Water and the Living Environment
Course Introduction

In this course, you will explore the factors affecting homeostasis (equilibrium) in an aquatic environment. At the start of your exploration you will review the animals and the landmass around the Hudson Valley. Professional scientists and students have collected vital statistics along the Hudson River that support the quality of water in the living environment. In order to get a better understanding of plant and animal survival in an aquatic environment, you will explore the composition of the surrounding land and the chemical composition of the water. The activities in this module will lead you to some of the major factors about the chemistry of water. For example, scientist use the term “dissolved oxygen” (DO) when they are determining how much oxygen is available to living environment. In order to see how dissolved oxygen can affect a real ecosystem, you will observe data from urban waterways, the Harlem River and the Hudson River. Similar data is also available from the fresh water streams of Black Rock Forest that drain into the Hudson River. This data will include parameters such as rainfall, pH, dissolved oxygen and temperature, which are collected hourly at these sites. You will be able to predict how well aquatic organisms, plants and animals can survive and reproduce. For instance, you can determine what effect water temperature has on a trout population in a stream. Using the graphing tool, you can create impressive graphs, use statistics to look for patterns, and create a report that you can give to a government agency to advocate for a better planet.

Water and the Living Environment
Files Checklist

Ensure you have downloaded all the appropriate files according to the chart below.

- Course Intro
- Introduction to Teacher's Guide
- Table of Contents

Activity	Teacher Guide	Student Guide	Student Journal	Additional Files
1	x	x	x	
2	x	x	none	Introducing Cascade Brook Resources for Research Project
3	x	x	x	
4	x	x	x	
5	x	x	x	Oxygen Underwater
6	x	x	x	A Daily DO Cycle Stud A Daily DO Cycle Tchrs
7	x	x	x	
8	x	x	x	Estuary Layers
9	x	x	x	
10	x	x	x	Sources Poster
11	x	x	x	Photo Link
12	x	x	x	

Water and the Living Environment
Teachers' Guide Intro

Acknowledgments

For use of data and technical assistance:

- Black Rock Forest Consortium
- HRECOS – Hudson River Environmental Conditions Observing System
- Harlem River Student Monitoring Project

Curriculum Writers

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Goals of project

- To give students an integrated approach to water quality and its importance to living organisms
- To provide experiences in the use of research data and analysis of graphs
- To increase student problem-solving ability
- To stimulate student questioning and independent investigation
- To give students experience in the use of varied web resources

Methods used

- In-class computer-based activities using data from BRF, HRECOS and Harlem River student monitoring project
- In-class activities and discussions to help student integrate new content with their prior knowledge and experiences. These will provide a social environment for brainstorming, problem-solving and reflection.
- Suggested hands-on experimental investigations.
- Field trips to BRF and ponds/streams/rivers in NYC

Intended Audience

The curriculum has been written for students in NYC public high school and middle school (7th-8th grade) having varying levels of proficiency and experience in science.

The activities are meant to be used sequentially and have been written to allow easy entry for those with less experience. The **Teacher's Guide** includes **Extensions,** activities that can help students with less experience as well as those wanting to explore a topic further.

Suggested Sequence

We recommend conducting the activities in numerical order as written, regardless of your students' prior science and/or reading skills. The activities have been written to move from simple concepts and activities to more challenging ones. The first few introduce concepts and skills one at a time, giving students time to feel comfortable with each one. Devote more time to these activities if needed. We've included many visual presentations of information (diagrams, video, animations) as well as text, to assist students who are not strong readers. The last activity gives students the opportunity to investigate questions of their own selection, using the tools and techniques practiced in earlier activities.

Curriculum Format

1. **Student Guide -** Each includes:
   Activity Number Activity Name
   Instructions
   Resources (embedded in text)

2. **Student Journal** (corresponding to each Activity)
   Activity Number Activity Name
   Specific questions to answer

3. **Teachers' Guide,** with sections keyed to each Student Activity
   Each section is formatted as follows:
   Activity Number Activity Name
   Overview of student instructions
   Teacher Background, including Resources
   Teaching Suggestions
   Extensions (Optional)

Questions

This curriculum emphasizes and encourages questions. They might be:

- Posed by teachers to start class discussions
- Ideas for future investigations by students
- Wondering out loud
- Ways of clearing up confusion
- Assignments for students to complete

The context will make it clear which is intended. Create a mood in which students feel comfortable asking questions of all kind and encourage students to help answer each other's questions.

Study and Use of Graphs

Throughout the curriculum, students use real data collected in the field, construct graphs of that data and analyze those graphs to learn about water quality and its impact on living organisms. The Columbia Center for New Media Teaching and Learning at Columbia University (CCNMTL) has created an easy to use Graphing Tool to allow students to construct graphs made to their own specifications. Students have a choice of 3 types of graphs: time-series, scatter-plot and box-plot.

- Time-series graphs are the most familiar and the ones most commonly used in this curriculum. They have one independent variable (time) and one dependent variable (temperature or salinity or pH, etc.).
- Scatter-plots also use two variables but the plot is a way of exploring whether there is a relationship between them and if so, what that relationship is. For example, does air temperature affect stream water temperature? Does salinity affect dissolved oxygen? The pattern (or lack of pattern) of the points on the graph gives information about the relationship (or lack of one). Scatter-plots are used at several points in this curriculum.
- Box-plots describe the data in terms of their minimum, maximum, median, lowest percentile and highest percentile. They are used to compare distribution between several sets of data. Box-plots are best used by students who already have some experience in examining distribution of data - or at the discretion of the teacher.

An excellent teacher resource for how to use graphs to raise questions and to stimulate student thinking can be found at http://www.ldeo.columbia.edu/~kastens/curriculum/BRF/orientation/realtime/index.html

We strongly suggest that you prepare for the classes that use graphs by constructing them yourself before class. Doing so will help you prepare for questions that may come up beyond those raised in the curriculum.

Student Journal
Students will keep an online Journal to hold their writing, reports and graphs. Most activities have an accompanying Journal page to complete and save. These Journals will allow you to monitor student work throughout this unit. The Journal pages also help students by serving as a central location for storing graphs, notes, illustrations and research reports. Instructions for setting up the Journal are embedded in each activity.

Note: This curriculum does not directly deal with issues of pollution since the chemistry of pollutants is usually complex and beyond the scope of high school science. However, the curriculum does focus on those aspects of changing water quality that seriously affect living things, such as lowered available oxygen or increasing acidity in water bodies. We encourage you to draw on current issues that affect water quality and watershed health and integrate them into the curriculum, using news articles, websites and videos. The Hudson River sewage outflow during the summer of 2011 would be an example of such an issue.

Water and the Living Environment
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ACTIVITY 1 The Hudson River Watershed
No graphing activities

ACTIVITY 2 Cascade Brook - Living in Water
No graphing activities

ACTIVITY 3 Cascade Brook - Water Temperature
Includes graphing

ACTIVITY 4 pH: Acidity and Aquatic Environments
Includes graphing

ACTIVITY 5 Introduction to Dissolved Oxygen
No graphing activities

ACTIVITY 6 Cascade Brook Dissolved Oxygen
Includes graphing

ACTIVITY 7 Dissolved Oxygen and Aquatic Animals
Includes graphing

ACTIVITY 8 Hudson River Estuary – Salinity and Tides
No graphing

ACTIVITY 9 Hudson River– Fish Life Cycles and Habitat
Includes graphing

ACTIVITY 10 DO: How Low Will It Go
Includes graphing

ACTIVITY 11 Harlem River – Student Monitoring and Data
Includes graphing

ACTIVITY 12 Students' Research Questions
Includes graphing

Teacher's Guide   Activity 1   Hudson River Watershed

Overview of Activity

Students will:

1. Use Google Earth to explore the path of the Hudson River from its mouth to its source.
2. Learn about watersheds in general and the Hudson River Watershed, in particular.
3. Take a photographic "tour" of the Hudson River and learn about the differences between the Upper and Lower Hudson River.
4. Use GPS coordinates and Google Earth to locate the three water quality monitoring sites used in this curriculum.

Teacher Background

Hudson River Watershed information and simple map
http://www.hudsonwatershed.org/watershed.html

Hudson River Watershed detailed map
http://www.dec.ny.gov/education/63069.html

Teaching Suggestions

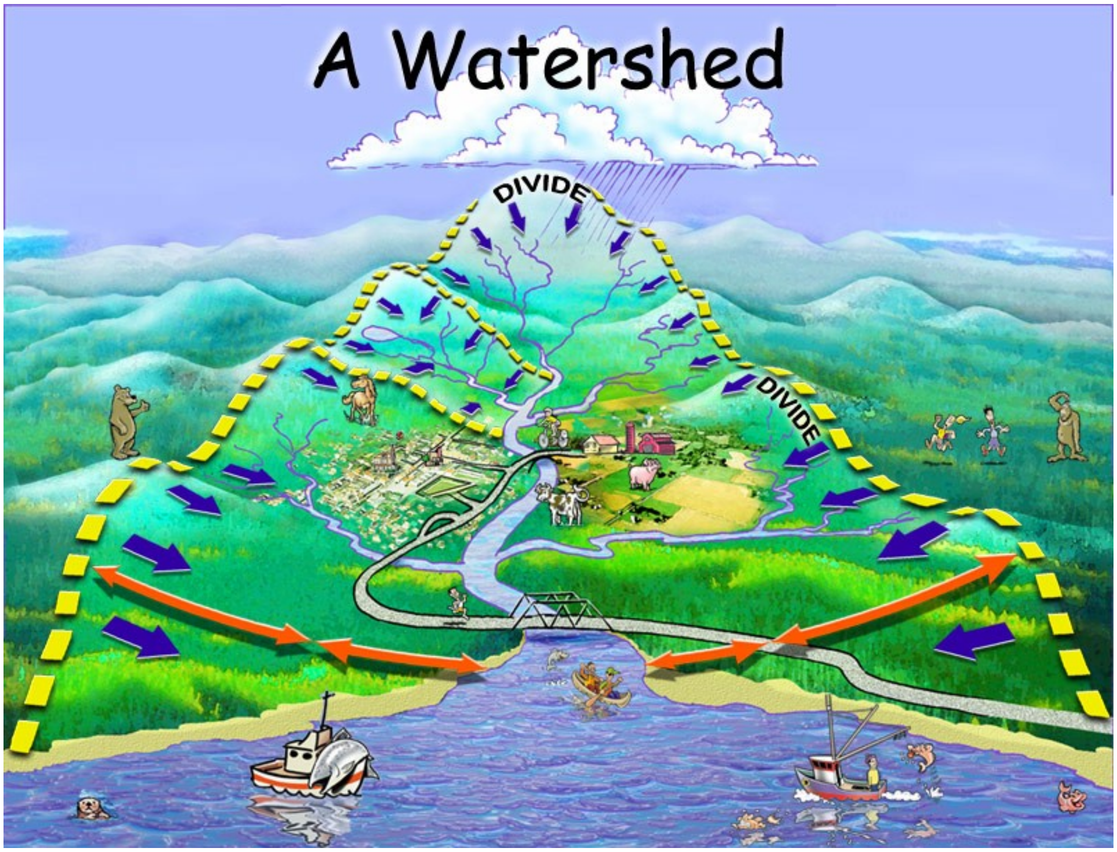
A.   Trace the Hudson River on Google Earth

Some students may never have used Google Earth. Have experienced students work with less experienced students. They will all probably want to "play around" for a while, locating their neighborhood and even specific apartment houses. Allow time for them to do so since they're practicing navigation skills at the same time.

At some point, focus their attention on the directions in the Student Guide. Students may be familiar with the urban stretches of the Hudson but know less about the upper reaches. As they "travel" upriver in Google Earth, mention place names and encourage sharing of knowledge. Point out towns, cities, highways, bridges, forested areas and farmlands. If students want to find some specific place, they can type its name into the **Fly to** box. When they describe their observations in their Journal, they can include many of the features you've discussed. Point out that the color of the river in Google Earth is sometimes realistic and sometimes just an odd product of the aerial photographic image.

