Biosphere Learning Progression
Grades 9-12: GLOBE Protocols Aligned with NASA and NGSS

NGSS Disciplinary Core Ideas Content Progression: Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies. Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem. Using GLOBE and MY NASA DATA educators and students will access NASA satellite data to examine a variety of Earth system interactions.
(NASA Langley GLOBE Resource Page: www.globe.gov/web/nasa-langley-research-center/home/resources)

Performance Expectations: (Note: the following Performance Expectations and 3 Dimensional Learning are aligned with GLOBE and NASA Resources and are meant to support the development of the associated content and skill development but may not lead to complete mastery)

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

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

HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

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.

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

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

HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

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

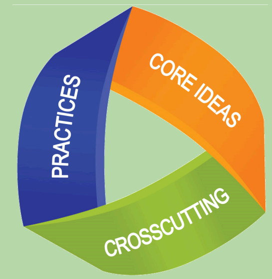
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

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

NGSS Science Practices:	NGSS Disciplinary Core Idea:	NGSS Crosscutting Concepts:
Using Mathematics and Computational Thinking: Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1) Use mathematical representations to support and revise explanations and/or claims. (HS-LS2-2, HS-LS2-4) Create a computational model or simulation of a phenomenon process or system. (HS-ESS3-3) Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6) **Constructing Explanations and Designing Solutions**: Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student generated scenarios of evidence, prioritized criteria, and trade off considerations. (HS-LS2-7, HS-ESS3-4) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria,	**LS2.A Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.B Cycles of Matter and Energy Transfer in Ecosystems** 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 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. (HS-LS2-4) 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. (HS-LS2-5) **LS2.C Ecosystem dynamics, functioning, and resilience**: A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2, HS-LS2-6) Moreover, anthropogenic changes (induced by human activity) 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	**Cause and Effect:** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-5) **Scale, Proportion, and Quantity:** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1) Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2) **Stability and Change:** Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6, HS-LS2-7) Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3, HS-ESS3-5) Feedback (negative and positive) can stabilize or destabilize a system. (HS-ESS3-4) **Systems and System Models:** Models (physical, mathematical, computer models) can be used to simulate systems and interactions-including energy, matter, and information flows-within and between systems at different scales. (HS-LS2-5) 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-ESS3-6) **Energy and Matter**

and trade off considerations. (HS-ETS1-3) **Developing and Using Models** Develop a model based on evidence to illustrate the relationships between systems and components of a system. (HS-LS2-5) **Analyzing and Interpreting Data** Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5) **Engaging in Argument from Evidence** Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6, HS-LS4-5)	induced, have thus contributed to the expansion of some species, the emergence of new and distinct species as populations diverge under different conditions, and the decline - and sometimes the extinction-of some species. (HS-LS4-5) Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5) **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) Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) **ESS3.D Global Climate Change**: 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. (HS-ESS3-5) 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. (HS-ESS3-6) **ETS1.B Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. ((HS-ETS1-3)	Energy cannot be created or destroyed - it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4) 
GLOBE Application		

GLOBE Protocols:

Air Temperature

Biometry

Carbon Cycle

Green Up/Green Down

Land Cover Classification

Precipitation

Soil Fertility

Surface Temperature

Soil Temperature

GLOBE Data Sheets

Green-Up Trees/Shrubs

Green Down

Fire Fuel

Land Cover Sample Site

Land Cover Summary Data Sheet

Tree Height on Level Ground

Tree Circumference

Soil Temperature

GLOBE Supporting Resources:

GLOBE Investigation Instruments

Clinometer Instructions

Clinometer Sheet

Earth System Science Posters

Supporting Research Article (Demonstrates How GLOBE

GLOBE Learning Activities:

1. Components of the Earth System Working Together: To develop familiarity with interactions among the major components of the Earth system at the global scale. (HS-LS2-4, HS-LS2-6, HS-ESS3-5, HS-ESS3-6)
2. Using Graphs to Show Connections: To show how graphs of GLOBE data over time display the interconnectedness of Earth's system components at the local level. (ALL)
3. Effects of Inputs and Outputs on a Region: To identify what enters and leaves the regional system, and how changes in the input or output of one component can affect other components. (HS-LS2-4, HS-LS2-5, HS-LS2-6)
4. Biomass Accumulation Model: In this activity, learners will use a simple model that predicts the biomass and average growth rate of ecosystems, Net Primary Productivity, based on annual temperature and precipitation. (HS-LS2-1, HS-LS2-2, HS-LS2-4, HS-LS2-5, HS-LS2-6)
5. Change Detection Tutorial: This tutorial requires the user to be comfortable with the software MultiSpec©, produced at Purdue University, and distributed freely on the Internet. MultiSpec© is used in The GLOBE Program to analyze Landsat images and to prepare digital land cover maps. (HS-LS2-2, HS-LS2-6, HS-LS2-7, HS-LS4-5, HS-ESS3-6)
6. Land Cover Change Detection: Using Multispec software, evaluate and investigate changes that have occurred in the major land cover types of your GLOBE Study Site by examining the digital files of two Landsat satellite images that were acquired a few years apart. (HS-LS2-2, HS-LS2-6, HS-LS2-7, HS-LS4-5, HS-ESS3-6)
7. Using GLOBE Data to Analyze Land Cover: To develop hypotheses about which environmental factors are most important to plants growing in a local Land Cover Sample Site by comparing local GLOBE data to those of other GLOBE schools reporting the same MUC class. (HS-LS2-2, HS-LS2-6, HS-LS2-7)
8. Getting to Know Your Satellite Imagery and GLOBE Study Site: To introduce learners to the Landsat images of the GLOBE Study Site, the iterative nature of mapping and how to identify land cover types in images. (HS-LS2-2, HS-LS2-6)
9. Manual Land Cover Mapping: To produce a land cover type map of the 15 km x 15 km GLOBE Study Site from hard copies of Landsat satellite images. (HS-LS2-2, HS-LS2-6)
10. Computer Aided Land Cover Mapping Protocol: Learners produce a land cover type map of the 15 km x 15 km GLOBE Study Site from the digital file of their Landsat satellite image using MultiSpec software.

Guiding Question(s):

1. How can mathematical models, such as population growth curves (e.g., exponential, logistic), be used to represent and predict changes in the size of specific populations within a given ecosystem?
2. A scientific article argues that keystone species play a critical role in maintaining the biodiversity and stability of an ecosystem. Evaluate the evidence and reasoning presented in the article. What types of data would strongly support this claim?
3. A claim states that increased atmospheric carbon dioxide levels will lead to an increase in the population size of certain plant species while potentially causing the extinction of others. What evidence supports the claim of increased populations for some species? What evidence supports the claim of extinction for other species? Explain the reasoning that connects these environmental changes to these biological outcomes.
4. Design a computational simulation that models the impact of different forestry management practices (e.g., clear-cutting vs. selective logging) on timber yield (sustainability of human populations) and the diversity of forest species (biodiversity) over a 50-year period. Describe the variables and relationships you would include in your model and explain how the simulation could illustrate potential trade-offs.
5. Consider regional climate data (e.g., precipitation patterns, frequency of extreme weather events) for a specific

