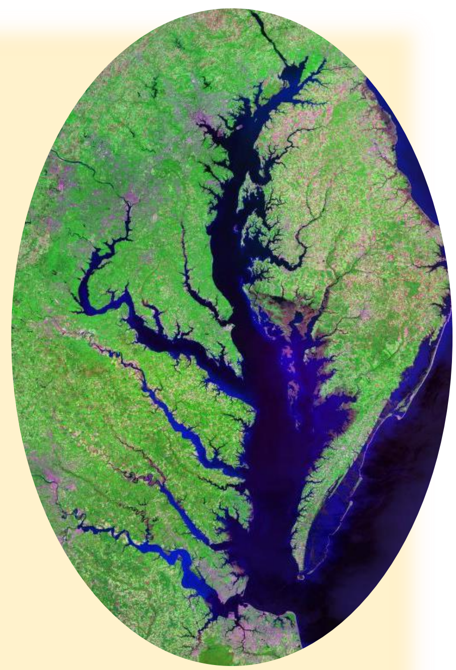
MODULE 4

Air & The Chesapeake Bay

Dead Zones, Deposition, and Nitrogen Pollution

Module Overview



The Chesapeake Bay is a natural treasure: it provides innumerable resources and ecosystem services to the living things in its watershed, especially humans. Yet the Bay is also a fragile ecosystem that has been inundated with pollution of all kinds. One of the oft-overlooked sources of pollution to the Bay is air pollution, which contributes a significant amount of nutrient pollution to its waters. In this Meaningful Watershed Educational Experience (MWEE) based module, students start by investigating a fish kill in the Bay, tracing the cause of this phenomenon back to algae blooms and nutrient pollution. Then they continue to work backwards to understand the sources of this nutrient pollution. Along the way they learn about watersheds and airsheds, and collect data on atmospheric deposition. Using this information, they build a model of pollution to the Bay, which they draw upon to create and implement an action plan to combat pollution. As a culmination of their investigation, students present their model and findings to local stakeholders.

Anchor phenomenon: A large area of dead fish floating in the Chesapeake Bay.

Pacing

- 12 activities (1 optional) including action project and presentation
- Approximately 12-13 class periods (plus 1 optional) plus time for action project and presentation (4+ class periods)

Module Contents

When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecosystems**: Air pollution can have a tremendous effect on the health of ecosystems, including the Chesapeake Bay. With activities focused on algae blooms, dissoved oxygen, and modeling cause-effect relationships in the Chesapeake Bay, this module would fit well as part of an ecoystem unit, especially in connection with food webs and energy transfers.

- **Connection to Human Impacts on Earth Systems**: Because this module focuses specifically on how *pollution* affects the Chesapeake Bay, it would work well as an addition to a unit on human impacts on earth systems by exploring the mechanism of how human activities affect ecosystems.

- **Meaningful Watershed Educational Experience (MWEE):** This module fulfills a component of the Cheseapeake Bay Agreement that all students in 6-8th grades experience a Meaningful Watershed Eductational Experience. To learn more about MWEEs, see the Teacher Background Information section below.

Timing Notes

The timing for this module can be tricky due to a few specific activities. Keep the following things in mind when planning out the schedule for the module:

- Activity 3 (Algae in a Bottle) is an experiment that runs for two weeks. There are a few different options for when to run the experiment that are noted in the activity itself. The activity also works well during a time when students will be in and out of normal class (ex. during holidays, testing, etc.), as long as they have intermittent times to check in with their results.

- Activity 11 (Measuring Wet Deposition of Nitrogen) requires rainwater. You can adjust when to lead this activity based on when it rains, or you can collect and freeze rainwater. See the activity itself for details.

- Activity 12 (Doing our Part) is a action project that requires some advance planning and additional time and resources to complete. Make sure to plan well enough ahead, and to provide enough class time to complete the project.

- Activity 13 (Presenting the Chesapeake Bay) is based on student presentations that will require some advance planning time and class time to complete, especially if you want students to present for an authentic audience.

Standards Overview

Middle School NGSS standards alignment:

Performance Expectations

Focus PE:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

Science & Engineering Practices

Focus SEP: Constructing explanations and designing solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Construct an explanation using models or representations.
- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

Background SEP: Developing & Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and/or use a model to predict and/or describe phenomena.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Background SEP: Planning and carrying out investigations

Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Disciplinary Core Ideas

Focus DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Background DCI: ESS3.C: Human Impacts on Earth Systems

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus SEP: 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Background SEP: 5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Science & Engineering Practices

Focus SEP: Constructing explanations and designing solutions
The goal of *science* is the construction of theories that provide explanatory accounts of the material world.
The goal of *engineering* design is a systematic approach to solving engineering problems that is based on scientific knowledge and models of the material world.

Background SEP: Developing & Using Models
Science often involves the construction and use of models and simulations to help develop explanations about natural phenomena.
Engineering makes use of models and simulations to analyze systems to identify flaws that might occur or to test possible solutions to a new problem.

Background SEP: Planning and carrying out investigations
A major practice of *scientists* is planning and carrying out systematic scientific investigations that require identifying variables and clarifying what counts as data.
Engineering investigations are conducted to gain data essential for specifying criteria or parameters and to test proposed designs.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

Background DCI: ESS2.A: Earth Materials and Systems
Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain new contexts.

Background CCC: Systems and System Models – Defining the system under study – specifying its boundaries and making explicit a model of that system – provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (b)	Planning and carrying out investigations. The student will… • collaboratively plan and conduct investigations to produce data • take metric measurements using appropriate tools
5.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct and/or support arguments with evidence, data, and/or a model
5.1 (e)	Developing and using models. The student will… • develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution
6.1 (b)	Planning and carrying out investigations. The student will… • independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate, and include the safe use of chemicals and equipment • take metric measurements using appropriate tools
6.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
6.1 (e)	Developing and using models. The student will… • use, develop, and revise models to predict and explain phenomena
Content Standards	
6th Grade 6.8	The student will investigate and understand that land and water have roles in watershed systems. Key ideas include: a) a watershed is composed of the land that drains into a body of water; c) the Chesapeake Bay is an estuary that has many important functions; d) natural processes, human activities, and biotic and abiotic factors influence the health of a watershed system.
Life Science LS.8	The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include: b) changes in the environment may increase or decrease population size; c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.
Life Science LS.9	The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include: b) changes in habitat can disturb populations; c) variations in biotic and abiotic factors can change ecosystems.
Biology BIO.8	The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems. Key ideas include: d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include d) human actions, including economic and policy decisions, affect the atmosphere.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.1	Write arguments focused on discipline-specific content.
WHST.6-8.1B	Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research.
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Math Standards	
6.SP.B.5	Summarize numerical data sets in relation to their context

5E Module Flow

Activity 1 (Engage): The Dead Zone
Timing: 30 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will make observations of the anchor phenomenon
- ✓ Students will ask questions to better define the anchor phenomenon
- ✓ Students will develop preliminary hypotheses about what causes dead zones

Activity 2 (Explore): Introducing the Chesapeake Bay
Timing: 45 minutes
Purpose: Building background knowledge about the Chesapeake Bay and developing questions about it.
- ✓ Students will know key information about the Chesapeake Bay
- ✓ Students will develop questions about the Chesapeake Bay

Activity 3 (Explore/Explain): Algae in a Bottle
Timing: 2 class periods + intermittent time to collect data
Purpose: Performing an experiment to show how nutrient pollution affects algae growth
- ✓ Students will perform an experiment to determine the effects of excess nitrogen in natural bodies of water
- ✓ Students will understand that eutrophication, nutrient pollution (specifically nitrogen), and dead zones are all connected

Activity 4 (Explain): Algae: The Silent Killer
Timing: 60 minutes
Purpose: Using real-world data to show the connection between algae blooms, low dissolved oxygen levels, and dead zones
- ✓ Students will interpret a graph and read a text to learn how algal blooms result in dead zones.

Activity 5 (Explain): Where is the Pollution Coming From?
Timing: 30 minutes
Purpose: Identifying the major sources of nitrogen pollution to the Chesapeake Bay
- ✓ Students will be able to name the primary sources of nitrogen pollution to the Chesapeake Bay

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds
Timing: 45 minutes
Purpose: Building background knowledge about watersheds, and how they transfer pollution to the Chesapeake Bay
- ✓ Students will be able to define watershed, geosphere, and hydrosphere, and explain how they connect
- ✓ Students will be able to describe how land-based nutrient pollution gets into the Chesapeake Bay
- ✓ Students will know that some pollution gets into the Bay when it washes off the land

Activity 7 (Explore): How Do Gases Get Into Liquids? (optional)
Timing: 30-45 minutes
Purpose: Understanding the concept of dissolving in order to understand how oxygen can be dissolved in water and air pollution can be dissolved in rainwater

- ✓ Students will understand the concept of a gas dissolved in a liquid
- ✓ Students will understand that "polluted rain" can have a significant effect on objects

Activity 8 (Explain): Air Pollution in the Chesapeake Bay
Timing: 45 minutes
Purpose: Understanding different ways air pollution can get into a body of water like the Chesapeake Bay, and where that air pollution comes from

- ✓ Students will be able to describe how air pollution gets into the Chesapeake Bay
- ✓ Students will know the definition of airshed
- ✓ Students will know the term "deposition"

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay
Timing: 45 minutes
Purpose: Using modeling to put together all the pieces of what students have learned thus far

- ✓ Students will begin to create a model of how pollution enters the Chesapeake Bay

Activity 10 (Explain): What's Going on in our Airshed?
Timing: 45 minutes
Purpose: Learning the sources of nitrogen pollution in the Chesapeake Bay airshed

- ✓ Students will identify major sources of pollution in the airshed

Activity 11 (Explore): Measuring Wet Deposition of Nitrogen
Timing: 2-3 class periods
Purpose: Conducting an experiment to determine if rainwater in the school community has been polluted with nitrogen

- ✓ Students will collect and analyze data to determine if rainwater in the school community is polluted with nitrogen

Activity 12 (Elaborate): Doing Our Part
Timing: variable
Purpose: Providing students a way to make a positive change for the Chesapeake Bay ecosystem

- ✓ Students will plan and implement an action project to decrease pollution inputs into the Chesapeake Bay

Activity 13 (Evaluate): Presenting the Chesapeake Bay
Timing: variable
Purpose: Demostrating student learning by presenting to an authentic audience

- ✓ Students will use their models and research to create a presentation of the problem of nitrogen pollution in the Chesapeake Bay.

Module Materials

Activity 1 (Engage): The Dead Zone

- ❒ Handouts: Phenomenon Observations, Hypotheses, and Questions
- ❒ Materials needed: "Clues" board with sentence strip about the dead fish
- ❒ Optional materials: none

Activity 2 (Explore): Introducing the Chesapeake Bay

- ❒ Handouts: I see & hear, I think, I wonder: The Chesapeake Bay (with teacher guide), About the Chesapeake Bay reading
- ❒ Materials needed: Projector & speakers, Chart paper (or other way to display document)
- ❒ Optional materials: none

Activity 3 (Explore/Explain): Algae in a Bottle

- ❒ Handouts: Algae in a Bottle experiment procedure, Data collection sheet, Analysis & summary sheet
- ❒ Materials needed: Materials for Algae in a Jar experiment (see below), Dissolved oxygen test kit, Additional glassware (ex test tubes) so multiple students can test at the same time, For clues board: "Lots of algae in the Bay before fish died", Algae in a Bottle Teacher Guide
- ❒ Optional materials: none

Activity 4 (Explain): Algae: The Silent Killer

- ❒ Handouts: Reading: Algae & Dissolved Oxygen (double-entry journal)
- ❒ Materials needed: Computer & projector, Word wall words: dissolved oxygen, algae, algae bloom, decomposer
- ❒ Optional materials: none

Activity 5 (Explain): Where is the Pollution Coming From?

- ❒ Handouts: Where is the Pollution Coming From?
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: none

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds

- ❒ Handouts: Watershed Notes sheet
- ❒ Materials needed: Plain paper (enough for all students, Spray bottle(s) with water (one or more), Water-soluble markers (see below for more details) – enough for all students, Paper towels for cleanup, Crumpled Paper Watershed teacher guide, Word wall words: watershed, geosphere, hydrosphere, Computer & projector
- ❒ Optional materials: none

Activity 7 (Explore): How do Gases Get Into Liquids? (optional)

- ❒ Handouts: Disappearing salt
- ❒ Materials needed: Salt, Cups of water, Stirrers, Bottle of carbonated beverage (ex. soda), Word wall words: dissolve
- ❒ Optional materials: none

Activity 8 (Explain): Air Pollution in the Chesapeake Bay

- ❒ Handouts: Welcome to the Airshed
- ❒ Materials needed: Word wall words: airshed, dry deposition, wet deposition; Blank paper (enough for all students); Spray bottle(s) with water (one or more); Chocolate pudding mix in small cups; Cotton balls; Water in small cups
- ❒ Optional materials: none

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay

- ❒ Handouts: none
- ❒ Materials needed: Computer & projector, Pre-printed/written parts of the Chesapeake Bay pollution model (these can be on paper or on sentence strips) including lots of arrows, Extra paper and markers to add components to the model
- ❒ Optional materials: none

Activity 10 (Explain): What's Going on in our Airshed?

- ❒ Handouts: Nitrogen Air Pollution
- ❒ Materials needed: Computer & projector, Animated nitrate maps (downloaded from http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf), Animated ammonium maps (downloaded from http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf), Sentence strips for Chesapeake Bay pollution model: nitrate, ammonium, power plants, agriculture, cars, trucks, etc.
- ❒ Optional materials: none

Activity 11 (Explore): Measuring Wet Deposition of Nitrogen

- ❒ Handouts: Nitrogen Deposition in Rainwater
- ❒ Materials needed: Nitrate and ammonia test kits (see note on materials), Additional glassware (ex. small beakers) to allow for multiple groups to test at the same time if necessary, Rainwater collectors (ex. jars), Distilled water (to use as a control), Safety & cleanup materials (safety goggles, paper towels, etc.), Tips for Measuring Nitrogen Deposition in Rainwater (teacher guide)
- ❒ Optional materials: none

Activity 12 (Elaborate): Doing Our Part

- ❒ Handouts: none
- ❒ Materials needed: Vary depending upon project chosen
- ❒ Optional materials: none

Activity 13 (Evaluate): Presenting the Chesapeake Bay

- ❒ Handouts: Student Presentation Rubric
- ❒ Materials needed: Student Presentation Planning Guide
- ❒ Optional materials: vary depending upon presentation type(s) chosen

Cost considerations

Unlike most of the other On the Air activities, this module contains a few different activities that have more significant costs. Algae in A Bottle (Activity 3) can be done with several recyclable materials, but it also requires fertilizer and a dissolved oxygen test kit. Measuring Wet Deposition of Nitrogen (Activity 11) requires at least one test kit for nitrate and/or ammonium. In addition, the action project (Activity 12) may require additional materials depending on what you and your students choose to do.

Below are a few suggestions to help manage some of these costs if they are a concern:

- **Create a Donors Choose page with the required materials.** Everything that is needed for the module can be purchased online, so creating a way for donors to provide the materials can be very straightforward.

- **Ask for donations from local stores**. The dissolved oxygen test kit (Activity 3) is sold at most pet stores and aquarium shops. The fertilizer (Activity 3) can be found at many garden stores or nurseries (just make sure to get the proper fertilizers). Materials for action projects (Activity 12) can often be found at local retailers.

- **Reach out to local environmental organizations**. There are many local branches of groups such as The Sierra Club and the Audubon Society who may be willing to provide funding for small projects such as this.

- **Apply for a mini-grant.** In the past, the Chesapeake Bay Trust (CBT) has offered small grants (up to $5,000) for schools to conduct MWEEs. Other organizations offer similar grants. The CBT MWEE grant page is here: https://cbtrust.org/grants/environmental-education-mini/ and Bay Baypack's funding page which lists lots of similar funding opportunities is here: http://baybackpack.com/funding

What is a MWEE?

This module is designed as a MWEE or Meaningful Watershed Educational Experience, as defined by the Chesapeake Bay Watershed Agreement. Students in Maryland, DC, and Virginia are expected to complete at least one MWEE during their middle school education.

If you are new to MWEEs, the information below will help you understand why certain elements of the module are written as they are. There are lots of MWEE resources available online which you may find helpful to access during the module, especially towards the end during the student presentation and action project activities. Links to a few of these resources are below.

The following information comes from the Chesapeake Bay Program's "An Educator's Guide to the Meaningful Watershed Educational Experience"

What is a MWEE?

MWEEs are learner-centered experiences that focus on investigations into local environmental issues that lead to informed action and civic engagement. Both teachers and students play important roles in the MWEE by working together in partnership. Teachers present unbiased information and assist students with their research and exploration, while students go through the inquiry process and ultimately take action to address the issue. Four essential elements and four supporting practices build upon each other to create this comprehensive learning experience for students

What are the parts of a MWEE?

The MWEE consists of four essential elements that describe "what students do." These elements promote a learner-centered approach that emphasizes the role of the student in actively constructing meaning from the learning experiences. Throughout the process students have time for reflection, allowing them to refocus on how what they are learning and experiencing affects the driving question of their investigations. The four elements are Issue Definition, Outdoor Field Experiences, Synthesis & Conclusions, and Stewardship & Civic Action.

To learn more about MWEEs, check out these resources:

- An Educator's Guide to the Meaningful Watershed Educational Experience: https://www.cbf.org/document-library/education/teachers-guide-to-meaningful-watershed-education-experience.pdf. This is the definitive guide to MWEEs

- Bay Backpack: http://baybackpack.com/. This website has innumerable resources for learning more about MWEEs, as well as ideas for creating action projects, teaching resources centered on the Chesapeake Bay, field studies, and funding ideas

- The National Oceanic and Atmospheric Administration (NOAA) supports MWEEs through grants and training experiences. Check out their MWEE website at: https://www.noaa.gov/education/explainers/noaa-meaningful-watershed-educational-experience

- The Chesapeake Bay Foundation is one the largest supporters of MWEEs in the area through training and field experiences. Check out their MWEE page, which includes links for trainings, field experiences, and resources here: https://www.cbf.org/join-us/education-program/mwee/

Teacher Background Information

Nutrient Pollution

Nutrient pollution is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.

Too much nitrogen and phosphorus in the water can have diverse and far-reaching impacts on public health, the environment and the economy. Photo credit: Bill Yates

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen is also the most abundant element in the air we breathe. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

Excess nitrogen in the air can impair our ability to breathe, limit visibility and alter plant growth.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Nutrient pollution in ground water - which millions of people in the United States use as their drinking water source - can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Excess nitrogen in the atmosphere can produce pollutants such as ammonia and ozone, which can impair our ability to breathe, limit visibility and alter plant growth. When excess nitrogen comes back to earth from the atmosphere, it can harm the health of forests, soils and waterways.

Source: Nutrient Pollution, US EPA, https://www.epa.gov/nutrientpollution

Nitrogen Dioxide Basics

What is NO_2 and how does it get in the air?

Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides.

NO_2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.

Effects of NO_2

Health effects

Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.

Environmental effects

NO_2 and other NO_x interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests.

The nitrate particles that result from NO_x make the air hazy and difficult to see though. This affects the many national parks that we visit for the view.

NO_x in the atmosphere contributes to nutrient pollution in coastal waters.