B.   Hudson River Watershed

If students haven't encountered the definition of watershed before, take time to discuss it. The diagram below is childlike but it does contain features worth pointing out. As they complete this section of the Journal page, encourage them to seriously consider and discuss possible impacts of the activities depicted. They can add other human activities that might affect the health of waterways.



Source: http://www.recycleworks.org/images/watershed_800.jpg

Students also examine a poster of the Hudson River Watershed to become used to various ways of depicting watersheds. They download the poster and paste it into their Journal for future reference.

C. Hudson River Photographic Tour

Since many students may only be familiar with the Hudson as it runs through NYC, the photographs at http://www.dec.ny.gov/lands/25606.html may surprise them. They'll see woodlands, farm areas and even large healthy fish! Encourage students to share any experiences they've had in upstate New York as they watch the slides.

Students can look at the slides in order or skip around following their interest. However, be sure to focus their attention at Slides 7, 10 and 11, which explain the difference between the upper and lower parts of the Hudson River. The lower Hudson River estuary will be studied in more detail in later activities. For this introduction, it is only important that students realize that the upper Hudson contains only fresh water whereas the lower Hudson has significant mixing of fresh and salt water. The dam at Troy is the dividing point.

D. Three Study Sites on Google Earth

When using Google Earth, tell students to copy and paste the GPS coordinates **exactly** as shown in the Student Guide to avoid typing or space errors.

Extensions

- **Watershed Activity for the Entire Class -** Project the Hudson River Watershed map at http://www.dec.ny.gov/education/63069.html onto a large piece of paper mounted on the wall and have two students trace around its boundaries. Other students can then come up to the paper and enter the names of features they've discovered or known before. Features might include cities, parks, bridges, highways, small towns, state parks or tourist attractions they've visited. Accept all ideas as long as they are placed on the map accurately and names written clearly so that everyone can read them.

- **Make a Watershed hands-on activity**
  www.cof.orst.edu/cof/extended/.../Individual%20**Watershed**%20**Models**.doc
  Students make a watershed model and then actually watch the water from a three-dimensional area flowing downhill.

- **Interesting facts about the Hudson River Watershed**
  http://www.hudsonwatershed.org/watershed.html

- **Where does NYC's drinking water come from?**
  Use this map to encourage students to learn more about NYC's drinking water. Additional information can be found at
  http://www.nyc.gov/html/dep/html/drinking_water/index.shtml

- **GPS coordinates – more practice and explanation**
  If this is students' first experience with GPS on Google Earth, they may want to practice more. Have them type in the name or address of any familiar NYC landmark (like Yankee Stadium) and click on the magnifier icon. When the location appears, ask them to record the GPS coordinates shown at the bottom of the screen. They'll soon notice that the coordinates at the bottom of the Google Earth Image include symbols for degrees, minutes and seconds. However, when students enter their own coordinates, they should enter them as given in the Student Guide (without degree, minutes or second symbols)**.**

  To help make sense of the GPS coordinate system (like the latitude/longitude system), have a large globe available. Use the globe to show students how the references to E, W, N and S are determined and what the subdivisions into minutes and seconds refer to. Use the page below as a reference for yourself but students' experience should be more practical, using the globe and Google Earth as their learning tools.
  http://facweb.bhc.edu/academics/science/harwoodr/geog101/study/LongLat.htm

Teacher's Guide Activity 2 Cascade Brook - Living in Water

Overview of Activity

Students will:

1. Brainstorm characteristics of aquatic habitats
2. View a slideshow of Cascade Brook to get a visual sense of this environment and activities occurring there
3. Brainstorm and discuss characteristics of an aquatic habitat essential for maintaining aquatic organisms and therefore important to monitor
4. Choose an aquatic animal from preselected list of vertebrates and macroinvertebrates and carry out a research assignment on that animal

Teacher Background

Cascade Brook and the two other monitoring sites featured in later activities are valued and used by humans, but they are also aquatic ecosystems that support communities of animals and plants. The unique characteristics of aquatic environments—both natural conditions and those caused by human activities—determine the kinds of organisms living in them. It's important for students to be able to view the Brook not just as flowing water but also as habitat for aquatic animals. They'll then recognize the value of monitoring physical conditions in the Brook and determining whether certain animals can live there, based on their needs.

Freshwater wetlands are home to a diverse collection of aquatic vertebrates and what are known as macroinvertebrates - mainly the larval form of certain insects, some adult insects and members of several other invertebrate groups. These animals vary in their sensitivity to habitat conditions and so their presence tells us about the health of aquatic ecosystems. Learning to identify macroinvertebrates is not difficult for students, and in schools with accessible streams nearby, teachers can involve classes in environmental monitoring using macroinvertebrate studies.

Sources of further information on freshwater ecosystems, macroinvertebrates and monitoring:

- An EPA document that includes threats to freshwater ecosystems: http://www.howstuffworks.com/framed.htm?parent=freshwater-habitat-threat.htm&url=http://www.epa.gov/bioiweb1/aquatic/freshwater.html
- Excellent page apparently created by high school students, with information and excellent visuals on macroinvertebrate ecology: http://ecologyadventure2water.edublogs.org/macroinvertebra-information/
- Life cycles of aquatic insects: http://www.epa.gov/bioindicators/html/lifecycle.html
- Why Study Macroinvertebrates?: http://people.virginia.edu/~sos-iwla/Stream-Study/StreamStudyHomePage/WhyStudyMacro.HTML
- Aquatic Invertebrates: http://chamisa.freeshell.org/inverts.htm#insects)
- Macroinvertebrates as Bioindicators of Stream Health – a PowerPoint

presentation as a pdf:
http://wupcenter.mtu.edu/education/stream/Macroinvertebrate.pdf

- Slide show of photographs of aquatic organisms, with information: http://www.mbgnet.net/fresh/rivers/index.html (To get to this slide show, select River Creatures on sidebar, then click on Aquatic Critters Slide Show in main window.)
- Introduction to importance of biological stream monitoring http://www.iwla.org/index.php?ht=display/ContentDetails/i/1479/pid/1976

Teaching Suggestions

The following series of classroom activities are suggested **before** students begin the activities in their Student Guide. They set the stage for students' investigations of aquatic animals and help them understand the purpose of monitoring environments like Cascade Brook.

Aquatic Environments: Cascade Brook (classroom discussion)

If your students haven't had much direct experience with the natural world, begin with a Group Brainstorm. Students can share their ideas about different types of aquatic environments, drawing on their own personal experiences and prior knowledge. Almost everyone will be able to contribute something to this discussion. Record their ideas on the board and help them organize their descriptions into categories such as lakes, streams, oceans, rivers, etc. Help them clarify the distinctions between them—flowing water or not, fresh water, salt water, or a blend.

Next, transition the discussion to the specific aquatic environment of Cascade Brook, the first of three monitoring sites the students will "visit." Remind students where Black Rock Forest is located, and review other pertinent information from Activity 1, Hudson River Watershed.

Use the Introducing Cascade Brook slide show to get students thinking about Cascade Brook as an aquatic environment. Before showing the slides, ask students to watch for clues about the environment of the brook. Afterwards discuss the photos and have them share their impressions of Cascade Brook. Ask students why they think scientists and students are monitoring conditions in Black Rock Forest. You can point out that the Forest has been protected as a study area and preserve for over 80 years. Even with this protection, students can probably imagine some ways that environmental changes outside the reserve could impact the forest and waterways inside it.

Cascade Brook: Aquatic Habitat (classroom discussion)

Raise the topic of Cascade Brook as an ecosystem. The brook has many non-living components—flowing water, the rocks it flows over, etc, but it also is home to living organisms. Ask students to suggest a few animals that might live in a stream like Cascade Brook and write their ideas on the board. (It's not important at this point exactly which animals students suggest or whether these actually live in Cascade Brook.)

Tell them: *Let's pretend you had to make a temporary home for one of these animals, say, set up an aquarium for a week that would keep the animal alive. What would you need to provide for the animal to survive and be comfortable in your aquarium?* (If necessary, have students review the term ***habitat***, a home for living things, and what an organism needs from its habitat.) If convenient, let students work together to come up with a list of everything needed as well as the conditions they would need to control. After students have listed all their ideas, have each group share something they listed until all ideas have been shared.

Students are likely to suggest items like clean water, the "right" temperature, appropriate food, a place to hide, and perhaps air to breathe. If any of these aren't suggested, you can help students think of them.

More advanced students may mention adding plants as a source of oxygen, or raise questions about the animal's waste products. These ideas can stimulate discussion of important cycles that maintain natural environments. You might also have students consider ways their imaginary aquarium is a metaphor for the earth's life support system.

Monitoring Aquatic Environments (classroom discussion)
Remind students that even though all animals need these basic things, each species has slightly different requirements for them. Certain animals might require different temperatures, hiding places, kinds of food or amounts of oxygen. These different requirements determine where an animal can - or can't - live.

Explain that the same environmental factors they identified—clean water, adequate oxygen, a healthy water temperature, etc.—are among the variables (or parameters) that scientists and students are monitoring in Cascade Brook and at other sites in the Hudson River Watershed. Introduce the word ***parameter***, meaning a specific type of measurable information, such as water temperature or pH. The word ***parameter*** is used throughout this curriculum wherever students work with data.

Aquatic Animals Research Project (classroom—orienting students to assignment in Student Guide)
Post the List of Aquatic Organisms and explain that these are animals commonly found in streams and ponds. We don't know for sure which ones are living in Cascade Brook but as students collect information about the Brook, they will try to decide whether these animals <u>could</u> live there. Call attention to the two categories, vertebrates and macroinvertebrates. Explain the term macroinvertebrates and how their sensitivity to conditions makes them a useful tool for assessing the health of aquatic environments.

Each student will pick one of the animals to research. The form this research takes can vary; it might be a research paper, poster or PowerPoint or a combination of these. Since they'll be sharing their research with the other students, you may want to advise them on their choice of presentation. In most cases there will be more than one student doing research on each animal, so encourage them to use different resources to help diversify the information available to the class as a whole.

The student instructions for the research include the following requirements. Feel free to amend as needed.

- Common and scientific names of the animal.
- What are its physical characteristics? Find at least one adaptation this animal has for the life it lives.
- What does it eat and how does it get it?
- Is it a larva or an adult. If it's a larva, what does it turn into?
- If you the animal you are researching is a macroinvertebrate, how sensitive is it to pollution or to poor water conditions?
- Include a photograph or drawing.

Resources for Research Projects contains additional information and suggested links to help students get started.

Teacher's Guide Activity 3 Cascade Brook Water Temperature

Overview of Activity

Students will:

1. Use the Graphing Tool to construct a time-series graph of Cascade Brook water temperature for the year 2009 and examine its overall properties.
2. Examine the temperature requirements for the organisms they selected in Activity 2 and determine whether their organisms could live in Cascade Brook, whether they'd be stressed or whether they could not survive at all.
3. Use the Graphing Tool to construct a time-series graph of air temperature for 2009 and look at the relationship between the graphs of water and air temperature.

Teaching Suggestions

Temperature was selected as the first parameter to investigate since students are already familiar with temperature ranges from their daily lives. In several parts of this activity, you'll ask students to start by predicting (guessing, imagining) how their graphs will look. This gives them a chance to use their own life experience and helps them understand that they often act like scientists in their own lives, simply by noticing features of the world around them.

