SAV-ing Ecosystem Functioning with Water Quality Monitoring

Lesson Specifications

Grade Level

6-8

Timeframe

One 45-min class period

Materials

Teacher:

- Computer
- Projector
- Slide deck (linked)

Student or Small Group:

- Internet-enabled device
- Student Guide
- Self-reflection

Key Words

inference, interpret, evaluate, analyze, argue from evidence, human impacts

Standards

NGSS: MS-LS2-4, MS-ESS3-3, Ocean Literacy Principle #6, Climate Literacy Principle #6

A paddler explores the remains of ships in Mallows Bay-Potomac River National Marine Sanctuary. Photo: Matt McIntosh/NOAA

Activity Summary

Individually or in small groups (2–3), students are introduced to Mallows Bay-Potomac River National Marine Sanctuary and the "Ghost Fleet." Students make inferences about how human actions affect the environment. Students analyze and interpret data from the Mallows Bay water quality monitoring buoy to make an argument from evidence about the impact of turbidity on submerged aquatic vegetation (SAV).

Learning Objectives

Students will be able to:

- **Make inferences** about how human actions affect the environment.
- **Analyze and interpret** water quality monitoring data.
- **Make an argument from evidence** for the impact of turbidity on submerged aquatic vegetation (SAV).

Aerial view of shipwrecks in Mallows Bay; note the vegetation growing from the submerged hulls. Photo: Marine Robotics & Remote Sensing/Duke University

The Ghost Fleet, brought to the Potomac River to be salvaged for scrap metal, was grounded in Mallows Bay. Photo: Don Shomette

Background Information

Mallows Bay-Potomac River National Marine Sanctuary

Since 1972, NOAA's Office of National Marine Sanctuaries has served as the trustee for a network of underwater parks encompassing more than 600,000 square miles of marine and Great Lakes waters. The network includes a system of 15 national marine sanctuaries as well as Papahānaumokuākea and Rose Atoll marine national monuments. Few places on the planet can compete with the diversity of the National Marine Sanctuary System, which protects America's most iconic natural and cultural marine resources. The system works with diverse partners and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. Healthy aquatic ecosystems, whether fresh, brackish, or marine, are the basis for thriving recreation, tourism, and commercial activities that drive coastal economies.

Mallows Bay is most renowned for its "Ghost Fleet," the partially submerged remains of wooden steamships that were built in response to threats from World War I-era German U-boats that were sinking ships in the Atlantic. Photo: NOAA

Mallows Bay-Potomac River National Marine Sanctuary was designated in 2019 and is the first marine sanctuary in the state of Maryland. Located on the Potomac River approximately 30 miles south of Washington, D.C., the sanctuary protects a diverse collection of shipwrecks and habitats for hundreds of estuary species including birds, aquatic mammals, and invertebrates. Mallows Bay is also a popular recreation area, renowned for its paddling and fishing.

Visitors to Mallows Bay cannot help but be impressed by the collection of nearly 200 historic shipwrecks, some dating back to the Revolutionary War, and the remains of the largest assemblage of World War I wooden steamships known as the famed "Ghost Fleet". These ships were commissioned by President Woodrow Wilson in 1917 as part of the US Emergency Fleet during World War I.

Human Actions Impact the Mallows Bay Ecosystem

Fishing can be considered a non-material benefit derived from nature, while the fish caught are a harvestable good. Photo: NOAA

Human activities impact ecosystems in numerous ways, both positively and negatively. As ecosystems consist of interactions between both biotic, or living, and abiotic, or non-living components, changes to biological, chemical, or physical aspects will impact populations of organisms and overall function and resilience. Ecosystems benefit humans in many ways—a concept termed ecosystem services. Some examples of ecosystem services include the provision of harvestable goods, playing a role in making our environment habitable, and non-material benefits, like enjoyment from recreation in the outdoors. Human impacts on ecosystems can affect its ability to provide these services.