Source: Basic Information About NO_2, US EPA, https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2

Additional Information

Nutrient Pollution

- The EPA website on nutrient pollution has excellent information about sources and solutions, effects, action projects at home and in the community, and policy information. Access the main nutrient pollution site at: https://www.epa.gov/nutrientpollution for links to all this information

Air Pollution and the Chesapeake Bay

- The Chesapeake Bay Foundation's Interactive Slideshow "The Unseen Traveler" has excellent information on how air pollution from specific sources affects the Chesapeake Bay. Access the slideshow at: https://www.cbf.org/issues/air-pollution/the-unseen-traveler.html

Dead Zones, Dissolved Oxygen, and Nutrient Pollution

- Chesapeake Bay Dead Zones (animated) https://www.youtube.com/watch?v=zJ4l0fDq3MI

NOx in the News

- The Volkswagen diesel emissions scandal allowed cars to emit more than 40 times the legal limit of nitrogen dioxide into the air. Learn more about the scandal from BBC new here: https://www.bbc.com/news/business-34324772

Activity 1 (Engage): The Dead Zone

ACTIVITY DETAILS

Time: 30 minutes

Objectives

- ✓ Students will make observations of the anchor phenomenon
- ✓ Students will ask questions to better define the anchor phenomenon
- ✓ Students will develop preliminary hypotheses about what causes dead zones

Materials

- ✓ "Clues" board with sentence strip about the dead fish

Handouts

- ✓ Phenomenon Observations, Hypotheses, and Questions

Activity summary: In this introductory activity, students are introduced to the phenomenon of fish kills in the Chesapeake Bay by looking at photographs. They make observations of the fish in order to develop hypotheses and research questions that will guide the rest of the investigation.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning & Resilience
SEP: Asking Questions and Defining Problems
CCC: Cause & Effect

Warmup: What do you know about fish?

- The purpose of this warmup is to prime students' thinking about what fish need to live to help them better come up with questions and hypotheses about what caused the fish kill in the Chesapeake Bay.

1. **Frame the activity:** Tell students that today they are beginning a new investigation. For this investigation, they are going to be investigating a (murder) mystery to see if they can figure out whodunit.

2. **Introduce the Phenomenon:** Show students either a dead fish (from the grocery store) or a picture of one like this:

Hand out the phenomenon observations sheet, and have students write down observations. For example:

- The fish is on the sand (not in the water)
- The scales are silver
- The fish's eye seems to be missing

Next, show students a picture of a big group of dead fish in the water like one of these and tell them that these pictures come from the Chesapeake Bay:

Have students make more observations in the second row on their observations sheet. Key noticings:

- There are a lot of the same kind of fish
- There doesn't appear to be a net or a fishing line
- The fish have colors that make them look unhealthy

3. **Develop hypotheses:** Ask students what they think **caused** these fish to die. Have them take a moment to jot down some ideas on their observation sheet in the middle column. Afterwards, have them share out, and make a list on the board or chart paper and save the list for future activities. If they are stuck on hypotheses, have theme think back to what they know about fish that they shared during their warmup (ex. they have gills, they eat other fish, plants, and algae, etc.).

4. **Develop questions:** Ask students what questions they need to answer to find out what killed the fish. Their questions should be related to their hypotheses. For example, if they think the fish died because it didn't have enough food, we should ask, "How much food is in the water?" and "What do fish eat?" If our hypothesis is that they were killed by a disease, our question should be "Are there any diseases that kill fish in the Chesapeake Bay?" They may also add more general questions like "What do fish need to live?" and "What is the water like in the Chesapeake Bay?" Have them write their questions the right column. After students have had a chance to write some questions, have them share out, and make a list on the board or on chart paper that you can save for future activities.

TEACHER NOTES

Teacher Tip

- ✓ Make sure that when students are making observations, they are not drawing conclusions. For example, if students say "the fish are dead," push them to describe what observations they made to reach that conclusion (ex. they're not moving, they're at the surface, they're floating on their sides). These observations may provide valuable clues that "the fish are dead" does not.

Modification

- ✓ If students are uncomfortable sharing their hypotheses or questions out loud, have them write them on sticky-notes or slips of paper and put them up on a bulletin board.

TEACHER NOTES

Optional

- ✓ Have students read the interview with the module's Air Quality Champion to get them into the frame of mind of what they'll be investigating

5. **Framing the investigation:** Tell students that for this investigation, they are going to take on the role of marine biologists to try to solve the mystery of what killed these fish. They will use clues that they gather throughout the investigation to try to solve the mystery. Point out a spot on the wall where you have posted the word "Clues". Add your first clue: dead fish in the Chesapeake Bay.

6. **Formative assessment:** Have students use what they learned during the activity to write an observation, a hypothesis, and a question that go together into a single statement. For example:
   - I saw that there were a lot of dead fish together, so I think that they were killed by poison that someone dropped in the water. My question is: is there poison in the Chesapeake Bay?

Air Quality Champion

Dr. Lewis Linker is an environmental scientist who makes models of the Chesapeake Bay. His work allows leaders to make smart plans about how to clean up the Bay and restore it to good health. Learn more about Dr. Linker and his work at the end of the module.

STUDENT HANDOUT

Name ______________________________

Phenomenon Observations, Hypotheses & Questions

Cause & Effect

What do you see?	What do you think could have caused this?	What questions do we need to answer?
One fish		
Many fish		

Activity 2 (Explore): Introducing the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will know key information about the Chesapeake Bay
- ✓ Students will develop questions about the Chesapeake Bay

Materials

- ✓ Projector & speakers
- ✓ Chart paper (or other way to display document)

Handouts

- ✓ I see & hear, I think, I wonder: The Chesapeake Bay (with teacher guide)
- ✓ About the Chesapeake Bay reading

Modification

- ✓ For the warmup, put butcher paper out on a table (or tables) and have students write whatever they know about the Chesapeake Bay on it. Have enough paper so that all students can write on it at the same time.

Activity summary: In this activity, students get to know the Chesapeake Bay a little better by watching a video, looking at maps, and reading an article. The goal is for students to develop greater familiarity and connection with the Bay, while also learning some important facts for their investigation.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience

A Note About Place-Based Learning

Students may have a conceptual idea of the Bay, or they may have seen it when they rode over the Bay bridge, but few of them have the strong internal connection for the Bay that many conservationists have. Be sure to help students develop some of that connection, which goes beyond the technical definition of what they Bay is. The video students watch in this activity is designed to help with that. You may also consider putting up pictures of the Bay around the classroom during this module to help students build that connection, or even scheduling a trip with organizations like CBF to take students to the Bay.

Warmup: What do you know about the Chesapeake Bay?

- This warmup is designed to provide some information on students' background knowledge about the Bay. Some students may have a lot of background knowledge, and some will likely have none. Encourage all students to write something (ex. all students should know that it has water in it). Have students share after the warmup so that others can benefit from their background knowledge. You may want to look at students' answers beforehand and ask a few students to share specific important information.

1. **Frame the activity:** Remind students that they all know different things about the Chesapeake Bay. Tell them that in order for them to solve the mystery of what killed the fish in the Bay, it would help for everyone to know a little more about the Bay. If students included questions in Activity 1 that relate to knowing more about the Bay, connect today's activity back to answering those questions.

2. **Video: The Chesapeake Bay by Air (preview).** Pass out the "I see & hear, I think, I wonder: Chesapeake Bay" sheet for students. Explain that during the video, they are going to see and hear lots of information about the Chesapeake Bay. Their job is to make notes on things that they see and hear in the top section of their handout. Afterwards they will add some things that they think and wonder. When students are ready, show the preview version of the Chesapeake Bay by Air video: https://www.youtube.com/watch?v=FpJz1wsF6Z8

3. **Video Share**: Have students turn to a partner and share some of the things they heard and saw in the video. Then have each pair share something with the whole class. Record these for the class on chart paper or in a projected document.

4. **I think:** With their partners, have students write down some things that they think they know about the Chesapeake Bay in their "I think" section. They may ask if something is true or not, and it is okay to share answers if you know them. Otherwise, you can tell them to write their idea as a question in the "I wonder" section. They can use some things they said or heard during the warmup for this section as well.

5. **Reading: About the Chesapeake Bay:** Hand out the article, *About the Chesapeake Bay*. Have students start by looking for information from the two maps and writing it in the "I see" section at the bottom of their handouts. Then have them identify key information from the reading to add to the bottom of their handout in the "I think" section. Key takeaways:
   - The Chesapeake Bay is an estuary, which means it is where freshwater from rivers and the saltwater from the ocean meet and mix together
   - The Bay has more than 3,000 species of plant and animal life
   - The Bay is relatively shallow (average depth of 21 feet)
   - The Bay is 200 miles long
   - Freshwater comes into the Bay from 50 major tributaries (rivers that flow into the bay)
   - The Bay's watershed covers 6 states and Washington D.C.
   - The Chesapeake Bay has pollution in it

6. **I wonder**. Have students write down additional questions they have about the Bay from the video or the reading in the "I wonder" section. Have them share some questions, and add them to the list of student questions from Activity 1. Make sure that at least one "I wonder" question relates to pollution in the Bay (ex. "What kind of pollution is in the Bay?" or "Where does pollution in the Bay come from?"). This will be necessary for Activity 5.

TEACHER NOTES

Modification

✓ Consider showing the video without sound (or show it twice, without the sound the first time). This will help students to focus on visual observations.

The Chesapeake Bay Report Card

✓ The student reading includes a reference to a C- grade that the Chesapeake Bay received for health. For years, the Chesapeake Bay Foundation has published a "State of the Bay" report card grading the Bay's health on a number of indicators. In 2019, the University of Maryland Center for Environmental Science (UMCES) published the most recent report card. You can access that report card here: https://ecoreportcard.org/report-cards/chesapeake-bay/

TEACHER NOTES

Word wall

- ✓ Add the word estuary to the word wall at the end of this lesson when you are going over the exit ticket

7. **Return to the phenomenon.** Remind students about the dead fish in the Bay from Activity 1. Ask students if anything they saw or read might be a helpful clue in figuring out what killed the fish. For example, they may have written down that the Bay is polluted. This might be a clue as to what caused the fish to die. They may also have noticed that the water is sometimes brown. Don't pass any judgment on students' suggestions, and put a star by any questions that students think may be helpful for their investigation. You can also help students develop any new questions which might help in their investigation based on the video and the reading. For example:
   - Where does the pollution in the Bay come from?
   - How does the pollution get from there into the Bay?

   Encourage students to add any important new questions to their "I wonder" section.

8. **Formative assessment** (Exit ticket)
   - What is an estuary?
   - How does freshwater get into the Chesapeake Bay?
   - How does saltwater get into the Chesapeake Bay?

STUDENT HANDOUT

Name______________________________________

I See & Hear, I Think, I Wonder…

The Chesapeake Bay

Source	I See & Hear	I Think	I Wonder
Video			
Map & Reading			

TEACHER GUIDE

I See & Hear, I Think, I Wonder…

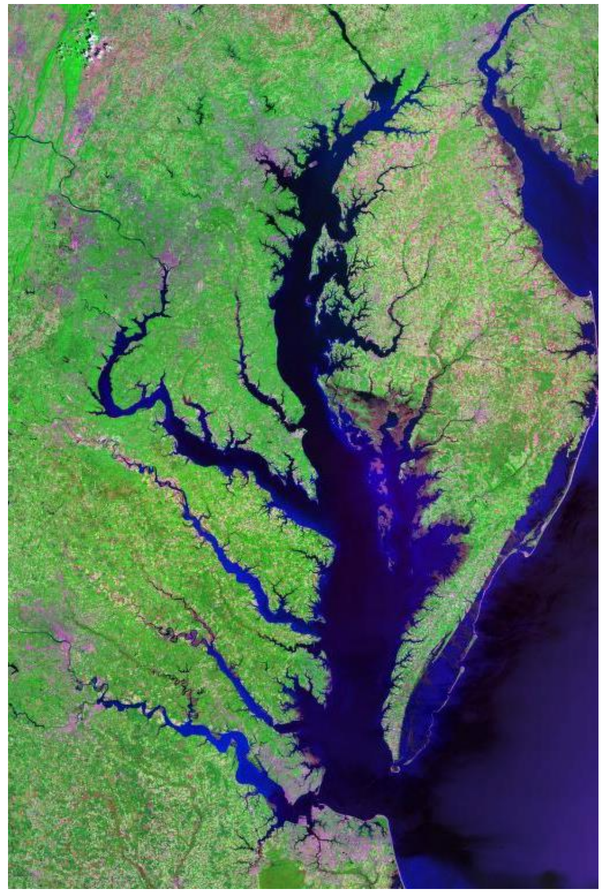
The Chesapeake Bay

Source	I See & Hear	I Think	I Wonder
Video	• Towns • Brown water • Bridges • The shoreline would stretch to the west coast and back • Potomac • James • Lighthouses • Farms • Marshes	• The Potomac is a river that goes into the Bay • The water is dirty • There is a bridge that goes over the Bay that leads to Ocean City	• How far away is the Bay from school? • Is the water really dirty? • What lives in the Bay?
Map & Reading	• The Bay is between Maryland, Delaware, and Virginia • The Bay looks like a big chicken finger • The Chesapeake Bay is long and skinny • The Chesapeake Bay is mostly north & south	• There are lots of different animals in the Bay like crabs, fish, and birds. • There are lots of plants in the Bay • The Bay is an estuary (salty and fresh water) • The Bay is mostly shallow • The Bay is very long (200 miles) • The Bay is connected to the Atlantic Ocean • Many rivers flow into the Bay • The Bay is polluted	• Can you swim in the Bay? • Can you drink the water? • Where does pollution in the Bay come from?

Name ______________________________

STUDENT HANDOUT

About the Chesapeake Bay



The Chesapeake Bay is a 200-mile-long body of water that connects many rivers in Maryland Washington D.C., and Virginia to the Atlantic Ocean. In fact, the Chesapeake Bay watershed – the area of land that drains its water into the Bay, includes 6 different states and Washington, D.C.! The Chesapeake Bay is an **estuary**, which means that it is a place where freshwater and salt water mix. More than 50 major streams and rivers flow into the Bay.

Many different living things depend on the Chesapeake Bay. More than 3,000 species of animals and numerous species of plants live in the Bay or use it for food or shelter. Blue crabs and oysters are probably the most famous animals in the Bay, but many birds, like pelicans and osprey live there too. So do rockfish, river otters, and diamondback terrapin turtles. Underwater grasses and algae are also very important parts of the Chesapeake Bay ecosystem.

The Chesapeake Bay is not very deep in most places. The average depth of the Bay is 21 feet, although the deepest point is 174 feet. However, because it is so big, the Bay can hold more than 15 trillion gallons of water.

The Chesapeake Bay is very important to humans for many reasons. 10 million people live along the shore of the Bay or nearby and use it for recreation, food, and work. We harvest more than 500 MILLION pounds of seafood from the Bay every year!

The Chesapeake Bay also has a pollution problem. In 2019, the Bay got a score of C- for its health. That means we all need to do what we can to help make the Bay healthy and safe again.

Source: Chesapeake Bay Foundation, Geography and facts: https://www.cbf.org/about-the-bay/chesapeake-bay-watershed-geography-and-facts.html

Activity 3 (Explore/Explain): Algae in a Bottle

ACTIVITY DETAILS

Time: 2 class periods + intermittent time to collect visual and dissolved oxygen data

Objectives

- ✓ Students will perform an experiment to determine the effects of excess nitrogen in natural bodies of water
- ✓ Students will understand that eutrophication, nutrient pollution (specifically nitrogen), and dead zones are all connected

Materials

- ✓ Materials for Algae in a Jar experiment (see below)
- ✓ Dissolved oxygen test kit
- ✓ Additional glassware (ex test tubes) so multiple students can test at the same time
- ✓ For clues wall: "Lots of algae in the Bay before fish died"
- ✓ Algae in a Bottle Teacher Guide

Handouts

- ✓ Algae in a Bottle experiment procedure
- ✓ Data collection sheet
- ✓ Analysis & summary sheet

Activity summary: In this extended experiment, students explore the effects of algal blooms on dissolved oxygen levels of water in a system by growing their own algae blooms in water bottles. They also connect excess nutrients to excess algae growth. This will prepare them for understanding how nutrient pollution affects the Chesapeake Bay.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Planning & Carrying Out Investigations, Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Experiment Guide

There are a lot of options for this experiment regarding materials and timing. At the start of the module, be sure to check out the Algae in a Bottle Teacher Guide below to help prepare.

Warmup: What kinds of living things do you find in the Chesapeake Bay? Don't forget living things that are not animals!

- The purpose of this warmup is to connect with the previous day's activity, and to determine whether students remember that algae live in the Bay.

1. **Frame the activity:** Tell students that you have another clue about the dead fish in the Bay. Before the dead fish appeared, scientists noticed that there was something strange about the water. It looked like this (show picture below). They thought there might be a connection between the color and the dead fish, but they had to find out for sure. We are going to start an experiment today to see what might cause this color in the Bay, and whether that might have caused the fish to die.

2. **Introduction to algae:** Ask students what they notice about the color in the picture. Key things for them to see are: it is a green color, it is closer to the shore than the center of the Bay, it seems almost like it is in waves. Ask students if they have any ideas what this color might be. Use questioning to help them realize that what they are looking at is a large quantity of algae. Lead a short discussion to see if/what students already know about algae. Then show them these pictures:

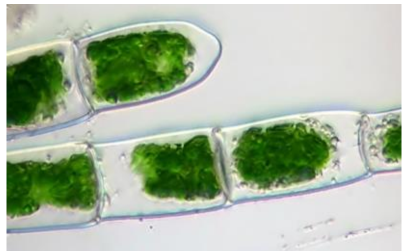


Photo by Felix Andrews (Floybix) - Own work, CC BY-SA 3.0,

Ask if any students have seen anything like the first picture. Tell them that the first picture shows algae growing in a pond. When this happens, it is called an algae bloom. The second picture shows what some algae look like under a microscope. Ask if students know why they have a green color. Use questioning to help students recognized that they can make their own food like plants (you don't need to discuss photosynthesis and chloroplasts). Students will learn more in depth about algae in Activity 4. Add the clue "Lots of algae appeared in the Bay before the fish died" to your clues board.

3. **Algae experiment setup:** Tell students that they are going to be performing an experiment to see if the algae are causing the fish to die. To do that, they are going to grow their own algae to observe what happens. Collaborate with students to develop a research question such as "How do algae affect the water they are growing in?" Hand out the "Algae in a Bottle Experiment Procedure" to students, and have them write the research question in the space at the top.

   Have students read through the materials first. When they get to the fertilizers, tell them that the different fertilizers will help the algae to grow. You don't need to go into detail at this point about why you are adding these particular fertilizers, but students will begin to understand in later activities in the module.

TEACHER NOTES

Source

- ✓ This experiment is based on "Bloomin' Algae!" https://www.education.com/science-fair/article/eutrophication/ which is itself based on "Eutrophication Lab" by D. Gioffre.

Modification

- ✓ If you are very pressed for time, another option for this experiment is to have students set up the containers, and then show them pictures of what it would look like along the way and give them sample dissolved oxygen data. This is not recommended, but it is a possibility.
- ✓ Phosphate is not a focus of this unit, so if you want to use just two bottles (control and nitrogen) or split up the experiments so that different students have different bottles (nitrogen, phosphate, nitrogen + phosphate) you can limit the amount of materials needed.