Using the Graphing Tool

- Be sure to practice using the Graphing Tool **before** presenting it to the students. In this way, you'll feel more confident and will be better able to help them.
- The Graphing Tool will be used throughout the curriculum. The steps involved in setting up the Tool may seem long at first but with practice students will be able to use it confidently and quickly. Take as much time as is needed at the beginning.
- The Graphing Tool allows students to download the graphs they make and paste them into their Journals. Instructions for the best way of doing so depends on the type of computer you're using (Windows or Mac) and the specific word processing program you use. Be sure to try downloading, copying and pasting **before s**tudents begin work so that you can advise them on the simplest method to use.
- Notice that the student instructions give the time interval as starting on 1/2/2009; for some reason, there is no data available for January 1.
- Scientific measurements always use metric units (degrees Celsius, cm, km) and so all graphs in this curriculum will use metric labels. Students may be more comfortable using the familiar English system (Fahrenheit, inches, feet) to make comparisons in their conversations. It's important for them to be comfortable with both systems.
- You'll use time series graphs for most of the activities in this curriculum. This simply means that time (months, days or hours) is plotted on the x-axis and the parameter (temperature, salinity, rainfall, etc) is plotted on the y-axis.

Which organisms can live in Cascade Brook?

- Students first determine whether their selected organism would be healthy, stressed or unable to live in Cascade Brook, based on temperature requirements and the data for 2009. Since each person chose one animal, it's important (and interesting) for students to share their information. Select the way that works best for your class. It can take the form of a group chart – or short informal presentations – or an art project that depicts Cascade Brook with photos of the organisms that **can** be found living there. Regardless of which presentation method you choose, have students enter the final list of organisms capable of living in Cascade Brook into their Journal.
- Discuss the students' answers to the questions in their Journal**.** Some students may prefer to explain their thinking aloud rather than in writing. Doing so also allows other students to add information about their organisms – similarities and differences – in an informal manner.
- Raise the following issues for discussion: Based on the graph, does it seem as if your organism might experience too high or too low temperatures that last a long time – or just a short time? Do you think your organism might be able to escape those stressful conditions? How?

Compare Air and Water Temperature Graphs

- Students compare two graphs, a feature that will be repeated often in this curriculum. As they work with graphs, they will become more skilled and comfortable with noticing details, including puzzles that leave them wondering. Encourage such wondering, helping them formulate hypotheses to possibly explain what they noticed and keep track of any interesting questions that arise. Activity 12 allows students to pursue their own questions and investigations.

Extensions

- To give students extra practice using the Graphing Tool, you might have each person select a different day of the year and then use the Graphing Tool to examine a graph of the water temperature changes during only that one day. They could then compare their graphs. This would help them understand the many wiggles they noticed in the yearly temperature graph and also show them that they can use different time scales to see different features of a graph.
- If your students are totally comfortable with the graphing and analysis found in this activity, challenge them by selecting a **scatter plot** instead of **time series.** Water temperature and air temperature will then appear on the same graph and you can see where the two are close and where they diverge from each other. For more information on scatter plots, visit http://mste.illinois.edu/courses/ci330ms/youtsey/scatterinfo.html

Teacher's Guide Activity 4 pH: Acidity and Aquatic Environments

Overview of Activity
Students will:
1. Learn/review what the pH chart represents and use it to compare the pH of common household substances.
2. Understand the causes of acid rain, learn about the damage it has caused, and become aware of progress made in controlling acid rain.
3. Examine the pH graph for Cascade Brook to find out if acid rain conditions occurred.
4. Compare low pH events with rainfall events in 2009 to see whether a correlation exists between them.
5. Compare the optimum pH requirements of aquatic organisms with pH levels at Cascade Brook.

Teacher Background
PH and the pH Scale
The three web resources below provide an introduction to pH and its relevance to environmental monitoring. You might also find the first two useful as supplementary reading for students. Because some of the graphics in the third website are also used in the Student Guide we recommend you not direct students to that page until after they complete their work.
- http://www.chem4kids.com/files/react_acidbase.html
- http://www.ei.lehigh.edu/envirosci/watershed/wq/wqbackground/phbg.html
- http://ga.water.usgs.gov/edu/phdiagram.html

Acid Rain
Acid rain is an important influence on pH in aquatic environments of the eastern states. In New York State, it has caused substantial damage, to human health, to property and to natural environments. Acid rain is caused mainly by emission of SO_2 and nitrogen compounds from out-of-state coal fired power plants. A 1990 EPA study showed that one quarter of the 3000 lakes and streams in the Adirondack Mountains had become too acidic to support fish life. Since then, clean air laws have brought down SO_2 emissions and brought about some recovery, but unless emissions are reduced further, these conditions are likely to return.

Acid rain is also a concern at Black Rock Forest. An on-line virtual tour of the forest includes a stop at a high elevation **vernal pond** (meaning that the pond is fed only by seasonal rainwater and snowmelt). It states: *It is important to monitor vernal ponds to determine the effects of acid rain on wildlife. In one study, pond pH, temperature, and amphibian life were monitored in five vernal ponds within Black Rock Forest. Each of the pools was above 1000 feet in elevation. Vernal ponds above 1300 feet in elevation consistently displayed an average pH of 4.0 and a decrease or absence of salamander life (fig. H-4a). This study showed the devastating effects acid rain could have on wildlife in the*

forest.
http://icp.giss.nasa.gov/education/modules/carbon/topic1/common/stop7.html

See the sites below for more information on acid rain.

- Summary on EPA website:
  http://www.epa.gov/acidrain/effects/surface_water.html
- EPA Acid Rain student site, with slide show:
  http://www.epa.gov/acidrain/education/site_students/whatisacid.html
- Thorough background on acid rain in New York, including the section, "What More Should be Done?" http://www.dec.ny.gov/chemical/8418.html

pH and Aquatic Organisms
The chart in the Student Guide gives information on the optimum pH range the animals they researched in Activity 2. Additional information on pH sensitivities of aquatic organisms can be found at these sites:

- General information on effects of acid rain on aquatic ecosystems
  http://www.epa.gov/acidrain/effects/surface_water.html
- A chart that shows effects of sub-optimal pH levels on certain animal groups:
  http://www.ncsu.edu/sciencejunction/depot/experiments/water/lessons/macropHeffects.htm

Teaching Suggestions
Most students should be able to follow the instructions and complete each of the activities for this section fairly independently. However, we recommend you look over the student activities and augment them with additional instruction or classroom activities appropriate to your students' needs. For example, the Introduction to pH in the Student Guide includes a basic summary of pH, but does not go into the chemistry behind pH. We encourage you to integrate this if you choose.

A. Introduction to pH and the pH Scale
Most students are likely to have had experience using litmus paper (or a litmus solution) to test the pH of common household products, such as lemon juice, vinegar, milk, baking soda, etc. If your students have never done this, it would be an excellent way to introduce these activities.

The two sites below have activities for getting your students involved in testing the pH of common substances using litmus paper or red cabbage juice—a fun alternative to litmus paper.
http://www.funsci.com/fun3_en/acids/acids.htm, and
http://www.carolina.com/category/teacher+resources/classroom+activities/red+cabbage+juice+a+homemade+ph+indicator.do

The following activity is computer based, not lab-based but may also be useful: http://mysciencelessons.wordpress.com/2010/02/10/ph-scale-activity-sort/

After students have used one of the colorimetric tests for pH, they may enjoy this interactive activity, based on the "cabbage juice" lab: http://scienceview.berkeley.edu/showcase/flash/juicebar.html

B. pH in the Environment and Acid Rain

Help students, as needed, as they look for examples of both natural factors and human activities that can affect pH in streams. They are asked to find the answers at this site: http://www.water-research.net/Watershed/pH.htm, in the section ***What Causes the pH of a Stream to Vary?***

Students may or may not be aware of acid rain and its effects in natural and human environments. Many buildings in New York City have been damaged by acid rain. The stone building surface of Rockefeller Center (site of a giant Christmas tree every year) is covered with small holes made by acid rain.

Through the activities in the Student Guide, students learn about the damage caused by acid rain and also the gradual recovery made possible by legislation controlling air pollution.

If you choose, you can take this a step further. In today's weakened economy there have been many calls to deregulate industrial practices and loosen environmental standards. This includes a proposal to roll back environmental laws that regulate air pollution crossing state boundaries. You might ask students to (1) search for news items to share with the class on proposals to weaken environmental laws, or (2) find out about the EPA's Acid Rain Program (ARP), part of the 1990 Clean Air Act, which has been successful in reducing the emissions that cause acid rain. (The ARP is also a cap and trade program, the same model proposed as a way of reducing CO_2 emissions.) You can learn about the ARP and its accomplishments here: http://www.epa.gov/airmarkets/progress/ARP09_4.html.

E. Acid Rain in Cascade Brook

When students graph pH data from Cascade Brook, they will see that it generally stays between 5.0 and 6.0, but drops below 4.5 on a few occasions and below 4.0 on two isolated occasions. The chart in their Student Guide uses pH 5.0 as the dividing line between normal and acid rain conditions (some other institutions use the higher cut-off of 5.5). Whichever is the accepted definition, students will find that Cascade Brook experiences occasional acid rain conditions.

It would be interesting to know whether acid rain conditions actually coincided with rainfall at Cascade Brook. In the Student Guide, students are led through the steps of graphing both pH and rainfall over a short interval that includes a sudden plunge in pH, in order to explore the event in more detail. One of the events they examine in this way will show rainfall occurring slightly ahead of the drop in pH, suggesting that the rainfall triggered the more acid conditions in the brook.

When they examine a second event however, they find no such correlation. It's important for students to realize that pH—along with other parameters they'll be looking at—may be affected by multiple factors. Rain may influence pH in one incident, but not in another. Unfortunately explanations will not be found for everything the students find in the data during the period of their study. Help them understand that natural systems are complex, and it takes a lot of patience and persistence to find answers to some of these questions!

Teacher's Guide Activity 5 Introduction to Dissolved Oxygen

Overview of Activity

Students will read and discuss the importance of oxygen to life in general, and of dissolved oxygen in aquatic environments. In particular, they will:

1. Answer a series of questions to help them clarify their existing knowledge about the topics below:
    a. The role of oxygen in the living world
    b. The oxygen cycle
    c. What is meant by dissolved oxygen (DO)
    d. Why oxygen is not as abundant in aquatic environments as it is above the surface
    e. Factors that raise or lower levels of dissolved oxygen in aquatic environments
2. Read a short article to help them fill in any gaps in understanding they may have.

Teacher Background

Dissolved oxygen (DO) is one of the best indicators of health of an aquatic system and is often the most important factor in determining which species can live there. DO levels are influenced by physical factors: whether the water is moving or still, saline or fresh, cool or warm. DO is also affected by biological factors: DO is produced by photosynthetic activities of aquatic plants; it's removed by the respiratory processes of animals and bacterial decomposers. But increasingly the activities of humans are impacting DO levels. The release of organic matter and nutrients into waterways stimulates blooms of algae followed by bacterial activity. A clear background summary can be found on p. 38 of *Eyes on Dissolved Oxygen* Lesson plan,
http://mddnr.chesapeakebay.net/eyesonthebay/lesson_plans/do_lesson_plan.pdf
part of the *Eyes on the Bay* program through Maryland DNR.

Teaching Suggestions:

1. This activity is a review for students who may already be familiar with the content. It also gives others with less background a chance to pick up needed information. Students' knowledge of the topics in this lesson may vary a great deal. We recommend letting students first reflect on what they already know about oxygen and dissolved oxygen, and then give them a chance to fill in their knowledge gaps.

    Students begin by answering questions about DO on the Student Journal page. Explain that these questions are **not** a test but just a chance for them to examine their own knowledge of DO. After writing their initial responses, let them share their ideas in small groups or with the full class. Next they read the Student Reading entitled **Oxygen Underwater**. After they finish, allow them to modify what they wrote earlier, adding new information they picked up from the reading. A full class discussion is recommended to make sure all students are clear on this content.

