SEDIMENT STORIES: EXPLORING CARBON IN SEAGRASS ECOSYSTEMS

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Grade Level
9th Grade

Subject Area
Environmental Science

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Science Foundation and William & Mary's Society of 1918 Endowment.

Title: Sediment Stories: Exploring Carbon in Seagrass Ecosystems

Focus: This lesson will introduce students to long-term carbon storage in seagrass meadows. It will first introduce the importance of carbon storage in coastal systems and introduce ideas of why we care about carbon storage and how we might study sediment carbon. The lesson will also introduce students to seagrass meadows in the Chesapeake Bay and allow them to core "sediment" in order to see if species store different amounts of carbon.

Grade Level: 9th Grade, Environmental Science

Virginia Standards of Learning:

ENV.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information
- determine which questions can be investigated within the scope of the school laboratory or field to determine relationships between independent and dependent variables
- generate hypotheses based on research and scientific principles
- make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
- define design problems that involve the development of a process or system with multiple components and criteria

b) planning and carrying out investigations
- individually and collaboratively plan and conduct observational and experimental investigations
- plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects
- determine appropriate sample size and techniques
- select and use appropriate tools and technology to collect, record, analyze, and evaluate data

c) interpreting, analyzing, and evaluating data
- construct and interpret data tables showing independent and dependent variables, repeated trials, and means
- construct, analyze, and interpret graphical displays of data
- use data in building and revising models, supporting an explanation for phenomena, or testing solutions to problems
- analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution

d) constructing and critiquing conclusions and explanations

- make quantitative and/or qualitative claims regarding the relationship between dependent and independent variables
- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including students' own investigations, models, theories, simulations, and peer review
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and design solutions
- compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence
- construct arguments or counterarguments based on data and evidence

e) developing and using models

- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships
- develop and/or use models to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems
- read and interpret topographic and basic geologic maps and globes, including location by latitude and longitude

f) obtaining, evaluating, and communicating information

- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

ENV.3 The student will investigate and understand how matter flows in the fundamental processes of Earth systems. Key content includes

- the movement of atoms and elements through the biosphere, lithosphere, hydrosphere, and atmosphere as biogeochemical processes to include the carbon, oxygen, nitrogen, and water cycles;
- the atmosphere, lithosphere, and hydrosphere each have processes through which matter flows; and
- interrelationships exist among the atmosphere, geosphere, anthrosphere, and the hydrosphere.

ENV.5 The student will investigate and understand that the Earth is one interconnected system through which energy and matter flow. Key content includes

- Earth's terrestrial and aquatic biomes have distinct characteristics and components;
- an ecosystem is composed of both biotic and abiotic factors;
- energy and matter flow within an ecosystem;

- the movement of energy through the living world to include food webs, food chains, trophic levels; and
- biotic and abiotic factors may limit population growth in a given area (carrying capacity).

ENV.11 The student will investigate and understand that global climate change is occurring. Key content includes
- scientific evidence such as changes in average global temperature, greenhouse gases, quantities of artic and land ice, ocean temperature, ocean acidification, and sea level rise are indicators of climate change;
- there exists a relationship between global climate change and the frequency or magnitude of extreme weather events;
- sea level rise is currently affecting coastal areas of Virginia and will lead to the destruction of current habitats; and
- consequences of climate change will affect the biosphere on many levels including species migration and extinction, disease spread, and ecosystem health (e.g. bleaching corals and dying forests).

Learning Objectives:

By the end of this lesson, students will be able to:

1. Identify the use of sediment cores in studying sediment carbon content.
2. Explain the importance of seagrass meadows in carbon storage within marine ecosystems.
3. Collect and calculate simulated sediment core samples to determine how species impact seagrass meadow carbon in the Chesapeake Bay.
4. Interpret data and conclude how climate change might impact seagrass meadow carbon storage in the Chesapeake Bay.

