Science Unit: *Marine Pollution*
Lesson 1: *Modeling Estuaries*

School year:	2006/2007
Developed for:	David Oppenheimer Elementary School, Vancouver School District
Developed by:	Sara Harris (scientist), Liza Archer and Scott Lundell (teachers)
Grade level:	Presented to grades 4-5; appropriate for grades 4-7 with age appropriate modifications.
Duration of lesson:	1 hour and 20 minutes
Notes:	Extension activities pre- and post-lesson

Objectives

1. Explore the relationships between temperature, salt content (salinity), and density of water
2. Practice making predictions and testing them
3. Model mixing of water of different densities
4. Model an estuary

Background Information

Estuaries are located where the land and sea meet, where fresh and salt water mix. These are dynamic and important habitats for many organisms. Here in Vancouver, the Fraser River flows into Georgia Strait at a major estuary (and some of our sewage is pumped out here). In estuaries, the water column is stratified based on temperature and salinity differences between the river water and the ocean water. The fresher river water flows on top of the saltier sea water. Temperature and salinity primarily control the density of the water, and density differences dictate water column structure. Mixing happens at the boundaries between the different water masses.

What processes can change the salinity of a water mass in the ocean? Primarily processes that add or remove fresh water, for example, evaporation, precipitation, river input, ice formation, and ice melting. Another way to change salinity is to mix water masses of different salinities together.

What processes can change temperature? Changes in temperature primarily occur by heating and cooling the surface layers of the ocean. Input of energy from the sun causes surface heating, and more solar energy is received at low latitudes than at high latitudes. Surface waters in the tropics are much warmer than those in the polar oceans. Cooling mostly occurs when the ocean loses heat to the atmosphere via evaporation (latent heat transfer) or via conduction (sensible heat transfer). High-latitude regions lose more heat at the ocean's surface than they receive and the situation is the reverse for low-latitude regions. As with salinity, mixing water masses together can also change the water's temperature.

Density increases with (1) increasing salinity and (2) decreasing temperature. High salinity, cold water is more dense than low salinity, warm water. What about high salinity warm water and low salinity cold water? The answer depends on the particular temperature-salinity combination. In some places in the ocean, high salinity warm water overlies lower salinity cooler water (e.g. the subtropics) and in other places low salinity cool water overlies higher salinity warmer water (e.g. some areas of the polar oceans).

Vocabulary

Estuary:	The place where fresh water from rivers meets salt water in the ocean.
Salt:	Regular table salt is a crystalline substance called sodium chloride. Salts dissolved in the ocean are mostly sodium, chlorine, with a little bit of sulphate, magnesium, calcium, and potassium.
Dissolve:	To mix a solid into a liquid and make the solid break into its tiny component parts.
Salinity:	The amount of salt dissolved in water, usually expressed in parts per thousand. Typical ocean water is 35 ppt salt.
Density:	A measure of mass per volume, e.g. grams per cubic centimeter.
Stratification:	Layering of liquids according to density, with the more dense liquid on the bottom.
Siphon:	Transfer liquids through a tube with the help of gravity.

Materials

- Small aquaria (one per group of 4 students)
- Plexiglass dividers that fit snugly across the middle of the aquaria (one per group)
- Containers for mixing and measuring water (buckets, 2 buckets per group)
- Food coloring (blue and yellow for each group)
- Boxes or blocks (~5 cm high) to prop up one end of aquaria (1 per group)
- Masking tape and markers for labeling buckets
- Thermometers (one per group)
- Refractometers (for measuring salinity) OR densitometers (for measuring density)
- Beakers or jars for salt (one per group)
- Long-handled spoons or paint stirring sticks for mixing (2 per group)
- Rubber tubing in ~ 1 m lengths (one per group)
- Copies of data sheets, one for each student
- Tap water
- Salt (finely ground, like table salt)
- Bottle of oil and vinegar (optional demo)
- glass graduated cylinder (at least 15 cm tall), water (colored blue), cooking oil, and glycerin or corn syrup (optional demo)
- Apple, rock, and Styrofoam ball all about the same size (optional demo)
- Satellite image of the Lower Mainland, showing the Fraser entering Georgia Strait.

