Unit Summary
Would we treat our resources and life support system if we were on a rocket headed for Mars as we do in our community right now?   In this unit of study, *mathematical models* provide support for students' conceptual understanding of systems and students' ability to *design, evaluate, and refine solutions* for reducing the impact of human activities on the environment and maintaining biodiversity. Students create or revise a simulation to test solutions for mitigating adverse impacts of human activity on biodiversity. Crosscutting concepts of *systems and system models* play a central role in students' understanding of science and engineering practices and core ideas of ecosystems. Mathematical models also provide support for students' conceptual understanding of systems and their ability to develop design solutions for reducing the impact of human activities on the environment and maintaining biodiversity.
Student Learning Objectives
Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. *[Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]* **(HS-ESS3-3)**
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.]* **(HS-LS2-7)**
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.]* **(HS-LS4-6)**
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. (HS-ETS1-1)
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.(HS-ETS1-2)
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

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Unit Sequence

Part A: *How might we change habits if we replaced the word "environment" with the word "life support system"?*

Concepts	Formative Assessment
• The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources. • Change and rates of change can be quantified and modeled over very short or very long periods. • Some system changes are irreversible. • Modern civilization depends on major technological systems. • New technologies can have deep impacts on society and the environment including some that are not anticipated. • Scientific knowledge is a result of human endeavors imagination and creativity.	*Students who understand the concepts are able to:* • Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. • Quantify and model change and rates of change in the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Unit Sequence

Part B: *Does reducing human impacts on our global life support system require social engineering or mechanical engineering?*

Concepts	Formative Assessment
• 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. • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). • 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	*Students who understand the concepts are able to:* • Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. • Construct explanations for how the environment and biodiversity change and stay the same when affected by human activity. • Evaluate a solution for reducing the impacts of human activities on the

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. • Much of science deals with constructing explanations of how things change and how they remain stable. • When evaluating solutions, it is important to take into account a range of constraints—including costs, safety, reliability, and aesthetics—and to consider social, cultural, and environmental impacts. • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • New technologies can have deep impacts on society and the environment, including some that where not anticipated. Analysis of cost and benefits is a critical.	environment and biodiversity based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. • Analyze costs and benefits of a solution for reducing the impacts of human activities on the environment and biodiversity based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Unit Sequence	
Part C: *Is the damage done to the global life support system permanent?*	
Concepts	**Formative Assessment**
• Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. • 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 ecosystems’ 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. • Empirical evidence is required to differentiate between cause and	*Students who understand the concepts are able to:* • Create or revise a simulation based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations to test a solution to mitigate adverse impacts of human activity on biodiversity. • Use empirical evidence to make claims about the impacts of human activity on biodiversity. • Break down the criteria for the design of a simulation to test a solution for mitigating adverse impacts of human activity on biodiversity into simpler ones that can be approached systematically based on consideration of trade-offs. • Design a solution for a proposed problem related to threatened or

correlation and make claims about specific causes and effects. • 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. • Both physical models and computers can be used in various ways to aid the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs. • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology.	endangered species or to genetic variation of organisms for multiple species. • Analyze costs and benefits of a solution to mitigate adverse impacts of human activity on biodiversity.

What It Looks Like in the Classroom

In previous units, students learned that photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes, and that the chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways.

Students also have an understanding of how 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. This included examining how modest biological or physical disturbances or extreme fluctuations in conditions affect ecosystems. Anthropogenic changes causing disruptions to biodiversity in ecosystems and stability and resilience were also considered.

These understandings will support students as they continue to explore human dependence on Earth's resources and the nature and effects of human interactions with their environment.

In this unit we turn our attention to how humans depend on the living world for resources and other benefits provided by biodiversity. Students must know that the sustainability of human societies and the biodiversity that supports them require responsible management of natural resources. Change and rates of change in biodiversity and environmental conditions should be quantified and modeled by students over short and long periods of time. Students should keep in mind that some system changes are irreversible. Deforestation of tropical rain forests and desertification of grasslands are examples of changes students might research. In their research, students should synthesize information from multiple sources and evaluate claims about the impacts of human activity on biodiversity based on analysis of evidence.

Modern civilization depends on major technological systems. New technologies can have deep impacts on society and the environment, both anticipated and unanticipated. Examples of impacts include extinction of species and loss of habitat. These changes can lead to a decrease in biodiversity. To address these concepts, students should create a computational simulation or mathematical model illustrating the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Simulations should model change and rates of change in those relationships. When possible, students should symbolically and quantitatively represent natural resource management, sustainability of human populations, and biodiversity. Students should also map relationships discovered, considering limitations on measurement when reporting quantities or data.