Total length of time required for the lesson: One hour

Vocabulary:

- Carbon sink: an ecosystem that stores carbon
- Carbon Stock: the amount of carbon currently stored in some area (e.g., sediment carbon stock = carbon stored in sediment)
- Carbon core: A tool to take a sediment sample and measure sediment characteristics
- Seagrass: Underwater flowering plants that form seagrass meadows

Background Information:

Coastal habitats like mangroves, salt marshes, kelp forests, and seagrass meadows are important ecosystems. These ecosystems provide homes for animals, help clean the water, and store carbon. Carbon storage is important because it helps slow down climate change by removing carbon dioxide from the air. These coastal/underwater ecosystems act like rainforests by storing large amounts of carbon for long time periods.

Seagrasses, in particular, are flowering plants that grow underwater, forming ecosystems called seagrass meadows. These meadows are found along coastlines all over the world. Sadly, seagrass meadows are disappearing because of human activities like coastal construction, pollution, and climate change leading to higher water temperatures.

In the Chesapeake Bay, we have two species of seagrass: Eelgrass and Widgeon Grass. Over the years, Eelgrass has been dying because summer heat waves make it too hot to survive. Eelgrass used to dominate over half of the Bay's underwater meadows, but now it only covers 20%. As Eelgrass dies, Widgeon Grass is becoming more common, and the new dominant species.

We don't yet fully understand how this change might affect the environment. One big question is: does this change affect how much carbon seagrass meadows can store? In this lesson, we will explore that question together.

Materials & Supplies:

- Tubs of colored beads (e.g., blue or green for carbon and brown for soil). The depth of beads needs only to be around 3 inches deep.
    - How many beads are needed depends on the size of your Tupperware. Please see teacher preparation for more details on preparing the tubs.
- Empty toilet paper rolls for coring tools.
    - You can use any cylinder object, but note that changing the device will change some calculations on the answer sheets.
- Plastic trays, paper plates, or bags to collect "core" samples.
- Worksheets
- Calculator
- Rulers

Teacher Preparation:

Set up two tubs with beads, one for each seagrass species. Students will take turns "coring" from these bins per group. Eelgrass should have a color (carbon) proportion: brown beads (sediment) of about 0.30 while Widgeon Grass should have a proportion of about 0.15. See the attached table for reference. **Proportions do not need to be exact to meet the goals of the lesson; only that Widgeon Grass has less carbon than Eelgrass.** If you are not using beads or would prefer to use another medium (beads, colored rocks, etc.) that you have in excess, just measure out the proportions based on volume, like 1 cup of green to 3 cups of brown to get a proportion of almost 0.30!

Total beads needed:

The Volume of Tupperware / Plastic Tubs	Brown Beads Needed	Green Beads Needed
For two 2.5 Qt tubs	4,800	1,500

To prepare the two tubs:

Seagrass Species	The Volume of Tupperware / Plastic Tub	Brown Beads Needed	Green Beads Needed
Widgeon Grass	2.5 Qt	2,400	500
Eelgrass	2.5 Qt	2,400	1,000

Procedure:

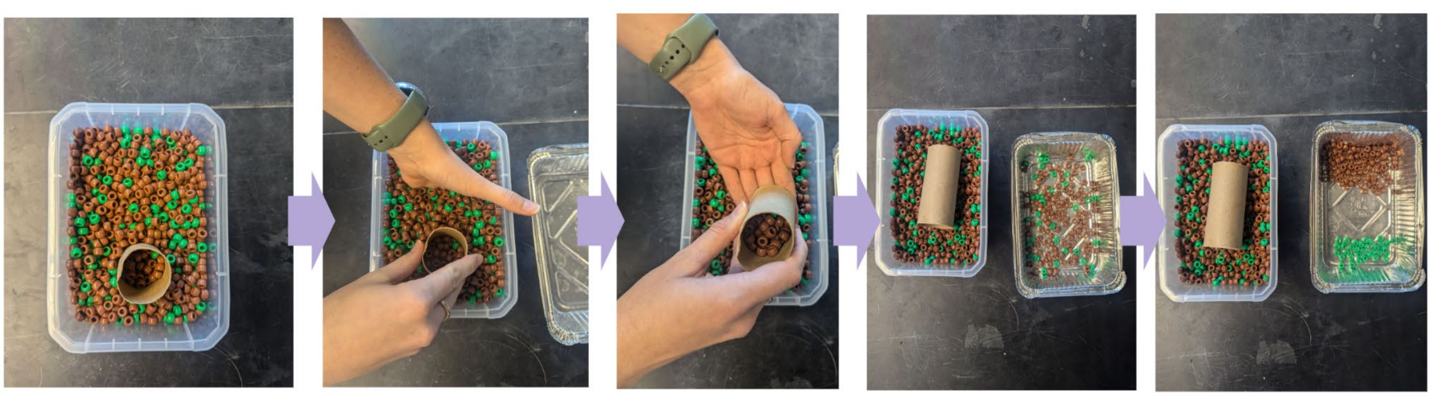
1. Introduction
    a. The instructor will introduce the lesson and activity using the provided PowerPoint. Throughout the PowerPoint, students will be exposed to carbon storage in marine ecosystems, learn how scientists study sediment carbon, get introduced to the seagrasses of the Chesapeake Bay, and understand the importance of seagrass carbon storage.
    b. Present until slide 19. Teacher should STOP here (
2. Prepare Materials
    a. The instructor will pass out the worksheets and prepare the coring buckets as described above.

** You may wish to prime students by first having them "core" something else, such as water or mud with a straw. This add another tactile element to the lesson.****

3. Core Activity (This activity is set up for five groups)
    a. Students will work through the activity and take sediment cores in the bead buckets as seagrass scientists would in a seagrass meadow
    b. Have students begin by generating a hypothesis and answering introductory questions on the worksheets.

   c. Then students will examine their cores (toilet paper rolls) and calculate the area of beads they will be coring.
   d. Each group will take one core from the Eelgrass and Widgeon Grass meadow and fill out the data sheet, counting how many beads there are of sediment grains and carbon grains and working through carbon stock equations.
      i. Cores can be taken almost exactly as researchers do in the field by:
         1. Pressing the tube into the beads
         2. Dig in a hand and cupping the bottom of the core
         3. Slowly pulling up and allowing all excess beads to fall back into the tub.
         4. Dumping the core into your tray/plate/bag.
         5. Separate and count the carbon and sediment grains
      ii. See the pictures below for guidance and/or on slide 19.
      iii. If students have larger hands, consider scooping out some excess beads to lower the depth, this will prevent overflowing.
   e. Students will share and report with other groups to calculate an average carbon stock per species and graph their results as a bar graph
4. Assessment
   a. Students will then fill out some reflection and challenge questions

*There is an optional section B that expands carbon stocks over time in the Chesapeake Bay. If you wish to have students continue, present slide 21 and have them work through the Section B part of the Worksheets.



1) Press core into beads | 2) Scoop hand underneath core | 3) Pull core up, allowing excess beads outside to fall back into the tub | 4) Dump core into tray/plate/bag | 5) Separate and count the carbon and sediment grains

Assessment:

5. Discussion/Reflection
    a. In slide 22 the teacher can lead discussion questions that introduce carbon storage and how scientists study carbon.
    b. Students are asked discussion questions at the end of each worksheet. Students may complete discussions independently or be led by the teacher.