The Mallows Bay Ghost Fleet provides an example of human impacts. The submerged hulls act as "flowerpots" that trap sediment, which has allowed the formation of vegetation "islands" that provide homes to numerous species of birds and aquatic mammals. Beneath the surface, these man-made "reefs" stabilize sediment allowing for the establishment of underwater grasses, collectively termed submerged aquatic vegetation (SAV), which are important habitats for fish and invertebrates.

It is important to realize that the impact of humans is often far-reaching and indirect. The concept of a watershed is useful in the illustration of this point. A watershed is a defined area of land from which precipitation and runoff are channeled to a stream or river. Watersheds can be various sizes. Some inland watersheds span thousands of square miles and may contain streams, rivers, lakes, and the underlying groundwater. Many watersheds eventually drain into large bodies of water, such as reservoirs, bays, and/or the ocean. As water moves through a watershed, its quality is impacted by various human activities. Pollution from sources miles away can enter a body of water and significantly impact its health.

The remains of a submerged ship hull, or "flowerpot," lies in Mallows Bay. The structure made it possible for sediment to collect, resulting in the eventual growth of terrestrial and aquatic vegetation. Photo: NOAA

Mallows Bay is located about 30 miles from the Washington, D.C. metro area and its estimated 5.3 million people. Nutrient pollution from wastewater, agricultural, other types of runoff, and air pollution impact Mallows Bay by fueling the growth of algal blooms, which can block sunlight from reaching submerged aquatic vegetation. Mallows Bay is a freshwater bay located on the Potomac River. Mallows Bay is affected by tides, resulting in a salinity of about 0.1 parts per thousand (ppt). The Potomac and its tributaries comprise the second largest watershed and drain into the Chesapeake Bay, one of the world's most productive estuaries and home to thousands of species. An estuary is a body of brackish water located where a river meets the sea. Freshwater from the Potomac, including Mallows Bay, and its tributaries mixes with saltwater from the ocean, resulting in brackish water of the Chesapeake. The salinity of an estuary ranges from 0.5ppt to 35ppt. Water quality monitoring of the impacts of nutrients and sedimentation are a major focus of conservation efforts in Mallows Bay and the larger Chesapeake watershed.

A map of the Chesapeake Bay watershed, including Mallows Bay. Photo: USGS

What is SAV, Why is It Important, and How Can It Be Conserved?

Submerged aquatic vegetation grows in shallow water. Photo: Will Parson/Chesapeake Bay Program

Submerged aquatic vegetation (SAV) provides many important ecosystem services. It provides habitat for commercially important species like blue crabs and striped bass, is a form of "blue carbon," and helps to buffer pH of estuary waters. In addition, SAV protects shorelines from erosion, captures suspended sediment, and reduces the impact of nutrient pollution. These ecosystem services are especially important as the human population continues to grow and the impacts of climate change increase.

SAV are important sentinel species as they are sensitive to changes in water quality. Approximately 90% of the historical extent of SAV in the Chesapeake Bay disappeared around the mid-1900's because of poor water quality. Nutrient pollution in runoff from fertilizer and animal waste increase levels of nitrogen and phosphorus in estuary waters. These nutrients fuel algal blooms, which increase the turbidity of the water, blocking the sunlight SAV need for photosynthesis and resulting in die-offs. In addition, sediment in runoff can bury SAV and increase turbidity, further blocking light. Recent conservation efforts in the Chesapeake focus on reducing both nutrient and sediment pollution, as well as, helping SAV reestablish in areas within its historic range. Water quality monitoring is an important tool in planning and assessing conservation efforts within the bay.

Important Aspects of Water Quality

The water quality data buoy in Mallows Bay provides important information that will be used for local resource management, including meeting the goals of the Chesapeake Bay restoration plan. Photo: Kimberly Hernandez/MD DNR

In 2018, a partnership between the National Marine Sanctuary Foundation and Maryland Department of Natural Resources established the operation of a water quality buoy in Mallows Bay. The buoy operates from April through October and uses built-in sensors to measure and report important aspects of water quality, including temperature, salinity, dissolved oxygen, turbidity, and chlorophyll concentration.