In the Classroom

Introductory Discussion

1. Where does our drinking water come from? How is drinking water different from the water in the ocean? Why is there salt in the ocean?
2. Where does the water go when it disappears down the drain? Where does the water in rivers go?
3. Density and stratification:
    - What are some examples of very dense things? What are some examples of not very dense things? Put a list of things in order according to density (e.g. lead, rocks, plastic, water, air…)
    - For a solids demo of density, pass around items of the same size but different densities (a rock, a Styrofoam ball, an apple…)

- Liquids with different densities: Demo with a glass graduated cylinder. First, pour a little colored water in the bottom of the cylinder (~3 cm high). Ask students what will happen when you pour a little oil in. The pour in a little oil (another 1 cm). Ask students what will happen if you pour in a LOT more oil, so the oil layer is thicker than the water layer. Then pour in more oil and see what happens. Repeat predictions and pouring with glycerin or corn syrup. One step further could be to then pour in some more water. What do students think happens to the oil in oil spills in the ocean?
- Another liquid density demo: Get three jars of the same size. Fill one with water, one with oil, and one with glycerin or corn syrup. Ask students which is most/least dense. Then weigh the jars to show that the oil is least dense, then water, then corn syrup.
- For a third possible liquid density demo, you could also use a bottle of oil and vinegar salad dressing – which is more dense/less dense? What happens if you shake up the bottle? What happens if you wait a while after shaking it up?
- What factors can change the density of water? (Salinity and temperature)

4. Show image of the Fraser River estuary. Ask for observations.
5. Discuss vocabulary.
6. Briefly describe activity.
7. Review scientific method, particularly predictions, observations, results, conclusions
8. Safety Guidelines: Food coloring can be washed off with warm water and soap. Thermometers and refractometers are breakable, so take care.

Science Activity/Experiment

Activity Title: Temperature, salinity, and density stratification

Purpose of Activity: The purpose of this activity is to observe how temperature and salinity affect the density of water, how density determines water stratification, and what happens in estuaries.

Experimental Observations: The effects of temperature and salinity will be observed separately. This is not an experiment with controls and treatments.

Before making your hypothesis, it helps to start with a question, or make observations and then ask a question. Use your prior knowledge of temperature and salinity to predict their effects on water density. Then we'll test your hypotheses. Record your hypothesis based on the following questions:

- Which do you think is MORE dense, cold water or warm water?
- Which do you think is MORE dense, fresh water or salt water?
- What do you think happens when river water meets ocean water?

Methods:

Set-up prior to experiment: Set out group equipment on tables.

Students will work in groups of 4. In their lab notebooks, or on their data sheets, they should record today's date and lesson title. Teachers may want to give a few directions at a time, on an overhead, and stop to discuss with the full class along the way. Suggested breakdown is (1) Steps 1-5 (temperature), (2) Step 6-7 (salinity), then (3) Steps 8-13 (estuary). Teachers could set up a data table on the blackboard to collect student data for wrap-up discussion.