2. The following website may also be useful as a source of information about oxygen for your students: http://peer.tamu.edu/curriculum_modules/water_quality/module_3/index.htm

3. Consider integrating one or more of the following lab activities available online from the Cary Institute of Ecosystem Studies. Most are designed for grades 9-12. Because they involve measuring DO, they require the use of DO test kits. http://www.caryinstitute.com/education/curriculum/ecosystem-dynamics.
   - **a.** ***Dissolved Oxygen Introduction***. Students practice using test kits to analyze water samples for DO. They test prepared samples with different DO concentrations. (If you use this activity we prefer that you postpone assigning the student reading which accompanies this activity until after your students have completed the next activity, Cascade Brook Dissolved Oxygen.
   - **b.** ***Dissolved Oxygen and Photosynthesis.*** Students discuss and measure dissolved oxygen given off by aquatic plants and experiment with different light sources and intensities. Two versions are available; Version 1 is a structured lab, in Version 2 students design their own experiments.

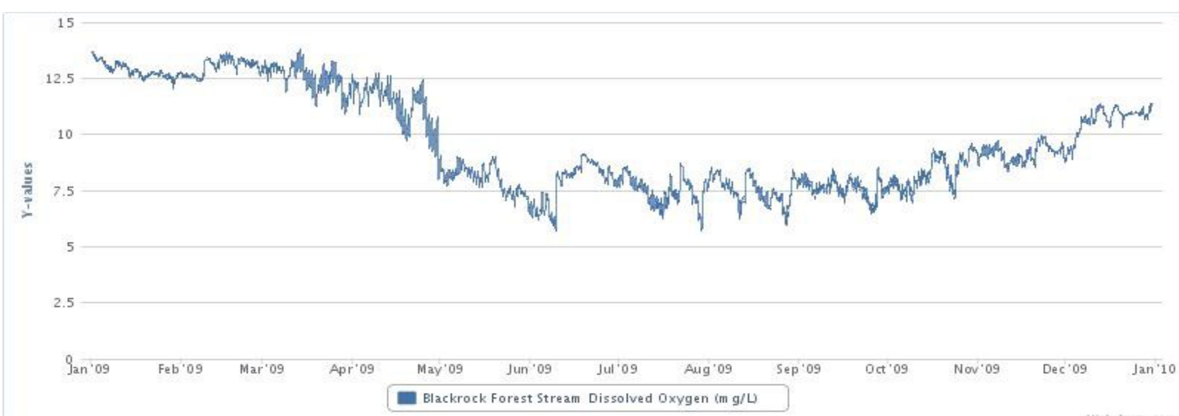
Teacher's Guide Activity 6 Cascade Brook DO

Overview of Activity
Students will:

1. Discover that dissolved oxygen in Cascade Brook shows an oscillating pattern in spring and summer months but less so in other seasons
2. Search for an explanation by comparing patterns in DO data with patterns seen in other parameters
3. Use scatter graphs to test the strength of relationships they find between parameters
4. Discover an inverse relationship between water temperature and dissolved oxygen during spring and summer
5. Learn, through discussion and optional classroom activities, that dissolved oxygen is less soluble in warm water than in cold water.

Teacher Background
If students have completed Activity 5 they will be aware of the importance of DO to the lives of aquatic animals. In this activity they will try to find out what makes DO change.

If you look closely at DO levels in the Cascade Brook over the full year, you're likely to notice it's at its highest in the winter. It begins to drop in March, then hovers all summer at a lower level—in this case around 7.5 mg/L--then slowly rises through the fall. Besides the overall dip and rise over the year, you might also notice an oscillating pattern in summer months, punctuated by sharp dips and jumps. These don't disappear in winter, the peaks and valleys just come closer together. Clearly there's nothing static about DO.

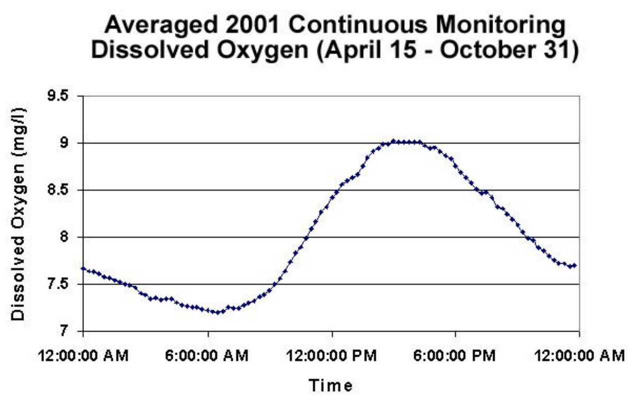


What causes DO to change? In Activity 5 we talked about photosynthesis as the source of oxygen in the atmosphere and in water. We also said DO from the atmosphere can dissolve in water where water and air come in contact: wave action, waterfalls, fast currents, or raindrops for example.

In Activity 6, students will look for factors that might be responsible for the rising and falling of DO in Cascade Brook. Unfortunately there isn't much data in the Graphing

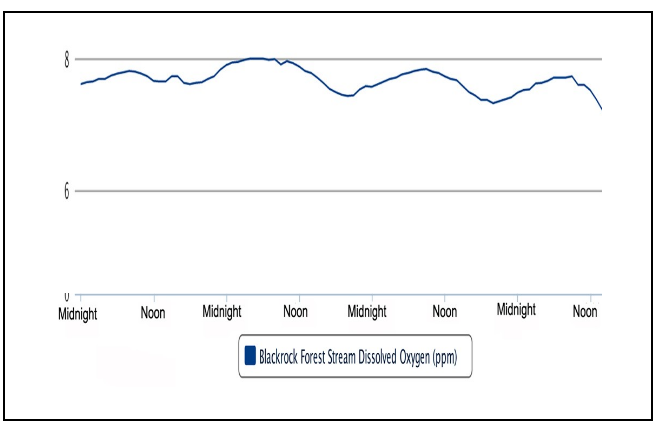
Tool to help them investigate most of the factors named above. There is a way, however, for them to determine whether photosynthesis by aquatic plants is behind these patterns.

Since plants can only perform photosynthesis during daylight hours, is it possible, by zooming in to a period of just a few days to see DO rising in the day and falling at night? Yes it is! In places where aquatic plants are abundant you can see this very clearly. The first of the two graphs below is from a monitoring station in Chesapeake Bay. It shows the level of DO as it changed over the course of 24 hours. (The graph represents 6 month of data.)



Will students be able to observe this in Cascade Brook? If they graph periods of 6-12 days during the growing season, they will see DO rising and falling more or less daily, but if they look closely at the times of day DO goes up and down, these times don't match up very well with periods of daylight and darkness. (See the second graph, below.)

The explanation is that a small stream like Cascade Brook doesn't support many aquatic plants. Its DO levels are actually influenced far more by water temperature, a factor that wasn't introduced in the student reading. This factor was left out in order to let students discover for themselves the important relationship between water temperature and DO as they examine the data.



Cold water is able to hold much more DO than warm water, so as water temperature rises, oxygen comes out of solution and returns to the atmosphere. In Cascade Brook, temperature increases in the morning and falls after sunset. DO does the opposite—it starts dropping in the morning and then rises at night. This relationship between temperature and DO is harder to see in fall and winter, since temperature rises and falls less during one day.

This inverse relationship between DO and water temperature is very important ecologically. It is one of the main reasons high water temperature is so stressful to aquatic life.

Students will discover the relationship between water temperature and DO by using the Graphing Tool to look for positive or negative correlations between DO and other Cascade Brook parameters, skills they have already practiced in Activities 3 and 4. In this activity there are several parameters they can compare with DO, but they are only likely to find a correlation between temperature and DO, and possibly one between rainfall and DO. (If you feel this presents too many options for your students, you can simplify the activity by giving them the parameters you want them to test.)

Since raindrops have been mentioned as one way oxygen can enter the water, students will no doubt look for correlations between rainfall and DO. They may be able to find instances when DO rises after a major rain storm but these are not very common. The easiest way to find them is to graph BRF Lowlands Rainfall to find dates when rain was recorded, then make short term graphs of rainfall and DO over those specific dates. DO and rainfall seem to correlate more in the fall than during other times of year—perhaps because water temperature has less influence over DO at that time. But the rainfall/DO correlation is hard to find in winter. Has rainfall turned to snowfall? What affect would this have on DO? There are always more questions than answers!

For information on why solubility of gases is dependent on temperature:

- http://www.elmhurst.edu/~chm/vchembook/174temppres.html, or
- http://antoine.frostburg.edu/chem/senese/101/solutions/faq/temperature-gas-solubility.shtml

Teaching Suggestions

In this activity students explore the puzzling circumstance described above. They will use the Graphing Tool to compare other parameters with DO, looking for correlations, either positive or negative, with patterns they see in DO graphs. Although the Student Guide provides instructions for their activities, you will need to introduce the problem to the students. You can follow the sequence below to do this, modifying activities as needed for the level of your students.

<u>Noticing Patterns</u>

Students will begin by observing the changes they see in DO at Cascade Brook over the full year. It is important for them to be able to see the DO curve in greater detail than is possible when the year is compressed into one page or one computer screen. A more detailed DO graph can be made by printing out each month separately and taping the pages together. If your students are already working in groups, you can have each group work together to make one long month-to month graph for theat group. Graphs can be extended over several tables pushed together, laid out on the floor, or taped to classroom walls. Alternatively, you could make a single year-long graph yourself and post it in a place that all students can access.

Give students time to carefully observe the changing DO levels over the year. Ask them to find where high and low DO levels occur, to look for places they see patterns in the data, and to notice how the graph changes at different times of year.

Encourage them to share their observations in small groups, and then lead a full group discussion to focus on the shape of the graph—the dips in the summer, the oscillating pattern, how the oscillation changes during the year, etc.

Explaining Patterns

Remind students how important DO is to organisms living in the stream, and that changes in just 1 or 2 mg/L can make an enormous difference to aquatic life. Have them recall the ways in which oxygen can be added or removed from the water (discussed in Activity 5). Ask for their thoughts about what could be causing the patterns seen in this graph.

Students will probably recall that plants are a source of DO. Explore with them what a graph over 24 hours would look like if the DO source were photosynthesis by plants. Display the graph, A Daily DO Cycle Tchr using a document camera or other projection device. Explain that this graph is based on data from a monitoring station on Chesapeake Bay. It shows the average DO levels recorded over a 24 hour period for six months, from April 15 to Oct. 31, 2011. Have them offer explanations for the oscillating pattern seen on the graph. If they suggest photosynthesis and respiration as a possible cause, explore with them the evidence they see in the graph for (or against) this explanation. Point out the time scale at the bottom and have them notice what time the DO level begins to rise and what time it starts to drop. It's important that all students understand that rising DO during daylight hours is probably caused by plants, but if it rises and falls other times, there must be another explanation.

Looking for Causes

Tell students that photosynthesis by plants is just one of many factors that influence dissolved oxygen. The challenge for them is to see if they can find out what is influencing DO in Cascade Brook.

Ask students how could they use the Graphing Tool to find this out. If necessary suggest that they compare a graph of DO with graphs of the other parameters they have examined—water temperature, rainfall and pH—over the same dates as DO. The graphs will be easiest to compare if they choose time periods of 1 – 2 weeks rather than a full year.

Discuss what they might find. If the graphs of two parameters have more or less the same pattern or shape, what might that mean? Or if the two curves moved in opposite directions, what might that tell you? Talk about what a positive correlation looks like and how it might be interpreted: an increase in one parameter may be causing an increase in the other. Talk about what a negative correlation between two graphs looks like, and how it might be interpreted: an increase in one parameter may be causing the other to decrease.

Also explain that finding a positive or negative correlation doesn't prove which of the two is causing a change in the other—or even that cause and effect is involved at all! It's better to think of it as evidence in support of a particular explanation.

Student Investigations

The Student Guide gives step by step instructions to get students started. Depending on their experience with more open ended inquiry, some students will be able to work independently, but others may need more help and guidance.

