Blue Carbon: The Ocean as a Climate Solution

Lesson Specifications

Grade Level

9-12

Timeframe

Three to five days of regular class blocks (~1hr each)

Materials

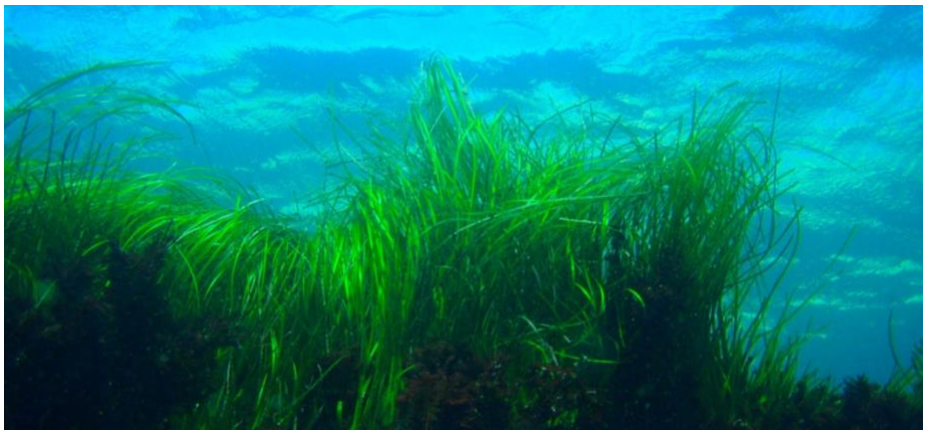
1. Printed versions of the sources and/or access to computer to read and interact with sources
2. Guiding Questions for Students/Worksheet
3. Vocabulary Organizer/Worksheet

Key Words

Blue carbon, carbon sequestration, carbon storage, carbon sink, carbon reservoir, carbon fixation, uptake or capture

NGSS Standards

HS-ESS3-6 Earth and Human Activity
HS-ESS2-6 Essential Principle Earth's Systems
HS-ESS3-5 Earth and Human Activity



Seagrass absorbs carbon dioxide from the water and can store it away in its roots system for long periods of time. Photo: Claire Fackler/NOAA

Activity Summary

When considering the carbon cycle, trees and terrestrial plants are often the first carbon absorption and storage tool that comes to mind. However, the ocean plays a primary role in the carbon cycle. This lesson plan is a performance task that introduces the role of coastal and ocean habitats and species as essential components of a healthy carbon cycle.

Learning Objectives

Upon successful completion (reaching proficiency level or higher in at least 2 of the 3 categories of the rubric) of this performance task students will:

- Have a deeper understanding of the carbon cycle and how blue carbon is involved in this process.
- Be familiar with various coastal and ocean habitats and their role in the carbon cycle, including what benefits they provide in relation to the amount of carbon dioxide in our atmosphere.
- Recognize how human activity plays a role in the health of various coastal and ocean habitats and therefore the overall health of our ocean and climate.
- Be able to identify ways in which they themselves, their community, and their elected officials may be able to help protect various coastal and ocean habitats and therefore the overall health of our ocean and climate.

Background Information

The impacts of climate change on our environment, like changing weather patterns and storm events, warming waters, declining ocean oxygen levels, ocean acidification, and sea level rise, are becoming more prevalent and significant around the globe. These impacts are affecting national marine sanctuaries and the overall health of our coasts and ocean, which is vital to our survival and quality of life.

At the same time, national marine sanctuaries and other marine protected areas are important nature-based solutions to human-caused climate change. By safeguarding essential ecosystems responsible for local and global contributions to biodiversity, carbon storage, livelihoods, coastal security, cultural heritage, and more, sanctuaries contribute to reducing or removing greenhouse gas emissions and adapting and building resilience to climate change impacts.

Science has never been more advanced. We have a deeper understanding about the Earth's systems than ever before, including how they act and interact. Innovations in renewable energy, carbon capture and sustainability are within our grasp. Thanks to historic investments in renewables and green technology, we have the resources and tools to make a real impact as we advance these solutions. The challenges we face are significant, but they are not insurmountable. We have the ability to change the future, starting now. The more we do, the better off we will all be. Every action and every choice matters. Governments and companies are creating innovative advances in renewable energy, carbon capture and sustainability. Historic investments in renewables and green technology are advancing real solutions. Advances occurring today will have impacts tomorrow and into the future. Individual, community, business, and government choices all play an important role, so does the ocean.

