Density Dynamics and Estuaries

Teacher Introduction

Estuaries are areas where river and ocean waters meet. In North Carolina, this occurs in sounds. In Pamlico Sound, ocean water moves through inlets to mix with waters from the Neuse and Pamlico rivers. The mouth of the Cape Fear River is also an estuary. Estuaries are biologically rich because available nutrients, marine grasses and fringing marshes provide food and shelter.

Chemically, the mixing of fresh and salt water is interesting. Salt water is denser than fresh water, and a density gradient occurs when the two waters meet. Vertically mixed and slightly stratified patterns of mixing are found in North Carolina's estuaries. Estuaries provide students with a concrete example of the importance of density and density gradients.

These activities are designed to give students practical experience with density and its calculation. Activities 1 through 3 are demonstrations that can be used to introduce density and specific gravity. An introduction to estuaries begins Activity 4. In this activity, students calculate density and compare the calculated values to known estuarine conditions. Activity 4 continues with biological examples of the effects of density changes on organisms. Review and test questions conclude this section.

Notes to the Teacher

1. To begin your discussion of density, students may find a demonstration helpful. See Activities 1 through 3.

2. Students should do a few density problems before beginning these activities.

3. A discussion of how the addition of salt to water increases density would also be helpful before students try these activities.

4. Students should use the correct number of significant figures in their calculations. Otherwise small variations in density may be missed.

5. The four estuarine density patterns presented are to be used as a comparison of density gradient possibilities. Students should not be expected to know these patterns, but they should be able to use them.

6. Figures 1 and 2 in Activity 4 can be used as overheads to help students with Activity 4 problems.

ACTIVITY 1

Salinity Stratification

Purpose

To demonstrate the layering effect of solutions that have different densities.

Equipment/Materials

3 100-ml graduated cylinders
sodium chloride
balance
stirring rod
food coloring
2 plastic squeeze bottles
four solutions:

Solution A (density = 1.148 g/ml): Combine 20 g NaCl with enough water to make 100 ml of solution.

Solution B (density = 1.071 g/ml): Dilute 50 ml of solution A to 100 ml.

Solution C (density = 1.034 g/ml): Dilute 50 ml of solution B to 100 ml.

Solution D (density = 1.000 g/ml): Use 30 ml of hot tap water.

Procedure

Use food coloring to make solution A yellow, solution B green, solution C red and solution D blue. Use three drops of coloring in each solution.

Put solution B in a plastic bottle. Gently squeeze approximately 30 ml of solution B into the graduated cylinder that already contains solution A. (Note: you may want to discard 20 ml of solution A before adding B so that the final layers have nearly equal volumes.) Let solution B trickle down the side of the graduated cylinder as you add it to solution A to minimize mixing of the two solutions.

In a similar manner, add approximately 30 ml of solution C on top of solution B. Finally, add solution D on top of solution C.

Questions

1. Why did the layers remain separated or stratified in the graduated cylinder?

2. What would have happened if you had changed the order of addition of the three solutions? Make a prediction and test it.

3. What will happen if the combination of solutions is stirred?

4. Estuaries are semi-enclosed coastal bodies of water in which seawater is diluted by fresh water from rivers. An estuary may contain water with different densities. Estuaries are named based on the extent of mixing of fresh and salt water. Name two ways in which nature could aid in the mixing of water in estuaries.

ACTIVITY 2

Salinity Predictions

Purpose

To predict the density of water in relation to salinity and to understand the layering in some estuaries and in the ocean.

Materials

small aquarium
food coloring (blue)
stiff piece of cardboard
box of salt
water

Procedure

Mix a gallon of tap water with one cup of salt. Have another gallon of water with no salt. Add enough food coloring to the saltless water to make it relatively dark (about 10 drops).

Place the cardboard in the middle of the aquarium. Make sure it fits tightly against the sides. At the same time slowly add the salt water to one side and the dyed water to the other. Let any water currents settle before lifting the cardboard. Lift the cardboard 5 to 7 cm, and observe the movement of the colored (non-salty) water near the bottom of the cardboard.

Lift the cardboard another 5 cm or so. Observe. Continue to lift in stages and enjoy what is happening. Once the cardboard is completely removed, notice the layering.

This can also be done with a gallon of cold water and a gallon of hot water (colored) to illustrate a thermocline in the ocean.

Questions

1. Which water is denser, the salt water or the fresh water?

2. Discuss what happened with the two volumes of water in the aquarium.

3. In estuaries, where would you expect to find the river water and where would you expect to find the ocean water?

4. If you were an oceanographer and took ocean samples from the surface to the bottom, where would you find the saltiest water?