TEACHER NOTES

Differentiation

- ✓ Adjust the level of data analysis for the experiment based upon students' grade level and what they are studying in math. By 8th grade, they should be able to calculate the rate of change of dissolved oxygen for each graph. At lower grades, you may want to stop at having them compare the difference between the starting and ending DO amounts in each bottle.

Read through the procedure with students and check to make sure they understand what each of the bottles is for. When students are ready to begin, divide them into groups and have them complete the Setup Day portion of the procedure. Make sure that students make observations of their bottles on Day 1. Since all their data will be the same, you can test the dissolved oxygen on the first day together to teach students how to use the kits. Use a mix of pond water and bottled water like in their experiments. Before testing, briefly explain to students what "dissolved oxygen" means (they will learn more about this in Activity 4).

4. **Observations and D.O. testing:** At regular intervals (ex. every two days), have students make observations of their bottles. Halfway through the experiment, have students test for dissolved oxygen in each of the bottles and record the data on their data sheets. On the last day of the experiment, have them test the dissolved oxygen one more time.

   By the end of 14 days, the bottles will look something like this:

5. **Results:** Have students graph their data for dissolved oxygen (you may choose to have them pool their data first). Discuss with students what kind of graph would be most appropriate. In this case, a line graph works best to show the change over time. Students should graph all their data on one set of axes to make comparison easier. They can use different colors or symbols for the different bottles. If technology is available, students can use Excel or Google Sheets to make their graphs.

6. **Analysis:** Have students analyze the change in dissolved oxygen (see note re: differentiation for different math levels), and describe the changes in the appearance of the bottles.

7. **Discussion:** Lead a class discussion with students about what their data means in the context of the experiment. Use the CER below as a guide to drive the discussion.

8. **Conclusion (formative assessment):** Make sure students have already completed Activity 4 before they do this section of this activity so they can make logical deductions about what happened in each of the bottles. Have students write a claim-evidence reasoning statement explaining their results. Because of the complexity of this CER, students will likely need some scaffolding and support. A sample explanation might be:
    - Claim: Algae grow fastest when there are extra nutrients in the water. The more algae there are, the more decomposers there will be to decompose them, causing the dissolved oxygen in the water to go down.
    - Evidence: In the bottles with the most fertilizer, we could see the most algae growing. In the bottle with no fertilizer (control) there was only a little algae growing. The bottles with the most algae and fertilizer had the least dissolved oxygen at the end, and the bottle with the least algae (control) had the most dissolved oxygen at the end.
    - Reasoning: Algae need nitrogen and phosphorus to grow. When they have extra nitrogen and phosphorus, more algae will grow. Eventually the algae die and decompose. Decomposers use oxygen to break down the algae. In the bottles with the most algae, there were more decomposers, so they used more oxygen, causing it to go down the most.

TEACHER NOTES

Differentiation

✓ If this is the first time students have written a claim-evidence-reasoning statement, be sure to scaffold appropriately (ex. give them sentence starters, write a simple example with them about a different topic, etc.). The discussion should also prepare them for writing the CER.

Modification

✓ Depending on where students are in the module, you can also connect the low D.O. levels back to the original phenomenon.

Name ______________________________

STUDENT HANDOUT

Algae in a Bottle: Experiment Procedure

Research Question: ______________________________

____

Materials

- ❒ 4 plastic ½ liter (500 ml) bottles or jars. The bottles should be the same or similar.
- ❒ Cheesecloth cut into small squares
- ❒ Rubber bands
- ❒ Masking tape
- ❒ Pond water
- ❒ High nitrogen fertilizer
- ❒ High phosphate fertilizer
- ❒ Bottled water
- ❒ Measuring cups and spoons
- ❒ Dissolved oxygen kit (from aquarium shop)
- ❒ Camera (optional)

Procedure for Setup Day (Day 1)

1. Label the bottles or jars with masking tape and a magic marker. The four labels should be: Control, Nitrate, Phosphate, Nitrate + Phosphate. Put your group initials on the labels so you know which bottles are yours.

2. Fill each bottle with 250 ml of pond water and 250 ml of bottled water. Use the measuring cups to be sure you put the same amount of water in each jar.

3. Add ½ teaspoon fertilizer to the jar that says Nitrate, and ½ teaspoon fertilizer to the bottle that says Nitrate + Phosphate.

4. Add ½ teaspoon detergent to the bottle that says Phosphate and ½ teaspoon detergent to the bottle that says Nitrate + Phosphate.

5. Cover the top of each bottle with a piece of cheesecloth and hold it tight with a rubber band.

6. Record observations of each bottle in the space on your data sheet that says Day 1. Make sure to observe the color of the water, if it is cloudy or clear, and if there is anything floating or growing in it.

7. Put the bottles in a sunny location.

8. As a class, mix 250 ml of pond water and 250 ml of bottled water. Then test the dissolved oxygen level of the mix using the procedure on your test kit. Write the dissolved oxygen level on your data sheet for Day 1.

Name ______________________________

STUDENT HANDOUT

Algae in a Bottle: Results & Conclusions

Results

Create a graph showing how the dissolved oxygen level has changed for each of your bottles. Use one set of axes for all of your data. Make sure to include a key to show what bottle each set of data represents.

Analysis

- How much did the dissolved oxygen amount change for each of the bottles?
  - Control: ______________________________
  - Nitrogen: ______________________________
  - Phosphate: ______________________________
  - Nitrogen + Phosphate: ______________________________

- How did the appearance of each bottle change from the start to the end of the experiment?
  - Control: ______________________________
  - Nitrogen: ______________________________
  - Phosphate: ______________________________
  - Nitrogen + Phosphate: ______________________________

Conclusions

Write a claim-evidence-reasoning statement to explain the change in dissolved oxygen levels and appearances for the bottles. In your statement, be sure to:

- Write a claim that answers your research questions
- Include your dissolved oxygen data and your observations in your evidence
- Use what you know about fertilizer (nutrients), algae, and decomposers to explain your evidence and prove your claim.

STUDENT DATA SHEET

Name ______________________________

Algae in a Bottle Data Sheet

Procedure for Days 2-14

1. Record your observations of the bottles using the data sheet. If you have a camera, take photographs of the bottles to show the changes.

2. On Day 7 and Day 14, take water samples from your bottles and test them for dissolved oxygen using the directions on your test kit. Record the dissolved oxygen level on your data sheet.

Day #	Observations	Dissolved oxygen (ppm)
1 Setup Day	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Starting dissolved oxygen level:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**

	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**

TEACHER GUIDE

Algae in A Bottle Teacher's Guide

Timing Considerations

This activity takes one day to set up, plus intermittent time for students to collect data, then time at the end to analyze the data and draw conclusions. Overall, the experiment takes about 2 weeks, but only one whole class period at the beginning, and one at the end.

There are few recommended options for timing:

- **Option 1:** Start the experiment right after Activity 1, and then check in with the results as time goes on. This has the benefit of helping students understand what they are setting up. However, students won't get results until later in the module.
- **Option 2:** Start the experiment in advance of the module so they will be able to draw conclusions by the time you get to this Activity. This has the advantage of providing results earlier, but students won't really understand why they are setting up the experiment.
- **Option 3:** Start one set of algae bottles in advance so that students can see the results earlier, then have them start their own experiments during the module. This way students can see results earlier, and also know why they are setting up the experiment. The downside to this is that students will know what happens in the experiment before their own bottles are done.

All three options have benefits and drawbacks. Choose the option that works best for you and your students.

Materials

Bottles: The experiment calls for 4 bottles or jars per group of students. The bottles should ideally be the same within a group, but they can be different for different groups. Consider having students bring in bottles or jars from home to use. If absolutely necessary, you can buy packs of water and use the bottles. The amounts for this experiment are based on 500ml bottles.

Fertilizers: The experiment calls for high nitrate and high phosphate fertilizers. You can find a variety of different fertilizers at local garden stores and online. For example, Amazon sells the two fertilizers below. You may be able to get a local garden store to donate them. Look for fertilizers that only have one of the two ingredients (nitrate or phosphate) to make the results more clear.

- Nitrogen fertilizer: Easy Peasy Plants Urea Nitrogen Fertilizer
- Phosphorus fertilizer: Easy Peasy Plants Triple Super Phosphate

Water: If you have nearby access to a pond or slow-moving stream that likely has algae in it, this is the easiest source. If you don't have access to either of these, you can likely get aquarium water from a local pet store that sells fish. You can also order blue-green algae from science suppliers such as Carolina. Make sure to get enough water for all your student groups.

Dissolved oxygen test kit: There are a variety of commercially available dissolved oxygen test kits that vary by price, accuracy, and ease of use. Generally speaking, the more accurate kits are more expensive, though not necessarily more difficult to use. Below are two suggested kits:

- Salifert Dissolved Oxygen Test Kit (less accurate, relatively easy, inexpensive)
- CHEMets Dissolved Oxygen Visual Kit (accurate, very easy, more expensive) – refill kits are less expensive

Activity 4 (Explain): Algae: The Silent Killer

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- ✓ Students will interpret a graph and read a text to learn how algal blooms result in dead zones.

Materials

- ✓ Computer & projector
- ✓ Word wall words: dissolved oxygen, algae, algae bloom, decomposer

Handouts

- ✓ Reading: Algae & Dissolved Oxygen (double-entry journal)

Teacher Tip

- ✓ The "algae" in these graphs is actually a bacterium (cyanobacterium) which is called blue-green algae because it shares a lot like of characteristics with algae. You can bring this up with students, but don't let it distract from the overall purpose of the activity.

Activity summary: In this activity, students analyze graphs of data from Sykes Creek, a stream in Florida that was the site of a fish kill in 2016 (the fish kill isn't revealed to students until the end). After looking at the graphs of algae and dissolved oxygen, they read about the connection between algae, dissolved oxygen, and decomposers. Finally, they use what they have learned from the graphs and the reading to explain what caused the fish kill.

Standards Connection

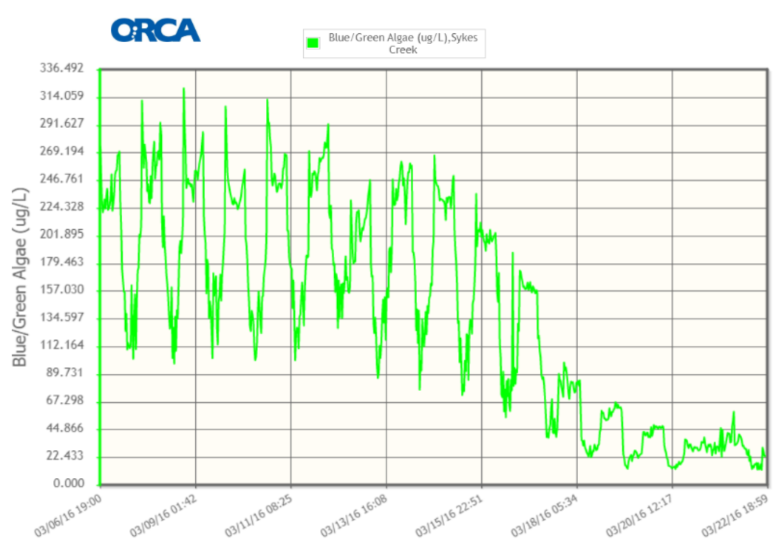
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Warmup: What happens to the bodies of animals and plants when they die? What other living things help out with this process?

- Answer: they decompose, break down, etc.; this is done mainly by bacteria and fungi, but also detritivores like worms and insects
- The purpose of this warmup is to gauge students' background knowledge on decomposition to prepare for the activity

1. **Frame the activity:** Tell students that as a class they need to do some research about algae to see how they could be connected to the dead fish in the Bay. To do this, they're going to analyze some graphs for algae growth from a place called Sykes Creek, and read a text about algae.

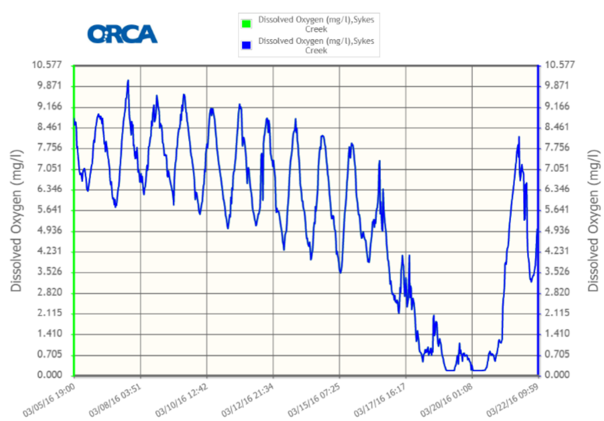
2. **Graph 1: Algae:** Hand out the Algae at Sykes Creek sheet to students and show it on a projector so students can see the color.



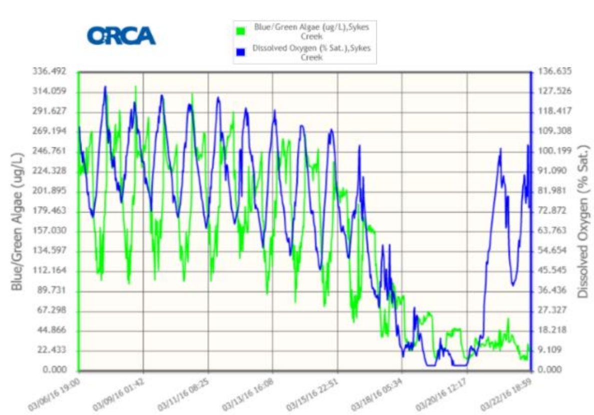
Make sure students understand that this is a graph of the amount of blue-green algae in a creek. Ask students what they notice about the graph.

Students should notice that the graph goes up and down a lot, and that it eventually goes down to a very low amount starting on March 15. Use questioning to help them realize that it goes up and down on a day/night cycle (up during the day, then back down at night). They will come back to this graph to think about why it went down so much at the end.

3. **Graph 2: Dissolved oxygen:** Display Graph 2 (Dissolved oxygen). Remind students that dissolved oxygen is just like oxygen in the air that is mixed into the water. Fish and other animals need dissolved oxygen to breathe underwater (they will learn more about it later in the activity). Have students share what they notice. They should see that it also goes up and down a lot, and then goes down to a very low level starting on March 15.



4. **Graphs 1 & 2 combined:** Show students Graph 3, which is Graphs 1 and 2 combined. Ask students what they notice. They should recognize that the two graphs fit together (the amount of blue-green algae and the amount of dissolved oxygen seem to be related up until the end). Ask students why they might be related.



TEACHER NOTES

Source Data

- ✓ The data source for these graphs is ORCA (Ocean Research & Conservation Association) based in Florida. The data comes from their public monitoring website: http://api.kilroydata.org/public/. More information about the March 2016 fish kills can be found here: http://blogs.ifas.ufl.edu/brevardco/2018/03/06/fish-kills-floridas-coastal-waters/

Discussion techniques

- ✓ For each of the graph discussions, consider using a turn-and-talk to have students share ideas with a partner before sharing with the whole class

TEACHER NOTES

Students may remember that algae make oxygen, so that could be one reason they are related. However, that doesn't explain why they both went down starting on March 15th. Depending on where students are with their Algae in a Bottle experiment, they may also be seeing similar results in their own data. Use discussion to help students reach the question: "Why do the algae and dissolved oxygen both go down at the same time?"

5. **Building background knowledge reading:** Hand out the double-entry journal reading "Algae & Dissolved Oxygen." Have students read and answer the questions.

6. **Discussion:** Have students share out key information they learned from the reading. Put up the word wall words dissolved oxygen, algae, algae bloom, and decomposers. Key ideas that students should share from the reading:
    - Algae are unicellular or multicellular living things
    - Algae can produce their own food and oxygen using sunlight
    - Algae can increase the amount of dissolved oxygen in the water
    - When there are too many algae, they die out and get broken down by decomposers
    - Decomposers use up the dissolved oxygen

7. **Return to Sykes Creek:** Have students go back to their graphs of Sykes Creek. Remind them of the drop on March 15th. Have them turn to a partner and talk about what they think happened starting on that day. Students should be able to connect their reading to the data to recognize that there were too many blue-green algae, and so they died. When they decomposed, the decomposers used up the dissolved oxygen, causing it to drop. After their turn and talk, have groups share out their conclusions.

8. **March 20, 2016:** Remind students of their original mystery (the dead fish in the Chesapeake Bay). Point out key clues that they've learned:
    - Dead fish in the Chesapeake Bay
    - Lots of algae appeared in the Bay before the fish died

    Have students add any more clues from today's activity such as:
    - When there is too much algae, they die, and the amount of dissolved oxygen goes down

Tell students that the reason they've been studying Sykes Creek in March 2016 is that it was the site of another mystery. Ask students if they can predict what happened at Sykes Creek on March 20th 2016 (point out the data on the graph). They may or may not be able to guess what happened. In either case, show them this photo:

Photo taken Mar 20

Use questions and discussion to help students realize that when the dissolved oxygen level gets too low, it will kill the fish. Have them add a clue to their clues board such as:

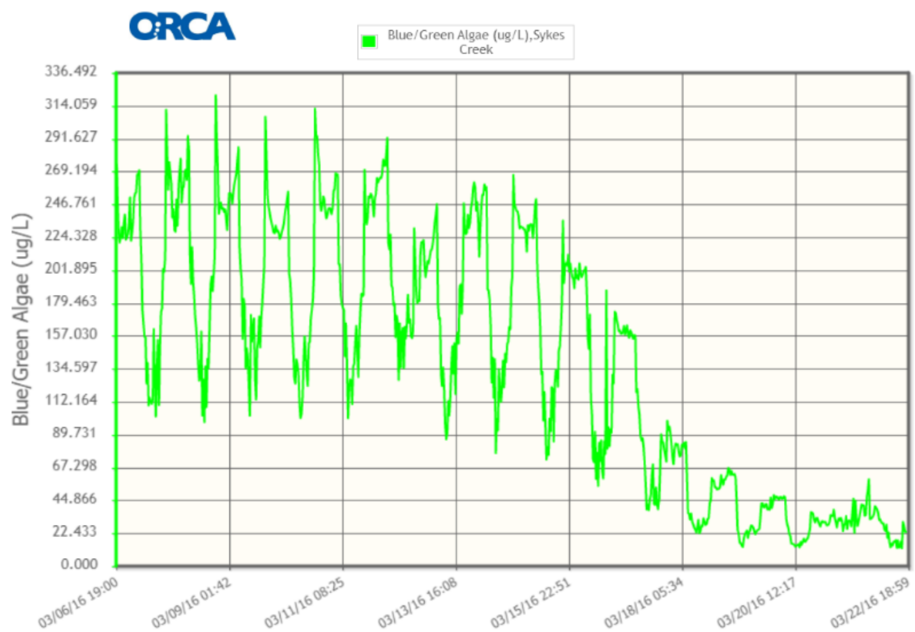
- Low dissolved oxygen can kill fish

9. **Formative assessment:** Have students answer the prompt on their graphs sheet as a narrative (or Claim-Evidence-Reasoning argument) explaining what caused the fish to die in Sykes Creek based on what they learned today. For example:
   - Claim: The fish died because there was not enough oxygen due to too many blue-green algae.
   - Evidence: On March 15, the amount of blue-green algae went down a lot. The amount of dissolved oxygen also went down a lot.
   - Reasoning: The amount of blue-green algae went down because there were too many and they blocked out the sunlight so they could not make enough food. When they decomposed, the decomposers used up the oxygen in the water. Because there was not enough oxygen, the fish couldn't breathe and they died.