Students will begin the investigation looking at periods of 1 to 2 weeks at a time, making a DO graph and comparing it visually with graphs of other parameters. (Graphs of 7-14 day intervals are suggested because they show some detail and repeating patterns can be seen.) If they find what looks like a correlation, they will test it with a scatter graph. Students may not find a correlation in any particular two-week period, but if given a little time to explore the data, they are very likely to.

As mentioned above, it's easiest to discover a correlation between temperature and DO during late spring and summer. But it's also important for some students to be able to move around within the data set to make their own discoveries, so the Student Guide does not direct them toward any specific time periods or dates. You can make it easier by pointing students toward weeks between May and mid September.

For students needing still more structure to be successful, give them specific dates to investigate. The following intervals, some one week, some two, should lead student to discover the inverse correlation between temperature and DO fairly quickly.

5/2 to 5/9	5/2 to 5/16	5/6 to 5/20	5/9 to 5/23	5/10 to 5/24	5/15 to 5/29
5/19 to 6/2	5/22 to 5/29	5/22 to 6/5	5/30 to 6/13	6/21 to 7/5	6/24 to 7/14
6/26 to 7/9	6/29 to 7/13	7/5 to 7/12	8/5 to 8/19	8/31 to 9/7	8/31 to 9/14

You can distribute the different dates among your students, insuring that each of their investigations is relatively unique. This gives them the chance to make their own individual discoveries even though the scope of the investigation is more limited.

All students will need to decide whether photosynthetic activity is causing the patterns they see in the DO graphs. They will have access to the graph A Daily DO Cycle Stud to help them. Offer any help needed. Remind them to notice the time of day DO rises and falls; if they notice DO dropping by mid-day, what should they conclude? Students may have trouble determining the time of day from the x-Axis scale on graphs of more than 7 days. You can suggest they reduce the number of days graphed and more detail will appear on the x-Axis.

When students suspect a correlation (or more likely an inverse correlation) they will need to test it by making a scatter graph. They should be able to do this after having practiced it in Activity 3. Give them help as needed in making and interpreting scatter plots.

If some students reach a conclusion supported by evidence before others have accomplished this, suggest that they explore whether their conclusion is valid at other times of year. If it doesn't, have them try to explain the discrepancy.

Sharing Discoveries and Understanding
As students complete their investigations, provide a time for them to share what they discovered. A good way to organize the reporting of findings is to arrange the order of presentations by topic. For example, begin with groups that took a common path or came up with a common finding, then moving on to groups that explored another common topic. This keeps the focus on the range of information learned, increases students' interest in what other groups are sharing, and increases everyone's knowledge. Since most students will have made the same discovery, be sure to highlight any slight differences in evidence and interpretation which can add richness to the discussion.

If you have given students some choice in how they conducted their investigation ,they undoubtedly gained a sense of ownership and motivation. However, it may also mean that not all students will necessarily come to the same conclusions. Most will discover the inverse correlation between water temperature and DO, but others may discover other relationships, or that DO and temperature don't correlate during the winter. What's important to remember is that whatever they do discover is valid evidence and contributes to a better understanding of Cascade Brook.

When they finish, call attention to other factors which they couldn't investigate (for example, days that were windy or sunny or cloudy, or how much water was flowing in the stream) factors that might also affect DO but for which information wasn't available. Explain that because of this, it's not possible to draw firm conclusions. Scientists studying natural processes are always facing the challenge of not being able to measure all inputs to a system, but even so, conducting investigations like this one gradually leads to a better understanding of what's going on.

Finish by explaining, at a level appropriate to their understanding, the relationship between temperature and DO, that water temperature determines the amount of oxygen that can be held in solution. All students should be familiar with its effects if they have seen air bubbles form inside a glass holding a cold beverage as it warms.

Extensions
You can enhance student understanding of the relationship between water temperature and DO by doing a lab activity in which students change the temperature of water and measure the corresponding change in DO. Different versions of this lab are found at the sites below:

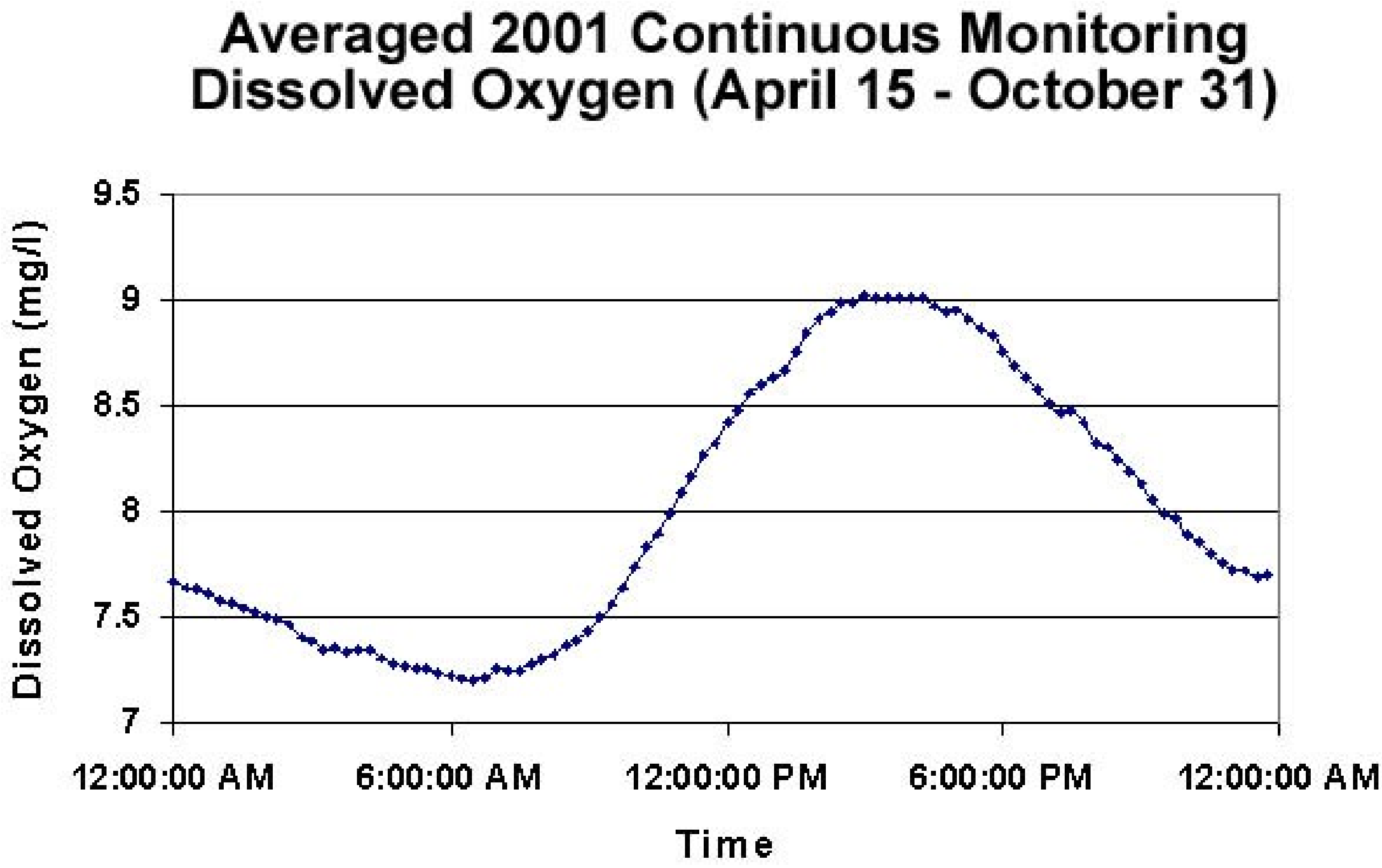
- http://www.caryinstitute.com/education/curriculum/dissolved-oxygen-and-temperature,
- http://www.sciencebuddies.org/science-fair-projects/project_ideas/EnvSci_p014.shtml,

- http://mddnr.chesapeakebay.net/eyesonthebay/lesson_plans/do_lesson_plan.pdf
  ,

You may also find the links on temperature and dissolved oxygen at the end of the Teacher Background section useful with your students.

A Daily DO Cycle (Teacher Copy)

From Eyes on the Bay DO Lesson Plan at
http://mddnr.chesapeakebay.net/eyesonthebay/lesson_plans/do_lesson_plan.pdf



Teacher's Guide   Activity 7   DO and Aquatic Animals

Overview of Activity

Students will:

1. Learn various strategies used by aquatic animals to get oxygen from their environments
2. Use a chart showing the DO requirements of aquatic animals to decide whether the animals would be able to live in Cascade Brook year round.

Teacher Background

Information on strategies used by aquatic invertebrates to obtain oxygen:
http://www.cals.ncsu.edu/course/ent425/tutorial/aquatic.html (inverts)

Information on how fish gills work:
http://www.earthlife.net/fish/gills.html
http://www.howstuffworks.com/question386.htm

Teaching Suggestions

A. How do aquatic organisms get oxygen?

Students will access the first website above, which contains pictures showing different ways macroinvertebrates obtain oxygen. They'll also examine the diagram in their Student Guide that briefly explains how fish collect DO with their gills. The website is written at a fairly high level, but the pictures, along with the questions in the Student Guide, will help them understand some of the diverse strategies used by aquatic animals.

B. Cascade Brook DO and Aquatic Life

Students will then compare minimum DO requirements of the 15 aquatic animals studied earlier, with DO levels recorded during the year. They will find that DO levels in Cascade Brook did not drop below the minimum requirements of any of the invertebrates, but several times during the summer they approached the level required by the fish and they were below the level needed for Brook Trout to spawn.

Ask the students if they can explain why DO is at its lowest level during the summer months. The answer relates back to what they learned in their previous investigation, that warm water loses the ability to hold oxygen in solution. In general the higher water temperature over the summer drives DO levels down, although other environmental factors may influence day-to-day DO levels.

Extensions

A classroom lab activity that would enhance these topics is ***Animals and Dissolved Oxygen*** from the Cary Institute. The primary activity is a student investigation on the response of goldfish to water with different DO levels. Write-ups for this activity can be found at two different links. Both are given here because slightly different resources are found on each:
http://www.ecostudies.org/chp/Module1/1C7_Animals_and_DO.pdf
http://www.caryinstitute.com/education/curriculum/introduction-dissolved-oxygen

The Cary Institute activity lends itself to discussion of real-world applications. You might ask students how the heated wastewater released by the Indian Point Nuclear Power Plant might affect animals in the Hudson River.

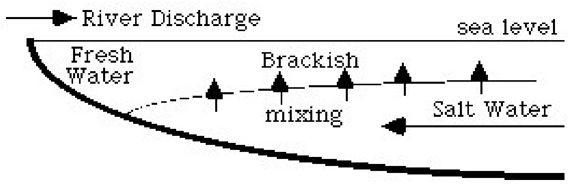
Teacher's Guide Activity 8 Hudson River Estuary – Salinity and Tides

Overview of Activity
Students will:
1. Understand the meaning of **estuary** and **salinity**
2. Use a web-based Animation to explore the tide's effect on **surface** salinity in Estuary waterways
3. Use the Animation to explore the **bottom** salinity in Estuary waterways and compare these results with surface salinity observations
4. Conduct experiments to observe the effect of salinity (and temperature) on density and discuss the effects of stratification (layering) on aquatic life.

Teacher Background
Our water quality study now moves away from Cascade Brook, down the Hudson River to the Hudson River Estuary. An **estuary** is a place where fresh water and salt water mix. The Hudson River Estuary extends from the New York Harbor up to the Troy dam. Above that, the water is 100% fresh water, with no saltwater flow at all. The Hudson River Estuary receives salt water from the changing tides in the Atlantic Ocean and in Long Island Sound. The Estuary receives fresh water from the Hudson River, the Bronx River and several small rivers in New Jersey. These waters combine in a constantly changing way.