Turbidity is measured by the buoy using a transmissometer, which measures the percentage of light transmitted along a fixed path and records values in nephelometric turbidity units (NTUs). The higher the NTU value, the higher the concentration of suspended solids and the cloudier the water. Turbidity values over 15 NTUs are normally considered to be harmful to the growth of SAV. A secchi disk is a tool used to measure water clarity, which is related to turbidity. Water clarity is defined as the depth to which light penetrates water. Turbidity is one factor that affects water clarity.

A major contributing factor to turbidity is the amount of algae suspended in the water. Algal blooms, usually caused by nutrient pollution, can block the light needed by SAV. The amount of algae in the water is measured as chlorophyll concentration (micrograms per liter (µg/l). The buoy's spectrophotometer determines chlorophyll concentration by measuring the absorbance of different wavelengths of light. Chlorophyll concentration is considered an indirect means of assessing the level of nutrient pollution. Generally, chlorophyll concentrations above 50 µg/l represent significant impacts and a value above 100 µg/l represents severe impacts. Some data suggest that harmful effects on SAV can occur at chlorophyll concentrations as low as 15 µg/l. Another major contributing factor to turbidity is suspended sediment. Runoff from agricultural fields, urban areas, and construction sites can carry away soil, producing turbid water.

The wake from a boat stirs up the algae present in a freshwater harmful algae bloom. Photo: NOAA

Water quality monitoring data has proven instrumental in monitoring and minimizing negative impacts on SAV. Total maximum daily loads (TMDL) have been set for different pollutants, prompting upgrades to wastewater treatment and improved agricultural practices. Everyone has a role to play in improving water quality. Individuals can work to reduce pollution by using less fertilizer, planting and protecting native vegetation, and maintaining one's septic system (if applicable). When recreating in estuaries, individuals can protect SAV by practicing responsible boating. Most importantly, individuals can help spread the word about the importance of SAV to estuary health.

Vocabulary	
blue carbon	carbon captured and stored by marine and coastal ecosystems, mitigating some impacts of climate change
chlorophyll concentration	measure of the amount of algae in the water column; an indirect measure of nutrient pollution
ecosystem services	benefits to humans provided by healthy ecosystem function
harmful algal bloom	events when algae, photosynthetic organisms that live in the sea and freshwater, grow out of control and produce harmful effects
nutrient pollution	the process by which excess nutrients, mainly nitrogen and phosphorus, are added to bodies of water and act like fertilizer, causing excessive growth of algae
sentinel species	organisms monitored as indicators of ecosystem health
submerged aquatic vegetation	term for rooted aquatic plants that grow completely underwater
turbidity	measure of particles suspended or dissolved in water
watershed	a defined area of land from which precipitation and runoff are channeled to a stream or river

Preparation

1. Review all digital and text assets listed in this Instructor Guide. Make sure you are familiar with the technology used to view and manipulate the 360° videos. Be prepared to model this for the students.
    - Explore the Blue: 360° Mallows Bay Ghost Fleet (video)
    - Instructional Image Slide Deck
    - Eyes on the Bay Charts and Data Summary
    - Eyes on the Bay Continuous Monitoring Data
2. Review all relevant background information.
3. Review the learning objectives and activity summary.
4. Familiarize yourself with how to manipulate the Eyes on the Bay data interfaces and the "Claim, Evidence, Reasoning" template.

Procedure

Engage

1. Give students time to watch and investigate "Explore the Blue: 360° Mallows Bay Ghost Fleet." Encourage them to pause the video and "look around." Have students record observations of evidence of human impacts on Mallows Bay. They may do this using bullet-point phrases.
2. From the slide deck, share the map of the location of Mallows Bay-Potomac River National Marine Sanctuary (slide 1). Prompt continued examination of potential human impacts on

Mallows Bay by pointing out that the sanctuary lies only about 30 miles from Washington, D.C. The Washington, D.C. metro area is home to around 5.3 million people and lies within the Potomac watershed, which includes Mallows Bay. The Potomac watershed is the second largest watershed to feed into the Chesapeake Bay.