Students will learn that natural and anthropogenic changes in the physical environment contribute to changes in biodiversity. Changes may include species expansion, invasive species, and extinction. Because humans depend on the living world for resources and other benefits provided by biodiversity, adverse human activities such as overpopulation, exploitation of resources, habitat destruction, pollution, introduction of invasive species, and human impact on climate change must be addressed. Students should understand that sustaining biodiversity is critical to maintaining functional ecosystems. Students might collect data on growth patterns (exponential, logistic) and carrying capacity using bacterial populations in a petri dish, status of local fish and mollusk populations in Narragansett Bay, erosion of eel grass beds, or continued Quonset Point dredging. Data could also be collected on Asian Shore Crab infestation and competition with local crabs, or the negative effect of warming coastal estuary water temperature on flounder reproduction rates. Students could use data to make informed decisions about how environmental issues affect their communities politically, economically, and ecologically.

Students should connect scientific knowledge to human endeavors, imagination, and creativity using conceptual simulations that illustrate relationships such as those between the management of natural resources in local New England fisheries or the lobster-harvesting industry, the needs of the human population, and the effect on marine diversity. Students can use data collected to model changes in marine animal populations to better understand the relationship between management of natural resources, biodiversity, and the sustainability of human populations. Students can also investigate and research major contributions of scientists and engineers who have developed technologies to produce less pollution and waste in order to prevent ecosystem degradation. Students should synthesize information from multiple sources to construct explanations and verify claims about how the environment and biodiversity change and stay the same when affected by human activity.

In this unit, students are tasked with designing and evaluating a solution for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species. As they consider a design solution, they should know that technological advances by modern civilizations have solved, and sometimes caused, problems related to human interactions with the environment. This relationship could be studied by examining impacts of past technological advances such as electricity generation/distribution, antibiotic production, advanced farming practices, and damming of rivers. This may set the context for a discussion of limits of technological solutions. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. Students may need to determine long- and short-terms goals of a potential solution, while considering that new technologies can have deep impacts on society and the environment, including some that were not anticipated. For instance, students might consider solutions that address the unanticipated negative impact wind farms have on birds, bats, and offshore fishing grounds.

Students might use empirical evidence of decreasing bird populations to differentiate between specific causes and effects. Students could choose an adverse practice and research solutions to associated problems. They might consider wind turbines, deforestation, waste management, noise pollution, or automobile fuel (hydrogen, electricity, water). Solutions for minimizing adverse effects should account for a range of constraints such as cost, safety, reliability, and aesthetics, as well as social, cultural, and environmental impacts, since practical solutions are more likely to be implemented by society. Students can use physical models and computer simulations to aid in the engineering process, test potential solutions, and refine designs.

As they work, project criteria should be broken down and approached systematically. By evaluating or refining a technological solution, such as alternative energy, that reduces impacts of humans on biodiversity, students should consider the cost, benefits, and risks of systems created by engineers. An example might be modeling a solution for addressing the melting of permafrost and the release of previously trapped methane. Students should analyze data for positive and negative feedback within natural systems to predict if there would be stabilization or destabilization of greenhouse gas concentrations. When evaluating solutions, students need to take into account a range of constraints, including costs, safety, and reliability, as well as social, cultural, and environmental impacts.

Integration of engineering-

In this unit, there are two related performance expectations, HS-LS2-7 and HS-LS4-6, that each identify a connection to HS-ETS1-3. Students will be examining solutions for reducing or mitigating impacts of human activity on the environment and biodiversity. Because they are asked to design, evaluate, refine or revise, and finally test a solution, this unit has been identified as an opportunity for students to experience the complete engineering cycle. All HS-ETS1 performance expectations have been included here.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Evaluate data to verify claims about the impacts of human activities on the environment and biodiversity, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Conduct short as well as more sustained research projects to determine the impacts of human activities on the environment and biodiversity, synthesizing information from multiple sources.
- Synthesize information from a range of sources about the impacts of human activities on the environment and biodiversity into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on the impacts of human activity on biodiversity and how to mitigate these impacts.
- Conduct short as well as more sustained research projects to determine the impacts of human activity on biodiversity and how to mitigate these impacts.
- Evaluate data presented in diverse formats in order to determine the impacts of human activity on biodiversity and how to mitigate these impacts.
- Evaluate data to verify claims about the impacts of human activities on biodiversity and how to mitigate these impacts.
- Synthesize information from a range of sources into a coherent understanding of the impacts of human activities on biodiversity and how to mitigate these impacts.

Mathematics

- Represent symbolically the relationships among management of natural resources, the sustainability of human populations, and biodiversity, and manipulate the representing symbols. Make sense of quantities and relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- Use a mathematical model to describe the management of natural resources, the sustainability of human populations, and biodiversity. Identify important quantities in relationships among management of natural resources, the sustainability of human populations, and biodiversity, and map their relationships using tools. Analyze these relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent symbolically the impacts of human activities on the environment and biodiversity, and manipulate the representing symbols. Make sense of quantities and relationships of the impacts of human activities on the environment and biodiversity
- Use units to understand the impacts of human activities on the environment and biodiversity and to guide the solution of multistep problems to reduce these impacts. Choose and interpret units consistently in formulas to determine the impacts of human activities on the environment and biodiversity. Choose and

interpret the scale and origin in graphs and data displays showing impacts of human activities on the environment and biodiversity.