ACTIVITY 3

Density and Buoyancy of the Ocean

Purpose

To demonstrate the difference between the densities of liquids.

Equipment/Materials

double-pan balance
2 1-gallon glass containers
tap water
1 can of diet soda*
2 cans of regular soda*
salt water (20 g NaCl/100 ml water)

*All sodas should be the same brand.

Procedure

Place one diet soda and one regular soda in two glass containers filled with tap water. The diet soda will float and the regular soda will sink.

Float a can of regular soda in salt water and another can of regular soda in fresh water. Observe what occurs.

Balance a double-pan balance. Put the regular soda on one pan and the diet soda on the other.

Lead students in a discussion of the different water densities in estuaries and the differences in the densities and buoyancies of ocean and fresh water.

Questions

1. How do you account for the difference in the densities of diet and regular soda?

2. In which environment does a soda float higher, salt water or fresh water?

ACTIVITY 4

Estuarine Stratification and Animal Adaptations

Purpose

To illustrate density through marine examples.

Background

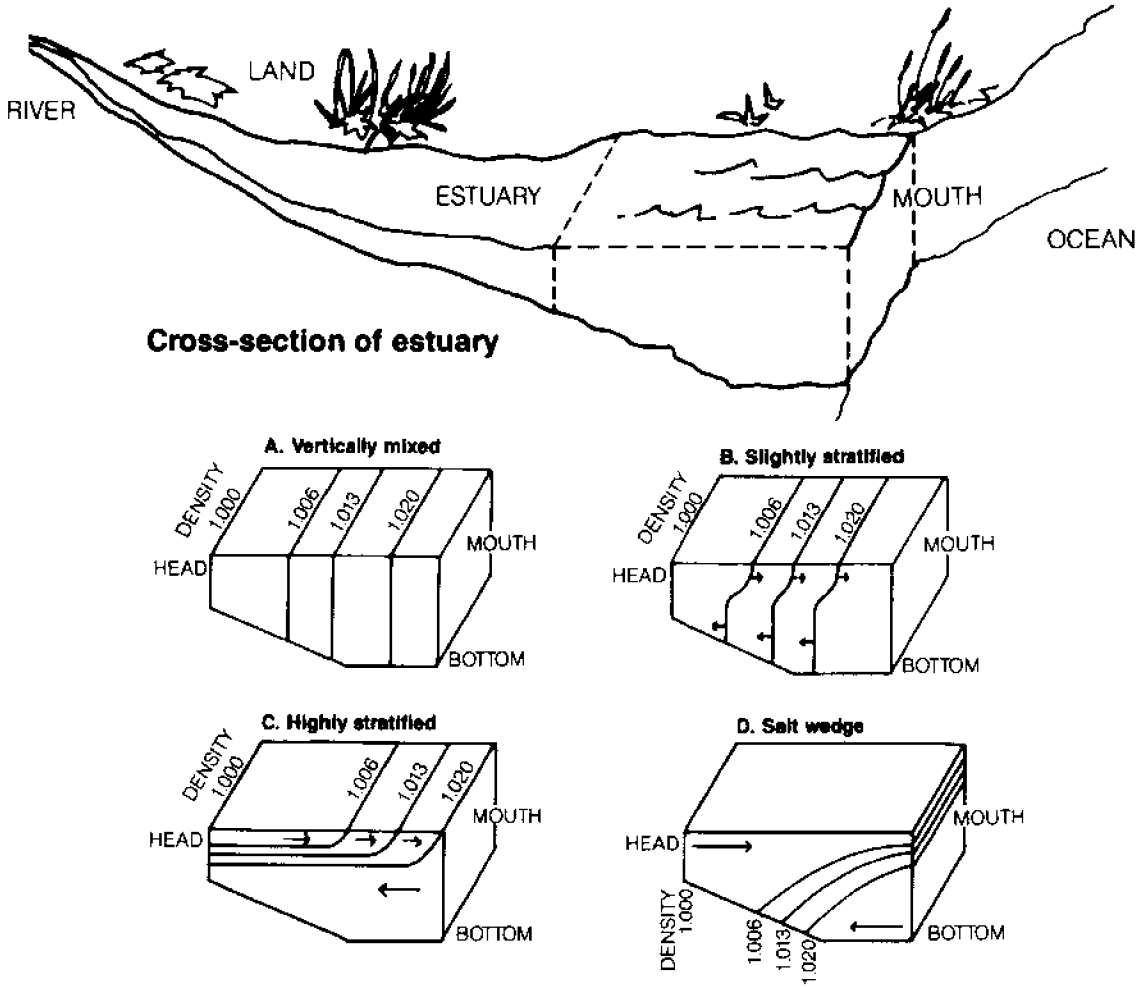
Estuaries are semi-enclosed coastal bodies of water within which seawater is diluted by fresh water from rivers. The density of fresh water is low (1.00). Ocean water with dissolved salts has a greater mass per volume and a greater density. Average seawater density is 1.034.