Salinity is a measure of the amount of dissolved salts in water. Students commonly assume that the word "salt" refers to sodium chloride, (NaCl) the familiar table salt. NaCl is just one example of a chemical "salt" in seawater, but it is by far the most abundant. In the past, salinity was expressed in the units "parts per thousand," written as ‰, referring to grams of salt per kilogram of water, but today salinity is expressed either in "psu" (practical salinity units)—or without units at all. Example: "Surface salinity of the open Atlantic Ocean ranges from 33 to 37."

Layering of fresh and salt water
When salt and fresh water mix, they don't result in a perfectly blended soup, as you might imagine. Instead, the differences in density means that the heavier salt water moves along the bottom while the fresh water flows along the top, like two different layers in a layer cake. When the surface layer is also warmer than the bottom layer, which is common in summer, the density difference between them intensifies stratification and prevents them from mixing. This exacerbates the problem of low dissolved oxygen in deep water, the topic addressed in Activity 10.



Source: http://earth.usc.edu/~slund/systems/topic5b/topic5b.html

Background Resources
Definition and description of Hudson River Estuary
http://www.dec.ny.gov/lands/4923.html

General introduction to natural history of Hudson River Estuary
http://www.hhr.highlands.com/nathist.htm

Thorough information on tides
http://www.ecostudies.org/chp/Module1/1A2_tides_reading.pdf
http://www.riverproject.org/riverdive_today.php#salinity

Teaching Suggestions
A. Explore a satellite image of salinity in the Hudson River Estuary
The satellite image in the Animation that students use does not include place names. They'll easily be able to find Manhattan and Central Park but it will be important for them to know their way around a larger area. They'll want to be able to refer to New York Harbor, Harlem River, East River and Long Island Sound; you can point these out when you first open the Animation. The map below is included in their Student Guide so that they can see how the waters of the Sound flow into NYC.

Source: http://en.wikipedia.org/wiki/File:Long_Island_Road_Map.gif

B. Start the Surface Salinity Animation – discussion

We've chosen a period of very high and very low tides so that students can see the changes more clearly.

We suggest that you allow time for the students to work from the instructions in the Student Guide for a while but then pull them together for a discussion so that you can find out how – and what – they're doing. It can be engaging to just watch the colors flow back and forth but it's important for them to describe what they're seeing and to use words such as **salinity** and **tides** so that you know they're extracting meaning from the Animation.

It can be confusing to see so many changes happening at the same time. Suggest that students focus on one spot where the color changes a lot and watch the changing salinity of the water moving by that one spot. Ask them to describe the changes they observed, describing them in terms of salinity, not just color.

Students may have gone swimming on local saltwater beaches, but they may not be familiar with the twice-daily changing tides that bring salt water from the Atlantic Ocean and pull it back again. As they watch the Animation, they will see this movement of high salinity water moving back and forth. They will be able to see that tides rise and fall twice each day in the estuary. Students may have been taught about tides and their causes based on planetary bodies – but they may never have realized that their effects can be seen locally.

After watching the Animation for a while, students may wonder whether the salt water would ever reach the Hudson near Black Rock Forest (or more correctly, West Point which is directly on the Hudson nearby). Ask students what conditions might allow that to happen and get their various ideas. [During an especially dry season, less rain falls and so there might be less fresh water coming down the Hudson. Then salt water being pushed up the Hudson River might reach West Point.]

C. Experiments with fresh and salt water

As students use the on-line Animation, they will discover that during tidal exchanges, saltwater moves in and out mainly in deep water, while the river's upper layer stays relatively fresh. Some students may be able to explain these observations in terms of the relative densities of salt water and fresh water, but others may not. While it's not necessary to explain density at this time, we do recommend giving them a hands-on lab that lets them find out for themselves what happens when salt water and fresh water meet. The hand-on activity Estuary Layers uses simple materials, but quickly demonstrates how fluids of different densities interact.

Since layering of water in estuaries is intensified when warm water lies over cold water, students can repeat the experiment using water of different temperatures. You can also let them design their own experiments using both variables (density and temperature), since the two variables are present in an estuary, and in combination they either reduce or intensify stratification (layering) of its water.

Discuss with students how stratified water conditions might impact animals, especially those living in deep water. Help them see that without mixing, DO remains in the surface layer.

Another version of the above activity can be found at this site:
http://new.coolclassroom.org/files/adventures/1/Activity_DensityCurrents.pdf
Its name, Density Currents, refers to the fact that density differences are important drivers of currents throughout the world's oceans, much like pressure differences between air masses produce air currents—and winds and weather—on the earth's surface.

Extensions

- A Hudson River Estuary poster that can be downloaded and pasted into Student Journals for reference

http://www.dec.ny.gov/lands/56523.html

- Learn more about tides. Examine a ready-made graph that shows the tides at the Battery for any day of the year

http://www.ezfshn.com/Tides/USA/New%20York/New%20York%20The

%20Battery/

Teacher's Guide Activity 9 Hudson River Fish Life Cycles and Habitat

Overview of Activity

Students will:

1. Learn about several Hudson River fish life cycles by conducting web research
2. Become aware of the varying salinity requirements for these fish at different stages in their lives
3. Understand the life cycles of anadromous and catadromous fish and then classify a group of fish as belonging to one of these categories or to neither one

Teacher Background

Students' study of water quality now moves to the second site, the Hudson River itself, monitored just below the George Washington Bridge on the New Jersey side. There are numerous monitoring sites along the Hudson throughout its entire length; this site was selected because of its proximity to New York City and students' familiarity with the Bridge. Their focus at this site will be the changing salinity of waters flowing by that site.

Introduction to Hudson River fish, related pollution issues and commercial vs. recreational fishing
http://nyfisherman.net/richardferreira.html

Fish ecology in the Hudson
http://www.riverproject.org/riverdive_today.php

Teaching Suggestions

In the previous activity, students used the animation to become aware of the constantly changing salinity in the Hudson River Estuary. Ask them what they noticed while observing that animation. Use a class discussion to bring out the following points:

- The salinity changes they saw are the result of daily ocean tides that push salt water into the estuary and then pull estuary waters back into the ocean.
- This happens every day of the year, twice a day, on a schedule that changes from day to day.
- Salinity is very often different at the surface and the bottom

These constantly changing conditions can be both challenging and rewarding for fish.

- Can fish and other animals survive under such conditions? If so, how?
- Do some fish require different salinity conditions at different stages of their lives?
- What are some advantages fish might find in the changing conditions of the Estuary?

The research project the students undertake will help answer these questions.

A. Research Project - Fish Habitat Requirements at Different Life Stages

This is a full class project where students can work individually or in pairs. Help them choose the fish to research and go over the Journal page with them to be sure they understand what is to be done. As they conduct their research, they may find that some sources give specific salinity ranges (15-20, for example) while others say “river,” “estuary” or “ocean.” Students should note both ways of specifying salinity. The following information will help them move between the two methods:

Type of water	**Where found**	**Salinity**
Fresh water	Rivers, lakes, ponds	0 - .5
Brackish	Estuary	.5 - 30
Salt	Ocean	30 - 50

The results of their separate research can be shared in any of the following ways:

- Students (individually or in pairs) can give a presentation to the class
- A group of students can prepare a PowerPoint presentation that incorporates all the collected photographs/illustrations and information.
- Each student (or pair) can make a scientific poster. Unlike posters that advertise special events, a scientific poster is a large format presentation that can contain written information, photos, maps or drawings, charts or graphs and a list of references used. Posters can be displayed around the room and students can read each other’s posters, collecting information to help them determine which fish can live in the Hudson River at the George Washington Bridge site.
- A large version of the chart below can be posted so that students can enter their findings for group discussion

For your convenience, we’ve filled in the results in the following chart, but please do not present this completed chart to the students. Conducting the research themselves is more important than the “answers” in the chart.

HUDSON RIVER FISH and LIFE CYCLE HABITATS

Fish	**Eggs**	**Juvenile**	**Adults**	**Anadromous , Catadromous or Neither**
American eel	Ocean	Estuary	River	Catadromous
American shad	River	Estuary	Ocean	Anadromous

Atlantic sturgeon	River	Estuary	Ocean	Anadromous
Blueback herring	Estuary	Estuary	Estuary	Neither
Bluefish	Ocean	Ocean	Ocean	Neither
Carp	River	River	River	Neither
Channel catfish	River	River	River	Neither
Mummichog	Estuary	Estuary	Estuary	Neither
Shortnose sturgeon	River	Estuary or river	Estuary or ocean	Anadromous
Spottail shiner	River	River	River	Neither
Striped bass	River	Estuary	Ocean	Anadromous
Three-spined stickleback	Ocean or river	Ocean or river	Ocean or river	Anadramous or neither
White catfish	River	River	River	Neither
Yellow perch	River	River	River	Neither

Help students notice that the estuary can be considered a nursery for many fish species. Even fish that spawn and hatch in river water often move to the estuary for their juvenile phase. The estuary provides abundant food and its muddy water allows young fish to hide from predators.

Students presenting their research may mention pollution and human health issues arising from contaminated fish. Be sure to mention that some fish are not themselves affected by the toxins and pollution in the estuary. However, humans can develop serious physical problems if we eat those fish.

B. Which Fish Can Live Near the Hudson River George Washington Bridge site?

The resources will enable all students to fill in the chart above but an additional step is needed for them to determine which fish might live near the Hudson River site. Making the salinity graph and matching their fish's salinity tolerance to the graph can help answer that question.

In the Graphing Tool, students will enter the same dates as were used in the previous activity's Animation, namely **June 18 – 25, 2009**. When they examine the graph, they may find puzzling points on the graph where the salinity seems to suddenly tumble down to zero. Actually, no data was recorded at those times but the computer program requires a value to construct the graph and so zero was selected. Just tell the students to ignore those zero points.

After examining the salinity graph, ask students write the names of those fish that might be found at the Hudson River GWBr site directly below the graph. If possible, have them include the appropriate life cycle if known.

Extensions
Students might be interested in further research on Hudson River fish. Here are two topics not included in this curriculum:

- **Fishing and human health** - Recreational fishing for many fish is allowed but specific advisories (warnings) are given about eating certain types of fish. Learn which fish in which locations have health advisories and the reasons for them.
  http://www.health.ny.gov/publications/2796.pdf

- **Commercial fishing** in Hudson River The Hudson once supported rich commercial fisheries throughout its tidal waters. Learn the various reasons why this is no longer true.
  http://www.riverproject.org/riverdive_today.php
  http://nyfisherman.net/richardferreira.html

Teacher's Guide Activity 10 DO: How Low will it Go?

Overview of Activity

Students will:

1. Learn how nutrients get into water and how excess nutrients leads to extreme low DO conditions.
2. Become aware that eutrophication around the world usually occurs near centers of human population.
3. Learn about both historic and current conditions in the Hudson River related to low DO.
4. Graph DO data from the Hudson River (GWBr) site and compare levels recorded there with other parts of the watershed and with Cascade Brook DO.

Teacher Background

The estuaries of most of the world's major rivers, especially those with drainage from large urban/industrial centers and land devoted to modern agriculture, suffer routinely from low oxygen conditions. The so-called Dead Zone off the Mississippi Delta in the Gulf of Mexico is a well known example, but low DO conditions, or ***hypoxia*,** are also common in rivers along the east coast, including the Hudson River.

The main cause of hypoxic conditions is eutrophication. Eutrophication is the technical term for a natural process by which lakes very slowly disappear through the gradual accumulation of plant material. Today the word is widely used for the degradation of any aquatic ecosystem by an overgrowth of aquatic plants resulting from the discharge of phosphates and nitrates into waterways.