3. Have students respond to the following prompt: Predict two ways you think Mallows Bay might be impacted by being so close to so many people. Establish the expectation that students must be able to provide reasoning for the potential impacts they list.
4. Place students into groups of two to three. Give them time to discuss how they think humans impact Mallows Bay. Model a productive discussion by encouraging students to restate and/or extend their peers' contributions. Each time a student shares an idea, other group members should facilitate the discussion by either restating the point in their own words or building upon the point with a new, but related, idea.
5. After small group discussions, bring the whole group together and help students understand that the human impacts affect ecosystems in both positive and negative ways. Share with students the positive impacts of the Ghost Fleet (providing habitat), as well as negative impacts of human activities (e.g., pollution) in the Mallows Bay watershed that affect water quality. Share that monitoring the presence of sentinel species, like underwater plants, and water quality are two ways scientists gather data that helps protect important areas like national marine sanctuaries.

Explore

1. From the slide deck, share the image of the Mallows Bay buoy (slide 2). Relate a summary of its purpose.
2. Give students time to investigate Mallows Bay buoy data from the most recent week using the data summary link. Demonstrate how to select graph parameters and manipulate both the x- and y-axes. Prompt students to generate at least two questions they have about or related to the buoy data using the prompt "I wonder…"

Explain

1. From the slide deck, display the images of submerged aquatic vegetation (slides 3-6). Prompt students to predict why SAV is important and how it might be affected by negative water quality. Establish the expectation that students must be able to provide reasoning for their predictions. After providing time for individual reflection, have students share their predictions and reasoning with a partner, and then solicit contributions from the whole group. Ensure students understand what SAV is and its importance.
2. Display the images related to turbidity, algae, and suspended sediment (slides 7-10). Prompt students to explain turbidity and predict how it might affect SAV. Establish the expectation that students must be able to provide reasoning for their prediction. After providing time for individual reflection, have students share their definition, predictions, and reasoning with a partner and then solicit contributions from the whole group. Ensure students understand the definition of turbidity, the link between nutrient pollution, algae, and turbidity, the link between suspended sediment and turbidity, as well as, how turbidity affects SAV.

3. Share the aerial footage of Mallows Bay (video, slide 11). Prompt students to predict whether they think the water is turbid and to look for evidence of algae. Prompt them to predict the health of SAV in Mallows Bay based on what they observe. Accept all reasonable predictions.

Elaborate

1. Prompt students to return to the Mallows Bay buoy data from the most recent week using the data summary link. Share with students that turbidity levels greater than or equal to 15 NTU are considered harmful to the growth of SAV. Help students understand that chlorophyll concentration, a measure of the amount of algae in the water, of greater than or equal to 15 µg/l could have harmful effects on SAV. Direct students to select both turbidity and chlorophyll concentrations to be displayed on the graph. Ask students to make a general statement about how SAV might be affected by both turbidity and chlorophyll concentrations based on the data from the previous week.
2. Prompt students to view the Mallows Bay buoy continuous monitoring data. Give them time to make a chart of turbidity chlorophyll concentrations over the most recent month. Demonstrate how to manipulate both the x and y-axes. If you find the y-axis scales to be quite different for each parameter, you can toggle on and off the parameters to view each separately. Ask students to make a general statement about how SAV might be affected by both turbidity and chlorophyll concentrations based on the data from the most previous month.

Evaluate

1. Direct students to use the Claim, Evidence, Reasoning (CER) format to evaluate the health of SAV in Mallows Bay based on the buoy data they have collected. Depending on your students' level of familiarity with this format, you may wish to model an example with a straightforward and familiar claim. Follow the CER template provided.
2. Prompt students to complete the Self Reflection.

Extension Opportunities

- Permit students the opportunity to use a secchi disk to measure the clarity of a local body of water.
- Build your own secchi disk from white bottle caps to measure water clarity.
- Create your own turbidity (clear to murky) models with materials found around the school yard.
- Perform various water quality tests (e.g., salinity, pH, clarity, dissolved O_2) on your local water.
- Observe the submerged aquatic vegetation growing in your local waterways.

