Into Extinction	https://www.youtube.com/watch?v=hivvTo6VSS8	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Coral Bleaching 5E	Introduction to a Coral Reef (optional stop at 2:30)	https://www.youtube.com/watch?v=J2BKd5e15Jc	NA	NA
Coral Bleaching 5E	Timelapse Video of Coral Bleaching	https://www.youtube.com/watch?v=bFdPmiwZzVE	NA	NA
Coral Bleaching 5E	HHMI BioInteractive: Coral Bleaching Animation	https://www.youtube.com/watch?v=_ZfGIKiSwwQ	NA	NA
Coral Bleaching 5E	Where Does Carbon Dioxide Come From?	https://www.youtube.com/watch?v=bpazvRVh4y0	NA	NA
Coral Bleaching 5E	What Is the Greenhouse Effect?	https://www.youtube.com/watch?v=SN5-DnOHQmE&t=3s	NA	NA
Kelp Forest 5E	Introduction to a Kelp Forest	https://www.youtube.com/watch?v=GcbU4bfkDA4	NA	NA
Kelp Forest 5E	Army of Sea Urchins? (optional)	https://www.youtube.com/watch?v=D3W4OCnHyCs	NA	NA
Kelp Forest 5E	Some Animals Are More Equal than Others: Keystone	https://www.youtube.com/watch?v=hRGg5it5FMI&t=1075s	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
	Species and Trophic Cascades			
Passenger Pigeon 5E	Passenger Pigeon Martha 100 Years Later - Cincinnati Zoo	https://www.youtube.com/watch?v=mvjoc8gwwK8&t=192s	NA	NA
Passenger Pigeon 5E	Extinction Is Not Forever: Reviving the Passenger Pigeon with The Long Now Foundation's Ben Novak	https://www.youtube.com/watch?v=xl919RABEbI	NA	NA
Unit Closing	We Can "Bring Back" The Woolly Mammoth. Should We?	https://www.youtube.com/watch?v=W1GAQLKXZj8	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Tuskless Elephants 5E	Analyzing Data on Tuskless Elephants Investigation Lab minutes: 30 minutes	
Coral Bleaching 5E	Coral Reef Investigation Lab minutes: 30 minutes	

Lesson	Lab	Materials needed (per group)
Coral Bleaching 5E	Carbon Cycle Investigation Lab minutes: 45 minutes	
Kelp Forest 5E	Kelp & Barrens Investigation Lab minutes: 45 minutes	
Passenger Pigeon 5E	Ecology of the Passenger Pigeon Investigation Lab minutes: 45 minutes	

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	❑ Post-it notes ❑ *Woolly Mammoth Scaffolded Question Set*
Tuskless Elephants 5E	❑ Tusked Elephant Image (image of a tusked elephant) ❑ Tuskless Elephant Image (image of a tuskless elephant) ❑ Developing an Explanation for Tuskless Elephants Student Handout (student handout) ❑ Analyzing Data on Tuskless Elephants (student handout) ❑ Internet access ❑ Trove of Mammoth Skeletons Excavated Near Mexico City Gives Clues About Hunting ❑ 25,000 Years Later, Javelin Is Still Embedded in Mammoth's Rib

Lesson	Materials needed
Coral Bleaching 5E	❑ *Visual Texts* (optional) ❑ NOAA's Data in the classroom: Investigating Coral Bleaching Activity (optional) ❑ Computers with internet access (optional) ❑ HHMI BioInteractive: Coral Reefs and Global Warming resource folder with all student materials ❑ different colored pencils or stickers ❑ Computers with internet access ❑ Chart paper ❑ No safe haven for coral from the combined impacts of warming and ocean acidification (optional text) ❑ Some Good News about Corals and Climate Change (podcast) ❑ What Helps Animals Adapt (or Not) to Climate Change? . Literacy Strategy: Chunking with Turn and Talk (optional) ❑ Driving Question Board from the start of the unit should be available ❑ *Visual Texts* ❑ Interactive Carbon Story (optional)
Kelp Forest 5E	❑ *Kelp Forest Visual* printed or displayed in color ❑ *Urchin Barren Visual* printed or displayed in color ❑ *Kelp Forest & Urchin Barren Map* ❑ Sea Urchin Barrens as Alternative Stable States of Collapsed Kelp Ecosystems Map (optional) ❑ *Kelp Forest & Urchin Barren Ecosystem Cards* ❑ *Kelp Forest & Urchin Barren Ecosystem Fact Sheet*

Lesson	Materials needed
	❑ poster paper ❑ computers with internet access ❑ Status and Trends for the World's Kelp Forests (optional) ❑ Driving Question Board from the start of the unit should be available ❑ computer access with internet
Passenger Pigeon 5E	❑ Poster paper ❑ Building a Paper Model of CRISPR-Cas9 (optional) ❑ Passenger Pigeon Project (optional) ❑ Passenger Pigeon Project (optional) ❑ Bringing extinct species back from the dead could hurt—not help—conservation efforts
Unit Closing	❑ Driving Question Board ❑ The Mammoth Project (optional) ❑ De-Extinction Debate: Should We Bring Back the Woolly Mammoth? (optional)