Eutrophication starts when nutrients, the same compounds used in chemical fertilizers, get into water. These compounds are essential to the growth of plants, but they're not especially abundant in nature, which is the reason we use fertilizers to increase the productivity of plants. If nutrients suddenly become plentiful in places where they don't normally occur, they cause an unnatural "bloom," or uncontrolled growth of algae and other plants.

Eventually the plants become so crowded that many of them can't get sunlight, so they die. The dead plant material sinks to the bottom where naturally occurring bacteria begin to cause its decay. The bacteria that do this require oxygen. The more organic matter is present, the more oxygen is removed from the water by bacteria. Eutrophication can quickly make an ecosystem uninhabitable to animals that depend on dissolved oxygen. Extreme low oxygen conditions typically occur mid to late summer just after the optimal growing season for plants.

Chemicals used in agriculture are not the only cause of eutrophication. Nitrogen and phosphorus are also present in:

- Organic matter such as animal waste, untreated or poorly treated sewage or septic waste entering waterways. Organic matter causes an immediate drop in DO through decomposition, and it releases nutrients that stimulate algae growth.
- Household products such as lawn chemicals, car wash detergents, and cleaning products in the home.
- Air pollution coming from coal fired power plants containing nitrogen compounds. These compounds cause acid rain and they also stimulate eutrophication.

In the Hudson River, the main nutrients sources are wastewater/sewage treatment facilities, agricultural activities and chemicals coming from the atmosphere. In the early part of the 20th century, the river suffered much more serious oxygen depletion than it does today. Conditions have improved substantially since the 1970s when the Clean Water Act brought about improvements in sewage treatment and when phosphates were banned from household detergents. However, low oxygen conditions continue to occur throughout the watershed in late summer.

For a glimpse of what happens to aquatic life during a low oxygen event, or to show to students, the following video was filmed by a diver in the marine waters of Hood Canal, Washington: http://www.youtube.com/watch?v=ANXIXbZmadk. You'll see lots of fish in the video, but they are behaving very abnormally. The large fish, barely moving in the water are rockfish, deep-water residents that have moved up to the shallows in search of more oxygen. Unfortunately, both deep and shallow water were affected in this low DO event, so the fish are hovering almost motionless, trying not to exert themselves. The fish lying on rocks are panting heavily as they wait for conditions to improve.

Consider teaching a hands-on lab activity on eutrophication in conjunction with this piece of the curriculum. Since plant growth and bacterial decomposition are often integral to this lab, it will take longer than one period to complete. The Cary Institute's Changing Hudson Project has a lab called **Eutrophication** that requires 10 minutes a day for 2 weeks, and uses pond water, microscopes and an optional turbidity meter. You can find it here: http://www.ecostudies.org/chp_waste_river.html along with other useful activities.

Additional background resources

Good information on hypoxia from Long Island Soundkeeper:
http://soundbook.soundkeeper.org/chapter.asp?ContentID=215&SectionID=7

Reading on Eutrophication from the Cary Institute:
http://www.caryinstitute.com/sites/default/files/education/curriculum/readings/4C3_eutrophication_reading.pdf

World Resources Institute website has some remarkable resources, including the Interactive Map used in the student guide, and a Gallery with photos, maps and videos: http://www.wri.org/project/eutrophication/about.

Teaching Suggestions
Introducing Eutrophication

Tell students that an important water quality issue affecting rivers like the Hudson River is eutrophication, a process that causes very low dissolved oxygen conditions, usually in mid-summer. Before looking at DO data recorded at the Hudson River (GWBr) site, it's important to find out what eutrophication is all about.

The following short animation is very useful in highlighting the chain of events that leads to eutrophication.
http://www.absorblearning.com/media/attachment.action?quick=v3&att=2228
(The animation is available online as a sample of learning tools at absorblearning.com, but if you want to download it, a paid subscription is required.)

You can either show this animation to the full class as you introduce the topic of eutrophication, or you can give students the web link and have them watch it individually. Either way, ask them to them summarize the process in their own words to make sure they understand it.

Ask students if they can explain why the most extreme low DO events caused by eutrophication always occur in late summer in the US, and rarely at other times of the year. (Eutrophication is associated with plant growth, which reaches its peak when days are longest. By late summer plants are dying and decomposition is well underway.)

The animation highlights runoff from farm fertilizers as the cause of eutrophication. Clarify to students that the actual cause of eutrophication is an excess of nitrates and phosphates. These compounds occur in urban areas as well as in fertilizers used agriculturally. Have students brainstorm other sources of these compounds, along with ways they might be getting into the river. (See list in Teacher Background, above.)

The link below takes you to a full size diagram showing sources of nutrient pollution you can print and give to students. Although the drawing depicts a rural or suburban scene, most of the sources are just as present in an urban setting.
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/sources.cfm

A. Interactive Map of Eutrophication

Next, students will follow directions in the Student Guide as they use an Interactive Map of Eutrophication to see the extent of eutrophication around the world. They will also use it to look up the eutrophication status of places along the Hudson River. You should become familiar with this site in order to help students with any problems they encounter.
http://www.wri.org/project/eutrophication/map

Before having students begin, make sure they understand the term "hypoxic" which is used on this website. Students may recall the term "*anoxic*," introduced in the student reading in Activity 5. Anoxic refers to a DO level of zero, or a level so low that no life form requiring oxygen can survive.

Explain that "*hypoxic*" refers to extremely low DO conditions, generally ranging from 1 to 3 mg/L. Most fish and invertebrates can't survive these conditions, but a few are able to.

The interactive map uses yellow, red and blue dots for places labeled as "*eutrophic*," "*hypoxic*," and "*improved.*" These terms are explained in the Student Guide as follows:

- Yellow Dot = Eutrophic—places with high nutrient levels and abnormal algae growth. Still, DO levels there aren't low enough to label them "Hypoxic."
- Red Dot = Hypoxic—places with extremely low dissolved oxygen due to eutrophication.
- Blue Dot = Improved—places that were hypoxic at one time but are now improving, usually because of some environmental action.

Directions in the Student Guide ask them to begin by moving about on the map, clicking on dots in different parts of the world to see what they find. If they single-click on a dot, an information panel opens. If they double-click on the dot, the information panel opens and the map zooms to that locality, allowing them to explore the area close in. (This is easier if they first close the information panel.) To zoom back out they will need to use the slider on the left.

The information displayed on the interactive map comes from many sources. Some of the information panels are long or use technical language while others are worded more simply. Due to the inconsistent language, student assignments have not been given for this initial exploration. But if you feel the texts are not above the reading level of your students you can assign questions that make them look more deeply, perhaps leading to richer follow-up discussions. Below are a few suggestions:

- Find a hypoxic site that surprises you. Why did you think this site would **not** have such a problem?
- Find a hypoxic or eutrophic site in which the problem was caused by something you hadn't realized could lead to eutrophication

- What are some different kinds of damage caused by eutrophication around the world?

Students are then asked to go to four locations along the Hudson River to learn a little about sources of nutrient contamination and become aware that considerable progress has been made in improving water quality conditions in the river. They can navigate to those places using the vertical alphabetic scrolling window to the right of the screen. Scroll down to US, then state by state to New York and then to the specific location name.

Students are asked specific questions at each of the following locations. Notes below refer to places where student might need help or clarification.

The Information frame for the Hudson River refers to “abatement of untreated sewage.” “Abatement” may be an unfamiliar word to some students. There’s also a reference to DO as “percent saturation”. Percent saturation is another format for expressing DO, but since it is not used in this curriculum, students should ignore this reference.

B. Hudson River DO Graph
Students graph DO in the Hudson River to find out whether DO levels measured at the George Washington Bridge showed signs of hypoxia. They will see that DO reached levels below 4 mg/L for a few days at the end of July but never dipped below 3 mg/L. They compare this to levels recorded in Cascade Brook where the lowest measured was just below 6 mg/L around June 10 and again at the end of July.

They also compare the DO graphs from the two sites – Hudson River and Cascade Brook. Students will probably notice the daily extremes between highs and lows are even greater at George Washington Bridge than at Cascade Brook. The reasons for this are not introduced in Activity 10, but are left among possible questions to be explored through student investigations in Activity 12.

For your own understanding, DO drops dramatically in the Hudson River as salinity increases, so the extremes in DO actually reflect the tidal influence. There are two likely reasons this is happening:

- Water is an excellent solvent, but its capacity to hold substances in solution is limited. As dissolved salt (salinity) increases, water’s ability to hold dissolved oxygen decreases.
- Saltwater moves in and out of an estuary along the bottom. Since DO is naturally lower in deep water than at the surface, the deeper layer tends to be both more saline and lower in oxygen, unless the layers become mixed.

DO in the Hudson River is also influenced by water temperature; students might choose to investigate this relationship in Activity 12.

Extensions

- **The Hudson River Clearwater Revival**
  It is a short, 2-part video filmed aboard the sailing vessel Clearwater. A group of middle school students on board conduct experiments, monitor the water and collect fish and plankton as they sail. They also have good discussions about how rivers become polluted and the effect this has on the environment and people. They discuss point and nonpoint pollution sources, a topic that integrates well with content presented here. The students and the youthful Clearwater crew share interesting and appealing ideas on personal ways to decrease pollution. We recommend using these videos, followed up with a short discussion, as closure to Activity 10.
  http://vimeo.com/3427861, 9:23 minutes
  http://vimeo.com/3427881, 5:48 minutes

- **Historical and current conditions**
  The following article provides perspective on sewage spills in the Hudson River and may be useful to use with your students. Dated August 2011, it was written after the sewage spill resulting from the fire at a Manhattan treatment plant. http://green.blogs.nytimes.com/2011/08/09/sewage-routinely-taints-hudson-study-shows/

Teacher's Guide Activity 11 Harlem River – Student Monitoring and Data

Overview of Activity
Students will:
1. Become familiar with the Harlem River – its history, physical features and importance
2. Learn about the Frederick Douglas Academy Student Monitoring Project
3. Examine tidal currents and changing salinity in the Harlem River using the Animation
4. Compare data graphs to learn how water in the Harlem River changes with tidal action
5. Check for hypoxia in the Harlem River

Teacher Background
The Harlem River separates Manhattan from the Bronx. It is not technically a river since it has no source and does not always flow into another body of water. It really is a "strait" or passageway connecting the Hudson River with the East River. It is about 13 km (8 miles) long. The Harlem River is strongly affected by tidal currents which exchange ocean water and river water twice daily.

Although the Harlem River once meandered, it has been straightened to make navigation easier. Today it is crossed by 13 bridges, reflecting the growth of traffic from Manhattan to the north as the city's population grew. Concrete walls, highways, warehouses, docks and bridge entrances line its shores – with two exceptions:
- The Harlem River Park, between 133rd St and 145 St. (For info, visit http://www.harlemriverpark.com/home.html
- The small bay and curved shoreline near Inwood Park, at the northern end. This is the only natural shoreline remaining.

More on the Harlem River can be found at
http://en.wikipedia.org/wiki/Harlem_River

Water quality data on the Harlem River used in this curriculum comes from a monitoring station maintained by students at the Fredrick Douglas Academy (FDA), under the guidance of their teacher Mauricio Gonzalez. They began monitoring DO, salinity and temperature in 2009, using a variety of equipment including a solar powered sensor at a depth of 20 feet. The sensor is attached to pilings and collects data every 15 minutes. Students use a wireless Bluetooth antenna to download data and analyze it back at school. They have presented their findings to neighborhood and community development groups and at Columbia University. They are hoping their project can help stimulate positive change in the use of the Harlem River waterfront.

Students will watch a short video to learn about this project.
http://www.ny1.com/content/special_reports/connect_a_million_minds/124107/st

udents-use-harlem-river-as-source-of-scientific-exploration/

You can find more information about the project at:
http://www.enn.com/press_releases/3122

Teaching Suggestions

A. Explore the Harlem River

Introduce the Harlem River as the final monitoring site students will "visit." In highlighting the Harlem River, our goal is to make the Harlem River come alive for the students – because it is frequently neglected – and to encourage them to use scientific tools to investigate the River. Please incorporate any local knowledge you have and that of your students.