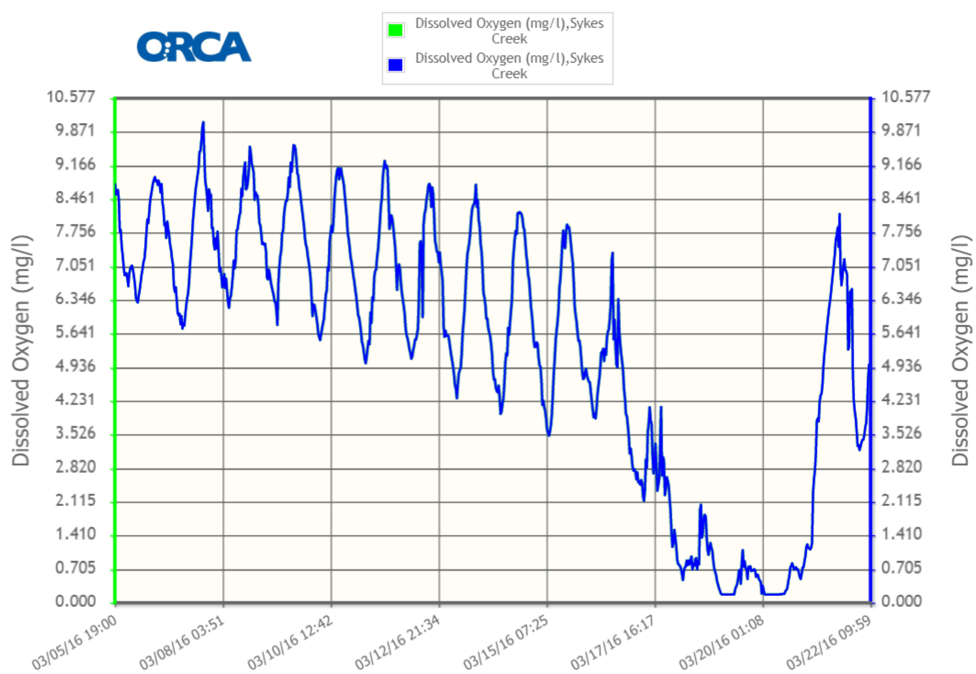
Name___________________________________

STUDENT HANDOUT

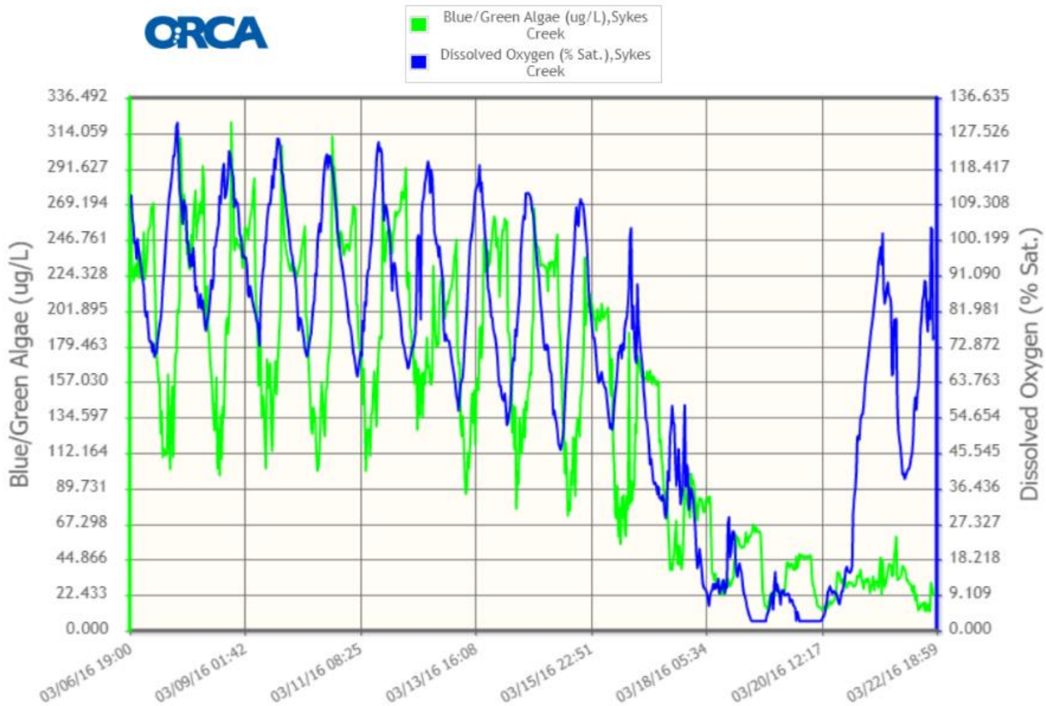
Blue-green Algae at Sykes Creek



Graph 1: Blue-Green Algae at Sykes Creek



Graph 2: Dissolved Oxygen at Sykes Creek



Graph 3: Blue-green Algae and Dissolved Oxygen at Sykes Creek

Conclusion

Explain what happened on March 20th in Sykes Creek using what you learned today from the graphs and the reading about algae and dissolved oxygen.

Name ______________________________

STUDENT READING

Algae & Dissolved Oxygen

Algae are living things that grow in all different kinds of water around the world. If you have ever looked at a pond and seen green scum on top, you're looking at algae! Algae can be very small, single-celled organisms, or they can be large multicellular organisms. Algae can also clump together to form thick mats which can completely cover the surface of a lake or pond. They can also grow into big "forests" in the ocean.	**Have you ever seen algae before? Where?**
There are many different kinds of algae. There is also a bacteria, called blue-green algae, which is not algae at all! It just gets its name because it has many similar characteristics as algae. The most common characteristics of algae are: they live in all types of water (freshwater and saltwater) and they conduct photosynthesis. This means that they can use sunlight to make their own food, just like plants. However, unlike plants, algae do not have roots stems, or leaves.	**What are common characteristics of algae?**
Photosynthesis makes food, and it also produces oxygen. When algae make oxygen, it is often dissolved in the water. When something is dissolved in water, it means it is mixed in with the water molecules. For example, if you stir sugar into a glass of iced tea, the sugar will dissolve into the tea. Dissolved oxygen is oxygen that is mixed into the water. Fish, crabs, shrimp, and other animals that live in water need the dissolved oxygen to breathe, just like we need oxygen in the air to breathe.	**Where does the oxygen go that algae make?**
Algae can help add oxygen to the water, but sometimes there can be too much algae. This is called an algae bloom. During an algae bloom, the algae blocks the sunlight from getting into the water. This causes the algae and underwater plants to die. When the algae die, decomposers like bacteria and fungi break down the algae. This uses oxygen. When there is a lot of dead algae, the decomposers use a lot of dissolved oxygen up from the water.	**What do you think happens to the amount of dissolved oxygen in the water if there is too much algae?**

Activity 5 (Explain): Where is the Pollution Coming From?

Activity summary: In this short activity, students study an infographic to learn that the main source of nitrogen pollution to the Bay is from agriculture and air pollution. They use this new information to help understand where the algae bloom came from.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
CCC: Cause & Effect

Warmup: What do plants need to grow?

- The purpose of this warmup is to start laying the groundwork for students to make the connection between nutrient pollution and algae blooms. They will likely say things like water, air, sunlight, and soil. During the warmup discussion, ask students what plants need from the soil. If they don't know ask them if they've ever grown a plant or know someone who grows vegetables or flowers. Ask what they put on the soil to help their plants grow? (fertilizer). Students will discover some additional information about this later in the activity, so don't give away too much at this point. The goal is just to help students start making this connection.

1. **Frame the Activity.** Return to the clues board that you've been developing about the what killed the fish in the Bay. So far you should have at least these three clues (or something similar to them):
   - Dead fish in the Chesapeake Bay
   - Lots of algae appeared in the Bay before the fish died
   - When there is too much algae, they die, and the amount of dissolved oxygen goes down

   Ask students if they think they can solve the mystery of what caused the fish to die. Have them turn to a partner to share what they think happened. At this point, students should be able to explain:
   - The fish died because they didn't have enough oxygen to breathe (they suffocated). There was too much algae from the algae bloom so when the algae died and decomposed, the decomposers used up all the oxygen, so there wasn't enough for the fish.

ACTIVITY DETAILS

Time: 30 minutes

Objectives
- ✓ Students will be able to name the primary sources of nitrogen pollution to the Chesapeake Bay

Materials
- ✓ Computer & projector

Handouts
- ✓ Where is the Pollution Coming From?

Timing Tip
- ✓ Because this activity is on the shorter side, it works well on a day when students are also making observations of their Algae in a Bottle experiments.

ACTIVITY DETAILS

Timing note

- ✓ If students are already into Week 2 of their Algae in a Bottle experiments, they may have an idea of where the algae came from. Tie this in as much as possible to help students make the connection between the algae bloom and nutrient pollution.

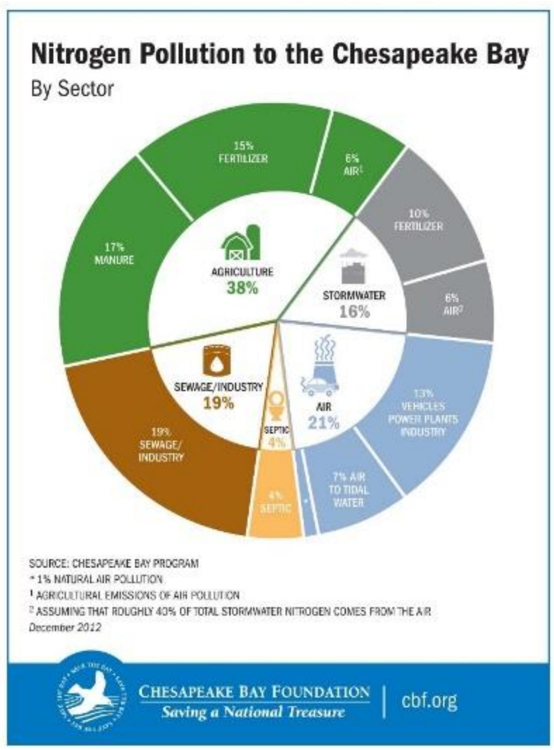
Note on Source Data

- ✓ The information in this infographic is constantly changing due to changing human behaviors and land use. Scientists like Lewis Linker (our Air Quality Champion for this module) create models to better understand all the nutrient inputs into the Bay to better understand the source of the problem. While more updated percentages may be available, the general sources of the pollution have not changed significantly.

If all students haven't quite reached this stage of articulating an answer, it is okay, because they will have additional time in the future. As long as some students can reach this point, tell them that they're close to solving the mystery, but there's still at least one more question they need to answer: **Where did all the algae come from?** Tell them that during class today they're going to begin investigating that question.

2. **Fiendish fertilizer:** Remind students that one of their "I wonder" questions from the Chesapeake Bay video was about pollution in the Bay. Tell students that there are four main kinds of pollution that enter the Chesapeake Bay: toxic chemicals, nitrogen, phosphorus, and sediment (ex. sand). Go through each one, and ask students whether they think it could have caused the algae to grow into a bloom. Use questions to help them remember that nitrogen and phosphorus are in fertilizer (they should be able to remember this from their algae experiments). Help them reach the conclusion that nitrogen and phosphorus are likely what is causing the algae to grow.

3. **Where is the pollution coming from?** Ask students where they think the majority of this pollution is coming from? Acknowledge students' responses, but don't give away whether they are right or not. Next, hand out the "Where is the Pollution Coming From?" sheet for students and have them use the infographic to answer the questions.



Afterwards, lead a short discussion to ensure students understand the key takeaways:

- The majority of nitrogen pollution to the Bay comes from agriculture.
- 25% of the nitrogen pollution comes from fertilizer
- 33% of the nitrogen pollution comes from air pollution
- Nitrogen pollution from manure and fertilizer is washed into the Bay (more on this in the next activity)
- Nitrogen pollution from sewage and industry comes from sewage that is dumped into tributaries or into the Bay directly. It also comes partly from people dumping into the Bay.

Ask students if they were right in their guess about where the nitrogen pollution is coming from. Then ask them how they think pollution in the air gets into the Bay. Again, don't tell them if they are right or wrong, just acknowledge their guesses. The point of this question is to get their minds thinking about how air pollution could possibly get into the water.

4. **Return to the clue board:** Go back to the clue board and see if there are any more clues to add. For example, you might add:
    - Nitrogen and phosphorus pollution are causing the algae bloom
    - Most nitrogen pollution comes from agriculture

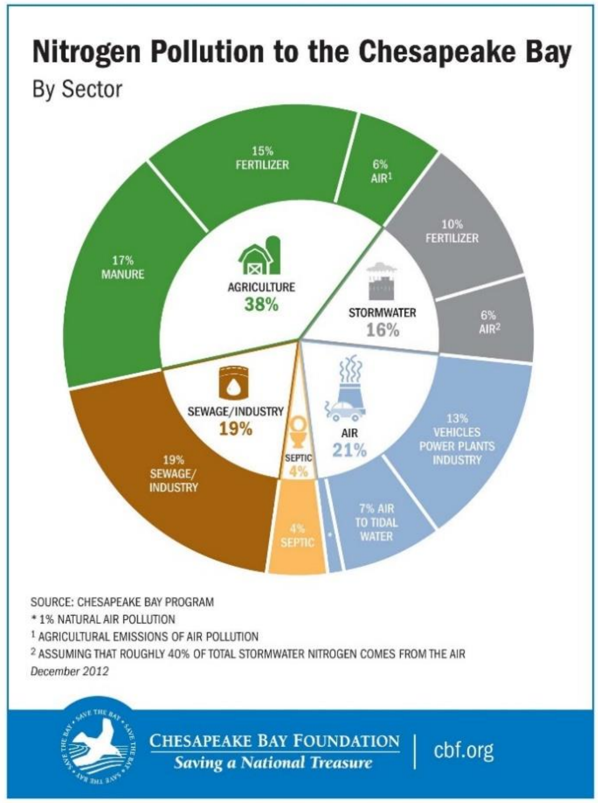
    Tell students that they now have a good idea what is causing the fish to die, but if they want to stop the problem, they need to go to the source of it.

5. **Formative assessment:** Have students complete the "Conclusion" prompt on the back of their sheet: Do you think most of the pollution in the Bay comes from people dumping it into the water on purpose? Use information from the infographic to support your answer.
    - Answer: No, most of the nitrogen pollution to the Bay is unintentional. It is from pollution from the land and the air that ends up in the Bay accidentally. Only a small portion of the pollution in the Bay is dumped there intentionally.

Name ______________________________

STUDENT HANDOUT

Where is the Pollution Coming From?



1. What sector (ex. sewage/industry, air, etc.) does the largest portion of nitrogen pollution to the Bay come from?

____

2. What percentage of the nitrogen pollution to the Bay comes from fertilizer? (make sure to look in all sectors):

____

3. What percentage of nitrogen pollution to the Bay is air pollution? (make sure to look in all sectors):

____

4. How do you think nitrogen pollution from things like fertilizer and manure gets into the Bay?

____

____

5. How do you think nitrogen pollution from things like sewage and industry gets into the Bay?

____

____

Conclusion

Do you think most of the nitrogen pollution in the Bay is dumped there intentionally? Use information from the infographic to support your answer.

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will be able to define watershed, geosphere, and hydrosphere, and explain how they connect
- ✓ Students will be able to describe how land-based nutrient pollution gets into the Chesapeake Bay
- ✓ Students will know that some pollution gets into the Bay when it washes off the land

Materials

- ✓ Plain paper (enough for all students.
- ✓ Spray bottle(s) with water (one or more)
- ✓ Water-soluble markers (see below for more details) – enough for all students
- ✓ Paper towels for cleanup
- ✓ Crumpled Paper Watershed teacher guide
- ✓ Word wall words: watershed, geosphere, hydrosphere
- ✓ Computer & projector

Handouts

- ✓ Watershed Notes sheet

Activity summary: In this activity, students learn about watersheds, and how pollution that is initially on the land gets into the water. They do this by making a simulated watershed from a crumpled piece of paper, and then "raining" on the watershed to wash pollution into waterways. Using their paper watersheds, students create definitions and apply their definitions to understanding the Chesapeake Bay watershed.

<u>Standards Connection</u>

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: Where would you find things like manure and fertilizer? What about other kinds of animal feces?

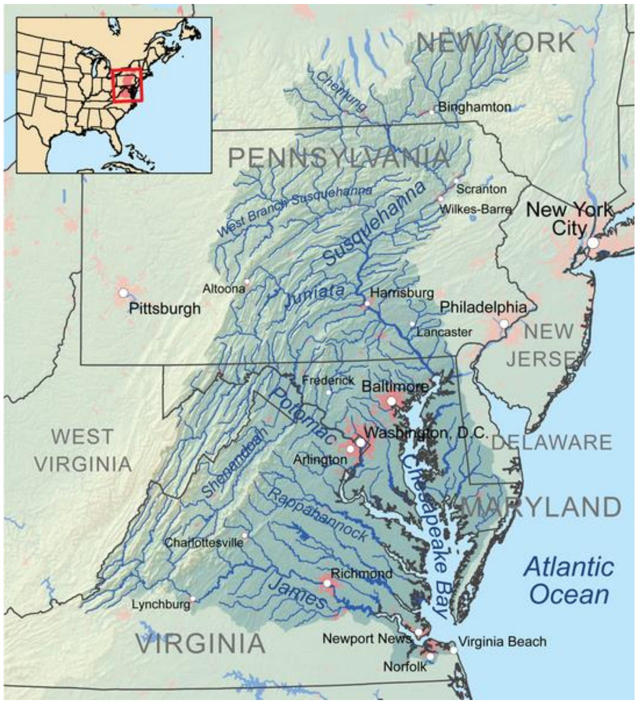
- Use this warmup to help kids make the connection that these things are often found on farms, but they also are commonly found in other places too. Pet feces are a major contributor to pollution in Rock Creek Park (DC) and fertilizer from lawns is a problem in both urban and suburban communities. You can use the graphic from the previous activity to point out that "fertilizer" appears in both the agriculture sector and the stormwater sector.

1. **Frame the Activity:** Remind students that during the last activity, they shared some ideas about how pollution on the land gets into the water. For example, how manure from a farm or fertilizer from a lawn might get into the water. Today they're going to figure out how that happens. Since a lot of the nitrogen pollution that is making the algae grow is coming from the land, figuring out how it gets into the water will provide some clues as to how to stop it.

2. **Crumpled paper watershed**. Follow the teacher guide below to lead this activity with students. Make sure to clean up before moving to the next part of the activity so the wet watersheds are not a distraction.

3. **Defining the Chesapeake Bay watershed**: Ask students to think about the Chesapeake Bay watershed. Where do they think the Chesapeake Bay watershed is? (It is the area of land around the Chesapeake Bay. Put up a map of the Chesapeake Bay watershed like the one below and point out the area of land that is the Bay's watershed.