Blue carbon is the carbon captured and stored in coastal and marine ecosystems, such as tidal salt marshes, mangroves, and the deep ocean floor. Blue carbon ecosystems can help address climate change resulting from the global emission of carbon dioxide into the atmosphere by removing and

storing some of that atmospheric carbon dioxide for long timescales in sediments and deep water. By protecting ecosystems on the coast and in the ocean, we also help to store carbon in ecosystems, both by protecting the carbon already stored in their natural habitat and by helping nature absorb even more carbon. Through their interactions within the web of life, wild animals help to capture carbon in plants and, ultimately, in soils and sediments. National marine sanctuaries contain blue carbon ecosystems; by protecting and restoring these ecosystems they preserve and grow an important nature-based climate solution. This topic is important because it increases understanding about how living organisms and coast and ocean habitats play a critical role in the carbon cycle and are overlooked in their value for helping contribute to sustaining life on earth. By better recognizing the coast and ocean for their role in the carbon cycle, we can increase solutions and actions to preserve these vital cycles and processes in the ocean.

With this performance task, students will investigate different information sources to learn what blue carbon is, how coastal and ocean habitats cycle and store carbon, and demonstrate their learning by completing a task that uses their investigations and research to explain their reasoning. There are optional guiding questions to help guide the students' exploration through the resources and a graphic organizer to take notes to refer back to.

Prerequisite Knowledge

Before starting this lesson plan/performance task students should have a basic understanding of:

- The carbon cycle
- Processes such as photosynthesis, respiration, and combustion
- Chemistry of carbon dioxide
- The structure and interaction of Earth's spheres (lithosphere, hydrosphere, biosphere, atmosphere, etc.)
- The current state of our climate and ocean health in relation to different species and habitats (including humans)
- Interactions between Earth's habitats and the species that rely on them
- How changes in the ocean and climate lead to large scale consequences for both humans and animals
- How human activity can impact the ocean and climate (both positively and negatively)

Vocabulary	
Blue carbon	any carbon stored in coastal or ocean ecosystems.
Carbon sequestration	the process of absorbing or drawing down atmospheric carbon dioxide.
Carbon sink	an environment that absorbs more carbon than it releases.
Carbon reservoir	a location where carbon is stored for long periods of time, such as ocean sediments. Note: a place can be both a carbon sink and a reservoir (e.g. mangrove forest).
Carbon fixation, uptake or capture	term for the part of the plant growth process, where plants capture carbon dioxide from the air and convert it into plant parts such as leaves, stems, or roots.

Preparation

To best facilitate this performance task with your students;

1. Review the prerequisite knowledge and the sources to ensure that your students are well prepared to begin this task.
2. Provide your students with the Optional Guiding Questions for Students and the vocabulary organizer to help facilitate their learning.
3. Present the performance task prompt to your students and review the rubric with them.
4. Allow students to explore the sources and begin to craft their response to the prompt.

Student Directions

To plan and compose your response;

1. Review all suggested sources (including video, infographics, and articles). Use the Optional Guiding Questions for Students and Vocabulary Organizer to help you stay focused as you explore the sources.
2. Answer the focus questions using information from the sources to guide your understanding and inform the creation of your final product.
3. Create a final product that addresses the following prompt:
    a. In what way(s) does activity (at a personal, local, or state level) impact the blue carbon ecosystems?
    b. What would be your suggestion to balance the use of coastal habitats and the ocean for various purposes, including human needs?
    c. How would your plan reduce the negative human impact on the relationship between Earth's spheres (or on a healthy blue carbon cycle)?

Use evidence and reasoning to support your claim.

You may present your response as an essay, poster, or presentation of your choosing.

Sources

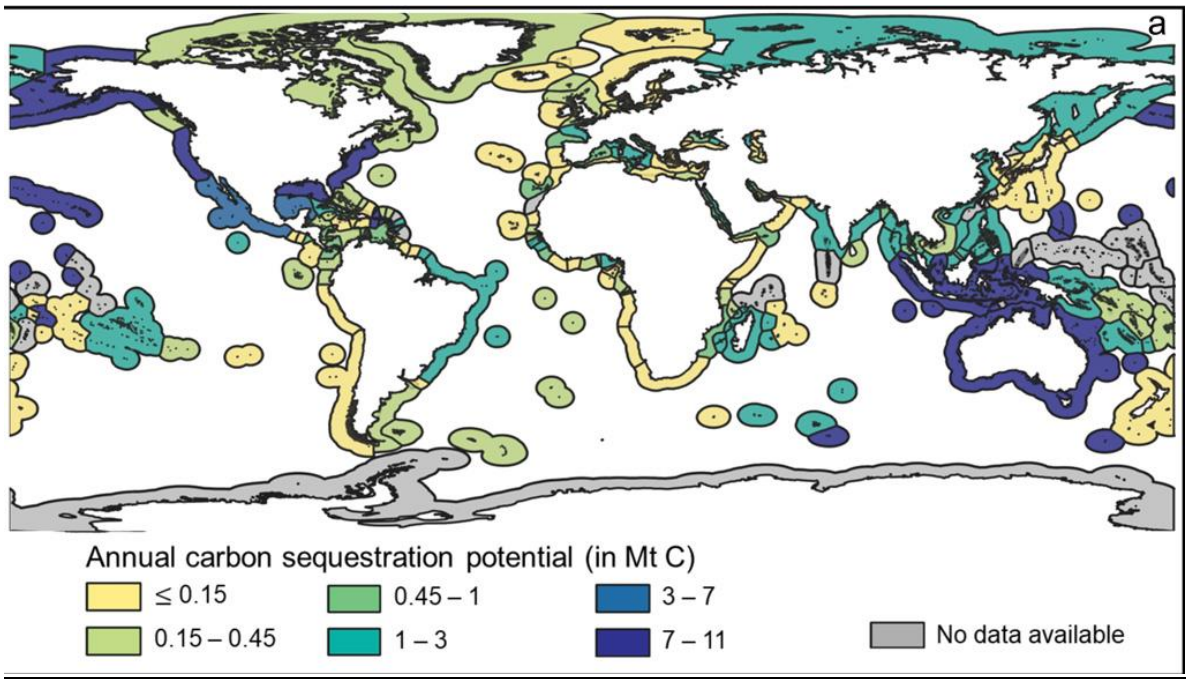
Source 1:Video: Blue Carbon - A Story from the Snohomish Estuary