References:

Hensel, M. J. S., Patrick, C. J., Orth, R. J., Wilcox, D. J., Dennison, W. C., Gurbisz, C., Hannam, M. P., Landry, J. B., Moore, K. A., Murphy, R. R., Testa, J. M., Weller, D. E., & Lefcheck, J. S. (2023). Rise of Ruppia in Chesapeake Bay: Climate change–driven turnover of foundation species creates new threats and management opportunities. *Proceedings of the National Academy of Sciences*, *120*(23), e2220678120. https://doi.org/10.1073/pnas.2220678120

Handouts/Worksheets:

Seagrass Sediment - Worksheet 1

Name(s) ____________________

Date______________________

Section A

Introduction

You are working with a group of marine scientists to measure the amount of organic carbon in the sediment of two meadows in the Chesapeake Bay that are dominated by different species. Seagrasses are underwater plants that live in marine, salty, water. Like all ecosystems, like rainforests, they capture and store carbon in their sediments over long timescales.

Answer the following questions before beginning

1) Why are seagrass meadows important ecosystems?

2) What other ecosystems besides seagrass meadows might be good at carbon storage? List at least three examples. *Think about both aquatic and terrestrial habitats!*

3) What factors might affect the amount of carbon stored in seagrass sediments?

Form a hypothesis on which species will store more carbon

1) Write your hypotheses below.
    a) Why?

Measure the size of your core

When we measure carbon through sediment cores, we need to know how much sediment we take in a sample. Record the dimensions of your core below:

Core Radius:

Now, we can calculate the area of sediment we might sample using the equation for an area of a circle. Show your work:

**remember the equation for an area of a circle* $A = \pi r^2$*

Record the amount of carbon

Take a sediment core from each bucket. Count the number of colored beads (carbon) and the number of neutral beads (sediment particles) and record them in your data table. Get the counts from the other groups' (replicates) cores and record them as well. Calculate the average carbon stock for each species.

Remember: Carbon Stock can be calculated from:

$$Carbon\ stock\ (\frac{Pieces\ Carbon}{cm^2}) = \frac{Carbon\ Grains}{All\ Grains}\ x\ \frac{1}{Core\ area\ (cm^2)}$$

<u>Eelgrass Sediment Cores</u>

Replicate	Sediment Grains (pieces)	Carbon Grains (pieces)	All Grains (Pieces)	Proportion Carbon in Sample $(\frac{Grains\ Carbon}{All\ Grains})$	Carbon Stock $(\frac{Grains\ Carbon}{cm^2})$
1					
2					
3					
4					
5					
				Average:	

Widgeon Grass Sediment Cores

Replicate	Sediment Grains (pieces)	Carbon Grains (pieces)	All Grains (Pieces)	Proportion Carbon in Sample $(\frac{Grains\ Carbon}{All\ Grains})$	Carbon Stock $(\frac{Grains\ Carbon}{cm^2})$
1					
2					
3					
4					
5					
				Average:	

Graph the carbon stocks for each species. *Don't forget to fill in the legend if needed!*

1) What type of graph should we use, and why?

Answer the following questions

1) Which species had the larger carbon stock? What does this mean for a meadow of Eelgrass vs a meadow of Widgeon Grass?

2) What would happen if a meadow that had Eelgrass switched to one with Widgeon Grass?

Challenge Question:

3) Why might these species differ?

4) How can we protect seagrass meadows? Brainstorm a specific solution.

Seagrass Sediment - Worksheet 2

Name(s) ____________________

Date______________________

Section B

Scaling Up in Space

Seagrass coverage in the Chesapeake Bay changes yearly. Scientists at the Virginia Institute of Marine Science use annual aerial images taken from planes to map how much seagrass there is per year. Use some of these values to see how Bay-wide carbon stocks might change over time depending on coverage and species identity.

*Note: **Many things impact carbon storage, including the age of a meadow and temperature, which will have changed between 1990 and 2020, but we can estimate the net change using our values***

2020

In 2020 Scientists found that there were 55,000 square meters of Eelgrass and 80,000 square meters of Widgeon Grass in the Chesapeake Bay. Our sediment stocks are per square cm. How can we make the units match? We can multiply our rate by the same number of square cm in a square meter, which is equal to 10,000!