1. Fill a bucket with COLD water from the tap. Label the bucket “cold”. Add 10 drops of blue food colouring and mix the solution well. Fill another bucket with HOT water from the tap and label it “hot”. Add 10 drops of yellow food colouring and mix well.
2. Measure water temperatures with thermometers and record temperature and water colour in lab notebooks or on data sheets.
3. Install a partition firmly in the middle of an aquarium. Simultaneously pour the coloured solutions into the aquarium, one colour on each side of the partition. Both sides of the aquarium should be filled to exactly the same height (5-10 cm high is fine).
4. Make a prediction about what will happen when the partition is removed. Write it down.
5. Allow the solutions to calm and then carefully remove the partition. Observe what happens to the solutions through the sides of the aquarium. Record observations.
6. Empty the buckets and the aquaria to prepare for the salinity experiment. Teacher and any helpers can do this while students are completing their answers to the temperature experiment.
7. Repeat steps 1-5 with SALTY water (use blue) and FRESH water (use yellow). Label the buckets “salty” and “fresh”. Make both water batches the same temperature. For the salty water, add at least 35 grams of salt to each litre of water to make a solution that’s at least 35 ppt. Students will have to mix for a while to get the salt dissolved. If you have refractometers, measure and record the salinity of the salty and fresh water. Or, if you have densitometers, students can record the density. If you have neither, students can taste a bit of each and record their observations (if the containers are reasonably clean!)
8. Now we’ll model an estuary. Prop up one end of the aquarium on a box or block so that the bottom is sloped.
9. Mix up COLD, SALTY “sea water” (use blue) and FRESH, WARM “river water” (use yellow). In reality, river water temperature is not much different from seawater, but these combinations will show the best contrast.
10. Pour enough “sea water” into the aquarium so that there’s still a little “beach” at the high end.
11. Make a prediction about what will happen when “river water” flows down the beach into the “sea water”. Write it down.
12. Put the bucket of “river water” on a stack of books or something, so that it’s higher than the “beach”. Use the tubing to siphon “river water” out of the bucket onto the beach, simulating a river flowing into the ocean. [Hint on effective siphoning: put one end of the tubing in the bottom of the “river water” bucket, then carefully submerge the rest of the tubing so that no air bubbles are trapped in the tube. While the full tube is under water, put a thumb or finger over each end. Take one hand out and put that end of the tube on the beach, keeping the other end of the tube (and your other hand) submerged. Release both thumbs to let the water siphon out of the bucket onto the beach.]
13. Observe what happens (students should look directly from the side of the aquarium). Write down observations.

Closure Discussion

1. Did your observations match your predictions? How/why were they the same/different?
2. What happens to Fraser River water where it enters the Georgia Strait? How might this show up on satellite images?

3. Where have you seen materials stratify according to density in your everyday life? (salad dressing, oil on puddles, anything floating on water, or materials sinking through water…)
4. What do you think would happen if the "ocean" was warm and salty and the "river" was cold and fresh?

References

1. Any introductory oceanography textbook (look up "estuary").
2. http://www.gvrd.bc.ca/education/curriculum-resources.htm Greater Vancouver Regional District curriculum resources, for satellite map, and information about drinking water and wastewater in the GVRD.
3. http://www.waterencyclopedia.com/Re-St/Sea-Water-Physics-and-Chemistry-of.html for general information about salinity in the oceans, density stratification, and ocean circulation.
4. http://www.windows.ucar.edu/tour/link=/earth/Water/overview.html A surfable site for general and specific information about Earth's hydrosphere. Keep clicking on links!

Extension of Lesson Plan

1. Prior to this lesson, the class could complete the Scientist in Residence Program lesson "Surface Water and Groundwater" to learn about dissolution and salinity. See lessons 2 in the Water science unit, Earth Science curriculum area, available from the Scientist in Residence Program website http://www.scientistinresidence.ca).
2. This lesson could be extended to include simulation of deep water formation (by floating a sponge with a well in it on a warmish, fresh-ish "ocean" (use yellow), then siphoning cold salty water from a bucket into the well (use dark red or dark blue)). This simulates deep water sinking in the North Atlantic Ocean, a key component of Earth's climate system. EXTRA SUPPLIES NEEDED: Sponges with wells cut in them.

STUDENT DATA SHEET – Modeling estuaries

Name_____ **Date**_____

Temperature data:

1) **Write down the temperature of the "COLD" water _____. What color is it? _____**
2) **Write down the temperature of the "WARM" water _____. What color is it? _____**
3) **Draw a picture of what the tank looks like before you take out the wall.**

4) **Draw a picture of what the tank looks like AFTER you take out the wall.**

5) **Write down what happened when you took out the wall.**

6) **Which kind of water is more dense, COLD water or WARM water?**

Salinity data:

1) **Write down the salinity of the "FRESH" water _____. What color is it? _____**
2) **Write down the salinity of the "SALTY" water _____. What color is it? _____**
3) **Draw a picture of what the tank looks like before you take out the wall.**

4) **Draw a picture of what the tank looks like AFTER you take out the wall.**

5) **Write down what happened when you took out the wall.**

6) **Which kind of water is more dense, FRESH water or SALTY water? Which kind of water is more like river water? Which kind of water is more like sea water?**

Estuary model

1) **Draw a picture of the tilted tank with the estuary model.**

2) **Write down what happened when the "river" water flowed into the "ocean" water.**