<table>
<tr><th colspan="4">Education Standards</th></tr>
<tr><td rowspan="3">Next Generation Science Standards</td><td colspan="3">Performance Expectations
MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3 Earth and Human Impacts
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.</td></tr>
<tr><td>Disciplinary Core Ideas</td><td>Science and Engineering Practices</td><td>Crosscutting Concept(s)</td></tr>
<tr><td>LS2C: Ecosystem, Dynamics, Functioning, Resilience
ESS3C: Human Impacts</td><td>Analyzing & Interpreting Data
Engaging in Argument from Evidence</td><td>Stability & Change
Cause & Effect</td></tr>
<tr><td>Ocean Literacy Principles</td><td colspan="3">6. The ocean and humans are inextricably interconnected.</td></tr>
<tr><td>Climate Literacy Principles</td><td colspan="3">6. Human activities impact the climate system.</td></tr>
</table>

Additional Resources

The inclusion of links in this guide does not imply endorsement or support of any of the linked information, services, products, or providers.

A Eyes on the Bay: https://eyesonthebay.dnr.maryland.gov/eyesonthebay/index.cfm

A Habitat Worth SAV-ing: https://www.fisheries.noaa.gov/feature-story/submerged-aquatic-vegetation-habitat-worth-sav-ing

Mallows Bay-Potomac River National Marine Sanctuary: https://sanctuaries.noaa.gov/mallows-potomac/

Mallows Bay and the Ghost Fleet: https://projects.wamu.org/the-ghost-fleet/

Climate Change Impacts: https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/docs/20201214-mbprnms-climate-impacts-profile.pdf

Nutrient Pollution: https://oceanservice.noaa.gov/facts/nutpollution.html

https://www.chesapeakebay.net/issues/nutrients#:~:text=Nutrient%20and%20sediment%20pollution%20are,can%20float%20in%20the%20water.

Water Quality Monitoring: https://coast.noaa.gov/digitalcoast/topics/water-quality.html

Monitoring Explained: https://eyesonthebay.dnr.maryland.gov/eyesonthebay/whatsitmean.cfm

Chesapeake Bay: https://www.fisheries.noaa.gov/topic/chesapeake-bay#:~:text=The%20Chesapeake%20Bay%20and%20its%20watershed%20provide%20habitat%20for%20more,Chesapeake%20is%20a%20diverse%20ecosystem.

Blue Carbon: https://oceanservice.noaa.gov/facts/bluecarbon.html

For More Information

This lesson was developed by NOAA's Office of National Marine Sanctuaries in partnership with Ocean First Education. This lesson is in the public domain and cannot be used for commercial purposes. Permission is hereby granted for the reproduction, without alteration, of this lesson on the condition its source is acknowledged. When reproducing this lesson, please cite NOAA's Office of National Marine Sanctuaries as the source and provide the following URL for further information: https://sanctuaries.noaa.gov/education. If you have any further questions or need additional information, email sanctuary.education@noaa.gov.

Wooden ships that would eventually become part of Mallows Bay-Potomac River National Marine Sanctuary are tied together in 1925. Photo: Library of Congress, National Photo Company Collection

Name:

Instructor Evaluation Rubric

Glows: Things I can do well	Standard	Grows: Things that I need to improve
	Student appropriately contributed to both small and whole group discussions.	
	Student produced detailed observations, predictions, and reasoning when prompted.	
	Student was able to use the Eyes on the Bay data interface	
	Engage: Student can make inferences about human impacts on Mallows Bay-Potomac River National Marine Sanctuary.	
	Explore: Student can explain the importance of measuring water quality and monitoring sentinel species. Student can name specific parameters of water quality measured by the Mallows Bay buoy.	
	Explain: Student can explain with authority why SAV is important and how it is affected by poor water quality. Student can explain with authority the link between nutrient pollution, algae, chlorophyll concentration, and turbidity. Student can explain with authority the link between suspended sediment and turbidity.	
	Elaborate: Student can analyze and interpret water quality data to predict the health of SAV in Mallow Bay.	
	Evaluate: Student can make an argument from evidence about the health of SAV in Mallows Bay.	