ACTIVITY DETAILS



Have students turn to a partner and talk about what they notice about the Chesapeake Bay watershed. When they are ready, have students share with the class. Use questions to help make sure they identify key takeaways:

- The area of land around the Bay is much larger than the Bay itself.
- The map has lots of rivers marked on it (because these rivers all flow into the Bay)
- The watershed is in many states (6 + Washington, DC).
- They live in the Chesapeake Bay watershed.

Point at different parts of the map, and ask students "If it rains here, where will the water go?" Point to parts of the map that are in the watershed, and not in the watershed. You can be specific about where the water will go before it gets to the Bay (ex. it goes into the Susquehanna River and then into the Chesapeake Bay), but the key is that all the water in the Chesapeake Bay watershed goes to the Bay. Have students write the definition of the Chesapeake Bay watershed on their notes sheet: "All the land that drains its water into the Chesapeake Bay."

4. **Defining geosphere & hydrosphere**: Put the word "geosphere" on the word wall. Ask students if they know what the prefix "geo-" means as in "geography" or "geology". Use student responses to help them understand that geo- means Earth or land, and that the "geosphere" is

Teacher Tip

✓ Most of the land to the west of the Chesapeake Bay watershed is in the Mississippi River watershed. To the south is the North Carolina Sound watershed, to the east is the Delaware River and Atlantic Ocean watersheds, and to the north is mostly the Hudson River and Great Lakes watersheds.

TEACHER NOTES

NGSS-Connection

- ✓ The terms geosphere and hydrosphere (along with biosphere and atmosphere) are used extensively in NGSS, so brining these terms in here is designed to help students make the broader connection to Earth Science concepts. If you have already used these terms with students, this is a good time to make the connection to the atmosphere and the biosphere as well.

Phenomenon connection

- ✓ If it feels useful, take a moment to help students make a connection back to the original phenomenon. They're trying to figure out what made the algae grow so much. They know that it has something to do with nutrient pollution. The watershed helps them understand where the pollution is coming from.

the part of the Earth that is land. Ask students what part of the map represents the geosphere, and make sure that they understand it is the land.

Put up the word "hydrosphere" on the word wall. Ask students if they know what the prefix "hydro" means is in "hydrated" or "fire hydrant". Use student responses to help them understand that hydro- means water, and that the "hydrosphere" is the part of the Earth that is made of water including rivers, lakes, and streams. Ask students what part of the map represents the hydrosphere, and make sure that they understand that it is the water (rivers, the Bay, the ocean, etc.)

5. **Defining the watershed in terms of geosphere & hydrosphere.** Write or display the sentence: "A watershed map shows how the land connects to the water." Ask students what this sentence means. Use discussion to help students realize that a watershed map (like the Chesapeake Bay map they were just looking at) shows what land will drain into what water. In the sentence, replace the words "land" and "water" with "geosphere" and "hydrosphere" and ask students if the sentence still makes sense. Tell them that scientists use these words "geosphere" and "hydrosphere" to define the land and the water, just like they use the word "atmosphere" to talk about everything in the air.

6. **Formative assessment:** Have students explain in their own words how fertilizer from a lawn in Northwest Maryland could get all the way into the Chesapeake Bay.
    - Possible answer: When it rains, the fertilizer washes of the lawn and down into the storm drain. The storm drain connects to a local stream. That local stream connects to the Potomac River. The Potomac River connects to the Chesapeake Bay. So the fertilizer washes all the way from the lawn to the Bay.

TEACHER GUIDE

Crumpled Paper Watershed[1]

Materials

- ❒ Plain white paper (enough for every student to have a sheet)
- ❒ Water-soluble markers (enough for student groups to have a few different colors). These markers usually say water-washable. Markers that are not water-washable will not work!
- ❒ Spray bottle with water
- ❒ Paper towels for cleanup

Directions

1. Tell students that for this activity they are going to create a landform that they can use to learn about how pollution gets into the Bay.

2. Pass out a sheet of blank paper to every student and provide water-soluble markers to groups of students so they have a few different colors. Tell students that this piece of paper will represent the land around where they live like a map

3. Have students draw an overhead view on their paper of things like houses, the school, and other things in their community (don't include any water features (rivers, lakes, etc.). Give them enough time to draw a few different things, but not fill the whole paper

4. Go back to students' answers from their warmup, and remind them of different sources of pollution such as farms and animals. You can suggest one or two things from the previous activity's infographic such as a power plants and factories. Have students choose a different color marker and add these sources (as drawings) to their paper.

5. Remind students that the land is not completely flat. To add contour (high and lows) to their map, they should crumple the paper up into a ball, and then un-crumple it without flattening it. Their uncrumpled map should have a lot of high points and low points.

6. Tell students that it is about to rain. On their notes sheet, have them predict what will happen when it rains on their land. When they are ready, have students put their papers on paper towels or trays to help with clean-up. Take out a spray bottle (or pass spray bottles out to students), and gently spray down onto each students' map. You should spray enough that water flows down to the low points and forms tiny ponds, but not so much that the entire paper becomes soggy.

7. Have students make observations and answer the questions on their Watershed Notes Sheet. Some things they should notice:
    - Water flows down and forms small ponds in the lower places (and/or makes a pool off the side of the map)
    - The colors from the "pollution sources" flow with the water into the ponds, polluting them
    - The paper (ground) also gets wet as the water soaks into it

8. Lead a class discussion about the results of the demonstration:

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[1] Based on Crumped Paper Watershed, Alice Ferguson Foundation: http://fergusonfoundation.org/teacher_resources/crumpled_paper.pdf

- **Based on this model, how do you think pollution that is sitting on the ground gets into waterways?** Pollution washes off the ground and goes downhill into the closest body of water like a river or a stream
- **How do you think pollution that is on the ground gets into the Chesapeake Bay?** (It may be useful to show the Chesapeake Bay map here to remind students of how the rivers flow into one another). When pollution goes into a river, that river connects to the Bay or to another river that connects to the Bay.

After the discussion, have students write the answers to these questions in the Analysis section on the back of their Watershed Notes sheet.

9. Ask students if all the water that they sprayed on their paper ended up in the same place. (The answer is likely no for most students). Have them pick one of the "bodies of water" where their water ended up and give it a name like "Lake Sarah" or "The Sparkling Ocean". Once they've done this, ask them what part of their paper sent or drained water into "Lake Sarah". Can they point to it? Could they draw a line around it? (Circulate and help students point out the areas where their water came from – it should only be parts of the paper that are close by and not separated by a high point)

10. Ask students where the pollution in Lake Sarah came from (it is the same area they just pointed out). Tell students that scientists give a special name to this area of land to help them study pollution for a body of water like their little lake. They call this area of land "the watershed" (put this term up on the wall) and have students write a definition of watershed on their notes sheet: "A watershed is an area of land that drains into a specific body of water."

11. Tell students that the watershed is named after the body of water it flows into like "The Potomac River watershed". Ask students what the watershed they pointed out would be called ("Lake Sarah watershed" or "The Sparkling Ocean watershed"). Tell students that they can remember what a watershed is because a watershed "sheds it water" into a river, lake, ocean, or other body of water.

12. Clean up students' papers before moving on to the next part of the activity. If students want to keep their papers, pour out the extra water and find a place in the classroom where they can dry and keep their shape.

STUDENT HANDOUT

Name ______________________________

Paper Watershed Notes

Before the Rain

What do you think will happen when it rains on your land?

After the Rain

What do you see on your land after the rain?

Where does the water go?

What happened to the “pollution” from your different sources?

What happened to the “ground” (your paper)?

Analysis

How does pollution that is on the ground get into the water?   How does pollution from the ground get into the Chesapeake Bay?

Understanding Watersheds

What is a watershed?
What is the name of the watershed on your map?

The Chesapeake Bay Watershed

What is the Chesapeake Bay watershed?

Activity 7 (Explore): How Do Gases Get Into Liquids? (optional)

Activity summary: For this activity, students use a variety of phenomena including weathered and eroded tombstones, dissolving salt, and carbonated soda to explore the concept of dissolved substances. This is designed to lead them to an understanding of how gases can be dissolved in liquids, which will be important for understanding how air pollution can get into the Chesapeake Bay.

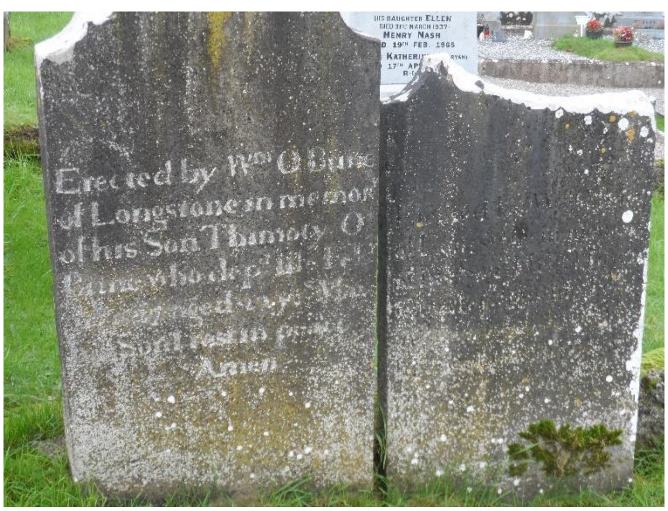
A Note about doing this activity

The activity after this one (Activity 8), as well as some of the activities before this one refer to gases dissolved in water, especially dissolved oxygen, dissolved nitrate, and dissolved ammonia. This activity is designed to help provide student background knowledge about how this is possible. It is not entirely necessary for students to understand gases dissolved in liquids to proceed through the module, so if you are pressed for time, it is okay to skip this activity. Nonetheless, it does provide valuable background knowledge for students, so if you have time, it is recommended.

Standards Connection

SEP: Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Warmup: Show students a picture of monuments or tombstones affected by acid rain, such as the one below, and have them write what they think happened to the monument/tombstone:



ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will understand the concept of a gas dissolved in a liquid
- ✓ Students will understand that "polluted rain" can have a significant effect on objects

Materials

- ✓ Salt
- ✓ Cups of water
- ✓ Stirrer
- ✓ Bottle of carbonated beverage (ex. soda)
- ✓ Word wall words: dissolve

Handouts

- ✓ Disappearing Salt

TEACHER NOTES

Teacher Tip

- ✓ This definition of the word "dissolve" is somewhat basic, but it is enough to help students understand the concept of something dissolving in something else. If your students have already studied phases of matter, consider showing students a model of what a solid or gas dissolved in a liquid looks like at the particle level, such as this one: https://qph.fs.quoracdn.net/main-qimg-55842a14783b241e28e9fbf7f1b13033.webp

Depending upon what they have already learned, students may discuss weathering and erosion, or them may say things like a piece broke off or the letters wore off. Use their responses as a way to gauge student background knowledge on the concept of acid rain and weathering/erosion, but do not give them a definitive answer.

1. **Frame the Activity**: Remind students that during the last activity, they investigated how pollution from the ground gets into the Chesapeake Bay. Show them the infographic from Activity 5 and remind them that 1/3 of the nitrogen pollution in the Bay comes from air pollution. How is that possible? How does air pollution get into the Bay? Today they are going to start answering that question.

2. **Dissolving a solid in water**. Pass out the "Disappearing Salt" handout. Then give each pair of students a small cup of water, a tablespoon of salt on a paper towel, and something to stir with. Have students write observations about the salt and the water on their sheets. For example, the salt is a solid, it's white, it's hard, it's opaque; the water is a liquid, it's colorless, it's clear.

   Have students mix the salt into the water, and then make an observation of what they see. For example: the salt slowly disappears. The mixture is a clear, colorless liquid.

   Ask students if they think the salt is still in the water. How can they tell? (If permitted, and students are interested, you can have one student from each group taste the water to verify that the salt is still in it).

   Ask students if they know what happened to the salt – some may know that the salt "dissolved" in the water. Put the word "dissolve" up on the word wall, and ask students what this means. Help them to develop the definition that when something dissolves in water it mixes with the water and changes form but it is still there. Have students write an explanation of what happened to the salt using the word dissolve in the space on their handout.

3. **Dissolving a gas in water:** Make sure students understand that the first example was a solid dissolved in a liquid. Ask them if they think gases can be dissolved in water. They should remember talking about dissolved oxygen earlier in the module, or they may have other examples.

   Take out a bottle of soda or another carbonated beverage. Have students write down observations of the liquid in the bottle in the "before" section of their paper. For example: it is brown, it is a liquid, it is opaque.

Ask students if they think anything is dissolved in the soda. They may say things like sugar or flavorings (which are correct). Ask students if they think there is a gas dissolved in the soda. They will likely know that there is.

Ask students how they could show that there is a gas dissolved in the liquid. There are many possible responses: when you open it, you can hear a sound, when you shake it or pour it, the gas will fizz, if you drink it you might have to burp, etc. After hearing student responses, have students prepare to make observations in the "after" section of their handout. Then shake the bottle and then open it so that the carbon dioxide is released quickly and becomes very visible (preferably over a sink or in a plastic bag). Have students write down their observations (ex. there are lots of bubbles coming out of the liquid, it changes shape, it changes color, etc.)

Ask students if they know what the gas is that was dissolved in the soda. Use questions to help them connect the idea of "carbonated" drinks with "carbon dioxide".

Have students answer the question at the bottom of their handouts: "What does it mean for something to be dissolved in something else" Student explanations should include the idea that the first thing changes form and mixes in with the other thing. Often the thing that is dissolved can no longer be seen.

Make sure students agree that solids and gases can both be dissolved in water. Have students think back to Activity 2 when they measured dissolved oxygen in water in order to help them make the connection that oxygen can dissolve in water, and that living things like fish need the dissolved oxygen to survive.

4. **Return to the tombstones:** Show students the picture of the tombstones again. Ask them again what they think may have happened to them. Use questions to focus their thinking around key ideas:
    - The tombstones are solid, but they partially washed away. Part of the tombstones must have dissolved in rainwater and washed away
    - Rainwater on its own is not strong enough to dissolve a tombstone
    - Something must be in the rainwater that allows it to dissolve the stone

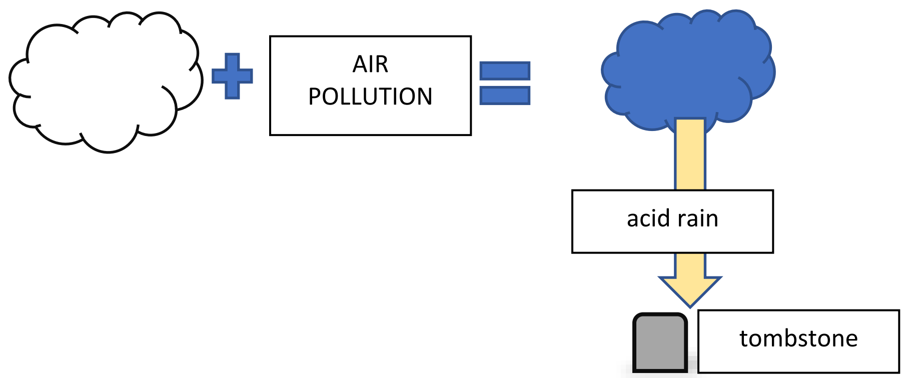
    Ask students what they think may be in the water that allows it to dissolve the tombstone. Depending on their background knowledge, you may or may not need to guide them towards the idea of acid in the rain.

TEACHER NOTES

Ask students where the acid in the rain could have come from. Use questions to help them narrow it down (it can't be from the ground – it must be from the air). Key takeaways:

- Air pollution in the atmosphere can dissolve in water in the air and clouds
- The dissolved pollution makes the water acidic
- When it rains, the acid rain can affect things on the ground

5. **Formative assessment:** Have students draw a simple picture showing how air pollution can get into the rain and end up affecting things on the ground. For example:



Name ______________________________

Disappearing Salt

Salt & Water

Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) Salt: Water:	Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) Salt + water:
What happened to the salt when you mixed it into the water?	

Soda

Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) Before:	Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) After:
What does it mean for something to be dissolved in something else?	

Activity 8 (Explain): Air Pollution in the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will be able to describe how air pollution gets into the Chesapeake Bay
- ✓ Students will know the definition of airshed
- ✓ Students will know the term "deposition"

Materials

- ✓ Word wall words: airshed, dry deposition, wet deposition
- ✓ Blank paper
- ✓ Spray bottle(s) with water (one or more)
- ✓ Chocolate pudding mix in small cups
- ✓ Cotton balls
- ✓ Water in small cups

Handouts

- ✓ Welcome to the Airshed

Activity summary: In this activity, students use the definition of a watershed to help them define an airshed – an area of land that shares a common flow of air. They then perform a variation on the crumpled paper watershed activity to show how air pollution, in the form of dry and wet deposition, can get into the Chesapeake Bay.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What is a watershed? Name two watersheds that you are currently in.

- The purpose of this warmup is to refresh student's memory of the term watershed, which will be important for this activity.
- Students should know that they are in the Chesapeake Bay watershed. If they don't know another watershed they are in, have them consider what large rivers are nearby. They may be in the Potomac River watershed, the Patapsco River watershed, or one of the other major watersheds around the region. To find out exactly what local watershed you are in, go to: https://mywaterway.epa.gov/community and type in your address. The waterway that comes up will be the name of your local watershed.

1. **Frame the activity:** Framing will vary slightly based upon whether you did Activity 7 with students:
   - If you skipped Activity 7: Show students the infographic from Activity 5 again, and remind them that in the last Activity they learned know how pollution from the ground gets into the Bay. But 1/3 of the nitrogen pollution in the Bay comes from the air. How can that happen? Today they are going to answer that question.
   - If you did Activity 7: Remind students that they learned during their last activity how gases can get dissolved into water. Today they're going to apply what they learned to explain how air pollution gets into the Bay.

2. **Where does our air come from?:** Pass out the student handout: "Welcome to the Airshed." Have students look at the map on the left side, and ask them what the gray area is (as a reminder). They may or may not recognize the Chesapeake Bay watershed, so be sure to remind them. Have them write Chesapeake Bay watershed in the space below the map on the left.

Next have students look at the map on the right. Remind them that they're trying to figure out where the air pollution that ends up in the Chesapeake Bay is coming from. Use questioning to see if they can figure out that the shape on the right represents the area that sends its air to the Chesapeake Bay and so it is called the Chesapeake Bay Airshed (the nitrogen airshed to be specific). Have students write Chesapeake Bay Nitrogen Airshed in the space on the right. Create a joint definition of "airshed" with students to write on their sheets. Airshed definitions can get very technical, but in general, an airshed is an area of land that shares a common flow of air. The Chesapeake Bay Nitrogen airshed defines the area of land that sends air and nitrogen air pollution to the Bay. Add the word airshed to the word wall.

Ask students what they notice about the Chesapeake Bay Nitrogen airshed. Key noticings:

- The airshed is bigger than then watershed (because the air can travel further, and can travel over mountains)
- The airshed include the 7 states from the watershed PLUS 9 more (Michigan, Ohio, Indiana, Kentucky, Tennessee, Georgia, North & South Carolina, and New Jersey)

Tell students that different kinds of pollution have different size airsheds. They are going to focus on the nitrogen airshed, because that is the pollutant they think is causing the algae to grow and kill the fish. Ask students to think about how big the nitrogen airshed for the Chesapeake Bay might be. After giving students a chance to share their ideas, put the actual nitrogen airshed. Have students draw the airshed on their handouts, and compare their guesses with the actual airshed.