Can Be Implemented as a Component of Student Research): Predicting Wildfire Risk Based On Land Cover Classification and Past Wildfire Data in California	(HS-LS2-2, HS-LS2-6) 11. Global Carbon Cycle Modeling: To understand that the carbon cycle is part of the Earth's interconnected system and that human actions have an impact on the global carbon cycle. (HS-LS2-4, HS-ESS3-5) 12. Global Carbon Cycle Modeling with Feedbacks: To gain a greater understanding of the complexity of models and how they are developed and how human actions have an impact on the global carbon cycle. (HS-LS2-4, HS-LS2-7, HS-ESS3-5) 13. How to Measure Trees: Learners develop an understanding of tree size and how scientists measure trees. Learners observe and measure tree cookies and explore the relationship between tree circumference and diameter. Learners compare the estimates of diameter made from circumference measurements (and vice versa). (HS-ESS3-5) 14. Data Entry: After learners have returned from the field with their paper data sheets, data can be shared with the GLOBE and scientific community by entering it into the GLOBE online science database (https://data.globe.gov). (All) 15. Data Visualization Tool: Use the GLOBE Visualization System to view and retrieve your data. (All)	geographic area. Analyze these data to identify any current trends. What evidence from these models and other geoscience data suggests potential future impacts on local ecosystems, water resources, or human infrastructure? 6. Design a computational model that demonstrates the interconnectedness of the biosphere (plant life) and the atmosphere (oxygen and carbon dioxide levels). How does your model represent the natural exchange of gases through photosynthesis and respiration? How can you use your model to simulate the impact of large-scale deforestation (a human activity) on atmospheric carbon dioxide and oxygen concentrations, and what are the potential cascading effects on other Earth systems?

NASA Assets

NASA Resources: • NASA Earth Observatory World Maps • NASA Climate Education Resources • NASA Worldview • Visible Earth • Carbon and Climate Resources • Landsat Science Education • Picture Post • Our Blue Marble **NASA Learning Activities:**	my NASA data **My NASA Data Visualization Tool: Earth System Data Explorer** (The Earth System Data Explorer is a data visualization tool that can be used by the educator to prepare lessons for the learner, or can be accessed by the learner to support independent research.) **MND GLOBE Biosphere Overview**: GLOBE resources are organized by protocol rather than phenomena. My NASA Data provides GLOBE Connections which pull together GLOBE resources by sphere and phenomena. **My NASA Supporting Resources:**	**MY NASA DATA Lessons/Activities:** • Estimating Biomass Loss from a Large Fire (HS-LS2-1, HS-LS2-2, • Computing Vegetation Health (HS-LS2-2, HS-LS2-6) • Computing Vegetation Cover (HS-LS2-2, HS-LS2-6) • Carbon Dioxide: Production and Sequestration (HS-ESS3-5, HS-ESS3-6) • Systems and System Models: Observing Carbon Dioxide in the Atmosphere (HS-ESS3-5) • Evaluating Natural and Human Activities Effects on Earth's Climate (HS-LS2-7, HS-ESS3-5, HS-ESS3-6) • Global Phytoplankton Distribution Sory Map (HS-LS2-5, HS-LS2-6, HS-LS4-5,

• Graphing Global Temperature Trends • Earth Science Data Visualizations: How to Read a Heat Map • NASA eClips: Biome Module • NASA eClips Secondary Engineering Design Packet • NASA eClips: Mapping Earth's Surface with ICESat-2	• Locating Data and Imagery for Student Investigations • Earth as a System Graphic Organizer • Using NASA Earth Observations (NEO) GLOBE Connections: Plant Growth Patterns • Data Collections: Earth System Data Explorer • About the Biosphere • Deforestation • Plant Growth Patterns • Land Use Change Over Time • GLOBE Earth System Poster • Global Phytoplankton Distribution Overview • GLOBE Connections: Phytoplankton Distributions • Urban Heat Islands	HS-ESS3-6) • Phytopia: Exploration of Marine Ecosystems (HS-LS2-5, HS-LS2-6, HS-LS4-5, HS-ESS3-6) • Analyzing Seasonal Phytoplankton & Energy Flow (HS-LS2-4) • Exploring the Tradeoffs of Surface Temperature Models (HS-ETS1-3) • Exploring Satellite Imagery and False Color Images (HS-ESS3-1) • Analyzing Land Changes Over Time (HS-ESS3-1) • Identifying Changes in Land Use (HS-LS2-2) • Comparing Global Land Use Over Time (HS-LS2-2) • Creation of Urban Heat Island Lesson Plan; Creation of Urban Heat Islands Story Map (HS-LS2-7, HS-ESS3-6)

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