When ocean water meets river water, the lower density waters float over the heavier, denser water. Estuaries are often defined by the type of water mixing that occurs. This can vary from a highly stratified, or layered, estuary to one that is mixed and shows no stratification.

Estuarine scientists generally describe four types of mixing.

Vertically Mixed Estuary: The fresh and salt waters are completely mixed so there is a uniform density from surface to bottom (Figure 1). This is

Figure 1 Water densities at various locations in different types of estuaries



(ARROWS INDICATE THE DIRECTION OF WATER MOVEMENT)

typical of shallow estuaries where winds keep the waters churned. However, density increases as you approach the ocean.

Slightly Stratified Estuary: The river water is not completely mixed within the estuary. The river water has a slightly stronger flow than the tidal ocean flow.

Highly Stratified Estuary: This occurs when a river empties directly into ocean, such as the Cape Fear River estuary. The river water and ocean water form separate layers. The density of the surface layers increases from nearly fresh at the head of the estuary to almost that of seawater at the mouth. Testing the water in one spot yields increasing density with depth.

Salt Wedge Estuary: The river water flows strongly over the ocean water. Ocean water is wedged against the bottom. This wedge moves in response to tidal flow and the velocity of the river flow.

The four patterns may appear in one estuary over time. Variations in mixing occur from changes in rainfall, wind direction and speed, and tidal cycle. For example, a rainy spring could increase river flow and produce estuaries with a salt wedge. Although most of North Carolina's sounds are vertically mixed estuaries, they may become stratified depending on the amount of rain runoff.

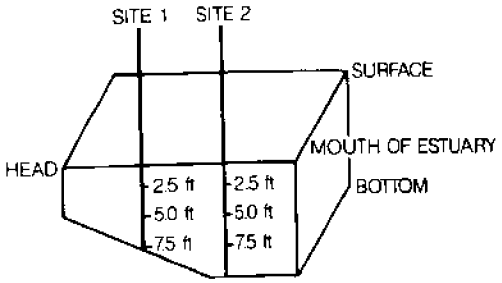
Questions

Estuarine Stratification

Calculate the density of the water (using the correct number of significant figures) at depths of 0, 2.5, 5.0 and 7.5 feet for each estuarine site. Figure 2 shows the two sites in the estuary where density data were taken. Figure 1 shows water densities at various locations in the different types of estuaries.

To determine the type of estuary described in a problem, superimpose Figure 2 over one of the estuaries in Figure 1 and hold the two pages up to the light. Roughly estimate the water densities for that estuary at sites 1 and 2 at the four depths marked on Figure 2. If the densities calculated in the problem correlate to the densities estimated from the two superimposed figures, you have identified the type of estuary. If the calculated and estimated densities do not match, repeat the superimposing process with a different estuary in Figure 1. Continue until you identify the estuary.

Figure 2 Sites where density data taken in estuary



Problem 1

Site 1

DEPTH	MASS	VOLUME	DENSITY
0 ft.	25.150 g	25.00 ml	_____
2.5 ft.	35.210 g	35.00 ml	_____
5.0 ft.	15.090 g	15.00 ml	_____
7.5 ft.	45.270 g	45.00 ml	_____

Site 2

DEPTH	MASS	VOLUME	DENSITY
0 ft.	10.160 g	10.00 ml	_____
2.5 ft.	40.640 g	40.00 ml	_____
5.0 ft.	30.480 g	30.00 ml	_____
7.5 ft.	45.720 g	45.00 ml	_____

This is a _____ estuary.

Problem 2

Site 1

DEPTH	MASS	VOLUME	DENSITY
0 ft.	20.020 g	20.00 ml	_____
2.5 ft.	22.044 g	22.00 ml	_____
5.0 ft.	30.120 g	30.00 ml	_____
7.5 ft.	33.198 g	33.00 ml	_____

Problem 2 (continued)

Site 2

DEPTH	MASS	VOLUME	DENSITY
0 ft.	40.081 g	40.00 ml	_____
2.5 ft.	30.120 g	30.00 ml	_____
5.0 ft.	35.525 g	35.00 ml	_____
7.5 ft.	38.836 g	38.00 ml	_____

This is a _____ estuary.

Problem 3

Specific gravity of the estuarine water was measured at sites 1 and 2. (Specific gravity of a liquid is the ratio of the density of the liquid to the density of water.)