3. **Return to the Crumpled Paper watershed**: Pass out plain paper and paper towels to each student. You can have them draw on the paper as before, but it is not necessary for this activity. Have students crumple and uncrumple (but not flatten) the paper just like they did for their watershed simulation in Activity 6. Spray each watershed like before so that the "ground" gets wet and creates small streams and ponds.

Hand out a small cup of chocolate pudding mix and cotton balls to each group of students. Have them stretch out the cotton ball to loosen it up. Tell students that for this activity, the cotton ball will represent clouds and air. The cup of pudding mix will represent a source of air pollution, and the pudding itself is the air pollution.

Have students use the cotton ball to pick up some of the air pollution. Ask students what they think will happen when the "air and clouds" pass over their watershed? (it will drop some of the pollution) Have them shake/tap their cotton balls over the

TEACHER NOTES

Defining an airshed

- ✓ Because different air pollutants travel different distances, the airshed changes depending on what pollutant you are talking about. Since this module focuses on nitrogen pollution, students will look at the nitrogen airshed, which includes the airsheds for nitrogen dioxide pollution and ammonia. It is useful to make this clear to students, but don't let it become overly confusing.
- ✓ For another map of the Chesapeake Bay airshed and watershed, go to: https://www.cbf.org/assets/images/misc/the-chesapeakes-airshed.gif This map is slightly different and may represent the airshed for additional pollutants.

TEACHER NOTES

watersheds to see what happens. They should see little specks of "air pollution" sticking to the watershed.

Tell students that this kind of pollution is called "dry deposition." Ask them why they think it's called "dry" (it's because the pollution is dry – it is not dissolved in water). Tell them it is called "deposition" because the pollution is being deposited on the land just like you might make a deposit in the bank. Put "dry deposition" on the word wall and have students add a definition to their notes sheet. Dry deposition is when air pollution falls to earth in solid or gas form.

Ask students if the dry deposition is polluting their water. For the most part, the water should still be clean except if some of the dry deposition fell directly in the water. Spray the watersheds again. Some of the dry deposition should wash into the water. Ask students what happened – just like with the original crumpled paper watershed, much of the pollution got washed into the bigger bodies of water, although some of it sticks.

Pass out the small cups of water to students. Have them dunk their cotton balls in the pudding mix again, then the water. Ask them what they think this represents (a rain cloud that has pollution in it). Students probably know what to do next: squeeze the cloud out over the watershed. Ask them what this represents? (polluted rain/acid rain).

Tell students that this is kind of deposition is called "wet deposition" because it is pollution that is dissolved in water and then "deposited" in the watershed. Put "wet deposition" on the word wall and have students add the definition to their notes sheet. Wet deposition is air pollution that falls to the earth dissolved in water. Acid rain is a form of wet deposition.

Have students look at the water in their crumpled paper watershed. What color is it? (it should be brown). What does this represent? Water that is polluted. How did it get this way? (pollution fell directly in the water, or it washed into the water)

After cleaning up, have students turn to the back side of their papers and jot down some things that they learned from this activity about how air pollution gets into the Chesapeake Bay. When they have had a chance to write, have them discuss with a partner, and then have partners share out to the class. Write down key takeaways on the board or chart paper, and have students add new ideas to their papers. Key takeaways:

- Air pollution can come into the watershed from an area called the airshed, which is bigger than the watershed
- The pollution can fall onto the ground/water as "dry deposition"

Connecting the spheres

- ✓ If you have time, this is another good opportunity to have students explain how the atmosphere is connected to the hydrosphere and the geosphere. The biosphere is connected as well, since much of the acid rain falls on land and is taken up by plants which filter the pollution out.

- The pollution can also mix with water in the atmosphere and fall into the watershed as "wet deposition".
  - Dry and wet deposition can fall directly into the water, or it can fall on the ground and be washed into the water.

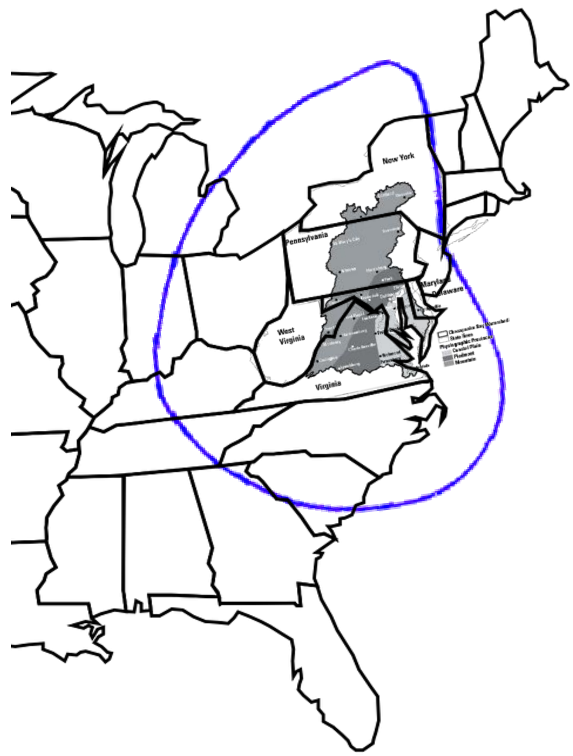
TEACHER NOTES

4. **Formative Assessment**: Have students explain in their own words how air pollution from a power plant in Ohio could get all the way into the Chesapeake Bay.
   - Possible answer: The air pollution goes up into the atmosphere, and the pollution mixes with water in a cloud and dissolves. Then the pollution falls onto the Potomac River as rain, and washes into the Chesapeake Bay.

Name ____

STUDENT HANDOUT

Welcome to the Airshed



________________________________ ________________________________

What is an airshed? ____

____

What is "dry deposition"? ____

____

What is "wet deposition"? ____

____

Conclusions

What did you learn from this activity about how air pollution gets into the Chesapeake Bay?

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will begin to create a model of how pollution enters the Chesapeake Bay

Materials

- ✓ Computer & projector
- ✓ Pre-printed/written parts of the Chesapeake Bay pollution model (these can be on paper or on sentence strips) including lots of arrows
- ✓ Extra paper and markers to add components to the model

Handouts

- ✓ none

Activity summary: In this activity, students begin the challenging task of developing a model showing how pollution gets into the Chesapeake Bay. They work collaboratively to come up with a list of what belongs in the model, and then they assemble the model together as a class.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Creating & Using Models
CCC: Cause & Effect, Systems and System Models

A Note about timing for this activity

The Chesapeake Bay pollution model can get rather complex. As such, you may want to build it slowly throughout the course of the module as opposed to waiting until this point. Either way, students will need support building the model, so be sure to consider ways to scaffold the model-building however you choose to implement it.

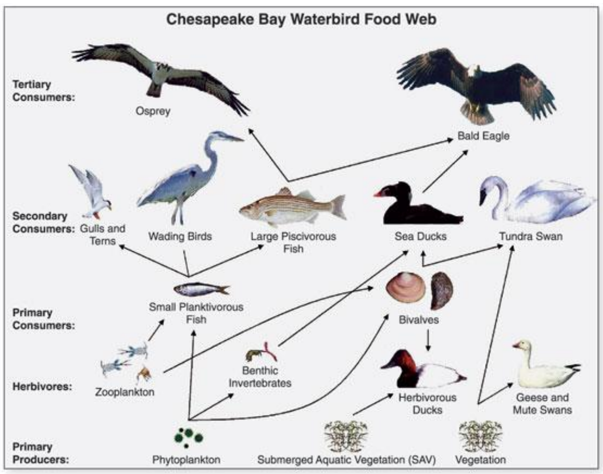
Warmup: Name three ways that nitrogen pollution can get into the Chesapeake Bay.

- Lots of answers are possible: air pollution drifts into the watershed and falls into the water; air pollution falls on the land in the watershed and get washed into the Bay, fertilizer runs off farms into the Bay, etc.

1. **Frame the activity:** Refresh students' memory of how far they've come in investigating what killed the fish in the Chesapeake Bay by reviewing the clues board. They know that the fish died from a lack of dissolved oxygen. They know that this was caused by an algae bloom which was caused by excess nutrients in the Bay. They know that those nutrients came primarily from agriculture and from air pollution. In order to see how all these pieces fit together, marine biologists like themselves would build a model of how pollution gets into the Bay.

   Tell students that modeling is a very important part of the scientific process, especially for scientists who study ecology and ecosystems like the Chesapeake Bay. Today they're going to learn about models and they will create a model together of how pollution affects the Chesapeake Bay. Their model will help them to figure out how to protect the fish and the water.

2. Food webs as a model: Display a food web diagram that all students can see, such as the one below. Ask if they have seen anything like this before and what it is. Students may or may not be familiar with food webs, so adjust the time you spend reviewing the food web to make sure all students understand what it shows. Tell students that food webs are one kind of model of an ecosystem. Ask students what they see in the model (arrows, names/pictures of animals, etc.). Tell students that in a food web model, the arrows show how energy moves through an ecosystem. Plants get their energy from the sun so they are at the base of the food web. The arrows show the energy going from the plants, to the animals that eat the plants, and then to animals that eat those animals.



3. Introducing the components of the Chesapeake Bay pollution model: Tell students that the model they are building will show how pollution gets into the Bay and affects the living things there. Ask students what things belong in a Chesapeake Bay pollution model. Encourage them to look through their notes from previous activities and at the word wall in the classroom. Possible student responses:

- The Chesapeake Bay water, dead fish, polluted rain, air pollution, the watershed, the airshed, fertilizer, algae, and wet/dry deposition.

As students name different things for the model, take out the preprinted sentence strip with each concept/object on it from your pre-printed materials and show it to students. If students name something that you have not premade, write it on a sentence strip or piece of paper and show it to students. Continue adding new components to the model until students' ideas are exhausted. If there are pieces missing, do not worry about introducing them. Students will likely recognize the missing pieces as they are building the model.

TEACHER NOTES

Teacher Tip

✓ The goal of introducing the food web model is not to teach food webs, it is to help students recognize the parts of a model using something that they may already be familiar with. Don't get too hung up on teaching the food web.

Modification

✓ Building the model will likely require a lot of hands-on attention from the teacher, but if you have a large class or you think students will be able to work more independently, consider breaking the class into two or more groups. This has the added benefit of allowing students to see a different version of the model.

TEACHER NOTES

Teacher Tip

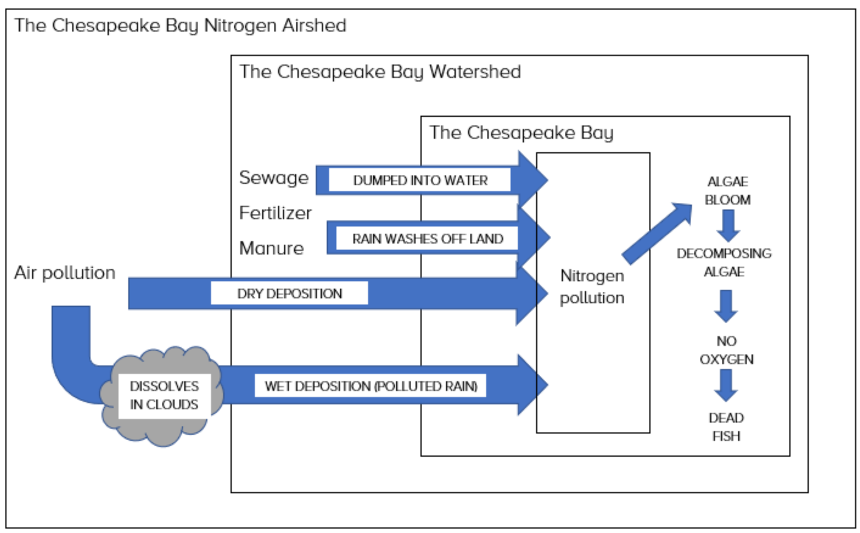
- ✓ Building the model works best if you can find a large open space in your classroom, or make a space on the floor where all students can see. You can also use a bulletin board and put up the model using push pins. If these types of spaces are not available, consider finding a space to use for the day like the cafeteria (when it is vacant), an outdoor space, or a stage in a school auditorium.

Teacher Tip

- ✓ Building a complex model like this is bound to be a challenge for middle school students. The key is to go step by step and make little improvements along the way. Use questions to help students make improvements and recognize missing components. Most importantly, let students do the hard work of figuring the model out themselves.

4. **Building the model**: Give one component of the model or arrow to each of the students in the class (depending on the number of students, you may want to have duplicates of some, or you may want to have students work with a partner). Save the dead fish for yourself. Tell students that this investigation started with the dead fish, so you're going to start the model with the dead fish in the Bay. Put the fish in the middle of the space. Tell students that you are going to work backwards from the dead fish all the way back to the air pollution. Ask who has something that connects to the dead fish (dead algae, no oxygen, algae bloom are all good places to start). Have these students add their concepts to the model, using arrows to show how one thing connects to another. Continue building this way, moving backwards. If you hit a point where it makes sense to go in a different direction, then do so. If students have questions or want to move an arrow or an object, that's fine, but have students talk to one another about it (ex. "I think this arrow should go here. Is it okay if I move it?"). If students recognize that something is missing, have additional paper on hand so they can add it to the model.

   A sample model students might come up with could look like this:



   Keep in mind that there is no "perfect" model, but the model should be accurate and make sense.

TEACHER NOTES

5. **Reviewing the model**: Once the model is finished (for now), take time to review parts of the model with students to check for understanding and clear up misconceptions. You may want to attach the model to butcher paper so it can be moved (you can also write additional labels on the butcher paper). Make sure to put the model up in a prominent place for students to use for the remainder of the module. It will be useful to reference the model, and add to or modify it if necessary.

6. **Formative assessment.** Have students reflect on the process of making the model. Here are some sample questions to consider:
   - What did you like about building the model?
   - What was the most challenge part about building the model?
   - If you built another model like this, what would you do differently?

Activity 10 (Explain): What's Going on in our Airshed?

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will identify major sources of pollution in the airshed

Materials

- ✓ Computer & projector
- ✓ Animated nitrate maps http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf
- ✓ Animated ammonium maps http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf
- ✓ Sentence strips for Chesapeake Bay pollution model: nitrate, ammonium, power plants, agriculture, cars, trucks, etc.

Handouts

- ✓ Nitrogen Air Pollution

Map sources

- ✓ The maps for this activity come from the National Atmospheric Deposition Program/ National Trends Network.

Activity summary: In this activity, students learn about the two major forms of nitrogen pollution in the Chesapeake Bay airshed: nitrate and ammonium. They interpret maps to understand how nitrate and ammonium pollution have changed over time, and they read about the two pollutants in order to compare and contrast them. Finally, students add to their Chesapeake Bay Pollution model and identify sources of nitrogen pollution in their communities.

Standards Connection

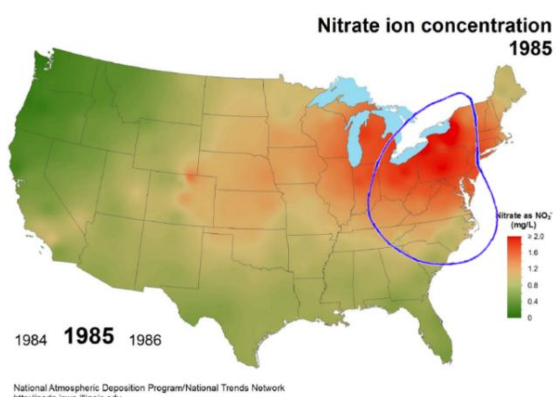
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Creating & Using Models
CCC: Cause & Effect

Warmup: What kinds of things produce air pollution?

- Possible student responses: cars and trucks, factories, power plants, fires
- If students have completed other modules in On the Air, they will likely be familiar with these answers. If they are new to studying air pollution, they may be less familiar and will need a brief introduction. Either way, the point of this warmup is to focus students' attention on specific sources of air pollution that affect the Chesapeake Bay.

1. **Frame the activity:** Now that we have a model of how pollution can get into the Chesapeake Bay, we need to figure out the actual sources of that pollution if we're going to do something about it. We know that the number one source of pollution is agriculture (farms). The second largest source of pollution to the Bay is air pollution. But where is that air pollution coming from? During our activity today, we'll work on figuring that out.

2. **Nitrate air pollution:** Display the map below so all students can see it.

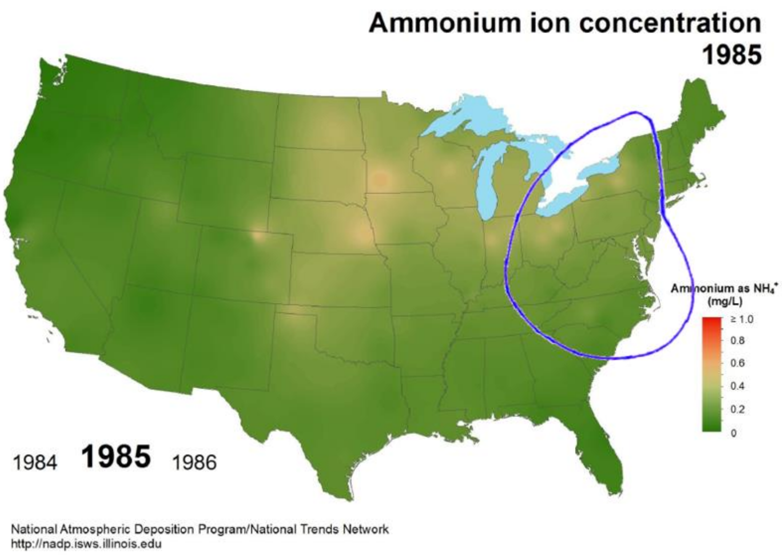


Remind students that the blue shape represents the Chesapeake Bay airshed – the area that shares air with the Chesapeake Bay. Tell them that this map shows one kind of nitrogen pollution in the air called "nitrate". Review the scale of the map with students (red is high, green is low), then ask them what they notice about the map. Key takeaways:

- The nitrate level is very high in the northeast
- The nitrate level is very high in the airshed

Point out to students that this map is from 1985, so the nitrate level was very high then. Tell student that in a few minutes they are going to read about nitrate in more detail.

3. **Ammonium air pollution:** Display the map below so all students can see it:



Tell students that this map shows a different kind of nitrogen pollution in the air called "ammonium". Ask students what they notice about this map. Key takeaways:

- The ammonium level is higher in the middle of the country
- The ammonium level is lower in the Chesapeake Bay airshed.

Based on these two maps, which type of air pollution (nitrate or ammonium) do they think is the bigger problem for the Chesapeake Bay?

- Students will likely say nitrate, although remind them that this isn't the end of the story (it's only 1985).

TEACHER NOTES

Accessibility note

✓ The maps for this activity depend on students seeing different colors. If you have students who are colorblind, they may need assistance in interpreting the maps.

TEACHER NOTES

4. **Nitrate and ammonia air pollution:** Hand out the reading: "Sources of nitrogen air pollution". As students read, they will identify key information about sources of nitrogen pollution, and fill in their Venn diagram.

   After students have finished the reading and filled in their Venn diagrams, lead a discussion to clarify important information.