Calculate an approximate carbon stock of each species and for all seagrass meadows in the Chesapeake Bay in 2020 using the coverage in square meters of each species as calculated in Section A.

Seagrass Carbon Stock in 2020

Species	Average carbon stock per square centimeter	Average carbon stock per square meter	The area of species is 2020	Carbon in all meadows in the Chesapeake Bay for this species

				Total carbon stock of all meadows in the Chesapeake Bay:

1990

In 1990 the area of species of seagrass in the Chesapeake was different: Eelgrass covered 1,010,000 square meters and Widgeon Grass covered 71,000 square meters.

Species	Average carbon stock per square centimeter	Average carbon stock per square meter	The area of species is 1990	Carbon in all meadows in the Chesapeake Bay for this species
				Total carbon stock of all meadows in the Chesapeake Bay:

Final Reflections

1) Was the average carbon storage of seagrass meadows higher in 2020 or in 1990? What is causing this?

Challenge Question:

1) What else might complicate this investigation?

Answer Keys:

Seagrass Sediment - Worksheet 1 ANSWERS

Name(s) ____________________

Date______________________

<u>Section A</u>

Introduction

You are working with a group of marine scientists to measure the amount of organic carbon in the sediment of two meadows in the Chesapeake Bay that are dominated by different species. Seagrasses are underwater plants that live in marine, salty, water. Like all ecosystems, like rainforests, they capture and store carbon in their sediments over long timescales.

Answer the following questions before beginning

1) Why are seagrass meadows important ecosystems?

They provide a lot of services or benefits such as acting as nursery habits for fish, capturing carbon, and protecting shorelines.

2) What other ecosystems besides seagrass meadows might be good at carbon storage? List at least three examples. *Think about both aquatic and terrestrial habitats!*

rainforests, salt marshes, mangroves, redwood forest, swamp, wetland, etc.

3) What factors might affect the amount of carbon stored in seagrass sediments?

The species of seagrass, height of leaves, temperature of water, pH of water, where the meadow is, depth of water, etc.

Form a hypothesis on which species will store more carbon

4) Write your hypotheses below.
    a) Why?

No right answer, but students should offer ideas on why they form the prediction they do. For example: Eelgrass will store more carbon because it is a bigger species!

Measure the size of your core

When we measure carbon through sediment cores, we need to know how much sediment we take in a sample. Record the dimensions of your core below:

****This lesson assumes a corer made of standard toilet paper tub (about 4 cm x 10 cm). If you use a different device, the answers will differ slightly****

Core Radius: 2 cm (half of the diameter!)

Now, we can calculate the area of sediment we might sample using the equation for an area of a circle. Show your work:

remember the equation for an area of a circle $A = \pi r^2$

A = 3.14*(2*2) = 12.56 cm^2

Record the amount of carbon

Take a sediment core from each bucket. Count the number of colored beads (carbon) and the number of neutral beads (sediment particles) and record them in your data table. Get the counts from the other groups' (replicates) and record them as well. Calculate the average carbon stock for each species.

Remember: Carbon Stock can be calculated from:

$$Carbon\ stock\ (\frac{Pieces\ Carbon}{cm^2}) = \frac{Carbon\ Grains}{All\ Grains}\ x\ \frac{1}{Core\ area\ (cm^2)}$$

****Every replicate sample will differ slightly!! These answers are just examples of what your student might get****

Eelgrass Sediment Cores

Replicate	Sediment Grains (pieces)	Carbon Grains (pieces)	All Grains (Pieces)	Proportion Carbon in Sample $(\frac{Grains\ Carbon}{All\ Grains})$	Carbon Stock $(\frac{Grains\ Carbon}{cm^2})$
1	120	49	169	$\frac{49}{169}$ = 0.29	$(0.29 * \frac{1}{12.56})$ = 0.0231
2	130	40	170	0.31	0.0247
3	125	35	160	0.28	0.0223
4	110	30	140	0.27	0.0215
5	150	45	195	0.30	0.0239