Comments:

Student Guide

Engage

Record observations of evidence of human impacts on Mallows Bay

Observations of Evidence of Human Impacts on Mallows Bay

Record potential human impacts on Mallows Bay, since the sanctuary lies only about 30 miles from Washington, D.C.

Ways Mallows Bay Might Be Impacted by Human Activities	
Prediction	Reasoning

Explore

After viewing the buoy data, generate at least two questions that you have about or related to the information.

Questions Prompted by Mallows Bay Buoy Data
I wonder...
I wonder...

Explain

After viewing the images of submerged aquatic vegetation, answer the following prompts and be sure to include your predictions and reasoning.

Questions Prompted by Importance of SAV *(include prediction and reasoning)*
SAV is important because...
SAV might be affected by negative water quality by...

After viewing the images related to turbidity, algae, and suspended sediment, answer the following prompts.

Relationship	Prediction	Reasoning
Turbidity & Algae		
Turbidity & Suspended Sediment		
Turbidity & SAV		

After viewing the aerial footage of Mallows Bay, answer the following prompts.

Is the water turbid? (*circle one*) YES NO Record evidence of algae:
Predict the health of SAV in Mallows Bay based on what you have observed.

Elaborate

Using the Mallows Bay Eyes on the Bay Charts and Data Summary, follow the prompts below.

Chlorophyll concentration impact on SAV scale:

- Chlorophyll concentrations 15 µg/l – 50 µg/l = may have harmful effects
- Chlorophyll concentrations 50 µg/l – 100 µg/l = significant impacts
- Chlorophyll concentrations greater than 100 µg/l = severe impacts

Turbidity concentration impact on SAV scale:

- Turbidity concentration below 15 NTUs = no harmful effects
- Turbidity concentration above 15 NTUs = harmful effects

Analyzing Water Quality Data Previous Week		
Relationship	Prediction	Reasoning
SAV & Chlorophyll		
SAV & Turbidity		

Now using the Mallows Bay Eyes on the Bay Continuous Monitoring Data, follow the prompts below, referencing the scales from above.

Analyzing Water Quality Data Previous Month		
Relationship	Prediction	Reasoning
SAV & Chlorophyll		
SAV & Turbidity		

Evaluate

CER Template

1. The **claim** is the conclusion that you have reached in relation to the health of SAV in Mallows Bay. Record your claim in the space below.

Claim:

2. State the evidence you have for your claim. The **evidence** is the credible information that you used to arrive at, and which supports the claim. To be considered evidence, the information used needs to be relevant to the question. In addition, to adequately support the claim, there needs to be multiple pieces of evidence in support of the claim. State your evidence below.

Evidence:

3. Write a paragraph (five to seven sentences) explaining the reasoning for your claim. The **reasoning** is a logical justification that explains why the information works as evidence to support the claim. You should elaborate on why you chose the information and how it supports the claim. In addition, you should make a connection to the significance of the claim by including appropriate scientific principles. It is here that you should explore the greater implications of the information and the real-world relevance of the claim.

Reasoning:

Self-Reflection

Glows: Things I can do well	**Standard**	**Grows:** Things that I need to improve
	I meaningfully contributed to both small and whole group discussions.	
	I produced detailed observations, predictions, and reasoning when prompted.	
	I was able to use the Eyes on the Bay data interface.	
	Engage: I can make inferences about human impacts on Mallows Bay-Potomac River National Marine Sanctuary.	
	Explore: I can explain the importance of measuring water quality and monitoring sentinel species. I can name specific parameters of water quality measured by the Mallows Bay buoy.	
	Explain: I can explain with authority why SAV is important and how it is affected by poor water quality. I can explain with authority the link between nutrient pollution, algae, chlorophyll concentration, and turbidity. I can explain with authority the link between suspended sediment and turbidity.	
	Elaborate: I can analyze and interpret water quality data to predict the health of SAV in Mallow Bay.	
	Evaluate: I can make an argument from evidence about the health of SAV in Mallows Bay.	

Respond to the following prompts in 1-2 sentences.

My favorite part of this experience was...

The most important thing I learned is...

Something I'd like to know more about is...