Modeling the interaction of salinity and diatom populations in the Hudson Estuary

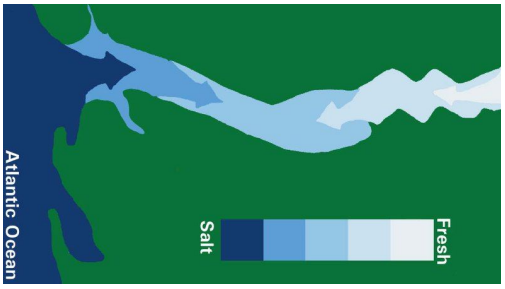
Time: Three 40 minute class periods
Setting: Classroom, Field, Lab
Objectives: Students will learn about salinity in the Hudson River Estuary and graph changes in salinity across time and space. They will collect diatom samples and compare diatom communities from their sampling site with salinity levels.

Lesson Overview

1. Students discuss what it means to be an estuary (in Algonquin, "*Mohicanituk*," "The River That Flows Both Ways") and construct a model of the Hudson Estuary to deepen their understanding of the interaction of various biotic and abiotic factors.

2. Students use data from the Hudson River Environmental Conditions Observing System (HRECOS) to graph and map salinity data at various sites throughout the lower Hudson Estuary.

3. Students collect and identify key Genera of freshwater and marine diatoms near their school.

Salinity Graphs at various HRECOS sites: student graphs will be displayed here
 **Hudson Estuary map** with abiotic and biotic factors linked to one another
Diatom populations

Materials

- Google Slides presentation **Modeling the Interaction of Salinity and Diatoms in the Hudson Estuary**
- Student worksheets **Day 1** and **Day 2-3**
- Large display surface (e.g. butcher paper, large magnetic whiteboard and magnetic pieces, Smartboard) for mapping biotic and abiotic factors
- Large map of Hudson River (poster, navigation maps, or drawn model on butcher paper) may use only lower Hudson River, from mile 0-90. A map of the Hudson River showing miles is available from the NYDEC at http://www.dec.ny.gov/docs/remediation_hudson_pdf/hrmilesmap.pdf
- HRECOS data files and graphs
- A computer with access to HRECOS and Excel/Google sheets OR printouts of HRECOS datasets and graph paper, pencil, ruler
- Post-it notes or something similar e.g. magnetic piece for adding components to model
- String and/or microplankton net and/or toothbrush and plastic tray
- Airtight glass bottles
- Permanent marker for labeling samples
- Diatoms & Hudson Estuary water samples
- Lugol's solution (no digestion), or hydrogen peroxide, drain cleaner, bleach, or other oxidizing agent
- Compound light microscopes
- Microscope slides (concave and flat)
- Coverslips
- Plastic pipettes
- Diatoms of the Hudson River cards (especially useful if students don't have access to samples, microscopes, drawings etc.)

Procedure

DAY 1: Graphing Salinity Data from HRECOS

Engage (Pre-assessment)

- Ask students to brainstorm names of organisms that they associate with the Hudson Estuary. Students can write their ideas in the chart on the Day 1 student worksheet (question 1). Have students report out, and write a list on the board.
- Have students characterize each organism as a producer, consumer, or decomposer on their worksheet. Remind students that a food web must contain all three kinds of organisms. If this reveals a lack of organisms, see if students can fill in those gaps. Depending on student level of prior knowledge, students can be provided with names of key organisms. Sample food webs are available from the Cary Institute at http://www.caryinstitute.org/educators/teaching-materials/hudson-river-ecology.
- Students can then draw the organisms on a magnetic sheet or Post-it note and place on the board. Discuss links and differences between them. Have students work together to draw arrows between organisms in order to create a food web.

- Brainstorm abiotic factors (possibilities include oxygen [DO and atmospheric], carbon dioxide, salt, etc.). Students can list these in the table on the Day 1 student worksheet (question 2). Draw arrows to show locations and movements of these abiotic factors in the ecosystem on the board. If students struggle with generating ideas, teacher can provide a list of factors and ask students to place them on the diagram and describe how a selected one would move through or affect organisms. Possibilities include acidity, temperature, water depth, dissolved oxygen, and turbidity. Data on each of these parameters can be found on the HRECOS website (http://www.hrecos.org/) for further research.