Students begin by opening Google Earth and locating the Harlem River monitoring site, then exploring up and down the Harlem River at close range. Students may recognize bridge and place names that they can share with each other. You can also suggest they look for specific familiar landmarks.

If your students have been doing these activities in sequence, they'll probably be comfortable using Google Earth, the Animation and the Graphing Tool. Detailed instructions are included in the Student Guide, but be prepared to help any students needing extra help.

B. The Frederick Douglass Academy (FDA) Student Monitoring Project

After students watch the video, give them a chance to share their responses.

C. View Harlem River in Salinity Animation

Student will again use the salinity animation introduced in Activity 8: http://hudson.dl.stevens-tech.edu/maritimeforecast/maincontrol.shtml, this time focusing their attention on the Harlem River. They will notice that the Harlem River is almost always more saline than the Hudson River. They will also see that it receives water from two directions: relatively fresh water from the Hudson and much more saline water from the East River and Long Island Sound.

They will also discover that the movement of saltwater up into the Hudson River during high tides doesn't happen at the same time as saltwater moving up the Harlem River. Instead, fresh water from the Hudson pours into the Harlem River. It's not until the tide falls in the Hudson River that that saltwater moves up the Harlem River from the other end. The labels "high tide" and "low tide" may be confusing to students in this context so they are not used in the student text. More important is watching how the river flow reverses direction during the tidal exchange, and how the water changes from relatively fresh to highly saline in a matter of just a few hours.

Seeing the interesting circulation patterns in the Harlem River will help students appreciate what an unusual "river" it is. It may also make them more interested in tides and how much their effects can vary from place to place, even places as near to one another as the Harlem and Hudson rivers.

D. Do other parameters in the Harlem River change along with salinity?
Students will use the Graphing Tool to construct the graphs of Harlem River salinity, temperature and DO over a one-week period beginning on June 18, 2009. They will copy and paste the three graphs, beginning with the graph showing salinity, into their Journal. They'll compare the cyclical patterns, all related to tidal action, which they find on the three graphs. As in earlier activities, where they looked for positive and negative correlations, they will need to pay special attention to the timing of these cyclical patterns, using a straight edge if needed to help them line up units on the X-Axes of their graphs.

As they decide whether temperature and DO have positive or negative correlations with changes in salinity, they'll fill in the chart below. The chart should help them characterize the changing water conditions in the Harlem River taking place twice each day.

When the Harlem River receives water from the ocean, its waters will have a			
higher	Salinity	Range (psu)	17-19
	Temperature	Range (°C)	
	DO	Range (mg/L)	

When the Harlem River receives water from the Hudson River, its waters will have a			
lower	Salinity	Range (psu)	
	Temperature	Range (°C)	
	DO	Range (mg/L)	

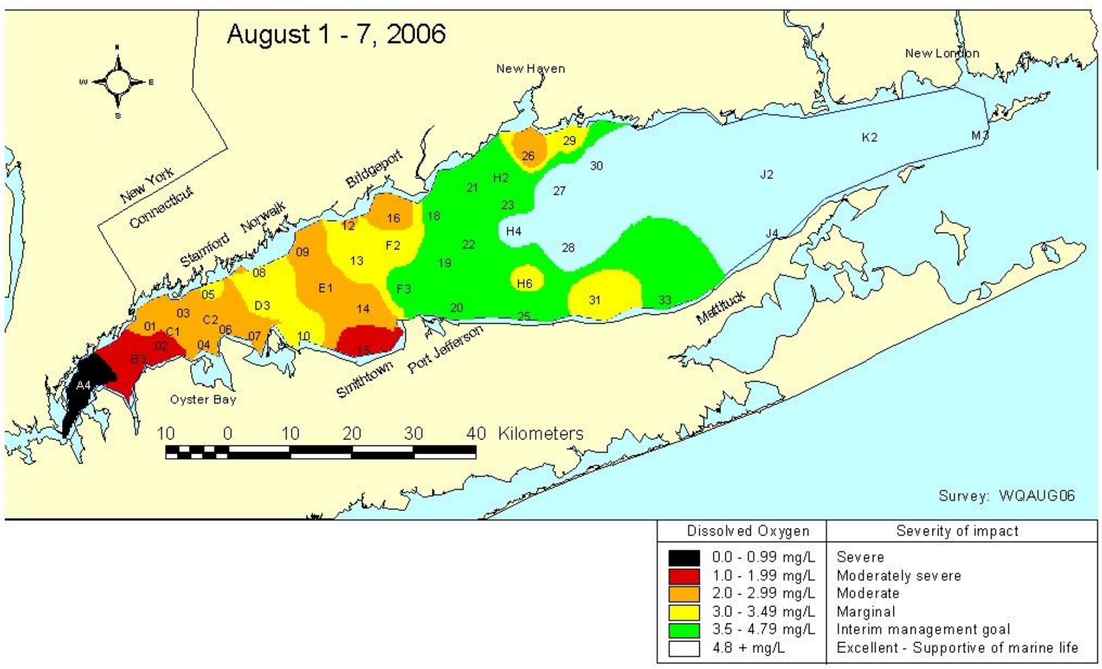
Question 8 in the Student Guide asks students whether or not they are surprised by the differences in temperature and DO as the salinity changes from relatively saline to relatively fresh. Students may remember the inverse relationship between temperature and DO and be surprised it doesn't occur in this saturation. Other students may recall that high salinity water is more dense than fresh water and for that reason likely to originate in deep water, colder and lower in DO because of this. Students may have trouble expressing these ideas; use class discussion to help this process

E. Hypoxia in the Harlem River?

Students look for hypoxia conditions in the Harlem River by using the Graphing Tool to explore DO levels during July and August, months in which eutrophication is most common. They will find that DO drops to below 3 mg/L a number of times between 2009-8-23 and 2009-8-31. Discuss with them some of the factors that contribute to low DO in the Harlem River

- Contamination from the urban environment it flows through, especially sewage waste
- Stratification which reduces the movement of oxygen surface layers to deep water.
- Flow of water coming from Long Island Sound, which has extremely low DO levels due to eutrophication, as you can see from the map below.

Dissolved Oxygen in Long Island Sound Bottom Waters



Source: http://www.stonybrook.edu/soundscience/graphics/sciencobjs/medium/wqaug02.jpg

Harlem River Photo

http://en.wikipedia.org/wiki/File:Aerial_view_of_the_Bronx,_Harlem_River,_Harlem,_Hudson_River,_George_Washington_Bridge,_2008-05-10.jpg

Teacher's Guide   Activity 12   Students' Research Questions

Overview of Activity:
Students will:

1. Review what they've learned from the data at the three sites.
2. Brainstorm and formulate new questions they might be able to answer by exploring the existing data.
3. Investigate the new questions, looking for evidence in the data.
4. After completing investigations, they share and discuss what they've learned.

Teaching Suggestions:

A. Introducing Data Investigation

Begin by having students brainstorm what they've learned about conditions at the three monitoring sites by examining data for the various parameters. Below is a summary of possible student responses. Please do not present these as written below. Instead let as many of them arise from student discussion as possible. If necessary, help them express their statements more precisely.

Cascade Brook

- Water temperature in Cascade Brook generally changes as air temperature changes, but air temperature varies more widely.
- Most aquatic organisms won't experience stress due to water temperature, but some will.
- pH briefly drops below pH 4 several times, which is within the range of acid rain. This is a stressful and possibly lethal level for some organisms.
- Low pH events may be related to certain rainfall events, but the evidence is not very conclusive.
- Water temperature has a strong influence over DO levels during spring and summer months.

Hudson River (GWBr)

- Water at the Hudson River (GWBr) site is saline because of the tidal influence. Salinity goes up and down twice daily.
- DO at the Hudson River (GWBr) site changes with the tides too. It drops to below 4 mg/L several times, which is very low, but not considered hypoxic.

Harlem River

- Water in the Harlem River is also saline and conditions change twice daily with the tides.
- DO and temperature both show a negative correlation with salinity in the Harlem River. All three change back and forth with changing tidal currents.

Remind them that they learned most of these "facts" by exploring the data using the Graphing Tool. Being able to use data to find answers to scientific questions is a powerful tool used by scientists. Explain that, in this final activity, they will try to think of any unanswered questions—including any that arose during previous activities—which could be investigated using these methods. Then each student will choose one to investigate.

B. Topics for Investigation

Have students brainstorm, first individually or in small groups, then as a whole class, a range of new questions they could investigate using the existing data. Here are some possibilities for you to be aware of:

- Comparisons between stations:
  - Compare parameters between any two sites for the same time period and suggest possible reasons for differences seen.

- Relationships between parameters. Students try to find other correlations than those already identified, or they try testing identified topics at different time scales to see if the relationships change or new ones appear:
  - Does rainfall affect temperature in Cascade Brook?
  - At Cascade Brook is there any relationship between rainfall or pH and DO? (Some students may have already explored these questions.)
  - At Cascade Brook we saw that water temperature has an inverse relationship with DO. Is there any evidence that water temperature influences DO at George Washington Bridge or at the Harlem River?
  - Is there a correlation between salinity and DO at the George Washington Bridge?
  - If you choose different dates at the Harlem River, do you still observe the same relationships between salinity, temperature and DO?

- Look for and investigate data patterns
  - Are there daily patterns in parameters we haven't looked at? (pH for example)
  - What factors could be influencing DO at the George Washington Bridge? What about at the Harlem River?
  - Is there any evidence that photosynthesis by aquatic plants affects DO at either the George Washington Bridge or the Harlem River?
  - Compare the patterns you see in Cascade Brook DO during the summer with DO patterns during other seasons of the year. Then try the same comparison at the George Washington Bridge, during the months for which data is available.

C. Student Investigations

Write all questions/investigation topics on a whiteboard or large sheet of paper so that they can be seen by the entire class. Ask each student to select a question that especially interests them. It's helpful to poll the students soon after they select their topic to find out what they plan to work on. If a large number of students have chosen the same topic you can encourage them to diversify so that the scope of the entire class' investigations is broadened.

Based on students' experience and comfort doing such an open-ended assignment, you can decide whether to have students work individually or in pairs. If you want the students to do a written report in addition to the format provided in the Student Journal, be sure to make those expectations clear. Decide in advance how you would like students to share their findings with the rest of the class. This can range from giving each student 3-5 minutes to briefly explain his/her investigation to having the students prepare PowerPoint presentations.

Once each student has chosen his/her question (or the focus for an investigation) they should examine it carefully to be sure it can be investigated using the data resources they have. They can then carry out the project using their Student Guides and Journals. Be ready to assist any students who need special help deciding on topics or knowing how to begin.

As they work, it's important to create an atmosphere that gives students the freedom to modify their investigation if new ideas or questions come to them. The Student Journal asks students to record any changes they make in the course of their investigation and to explain the decisions they make in terms of information they hope to gain.

D. Sharing Student Findings

Before students present to the class, take the time to find out what each one has been working on and what they have learned. By doing so, you can arrange the sequence of their presentations to generate interest in each other's presentations. Organizing the sequence will also help them get a fuller understanding of the big picture.

Arrange presenters investigating similar topics close together in sequence. This creates the atmosphere of a genuine search for answers and fosters student-to-student discussion. It's a good rule of thumb to begin the presentations with students working on broader, more general topics and then gradually move to more specialized investigations. In introducing each new presenter it's useful to point out connections between their topic and information shared by previous speakers.

After all students have reported, fill in any gaps in understanding that remain, bringing in any appropriate scientific information you have that might help explain the students' observed results. Above all, acknowledge that there will always be unanswered questions, waiting for more evidence and curious minds.