Source 2: Infographic: A Healthy Coast and Ocean Stores Blue Carbon

Source 3: Article: Coastal Blue Carbon

Source 4: Website/Storymap Blue Carbon in Marine Protected Areas (*If 1:1 technology is available*)

Source 5: Data visualization graphic showing a global map of average annual blue-carbon sequestration potentials by country.



Global map of average annual blue-carbon sequestration potentials by country. The shading indicates the size of the potential, from low (yellow) to high (dark blue), in millions of tonnes of carbon per year. Source: Bertram et al. (2021).

Source 6: Article: Coastal Wetland Habitat

Discussion Questions

1. What does the term “blue carbon” mean? What role does it play in the carbon cycle? Use information from more than one of the provided sources.
2. What benefits (including those related to the carbon cycle) do estuaries and other coastal habitats provide to people and other organisms? What are some consequences we would experience without these habitats? Provide several examples from the sources provided.
3. How might whales and other organisms (even as small as phytoplankton!) play a role in the ocean carbon cycle? What challenges might scientists face in researching the role whales and other organisms play in the blue carbon cycle?
4. How can we preserve and restore critical habitats for species that connect to carbon storage in coastal and ocean environments? What are some challenges that may be encountered through this process?
5. Using the map from Source 5, identify locations around the globe that have the highest potential of carbon sequestration. Is there a pattern of where these locations occur? How does your current location relate to this data?

Guiding Questions for Students: Worksheet	
Source	**Notes**
1 - video	What is an estuary? What benefits do estuaries provide? What is blue carbon and why is it called blue carbon? Why are wetlands better than forests to store carbon? How much carbon is captured in a restored estuary such as the Snohomish Estuary?
2 - infographic	What aquatic organisms play a part in carbon sequestration and storage? What kinds of aquatic plants play a part in carbon sequestration and storage? Give an example scenario of how atmospheric carbon can become deadfall carbon.
3- article	What is the difference between carbon sequestration and storage? What is coastal blue carbon? Where is carbon stored in coastal habitats? What happens to the carbon stored in a coastal habitat when the habitat is destroyed? Compared to tropical forests, how much carbon can a coastal habitat store?

Guiding Questions for Students: Worksheet	
4 - website	How much of the earth's carbon dioxide does the ocean store within living organisms? Explain one way that atmospheric carbon dioxide travels to become stored in the deep sea. What is oceanic blue carbon and how does it occur? What role does phytoplankton play in oceanic blue carbon? What role does kelp play in oceanic blue carbon? What role do fish play in oceanic blue carbon? What role do whales play in oceanic blue carbon? **Choose one coastal habitat to answer the following questions (salt marsh, seagrass, mangroves) Describe your chosen habitat. How does it relate to blue carbon/the carbon cycle? What is the current state of this habitat? (i.e.declining, restored, growing) What can we do to protect this habitat?
5 - map	What do you notice about where the carbon sequestration data is being collected? What patterns do you notice about areas that have the highest level of sequestration? What patterns do you notice about areas that have the lowest level of sequestration?
6 - article	What is a coastal wetland? Describe one benefit of a coastal wetland and why it is important to you. What impact does human activity have on coastal wetlands? What is one thing you can do to help protect coastal wetlands?