Explore

- If students have not mentioned salinity as an abiotic factor, introduce the idea that the lower Hudson is an estuary, a body of water where fresh and saltwater mix.
- Give each student HRECOS salinity data from one of the Hudson River stations.
- Have each student graph the change in salinity at their station, and use the data chart to calculate the average salinity at their station. Data can be graphed by hand, or using programs such as Google Sheets or Excel, but be sure to draw attention to scale if graphed by computer. If graphed by hand, teacher may want to have all students use the same scale to make differences in patterns more clear.
- Discuss the answers to the questions, “Does the salinity at your station change over time? If so, is there a pattern? What do you think might cause this pattern?” (question 3 on the student worksheet for day 1). Student answers may differ depending upon their assigned station. Review the idea of ocean tides as a class if necessary. An information sheet on tides in the Hudson is available at the Cary Institute website at http://www.caryinstitute.org/sites/default/files/public/downloads/curriculum-project/Tides_in_the_Hudson_I_2_pages.pdf.

Explain

- Ask students to locate their station on the Hudson River map, and place their graph at their assigned station.
- Students will walk along the length of the river map, observing the relative locations, salinity graphs, and average salinities for those locations.
- On the large display surface, write “Different” and “Same.” Give each student two Post-it notes. On one, have the student write one way in which the graphs are different at each station. Possible answers include the average salinity (decreasing from south to north), and the graph shape (flatter as you move north away from the ocean and the impact of high and low tide decreases). On the other, have the student write one way in which the graphs for each station are the same. Possible answers include the cyclical increase and decrease in salinity caused by the tide, and the presence of some amount of salt even in freshwater. Report out and discuss the answers.
- Have students answer the question, “How does the average salinity change as you travel from north to south on the Hudson River? What causes this change?” (question 4 on student worksheet for Day 1).

- Look at the “Graphic breakdown of water salinity, defining freshwater, brackish water, salt water, and brine water” sheet. Students have graphed salt concentration in practical salinity units (psu), which is equivalent to parts per thousand (ppt).
- Have students mark on the Hudson River map areas where water is fresh and brackish by comparing the average salinities they calculated for each station to the graphic sheet. Students may label each area of the map, color each area, or lab el each area with a Post-it note.
- Ask students to find the border between brackish and freshwater. The salt front is the leading edge of salt water entering an estuary. Have students locate the salt front on the Map, and answer questions 5 on the student worksheet for Day 1.
- Discuss with students what differences they would expect to find between freshwater and brackish ecosystems (question 6 on the student worksheet for Day 1). Encourage students to think about the differences in fresh and saltwater (conductivity, buoyancy, tonicity, etc), and what adaptations organisms would need to live in each. If students have completed the NYS Living Environment lab “Diffusion through a Membrane,” this discussion can be linked with what they observed of the movement of substances in and out of cells and the questions on the lab.

Extend

- As an extension, student can use the HRECOS site (http://www.hrecos.org/, “Current Conditions”) to graph data on other abiotic factors at their site (depth, DO, water temperature, acidity, etc.). These graphs can be saved or copied by right-clicking on the graph. Students can then print them, place them at the appropriate station on the map, and compare other abiotic measures at the locations.

Evaluate

- Students will construct a food web, showing relationships between organisms.
- Students will be able to name abiotic factors, and show their interactions with biotic factors.
- Students will accurately plot data and calculate averages.
- Students will identify and explain cyclical patterns from graphed data.

DAY 2: Using HRECOS data to find and map Freshwater and Saltwater Diatoms in the Hudson

Engage

Ask students:.

Q. What kind of a role do phytoplankton play in the aquatic food web. Are they producers, consumers, or decomposers?

A. They are primary producers, producing food (in the form of glucose) for primary and secondary consumers, as well as decomposers through the process of photosynthesis. They also produce oxygen as a byproduct of photosynthesis.

Introduction

Note: A Google Slides presentation, *Modeling the interaction of salinity and diatom populations in the Hudson Estuary"* accompanies this section and should be helpful in identifying the various algae, most of which are diatoms.

The Hudson Estuary contains floating communities of phytoplankton, comprised of algae and other tiny photosynthetic organisms. *Bacilliariophyta* or **diatoms** are the dominant algae, especially in the winter when other phytoplankton populations are low (Stanne, 2007).

Diatoms have transparent silica cell walls (called **frustules**) that are formed in two pieces which fit together like a pillbox. Silica is the main component of glass, so diatoms are often referred to as "algae in glass houses."