- Define appropriate quantities for the purpose of descriptive modeling of impacts of human activities on the environment and biodiversity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing impacts of human activities on the environment and biodiversity.
- Use a mathematical model to describe the impacts of human activities on the environment and biodiversity. Identify important quantities in the impacts of human activities on the environment and biodiversity and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe a solution to mitigate adverse impacts of human activity on biodiversity. Identify important quantities in the impacts of human activities on the biodiversity and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications
Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning
Nothing Applicable (NSDL, 2015).

Prior Learning

By the end of *Grade 8, students understand that:*

Physical science

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy; others store energy.

Life science

- 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.
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations or 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 very across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
- Food webs are models that demonstrate how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- 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. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Earth and space sciences-

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Connections to Other Units and Courses

Chemistry

- Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Biology or Environmental Science

- 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.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- 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. 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.

- Humans depend on the living world for 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.

Earth and space science

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.
- The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.
- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.
- Resource availability has guided the development of human society.

- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Sample of Open Education Resources
Cost-Benefit Analysis Primer: Students read this explanation about how cost-benefit analysis is derived and applied in order to apply this model to design solutions related to human sustainability. Students then read the application of CBA to water sanitation. Carbon Stabilization Wedge: Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios. One For All: A Natural Resources Game: Identify a strategy that would produce a sustainable use of resources in a simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations. Building Biodiversity and the PREDICTS project and GLOBIO project: Students explore this website to develop an understanding of how computational models of the impacts on biodiversity are created. Next, they explore Conservation Maps for a global perspective of land use and conservation efforts. Rainforest carbon cycling and biodiversity: Students apply this model to simulate how atmospheric CO2 concentrations, which influence global climate, increase with I=P*A*T Equation and Its Variants: Students read this article to learn how ecological economics models are developed and applied to further understand human impacts on our environment. National Climate Assessment: Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Stormwater Calculator or the Water Erosion Prediction Project: Students apply the stormwater runoff calculator to determine the impacts of land use change, precipitation variations, and other parameters on runoff. Alternatively, Catch It If You Can: students are scaffolded through the process of calculating stormwater runoff by exploring and applying this case study. The Bean Game: Exploring Human Interactions with Natural Resources: This activity explores the various influences of human consumption of natural resources over time. (use this as a primer for making a computational model). NSA Challenge: Recycling for a Cleaner World: Students will develop a strategy to increase recycling and waste diversion for their school. Land and People: Finding a Balance: This environmental study project allows a group of students to consider real environmental dilemmas concerning water use and provide solutions to these dilemmas. Reefs at Risk: and NOAA Coral Reefs at Risk: Students access and explore a series of interactive maps displaying coral reef data from around the globe and develop hypotheses related to the impacts of climate change (i.e. increased levels of carbon dioxide in our atmosphere) on coral reef health. GLOBE Carbon Cycle: Students collect data about their school field site through existing GLOBE protocols of phenology, land cover and soils as well as through new protocols focused on biomass and carbon stocks in vegetation. Students participate in classroom activities to understand carbon cycling at local and global scales. Students expand their scientific thinking through the use of systems models. Know Your Energy Costs: The goal of this activity is to become aware of how much energy you use at school — and the financial and environmental costs.

Earth: Planet of Altered States: Watch a segment of a NASA video and discuss how the earth is constantly changing. Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.

Appendix A: NGSS and Foundations for the Unit
Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. *[Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]* **(HS-ESS3-3)**
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.]* **(HS-LS2-7)**
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.]* **(HS-LS4-6)**
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. (HS-ETS1-1)
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.(HS-ETS1-2)
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6), (HS-LS4-6), (HS-LS4-7), (HS-ETS1-4) **Asking Questions and Defining Problems** • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)	**ESS3.C: Human Impacts on Earth Systems** • The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • 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) **LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-6) **LS4.D: Biodiversity and Humans** • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to 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	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ETS1-4) **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-3),(HS-LS2-7), (HS-LS4-6)

	biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. (*secondary to HS-LS2-7*) • Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (*secondary to HS-LS2-7*) **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. (*secondary to HS-LS4-6*), (HS-ETS1-2) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (*secondary to HS-LS4-6*),(HS-ETS1-2) **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (HS-ETS1-2)	

English Language Arts	Mathematics
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. **RST.11-12.7** (HS-LS2-7) Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-ETS1-3) Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3). 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.9-12.5 (HSLS4-6).	Reason abstractly and quantitatively. **MP.2** (HS-LS2-7), (HS-ETS1-3) Model with mathematics. **MP.4** (HS-ETS1-3) 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. **HSN.Q.A.1** (HS-LS2-7) Define appropriate quantities for the purpose of descriptive modeling. **HSN.Q.A.2** (HS-ETS1-3) Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSN.Q.A.3** (HS-ETS1-3)