Vocabulary Organizer: Worksheet

Using the following worksheet, list and define words that you encounter in the sources that you find interesting or might be unfamiliar with. Use words and/or drawings to help give examples for the words to deepen your understanding. *The first one has been completed for you using carbon dioxide as the sample word or phrase.*

<table>
<tr><td colspan="2">Blue Carbon Performance Task Vocabulary Organizer</td></tr>
<tr><td>Word or Phrase:
Carbon dioxide</td><td>Example:
Greenhouse gasses, including Carbon dioxide, contribute to the warming of our planet.
 

<u>OR</u></td></tr>
<tr><td colspan="2">Definition:
Carbon dioxide is a colorless and non-flammable gas at normal temperature and pressure. A molecule of carbon dioxide (CO2) is made up of one carbon atom and two oxygen atoms.</td></tr>
</table>

<table>
<tr><td>Word or Phrase:</td><td>Example:</td></tr>
<tr><td colspan="2">Definition:</td></tr>
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Word or Phrase:	**Example:**
Definition:	

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Word or Phrase:	**Example:**
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Education Standards	
Next Generation Science Standards	HS-ESS3-6 Earth and Human Activity HS-ESS2-6 Essential Principle Earth's Systems HS-ESS3-5 Earth and Human Activity
Common Core State Standards	CCSS.ELA-Literacy.RST.9-10.2 (Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.) CCSS.ELA-Literacy.WHST.9-10.9 (Draw evidence from informational texts to support analysis, reflection, and research.) CCSS.ELA-Literacy.R.CCRA.1 (Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.) CCSS.ELA-Literacy.R.CCRA.7 (Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.) CCSS.ELA-Literacy.W.CCRA.1 (Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.) CCSS.ELA-Literacy.SL.CCRA.2 (Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally) CCSS.ELA-Literacy.SL.CCRA.4 (Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.)
Climate Literacy Principles	Essential Principle 4: Climate varies over space and time through both natural and man-made processes. Essential Principle 6: Human activities are impacting the climate system. Essential Principle 7: Climate change will have consequences for the Earth system and human lives.

Final Product Rubric

	Emerging	Developing	Proficient	Advanced
Content	The project is unable to identify impacts on the health of the ocean and climate in relation to blue carbon systems or does so inaccurately, their suggestion for balancing use of coastal habitats in regards to blue carbon benefits and human development is incomplete or unreasonable, and they do not use evidence from the provided sources to support claims.	The project attempts to identify impacts on the health of the ocean and climate in relation to blue carbon systems, their suggestion for balancing use of coastal habitats in regards to blue carbon benefits and human development is incomplete or unreasonable, and they use evidence from only one of the provided sources to support their claims.	The project accurately identifies impacts on the health of the ocean and climate in relation to blue carbon systems, makes a reasonable and logical suggestion for balancing use of coastal habitats in regards to blue carbon benefits and human development, and uses evidence from two or more of the provided sources to support claims.	The project accurately identifies impacts on the health of the ocean and climate in relation to blue carbon systems, makes a reasonable and logical suggestion for balancing use of coastal habitats in regards to blue carbon benefits and human development, and uses evidence from three or more of the provided sources to support claims. The project identifies and addresses potential challenges that their suggestion may face and describes why these challenges may be present.

Creativity	The project provides a bare minimum approach to sharing a response to the prompt.	The project attempts to engage the audience in a response to the prompt but does so in a way that lacks organization or is confusing.	The project engages the audience in a response to the prompt in an efficient manner that leads to a better understanding of the topic.	The project uses unique and engaging techniques to pull the audience in and leads to a better understanding of the topic and encourages the audience to want to learn more.
Organization	The final product feels incomplete. Project is missing an introduction, evidence from sources, and/or a conclusion. Audience has a hard time following the information presented. The project does not use topic specific vocabulary.	The final product is missing an introduction, evidence from at least one source, or a conclusion. The product is difficult to understand and topic specific vocabulary is missing or inaccurate.	The final product includes an introduction, evidence from multiple sources, a conclusion and is easily understood by the audience and relates directly back to the evidence presented. Use of topic specific vocabulary is accurate and appropriate.	The final product includes an introduction, evidence from multiple sources, a conclusion and is easily understood by the audience and relates directly back to the evidence presented. Use of topic specific vocabulary is accurate and appropriate. Information from sources is properly cited using MLA or APA format.

Additional Resources

Blue Carbon in Marine Protected Areas reports Part 1 and Part 2

Blue Carbon in Marine Protected Areas Storymap

CC Adaptation in NMS

Sabine, C., DR. (n.d.). Ocean-Atmosphere CO_2 Exchange. Retrieved Feb 3, 2023. from https://sos.noaa.gov/catalog/datasets/ocean-atmosphere-co2-exchange/
The Blue Carbon Wealth of Nations, Betram et al.

For More Information

Bringing Wetlands to Market Curriculum

Bringing Wetlands to Market Performance Task

Climate Change Resource Collection/Office of National Marine Sanctuaries/NOAA