Because most diatoms are very sensitive to abiotic factors such as salinity, dissolved oxygen, pH, and temperature, they are often used as environmental indicators. Frustules do not decompose so they can be found in freshwater and saltwater sediments, providing information about historical conditions of the river (Diatoms of North America). Changes in diatom population size can reflect a change in a food web, as is the case with the boom and bust cycles of zebra mussels and diatom depletion and resurgence (Strayer, 2016). Salinity levels are known to impact phytoplankton growth and distribution in brackish waters, and may be particularly altered as a result of climate change (Floder, 2010).

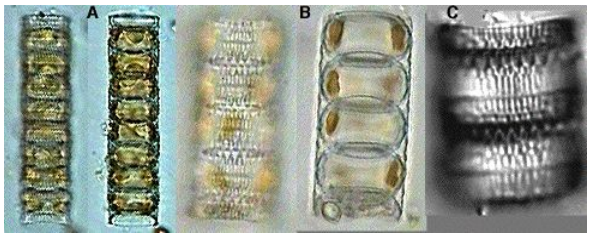
Ask students:

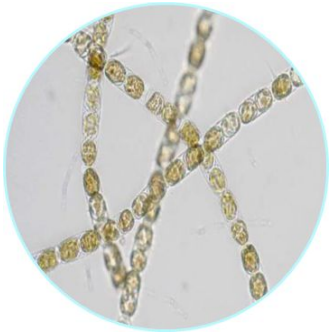
Q. Can you think of other ways in which diatoms may be environmental indicators in the Hudson Estuary? Hint: Which abiotic factors might impact their presence in certain locations in the estuary?

A Tides, the amount of rainfall, temperature, and pH are abiotic factors that can influence diatom presence and location. The presence of certain benthic diatoms (freshwater vs saltwater) deep in the sediment layers of the river can be studied to infer weather patterns. These samples are collected by taking core samples (similar to core samples used in A day in the life of the Hudson).

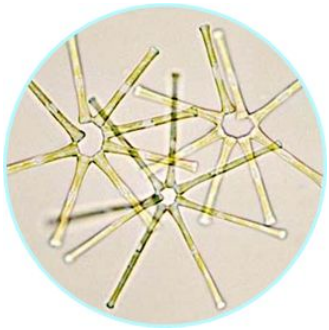
Three representative diatom populations commonly found in the Hudson River Estuary are:

Paralia sulcata (formerly Melosira sulcata) prefers salt to brackish waters

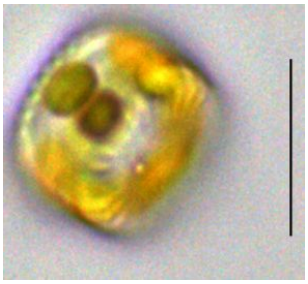


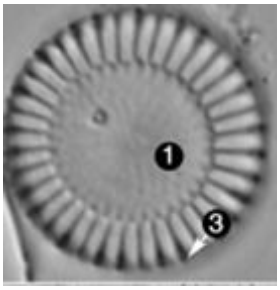


Asterionella formosa prefers fresh to brackish waters



Cyclotella are found in brackish to marine habitats throughout the Estuary.





A couple other common species are on the Diatom ID Cards.

Ask students:

Q. Where would you expect to find these diatoms in the Hudson Estuary? Place diatom cards on the appropriate location on the map model.

A. Most Cyclotella are marine so would be close to NY Harbor but some (e.g. Cyclotella meneghiniana in Constitution Marsh RM 55) can be found in far less salty conditions . Asterionella prefers fresh to brackish waters.

This process can be extended to include simulating various scenarios e.g. drought, flooding using all of the diatom population cards, especially if diatom samples and/or microscopes are not available.

Focusing on the five species on the Diatom ID Cards, have students write a hypothesis about the **relative abundance** (the percent of the diatom community) for diatoms at their sampling site.There are two variables that students should consider: the salinity of the habitat, or the type of habitat (planktonic or benthic).

Once students have a hypothesis, have them make a data table that they will use to collect their data. An example data table is given in the resources section of this lesson.

Sampling is done differently for planktonic and benthic diatoms, so you may want to decide which method you are using ahead of time, or allow the students to compare planktonic and benthic communities. **Note:** if you are planning to use the string method to collect planktonic diatoms (see Day 3 below), you will need to set it up a few days in advance. You

could take students out to the field to set it up at the beginning of Day 1, or set it up without students before beginning the lesson.

There are two primarily marine taxa; *Cyclotella* and *Paralia*, and three brackish-fresh taxa; *Navicula, Asterionella,* and *Cocconeis*. Based on the salinity of your sampling location, students can make predictions about what diatoms they will see in their samples.