5. **What's going on with nitrate?** Display the 1985 nitrate map for students to see. Ask them why they think the nitrate pollution was so bad in the Chesapeake Bay airshed in 1985. Use questions and discussion to help them recognize that there were a lot of power plants and a lot of transportation (cars and trucks) in this area at the time. Have students predict what has changed with nitrate since 1985. After they have made their predictions, click through the animated versions of the nitrate maps (download and use the right arrow to advance from map to map): http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf

   Were students' predictions right? Ask students why they think the nitrate pollution went down so much. Use questions to help them realize that the power plants we use got cleaner and the most polluting ones closed. Cars also began to pollute less. Nitrate reduction is a success story, but we need to keep moving in the right direction.

6. **What's going on with ammonium?** Display the 1985 ammonium map for students to see. Ask them why they think the ammonium level is worse in the middle of the country compared to the Chesapeake Bay airshed. Use questions and discussion to help them recognize that most of the country's agriculture is in the Midwest. Have students predict what has changed with ammonium since 1985. After they have made their predictions, click through the animated versions of the ammonium maps (download and use the right arrow to advance from map to map): http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf

   Were students' predictions right? Ask students why they think the ammonium pollution went up so much. Use questions to focus on the idea that increased fertilizer use is resulting in increased ammonium air pollution. While this has affected the Chesapeake Bay airshed less than other parts of the country, it is still going up. Right now, the amount of nitrate deposition and ammonium deposition in the Bay is about the same.

7. **Improving our model:** Ask students where nitrate and ammonium belong in their Chesapeake Bay pollution models. Have students add them to their models where appropriate to add detail to "nitrogen air pollution." Also ask about sources of these pollutants. Where can agriculture (fertilizer, manure), power plants, cars & trucks, and any other sources students think are appropriate be added?

8. **Formative assessment**: Ask students what they think is the largest source of nitrogen air pollution in their community? Why do you think so? What kind of air pollution does it produce?
    - Key things to look for: do students correctly match the air pollution to the kind of source, do they choose sources that are prevalent in their communities (ex. cars and trucks most likely, which contribute to the nitrate pollution)

STUDENT HANDOUT

Name ______________________________

Nitrogen Air Pollution

What are nitrate and ammonium?

Nitrate and ammonium are two molecules that are found in air pollution. Both of them contain nitrogen. Nitrate is nitrogen combined with oxygen and has the chemical symbol NO_3^-. Ammonium is nitrogen combined with hydrogen and has the chemical symbol NH_4^+.

Where does nitrate come from?

Nitrate comes from nitrogen dioxide or NO_2, which is a gas that comes from a lot of different sources. NO_2 mainly comes from burning fuel, so sources of NO_2 and nitrate are cars, trucks, power plants, and chemical factories. Nitrate is a main component of acid rain.

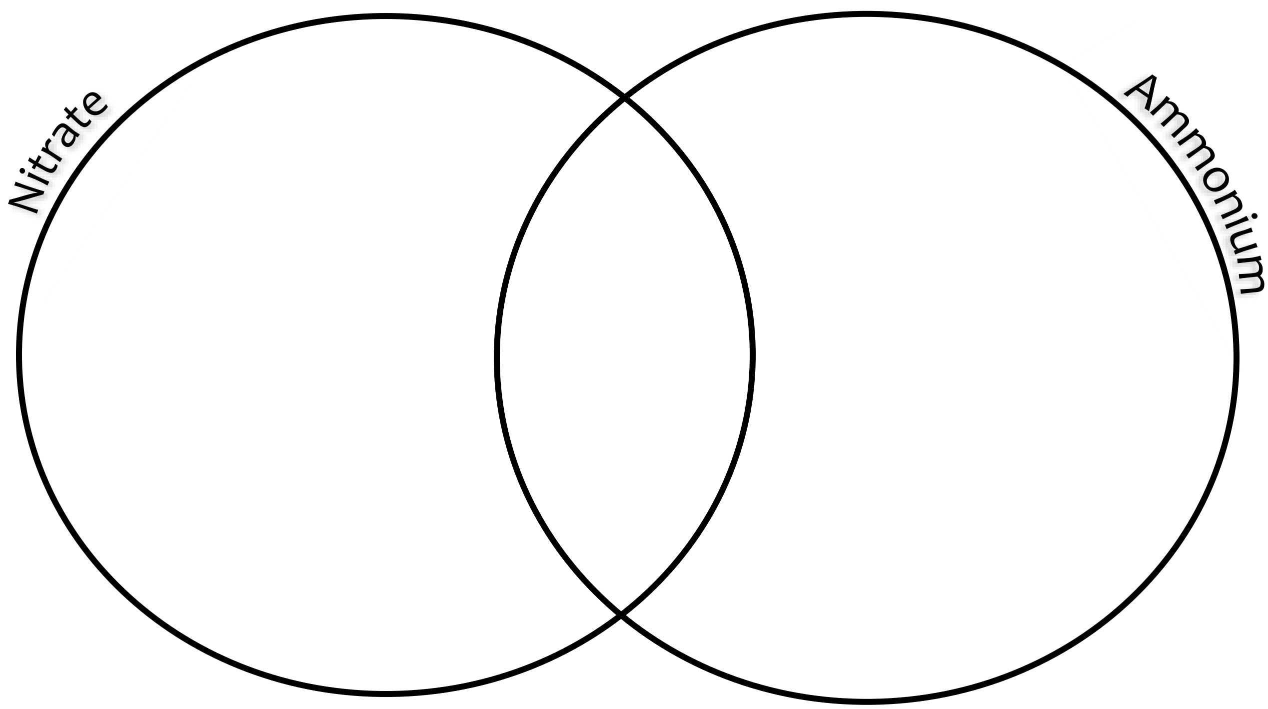
Where does ammonium come from?

Ammonium mainly comes from agricultural sources such as manure and fertilizer. You may have heard of ammonia because it is in some cleaning products. Ammonia and ammonium are very similar molecules.

How do nitrate and ammonium affect the Chesapeake Bay?

When nitrate and ammonium get into the Bay through wet and dry deposition, they can add extra nitrogen to the water. This allows more algae to grow, which can cause dead zones that have little to no dissolved oxygen in them. This can kill animals that need dissolved oxygen to survive.

Fill in the Venn diagram below based upon what you know about nitrate and ammonium.



Activity 11 (Explore): Measuring Wet Deposition of Nitrogen

Activity summary: In this multi-day activity, students collect data to test the accuracy of one portion of their Chesapeake Bay Pollution models. The activity is written for students to collect and analyze rainwater to see if the air has nitrate or ammonium pollution in it. Since MWEEs are designed to be student-driven, this experiment can be modified to test other aspects of their models as well, including water from nearby streams or from the Chesapeake Bay itself.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Planning & Carrying Out Investigations, Creating & Using Models, Constructing Explanations
CCC: Cause & Effect

A note about timing for this activity

This activity requires collecting rainwater from the school grounds. Since precipitation can be an unpredictable occurrence, consider having students make and put out their rainwater collectors as early as possible so that you have rainwater to use. The amount of nitrate and ammonium in the water will decrease if it is not tested soon after the rainfall, but they can be frozen and thawed without significantly affecting the nitrate and ammonium concentrations. Steps 1-4 of the activity introduce the experiment up through making rain gauges, and the remaining steps include water testing, data analysis, and conclusions.

Warmup: How does nitrogen pollution get into rainwater?

- When nitrogen pollution in gas form (NO_x) is released into the atmosphere, it dissolves into the water in clouds and rain.
- This warmup is designed as a reminder to make sure students understand why they are collecting and analyzing rainwater

1. **Frame the activity:** Tell students that when scientists create models to explain something, they also need to test the model to see if it's accurate. While the students cannot test their whole model, they can test part of it to see if what they believe is supported by data. For example, they could test water in local streams to see if it has nitrate in it from wet deposition, or they can test water near farms to see if it has ammonium in it from fertilizer and manure washing off the land. Tell students that there is one type of nitrogen pollution they can test anywhere in the airshed, even if they are not near a stream or a farm. Ask students if they know what kind of pollution they can test for no

ACTIVITY DETAILS

Time: 2-3 class periods

Objectives

- ✓ Students will collect and analyze data to determine if rainwater in the school community is polluted with nitrogen

Materials

- ✓ Nitrate and ammonia test kits (see note on materials)
- ✓ Additional glassware (ex. small beakers) to allow for multiple groups to test at the same time if necessary
- ✓ Rainwater collectors (ex. jars)
- ✓ Distilled water (to use as a control)
- ✓ Safety & cleanup materials (safety goggles, paper towels, etc.)
- ✓ Tips for Measuring Nitrogen Deposition in Rainwater (teacher guide)

Handouts

- ✓ Nitrogen Deposition in Rainwater

TEACHER NOTES

Student Choice

✓ MWEEs are designed to promote student choice, especially when it comes to the experimentation, field experiences, and data collection. What is presented here is one option for what students might do to collect data related to air pollution. Others might include collecting water from a local stream and testing for nitrates and ammonium (from runoff pollution), participating in a field experience with a partner organization to collect nitrate data from the Bay, or devising their own method for collecting emissions data from (for example) car exhaust. The important thing is to focus on the type of pollution that is local for students. For many students in the DC-Baltimore area, that pollution is air pollution from transportation.

matter where they are. Use questions to help them realize they can test rainwater to see if the air has nitrogen pollution in it. Ask students if they think the rainwater in their community is polluted. Tell them that they are going to perform the same experiments that scientists do in order to see whether there is wet deposition of nitrogen in their part of the Chesapeake watershed.

A note about materials for this activity

The amount of nitrate and ammonium in rainwater is relatively low, so sensitive tests are required to detect it. There are several companies that produce easy-to-use nitrate and ammonia water tests that are sensitive enough. Kits from CheMetrics are recommended because they are relatively inexpensive and very easy to use. To limit costs, you may consider using one test instead of both. In that case, the Nitrate kit is recommended because it is often present in higher amounts and so will be easier to detect. Refill kits are also less expensive, so if you use the kit in subsequent years, you only need to buy the refills.

- CheMetrics Nitrate test kit: https://www.chemetrics.com/product/nitrate-test-kit-chemets-visual-kit-k-6904/
- CheMetrics Ammonium test kit: https://www.chemetrics.com/product/ammonia-chemets-kit/

Hach also produces similar test kits which are slightly more expensive, but which also have the required sensitivity.

2. **Develop a research question:** Tell students that they will be testing rainwater for nitrate and/or ammonium using a chemical test kit. Before they do that, they need to write a research question based on their model. The research question should ask something about nitrogen pollution in rainwater. Help students to develop a research question related to testing nitrate and/or ammonium levels in rainwater. For example:
    - Does rainwater in our community have higher levels of nitrate than plain water?
    - Is the amount of ammonium in rainwater that falls in our community higher than it plain water?

    Hand out the Nitrogen Deposition in Rainwater sheet to students and have them write down their research question.

3. **Develop a hypothesis**: Ask students what results they expect from their experiment based on their model of Chesapeake Bay pollution. Because students have not discussed actual concentration numbers, their hypotheses can be general (ex. I think that there will not be any nitrate in the rainwater because the air in our community is very clean). Have them write their hypothesis on their handout.

4. **Make rain gauges:** Lead students through the process of creating rain gauges to collect water for their experiment. See the section of the teacher guide under "rainwater collection" for ideas about making and setting up the gauges. When they are ready, set the gauges out around the school grounds (some students may set them up at home) in safe locations.

Continue here after rainwater has been collected and is ready to test

5. **Review testing procedures:** Hand out copies of the nitrate and ammonia testing procedures to students. Review the directions for the procedures, and make sure to discuss with students why they need to test distilled water as well as the rainwater. You may want to complete one test as an example for students or have all students do each step together.

6. **Conduct the tests**: Have students take rainwater (either from their jars, or from rainwater that has been frozen and thawed) and distilled water, and complete the tests to determine the amount of nitrate or ammonium in each sample. Make sure students know where to record their data on their data sheets. Be sure to follow safety procedures and clean-up all materials appropriately.

7. **Pool data**: As students complete their experiments, have them share their data with the rest of the class, either using the board or a computer. Make sure that students record the data in the correct place on their data sheets (ex. nitrate control/experimental; ammonia control/experimental). When they have all the class data, have them calculate averages for each of the tests and write the averages on their data sheets.

8. **Convert units**: Scientists report out the amount of nitrogen in rainwater samples as concentrations of nitrate (ppm NO_3) and ammonium (ppm NH_4). However, most test kits report out on the concentration of nitrogen itself (ppm N-NO_3 and ppm N-NH_4). As such, students need to convert from one unit to the other in order to compare their data with data collected by scientists. The conversion is simple: multiply by 4.43 to convert from ppm N-NO_3 to ppm NO_3 and multiply by 1.29 to convert from ppm N-NH_4 to ppm NH_4. Review this information with students to the degree that they will understand it, and have them complete the conversions on their data sheets.

TEACHER NOTES

Modification

- ✓ If performing the experiments yourself is not possible due to cost constraints or other circumstances, you can have students review data from the National Atmospheric Deposition Program instead. While this is far from ideal, it will allow students to be able to see what the nitrate and ammonium concentrations are like in the rainwater in their area. See Step 9 for how to access these data.

Control Group

- ✓ The ideal control group for this experiment would be unpolluted rainwater. However, this is nearly impossible to obtain, so distilled water has been substituted. For information on the composition of unpolluted rainwater, see this website: https://tinyurl.com/cleanrain

TEACHER NOTES

Differentiation

✓ If students are new to the CER writing format, consider ways to scaffold the writing prompt. For example, you can have student groups work together to write the CER, or just one part of it. You can also have students write drafts of the reasoning portion, review them together to provide feedback, and have students complete a final draft afterwards.

Modification

✓ Because this experiment follows a traditional format, you may want to have students write up their results using a scientific paper format that includes the scientific question, hypothesis, methods, results and conclusion. Middle school students will likely require significant support and scaffolding with this format as it is likely new to them.

9. **Comparing with official data (optional):** Data collection stations around the country follow similar procedures to collect nitrate and ammonium wet deposition data. Go to the National Atmospheric Deposition Program website at http://nadp.slh.wisc.edu/data/ntn/ to find these data. Choose the interactive map option to find the weather station closest to you. Blue pins on the map show active sites. Click on the pin closest to the school to bring up information about that site.

   From the popup menu, click the Data Access link and then the Data tab to see what information is available. Here is a list of commonly available site data:
   - Weekly data (week-by-week deposition data in excel format)
   - Trend plots (graph of average deposition on an annual basis)
   - Annual averages (annual average concentrations in excel format)
   - Precipitation (rainfall timing and amount in excel format)

   The trend plot is easy to read and will allow you to compare your results with annual averages and trends. The weekly data will allow you to see how your data falls into the range of common concentrations. Unfortunately, there is a significant time delay for the national data to be posted, so you cannot get comparison information for recent rainfall events like the one your data come from. Use the link for "metadata" to learn what each of the columns in the spreadsheets represents.

9. **Data analysis:** The data from the rainwater testing will likely be very straightforward since the test kits do not have extremely precise measurements, and student data Is unlikely to have much variation. Unless there is significant variation among student results, students should graph the results of their class averages from each of the tests done (including control groups). Have students write a simple analysis of the data in the space on their data sheets (ex. the difference between the experimental and control group concentrations, and whether it was higher or lower).

10. **Conclusion (Formative assessment):** Have students write a conclusion to their experiment by answering the Claim-Evidence-Reasoning prompt. You may want to discuss conclusions beforehand to help students with their writing. Also consider using one or more of the scaffolding techniques in the differentiation note – or use another technique of your own.

TEACHER GUIDE

Tips for Measuring Nitrogen Deposition in Rainwater

Rainwater collection

Ideally, students should collect the rainwater for this experiment themselves. To do this, have students make simple rain gauges using a jar or bottle, masking tape, and a ruler to mark off the height on the bottle. You can find many "how to" videos on the internet on how to make simple or more complex rain gauges. Some guides suggest putting water in the bottom of the jar to weight it before setting it out. Be sure that your rain gauge is empty when you set it out because you only want to test rainwater.

Form students into groups, and have each group make a rain gauge with their initials on it. Assign each group a number to write on their gauge as well. When you set out rain gauges, choose a variety of locations, and be sure to mark the gauges as part of an experiment so they are not disturbed. You can also have students set up gauges at their houses. If so, make a plan for students to transport the water to the school by putting a lid or plastic wrap on the tops of the gauges.

Since precipitation is unpredictable, consider collecting rainwater well before you need it. Rainwater should be frozen to prevent any pollutants from evaporating or breaking down before testing. Just thaw the rainwater in advance of testing. If you can be flexible about when to do the test, wait until it rains, then perform the test the next day without freezing the water.

Rainwater testing

You may choose to have all students do both tests (nitrate and ammonia), one test, or split the class so that some groups do one test and other groups do the other. Make sure students know what test(s) they are performing.

Once you have results, use the color scales that come with the kit to have each group determine the concentration of nitrate or ammonium in their water. Make sure each group records their data next to the correct group number of their data sheet.

Converting units

Most chemical tests give results in the amount of nitrogen. To find the concentration of nitrate, you must multiply your results by 4.43. This is because one molecule of nitrate weighs 4.43 times as much as one atom of nitrogen. To find the concentration of ammonium, you need to multiply by 1.29 because one molecule of ammonium weighs 1.29 times as much as one atom of nitrogen.

Name ______________________________

STUDENT HANDOUT

Nitrogen Deposition in Rainwater

Research question: ______________________________

____

Hypothesis: ______________________________

____

____

Height of water in rain gauge: ______________________________

Follow the directions on your test kit to determine the amount of nitrate or ammonium in your rainwater.

Group Number	Nitrate (ppm N-NO_3)		Ammonium (ppm N-NH_4)	
	Rainwater	Control	Rainwater	Control
1				
2				
3				
4				
5				
6				
7				
8				
Class average				

Most chemical tests give results in the amount of nitrogen. To find the concentration of nitrate, you must multiply your results by 4.43. This is because one molecule of nitrate weighs 4.43 times as much as one atom of nitrogen. To find the concentration of ammonium, you need to multiply by 1.29 because one molecule of ammonium weighs 1.29 times as much as one atom of nitrogen.

Nitrate Class Average		Final Nitrate Concentration
Rainwater:	x 4.43	
Control:	x 4.43	

Ammonium Class Average		Final Ammonium Concentration
Rainwater:	x 1.29	
Control:	x 1.29	

Analysis

How does the amount of nitrate in your experimental group (the rainwater) compare the amount of nitrate in your control group?

____

____

How does the amount of nitrate in your experimental group (the rainwater) compare the amount of nitrate in your control group?

____

____

Do your results support your hypothesis or not?

____

Conclusion

Write a claim-evidence-reasoning statement that summarizes the results of your experiment. Use the guide below to help you with your statement.

- Your claim should answer your research question and include whether your results support or do not support your hypothesis and your model of pollution in the Chesapeake Bay.

- Your evidence should be a brief summary of the data from your experiment.

- Your reasoning should explain why your data supports your claim. Use what you know about nitrogen air pollution and your Chesapeake Bay Pollution model to explain the connection between nitrates and ammonium in rainwater, air pollution, and pollution in the Chesapeake Bay.

Activity 12 (Elaborate): Doing Our Part

Activity summary: Now that students have learned about sources of nitrogen pollution the Chesapeake Bay, and where it comes from, now is there chance to do something about it! In this multi-day activity, students plan and implement an action project to reduce pollution to the Bay. They will have to make choices about what project to do, and how to do it in order to be successful in doing their part to improve the health of the Bay.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
CCC: Cause & Effect

A note about student input & planning

Like other components of the MWEE, significant student input should be involved in planning their action project. Because project options are so diverse, the activity guide below can be somewhat vague at times. As always, consider what is best for you and your students, and be creative!