				Average:	0.0231

Widgeon Grass Sediment Cores

Replicate	Sediment Grains (pieces)	Carbon Grains (pieces)	All Grains (Pieces)	Proportion Carbon in Sample ($\frac{Grains\ Carbon}{All\ Grains}$)	Carbon Stock ($\frac{Grains\ Carbon}{cm^2}$)
1	128	30	158	$\frac{30}{158}$ = 0.19	$(0.19 * \frac{1}{12.56})$ = 0.0151
2	130	22	125	0.15	0.0119
3	125	23	148	0.16	0.0127
4	115	20	135	0.15	0.0119
5	135	25	160	0.16	0.0127
				Average:	0.01286

Graph the carbon stocks for each species as a bar plot.

1) What type of graph should we use, and why?

A bar plot! We are comparing the mean of two groups!

****These answers are just examples of what your student might get****

Answer the following questions

1. Which species had the larger carbon stock? What does this mean for a meadow of Eelgrass vs a meadow of Widgeon Grass?

Eelgrass has the larger stock! It means a meadow made out of Eelgrass will store more carbon in its sediment than a meadow made from Widgeon Grass

2. What would happen if a meadow that had Eelgrass switched to one with Widgeon Grass?

It may lose its ability to hold on to as much carbon!

Challenge Question:

1) Why might these species differ?

They are different in height and width!

2) How can we protect seagrass meadows? Brainstorm a specific solution.

We could help fight climate change by replanting rainforests, stopping boats from destroying seagrass meadows, planting more seagrass, etc.

Optional Section B / Worksheet 2 ANSWERS

Scaling Up in Space
Seagrass coverage in the Chesapeake Bay changes yearly. Scientists at the Virginia Institute of Marine Science use annual aerial images taken from planes to map how much seagrass there is per year. Use some of these values to see how Bay-wide carbon stocks might change over time depending on coverage and species identity.

*Note: **Many things impact carbon storage, including the age of a meadow and temperature, which will have changed between 1990 and 2020, but we can estimate the net change using our values***

2020
In 2020 Scientists found that there were 55,000 square meters of Eelgrass and 80,000 square meters of Widgeon Grass in the Chesapeake Bay. Our sediment stocks are per square cm. How can we make the units match? We can multiply our rate by the same number of square cm in a square meter, which is equal to 10,000!

****These answers are just examples of what your student might get, which will differ slightly depending on the average carbon stock they calculate****

Seagrass Carbon Stock in 2020

Species	Average carbon stock per square centimeter	Average carbon stock per square meter	The area of species is 2020	Carbon in all meadows in the Chesapeake Bay for this species
Eelgrass	0.023	230	55,000	12,650,000
Widgeon Grass	0.013	130	80,000	10,400,000

				Total carbon stock of all meadows in the Chesapeake Bay: 23,050,000

1990

In 1990 the area of species of seagrass in the Chesapeake was different: Eelgrass covered 1,010,000 square meters and Widgeon Grass covered 71,000 square meters.

****These answers are just examples of what your student might get, which will differ slightly depending on the average carbon stock they calculate****

<u>Seagrass Carbon Stock in 1990</u>

Species	Average carbon stock per square centimeter	Average carbon stock per square meter	The area of species is 1990	Carbon stock of all meadows in the Chesapeake Bay for this species
Eelgrass	0.023	230	1,010,000	232,300,000
Widgeon Grass	0.013	130	71,000	9,230,000
				Total carbon stock of all meadows in the Chesapeake Bay: 241,530,000

Final Reflections

2) Was the average carbon storage of seagrass meadows higher in 2020 or in 1990? What is causing this?

Higher in 1990! More seagrass overall means more carbon stored! Could be up to 10X higher (may change slightly depending on your average carbon stock)

Challenge Question:

2) Why has the carbon stock changed?

Changes to the environment such as temperature, pH, depth, etc., has led to changes in species coverage and overall seagrass cover!