If your classroom does not have access to a sampling site (pond, creek, Hudson River, etc.), you can have students look at permanent diatom slides from freshwater or marine environments and draw what they see. If you are short on time, you can collect and prepare the samples ahead of time.

Day 3:

Explore: Collecting, identifying, recording, and mapping diatoms in the Hudson Estuary

Note on collecting diatoms in the Hudson Estuary: Although diatom populations peak in early summer and fall, cyanobacteria such as *Anabena* are more abundant at that time. If you are not digesting the other algae from the samples, winter may be the best time to collect diatoms.

- Begin by having students review their hypothesis from Day 2 about the diatoms they expect to see. Then, take students out to the field site and use one of the methods below to collect diatom samples.
    - Planktonic diatom sampling:
        - **String Method:** Secure one end of a foot long piece of string on the bank of the water body, so that the length of the string is drifting in the water. You can use rocks or other materials to secure the string. Let the string drift in the water for several days as the diatoms attach to the string. After diatoms have attached to the string, take it out of the water and put it and a small amount of Hudson River water in a jar labeled with the collection date and location.
        - **2 liter bottle:** fill the bottle with water from the surface of the water body. Label it with the location and date.
        - **Microplankton net:** Use a specially designed net that filters out all but phytoplankton to collect planktonic diatoms. Drag the net back and forth just below the surface of the water for a few minutes. A net with a mesh size of no more than 25 micrometers (*um*) will collect diatoms. Place contents in a jar and label it with the collection date and location.
    - Benthic diatom sampling:
        - **Toothbrush Technique:** Collect golden brown- black layers from rocks and plants close to shore with a toothbrush, and store in airtight glass jar with a little Hudson River water. Try to avoid collecting sand with the samples. Label each jar with date and location of sample.

Preparing diatom samples

Living diatoms, especially benthic diatoms that are mobile, are interesting to view under the compound light microscope, however, it is easier to identify and count the samples when they are not alive. Collected samples can be divided so that some are observed as living samples and others can be further processed for viewing to identify them by their distinct frustules.

- Separate a small amount of the collected sample and use for viewing under the microscope alive.
- Option 1: Add Lugol's iodine solution to remaining collected samples and allow the organisms to settle to the bottom over 16-24 hours (Taylor, 2007).
- Option 2: If you would like to digest the organic material out of the samples in order to better see the frustules, follow the steps below. **Note:** This will add 1-5 days between collection and viewing, depending on if you have access to a centrifuge or not.
    - Separate a small amount (~0.1g) of the solid material from the sample into 50mL centrifuge tubes.
    - Add 5mL of 30% H_2O_2 to the tubes and let the samples sit overnight in a room temperature water bath. If you are involving students in this step, they should wear gloves, goggles, and lab coats, as 30% H_2O_2 is a powerful oxidizing agent. Other oxidizing agents that can be used include 20% bleach, or a drain cleaning solution, and the same precautions should be observed. See the video on slide preparation for a demonstration.
    - After digestion, rinse the samples by adding distilled water to the tubes until full, capping, and shaking gently.
    - Either run the tubes in the centrifuge at low speed, or leave the tubes undisturbed overnight so the diatoms can settle to the bottom before pouring off the H_2O_2/distilled water mixture, leaving ~10mL in the tube after each rinse. **Be careful not to pour out the diatoms at the bottom of the tube** (unlike in the video)**!** Diatoms may adhere to glass tubes, but not plastic, so it is safer to be careful. Because of the low concentration of H_2O_2 at this stage, liquid can be poured down a drain.
    - Repeat the rinsing step 4 more times, and leave 10-20mL of water after the final rinse, depending on how much material you have. You should be able to see the diatoms "sparkle" in the water when you gently shake the tube.
    - Resuspend the diatoms in the water by shaking gently just before transferring to a slide.
    - To make permanent diatom slides, students can mount them using corn syrup as a readily available mounting medium, which is less toxic and easier to get than toluene-based mounting mediums such as Naprhax.
        - Put a few drops of the cleaned diatom solution on a cover slip, and heat on low heat for a couple minutes to evaporate the water.

- Put a couple drops of the mounting medium on a clean slide, and flip the diatom coverslip face down on top of the medium.
- Heat the slide with the coverslip for a minute on low heat until bubbles are no longer forming under the coverslip.
- Remove the slide from heat, and gently press down on the coverslip with tweezers to remove the bubbles as the slide cools.