Warmup: What kinds of activities do *you* participate in that result in air pollution going into the Chesapeake Bay airshed? It may be helpful to put up the "sources of nitrogen pollution" graphic to help students complete the warmup.

- Possible answers: using electricity (playing video games, watching tv, surfing the internet, etc.), riding in a car

Gather students' answers, either by having them write their answers on post-its/slips of paper than can be posted, or by writing it on chart paper or a whiteboard so that they can be referenced later.

1. **Frame the activity:** Tell students that now that they understand how much of a problem air pollution can be to the health of the Bay, it's time for them to think about they we can do to help solve the problem. Today they'll start working on an action project to support clean air in the airshed and clean water in the watershed. They will brainstorm different actions we can take, and then we'll decide on a project to do together as a class.

2. **Addressing sources of air pollution**. Go back to the warmup list and have students discuss the ways that they (and the school community) contribute to air pollution. Is there anything missing from the list? Which ones are important to students to address? Which ones are easier for them to address?

ACTIVITY DETAILS

Time: variable depending on action project

Objectives

- ✓ Students will plan and implement an action project to decrease pollution inputs into the Chesapeake Bay

Materials

- ✓ Vary depending upon project chosen

Handouts

- ✓ none

TEACHER NOTES

Teacher tip

- ✓ You may want to jump ahead to the brainstorm activity to before deciding which sources of pollution are easier/harder to address. For example, reducing power plant emissions may seem like a difficult source to address, but in reality, it comes down to using less electricity, which may be easier to do.
- ✓ Remember that it is your role as the teacher to support the student brainstorm, not to make a series of suggestions. If you think students are overlooking a possibility, try asking them some questions to support their thinking rather than just making the suggesting yourself. You want this project to be theirs, not yours.

3. **Brainstorm ways to address these sources.** In groups, have students who are interested in a addressing a particular source work together to brainstorm ways to address that source. If you think students will need more support with this, brainstorm together as a class. Below is a list of suggestions for activities students can take in their school community:

   Transportation emissions:
   - Students create a campaign for a walk/bike to school day once a month/week
   - Students advocate/fundraise for a bike rack for the school
   - Students advocate for a no-idling zone and signs at the school
   - Students create a carpooling program at the school or make plans to carpool with other students
   - Create a transportation log that shows how many miles you ride in a car in a month. Pledge to reduce the number next month.
   - Students create a campaign to support buying locally-sourced food or supporting a local farmers' market

   Electricity usage:
   - Students fundraise to get Kill A Watt electricity use monitors for the school, then use them to monitor and lower electricity use
   - Students create signs around the school reminding teachers and students to shut off lights and electronics when they're not being used
   - Students create pledges for themselves and families to use less electricity at home by turning off lights and electronics, opening windows instead of running the air conditioning, using energy-efficient lighting, etc.

   If you live in a rural community, you can also consider options that support using less fertilizer and or preventing runoff from entering local waterways.

   For additional ideas of what you can do, see EPA's website on nutrient pollution mitigation: https://www.epa.gov/nutrientpollution/what-you-can-do

4. **Choose a class project:** The action project will be more successful if the class undertakes one project together. The same is true if you teach multiple classes. Have students come to a consensus about what project they feel is most important to them. You may want them to discuss/debate ideas, vote on them, etc. as way to reach a decision.

TEACHER NOTES

5. **Plan the project**: With your help, have students divide the project up into smaller pieces that groups of students can work on. For a campaign, some students may make posters, while others write a letter for school staff, administration, or parents. The project may require additional research, so be sure to plan ahead for this. You will likely need to do some planning outside of class, but try to include students in planning as much as possible. Once you have a plan developed, make sure to share that plan with students.

6. **Implement the plan**: Follow your plan, and make adjustments along the way as necessary. You may need to reach out to partners to help support your work with donations or advice. Be sure to document your students' work along the way with pictures, videos, etc.

7. **Celebrate success**: When the project is complete, take time to reflect on and celebrate what you and your students have accomplished. How many pledges have you collected to use less electricity? Have you created a no-idle zone outside the school? Write a story about it for the local newspaper or the school website. Share your success with others in the environmental conservation community.

Activity 13 (Evaluate): Presenting the Chesapeake Bay

ACTIVITY DETAILS

Time: variable depending on presentation format

Objectives

- ✓ Students will use their models and research to create a presentation of the problem of nitrogen pollution in the Chesapeake Bay.

Materials

- ✓ Student Presentation Planning Guide
- ✓ Student presentation look-fors

Handouts

- ✓ Student Presentation Rubric

Activity summary: In this culminating activity, students synthesize what they have learned during the module through their experiments, models, and research. Working together, they develop one or more presentations of their findings to share with stakeholders in the Chesapeake Bay conservation community.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Obtaining, Evaluating, and Communicating Information
CCC: Cause & Effect

A note about timing

The timing of the last two activities in this module (student presentation and student action project) are completely interchangeable. If you do the action project first, then it is will be easier for students to include "what you can do" suggestions in their presentation. However, sometimes it is easier from a logistical perspective to do the action project last. Choose whichever order works best for you and your students.

A note about student input & planning

Like other components of the MWEE, significant student input should be involved in planning their presentation. They may want to choose the format (poster vs. PowerPoint vs. video), what information is included, and who their audience will be. With this in mind, advance planning is required for the presentation to run smoothly. Try your best to provide as much student input as possible, balanced with the need to anticipate and plan in advance for various components of the project. Use the Planning Guide below to help reach this balance.

Warmup: What are the main sources of nitrogen pollution for the Chesapeake Bay?

- Transportation (cars, trucks, buses), power plants, chemical factories.
- The purpose of this warmup is to remind students where the pollution is coming from that they measured in the rainwater. This is important information for this activity and the action project

1. **Frame the activity:** Use students' clues board and Chesapeake Bay model to remind them how far they've come since they started investigating what happened to the fish in the Chesapeake Bay. Tell them that now it is time for them to present their findings to the community. Over the next few days, they will bring together everything they've learned to create a presentation explaining how nitrogen pollution affects the Chesapeake Bay. The presentation will be based on their model, and it will show all the steps in how nitrogen pollution affects the Bay.

2. **Return to the model**: Before starting to build their presentations, have students look at the model they've created. Discuss whether it is complete or not based on what they've learned. You can have students go back through their activity materials, or you can revisit some of the previous activities to make sure their model has all the important components in it. For example, you may want to label parts of the model that are in the atmosphere, hydrosphere, geosphere, and biosphere. The goal is to both put the finishing touches on the model, and to remind students of important components.

3. **Brainstorming**: Have students consider what important ideas they want to share in their presentation. For example, they should include:
    - The original phenomenon that started their investigation
    - Their "Algae in a Bottle" experiment and results
    - Sources of nitrogen pollution the Chesapeake Bay
    - Their Chesapeake Bay Pollution model
    - Their explanation of the phenomenon
    - Their Action Project
    - What individuals can do to help prevent nitrogen pollution from getting into the Chesapeake Bay

    Also have students consider what format they want to present their work in. They may want to create posters, make videos, make PowerPoint slideshows, or use a completely different format. As the teacher, use the planning guide (below) to set parameters on student options so they can be successful with available resources and time.

4. **Group presentation development:** Divide students into groups, and assign each group their respective roles and responsibilities based upon their choices and your guidelines.

    While students are working on their projects, provide support and feedback however necessary. You may need to teach a mini-lesson on how to use PowerPoint or to create a video using Flipboard. You may need to provide access to resources such as pictures you've taken during the module, images you've shown, or websites you have accessed.

TEACHER NOTES

Audience

✓ Students should have the opportunity to present their findings for an authentic audience. That could be a local environmental group, a community organization, or local elected officials. Consider who could benefit from students' information and ask knowledgeable questions.

TEACHER NOTES

Peer feedback

✓ When students are practicing their presentations with peers, have them use the peer feedback form found in the front part of the curriculum.

Students will also need frequent time checks to stay on schedule. If they are working on some of the presentation at home, consider what guidelines and expectations are necessary for this.

Also make sure that students understand how they will be graded on their presentations. A sample generic rubric is below, but it will need to be adapted based on the formats of different student presentations and what content they are expected to include.

6. **Practice:** Once students have finished their presentations, they may need time to rehearse with peers depending on their chosen format. This can be uncomfortable for middle school students, so consider ways to create a safe and calm environment where students can practice and get feedback. For example, have individuals or small groups present to one another instead of the whole class. Having a "glows and grows" feedback form based on the presentation rubric will keep peers active and engaged while their classmates are practicing.

7. **Present!** Have students make their presentations, either by showing videos they've made, explaining posters, leading a slideshow presentation, or doing whatever it is they've chosen. Document the presentations however appropriate. Use your grading rubric and look-fors sheet to assess students' knowledge, understanding, materials, and presentation skills.

8. **Celebrate!** Creating and leading presentations is challenging work. Make sure to celebrate student success in completing the presentation and the MWEE!

TEACHER GUIDE

Student Presentation Planning Guide

This guide is designed to help you answer key questions in planning to support student presentations. Giving students options for their presentations is fantastic. Not putting parameters and limits on those options is a recipe for disaster. Use the questions below to help frame student options and to plan ahead for their needs:

- What presentation formats are available? (ex. video, poster, PowerPoint, etc.)
- Will the class create one presentation together where they all work on different pieces of it, or do you want student groups to create their own presentations? (also, if you teach multiple classes, will each class make their own presentation, or will they all work on different pieces of one presentation?)
- If there will be multiple presentations, do you want each group to use the same format or can they use different formats?
- What materials will be necessary to create the presentation?
- Who will the audience be for the presentation?
- Do students need to learn additional skills to create the presentation (ex. to make a video or a PowerPoint)
- What is the timeline for students to create their presentation?
- Will students be working on their presentation entirely in class, or will they be expected to work on part of it at home?
- How will you grade student presentations? A generic rubric is below, but it will need to be modified based on different formats and expectations.

Student Name ______________________________

Pollution in the Chesapeake Bay Presentation Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Content	Student's presentation has significant factual inaccuracies and shows limited understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation has some factual inaccuracies, and shows some understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation is factually accurate, and shows strong understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation is factually accurate, and shows detailed and extensive understanding of Chesapeake Bay pollution issues and air pollution in general.
Completeness	Student's presentation is missing significant required parts.	Student's presentation addresses most required elements.	Student's presentation addresses all required elements, although some may not be fully complete.	Student's presentation addresses all required elements fully.
Answering questions (if applicable)	Student cannot answer questions about their presentation or answers incorrectly due to gaps in knowledge.	Student can answer some questions about their presentation, but struggles to answer others correctly because of gaps in their knowledge.	Student is able to answer questions about their presentation by drawing upon knowledge from the module, although they may have some gaps in their knowledge.	Student is able to fully answer questions about their presentation by drawing upon knowledge from the module
Craftsmanship	Student's presentation has numerous grammatical errors, and is not delivered smoothly.	Student's presentation has some grammatical errors, and may not be delivered smoothly.	Student's presentation is well-designed, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's presentation is very well designed, with few or no grammatical errors. Their presentation is delivered smoothly and comfortably.

TEACHER GUIDE

Pollution in the Chesapeake Bay Content Look-Fors

Below are some key ideas to look for in student presentations. This is by no means a comprehensive list, nor should it be considered a checklist for students to complete. Instead, it is a guide of key takeaways from the module that students will likely include in their presentations if they are thorough. It can also serve as a source of questions to students after their presentations to ascertain their understanding. For an excellent example of a short professional presentation that covers many of these topics, check out this video from the Chesapeake Bay Program: https://www.chesapeakebay.net/discover/videos/bay_101_air_pollution

- The Chesapeake Bay watershed is the land around the Bay that drains into the Bay.
- The Chesapeake Bay airshed is the area of land that shares a common flow of air.
- The majority of nitrogen pollution to the Chesapeake Bay comes from somewhere in the airshed.
- Algae blooms are caused when there are too many nutrients in the water
- Dead zones/Fish kills are created after an algae bloom when the algae die and decompose. Decomposers use up the dissolved oxygen, leaving not enough for animals like fish and crabs.
- Nutrient pollution to the Bay (nitrogen and phosphorus) comes mainly from agriculture, but also largely from air pollution
- Pollution that is in the watershed gets washed down to the Bay when it rains
- Air pollution to the Bay falls in the form of dry deposition and wet deposition (dissolved in rain)
- Modeling is a way that scientists can organize what they know about something (like an ecosystem) in order to explain how it works (ex. causes and effects)

Air Quality Champion in Our Commuity

Photograph courtesy of Chesapeake Quarterly, a magazine from Maryland Sea Grant.
Credit: Michael W. Fincham.

Name: Dr. Lewis Linker
Title: Modeling Coordinator and Team Leader for Science & Analysis
Organization: U.S. Environmental Protection Agency, Chesapeake Bay Program

How does your work relate to air quality?
I lead a team that creates models and simulations of the Chesapeake's airshed, watershed, and estuary so decision-makers can make a plan for how to clean up the Chesapeake Bay watershed and tidal waters. The plan is called a Watershed Implementation Plan (WIP) and it's a road map of all the actions we all need to do, from New York to Virginia to get healthy and safe air and waters in the Chesapeake region. Without computer simulations of the airshed and watershed we wouldn't know what a restored Chesapeake looks like or what would be the best way to get there. By problem solving, and communicating, we help decision-makers to deal with challenges like population growth and climate change in the Chesapeake region.

What motivates you to come to work every day?
Restoring the Chesapeake Watershed and Bay is a really, really big deal to me. When I was growing up, the Rouge and Cuyahoga rivers were catching on fire, the Potomac River next to the Nation's Capital stank in the summer heat, and the Chesapeake seemed to be in a death spiral. Now it's all coming back, very slowly, bit-by-bit, but coming back, and it's very satisfying that my Modeling Team has played our very small part in the Chesapeake recovery. Also, I know that my Modeling Team depends on me to do my job and to support them every day, and I depend on them too, so that's a big motivator - being there to support a team with an important mission.

What education and career path did you pursue to have the position that you have today?
My early career path was all over the place! At first, I thought I would go into medicine and I completed a biology and chemistry undergraduate degree at Towson State. Then I became very interested in marine biochemistry research. In the end, I decided that I really wanted to do something that had more promise of immediate, concrete, and significant results that I could point to, so I switched to environmental engineering and I have made that my career ever since. It now sounds all very thought out and methodical, but at the time it really was more of a hot mess! Ultimately though, my broad diversity of technical and scientific training prepared me well for a modeling background. I guess it shows that you never know how it's going to finally turn out. But if you are fortunate enough to really go after learning something that interests you, and if you can find a way for that learning to make a contribution to the general public, then things will turn out alright.

What is your workspace like?
Our Modeling Team works with computer simulations of air and water quality, so really our office can be anywhere! We could work on the far side of the moon as long as we had a good internet connection (and good snacks, of course!). Our Modeling Team runs our experiments and tests just like other scientists, but they are all run in a virtual computer space. In fact, our Airshed Model is simulated in North Carolina, the Watershed Model is done in Annapolis, Maryland, and our Estuary Model was run by in Vicksburg, Mississippi. So our Modeling Team is really all over the place - but not yet on the far side of the moon!

What accomplishment are you most proud of?
When my two boys were very young, they knew my work was to clean up the Bay. So naturally they assumed that once I got to work, I put on an orange jump suit, picked up a bag, and started cleaning up the Chesapeake Bay. Even though my Modeling Team is very accomplished, and have received many awards, I'm most satisfied in being able to join with my Team and with the all of the citizens in the watershed to "pick up a bag" in order to clean up the Chesapeake's airshed and watershed.

Glossary

acid rain - rainfall made sufficiently acidic by air pollution that it causes environmental harm, typically to forests and lakes. The main cause of acid rain is combustion of fossil fuels, which produces waste gases that contain sulfur and nitrogen oxides, which combine with water vapor to form acids. Other forms of acid precipitation are also possible.

airshed – an area of land that shares a common air flow. The Chesapeake Bay nitrogen airshed is the area of land where most of the nitrogen air pollution to the Chesapeake Bay comes from

algae (singular alga) - simple, nonflowering, and typically aquatic organisms of a large group that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue

algae bloom - a rapid increase in the population of algae in an aquatic system

ammonium $(NH_4)^+$ – an ion that is related to ammonia (NH_3). Both ammonium and ammonia are common air pollutants that are produced from agriculture and industry.

brackish - slightly salty, like the mixture of river water and seawater in estuaries

dead zone – a low-oxygen, or hypoxic, area of water that can be deadly to aquatic life

decomposer – an organism that breaks down dead or decaying organisms

deposition – the process by which substances are "deposited" on the land or in the water. In the case of air pollution, deposition refers to air pollution from the atmosphere is deposited on land or in the water

dissolve – (as a substance) to become incorporated into another substance so as to form a solution. Most commonly, when a solid or gas is dissolved into a liquid

dissolved oxygen - oxygen molecules that are dissolved in and which is available to living aquatic organisms.

dry deposition – the process by which air pollution is deposited directly from the atmosphere, either as a gas or a solid

ecosystem - a biological community of interacting organisms and their physical environment

estuary - a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean. Estuaries, and their surrounding lands, are places of transition from land to sea.

eutrophication – an excessive amount of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and may cause the death of animal life from lack of oxygen.

fish kill - the sudden and unexpected death of a number of fish or other aquatic animals such as crabs or prawns over a short period of time and often within a particular area in the wild.

food web – a model showing how energy and matter are transferred in an ecosystem by indicating what organisms eat or are decomposed by other organisms

geosphere – the solid components of Earth in comparison to the hydrosphere, atmosphere, and biosphere.

hydrosphere - all the waters on or below the earth's surface, such as aquifers, lakes, and seas. Sometimes hydrosphere is also used to refer to water vapor in the form of clouds.

menhaden – a common fish found in the Chesapeake Bay. Also known as mossbunker and bunker

MWEE (Meaningful Watershed Educational Experience) - an investigative or experimental project that engages students in thinking critically about the Chesapeake Bay watershed

nitrate $(NO_3)^-$ – an ion that is a common component of fertilizers. Nitrate often forms when nitrogen dioxide (an air pollution) reacts with other pollutants and dissolves in water vapor. Nitrate is common component of nutrient pollution.

nitrogen – an element found abundantly in the Earth's atmosphere. When combined with oxygen, nitrogen forms nitrogen oxides (NO_x), a common form of air pollution and a contributor to nutrient pollution

nitrogen dioxide (NO_2) – a highly reactive gas that is a common air pollutant. Nitrogen dioxide primarily comes from burning fossil fuels in power plants, cars, trucks, and other vehicles.

nutrient pollution - is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, causing excessive growth of algae.

phosphate $(PO_4)^3$ – an ion that is a common component of fertilizers. Phosphate is a common component of nutrient pollution.

phosphorus – n metallic element that commonly combines with oxygen to form the phosphate ion. In this form, phosphorus is a common contributor to nutrient pollution

rain gauge - a device for collecting and measuring the amount of rain which falls

watershed – an area of land that drains into a specific body of water

wet deposition – the process by which air pollution is deposited by mixing with precipitation