Identifying and recording diatom populations

- Use a pipette to put a droplet of sample on the center of the slide and gently place a coverslip on top of the sample. For living samples, use concave slides so pennate diatoms may be seen moving. For non-living samples, standard slides are fine.
- View at low power (10x eyepiece lens X 4x objective lens)
- Center diatom(s) of interest and increase to medium or high power magnification
- Using a pencil and the microscope drawing worksheet, have students create a detailed drawing of two types of diatoms they observe. Be sure they write down the eyepiece, objective and total magnifications they are using with the drawing.

Many students think they can't draw but if they are encouraged to simply record what they see and pay careful attention to detail, they may be pleasantly surprised.

- Have students count diatoms and fill out their data sheet.

(Optional) Sometimes the size of the diatom is helpful in identifying it. By measuring the diameter of the field of view at low power and using the following formula, specific cell dimensions seen at hp, can be determined.

$$\frac{\text{Low power magnification}}{\text{High power magnification}} = \frac{\text{High power field of view diameter}}{\text{Low power field of view diameter}}$$

$$\frac{40}{400} = \frac{X}{\text{low power field of view diameter (in mm.)}}$$

Students usually learn how to measure a cheek cell as a routine method. But here, students are learning how to measure a cellular structure e.g. the cell diameter because they need to correctly identify the specific diatom(s) collected.

Explain: Mapping diatom populations (species,collection date and location) with salinity data and location

Students attach their diatom drawings to the Hudson River map.

Ask students:

Q. Do the diatom populations coincide with salinity levels at the various locations? If a diatom is found in a location you wouldn't expect, provide a rationale for it.

A. The phytoplankton community floats so, for example, a marine diatom species may be found in a freshwater environment because it was moved by the force of the tide.

Q. Review your results, think through what you had hypothesized. Can you accept or refute it? If so, why? If not, why?

A. There needs to be evidence to support acceptance or refusal. Ask students to give examples of evidence, even if the group has not identified many samples.

Extend:

- Test the salinity of the water at the site of diatom collection. *How do the results compare with your prediction?*
- Correlate NY DEC fish data with salinity and diatom data (e.g. Menhaden, Atlantic silverside)

Evaluate:

- Student responses on Day 1 and Day 2-3 worksheets
- Question Diary: Student generates 1-3 questions about diatoms, salinity and other abiotic and biotic factors on a daily basis

Resources:

Articles

Caraco, N. F., Cole, J. J., Raymond, P. A., Strayer, D. L., Pace, M. L., Findlay, S. E., & Fischer, D. T. (1997). Zebra mussel invasion in a large, turbid river: phytoplankton response to increased grazing. *Ecology*, *78*(2), 588-602.

Chen, X., Zhou, W., Pickett, S. T., Li, W., Han, L., & Ren, Y. (2016). Diatoms are better indicators of urban stream conditions: A case study in Beijing, China. *Ecological Indicators*, *60*, 265-274.

Flöder, S., Jaschinski, S., Wells, G., & Burns, C. W. (2010). Dominance and compensatory growth in phytoplankton communities under salinity stress. Journal of Experimental Marine Biology and Ecology, 395(1), 223-231.

Hallihan, B. H., & Roeder, D. R. (2011). Benthic Diatoms and Heavy Metals in East Foundry Cove and Constitution Marsh, NY, Post Superfund Restoration. *Northeastern Naturalist*, *18*(1), 61-72.

Books

Stanne, Panetta, Forist, *The Hudson: an Illustrated Guide to the Living River*, 2007

Videos

David Strayer testifies before Congress on the damaging effects of invasive species (2016)

Introductory video of diatom collection

Instructional video of diatom digestion using drain cleaner

Websites

A Methods Manual for the Collection, Preparation, and Analysis of Diatom Samples
http://docs.niwa.co.nz/library/public/1770054839.pdf

Collecting, cleaning, and mounting of Diatoms
https://www.mccrone.com/mm/the-collecting-cleaning-and-mounting-of-diatoms/

Diatoms of North America

Phytoplankton of the Hudson River Estuary
http://www.dec.ny.gov/docs/remediation_hudson_pdf/hrlpixphytop.pdf

NYSSLS Standards:
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations could include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]
Disciplinary Core Ideas: LS2.A: Interdependent Relationships in Ecosystems
Science and Engineering Practices: Using Mathematics and Computational Thinking, Developing and Using Models
Cross-Cutting Concepts: Stability and Change, Systems and System Models
Graphic breakdown of water salinity, defining freshwater, brackish water, saltwater, and brine water