Site 1

DEPTH	SPECIFIC GRAVITY	DENSITY
0 ft.	1.003	_____
2.5 ft.	1.008	_____
5.0 ft.	1.022	_____
7.5 ft.	1.024	_____

Site 2

DEPTH	SPECIFIC GRAVITY	DENSITY
0 ft.	1.010	_____
2.5 ft.	1.013	_____
5.0 ft.	1.022	_____
7.5 ft.	1.024	_____

This is a _____ estuary.

Animal Adaptations

Problem 4

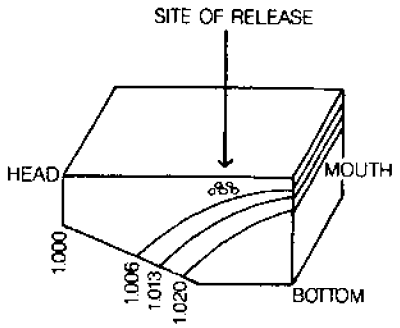
Many fish produce eggs of a specific density. This density affects the placement of the egg and thus larvae in the ocean or estuary. The eggs from different fish are collected and their densities are computed. The density of one set of eggs is 1.017. The eggs are released in a salt wedge estuary in the location indicated on Figure 3.

1. Where would the eggs be located after 1 hour? 2 days?

2. Why would the eggs be located in this region?

3. Are the eggs that are similar in density to the estuarine waters likely to move up the estuary into the river? Why?

Figure 3 Site of egg release in salt wedge estuary



Problem 5

Metridium is a common marine anemone. It is found in areas where the density of seawater is a constant value A.

In these areas with a density of A, the anemone is fully extended (as seen at 0 and 12 hours in Figure 4). An experiment to determine the effects of changing density on the *Metridium* obtained the results shown in Figure 4.

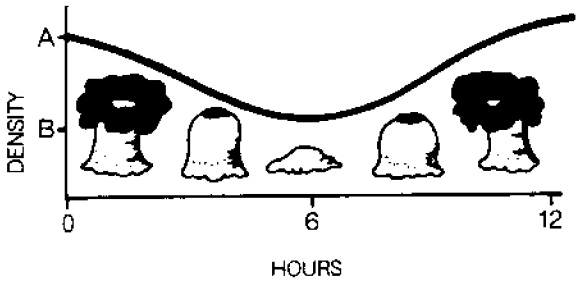
1. Determine the density of seawater at A and B.

SITE	MASS	VOLUME	DENSITY
A	28.784 g	28.00 ml	_____
B	31.279 g	31.00 ml	_____

Label Figure 4 with these densities.

2. Describe the behavior of the *Metridium* as the density of seawater changes.

Figure 4 Change in *Metridium* size over time



Problem 6

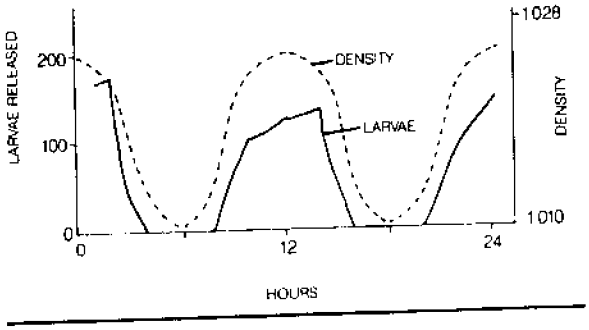
The barnacle, *Balanus balanoides*, is adapted to seawater with a density 1.028. Experiments were performed on the effects of density changes on the release of larvae by the barnacle. Figure 5 shows the results of experiments in which the number of larvae released were counted as density changed over time.

1. At what density does peak larval release occur?

2. At what density does the minimum larval release occur?

3. How does changing the density appear to affect larval release?

Figure 5 Barnacle larvae released over time



Test Questions

1. The greenhouse effect predicts that as we continue to burn fossil fuels, the amount of carbon dioxide in the atmosphere will increase, resulting in the atmosphere absorbing more heat and increasing the overall temperature on earth. This increase in temperature will bring about the melting of glaciers, providing more fresh water to the oceans. How will this affect the density of the ocean? How will this affect the density of estuaries?

2. The Northern Hemisphere has more land mass and less ocean than the Southern Hemisphere. If the Northern and Southern hemispheres receive the same amount of rainfall, will the ocean densities be the same for these two areas? If they differ, how? (Do not consider runoff from the land.)

3. The hermit crab, *Pagurus*, is not adapted for living in an estuarine environment. Figure 6 shows the crab's behavior when exposed to estuarine water. Describe the behavior seen. What might the behavior of the crabs be if placed in higher density salt water?

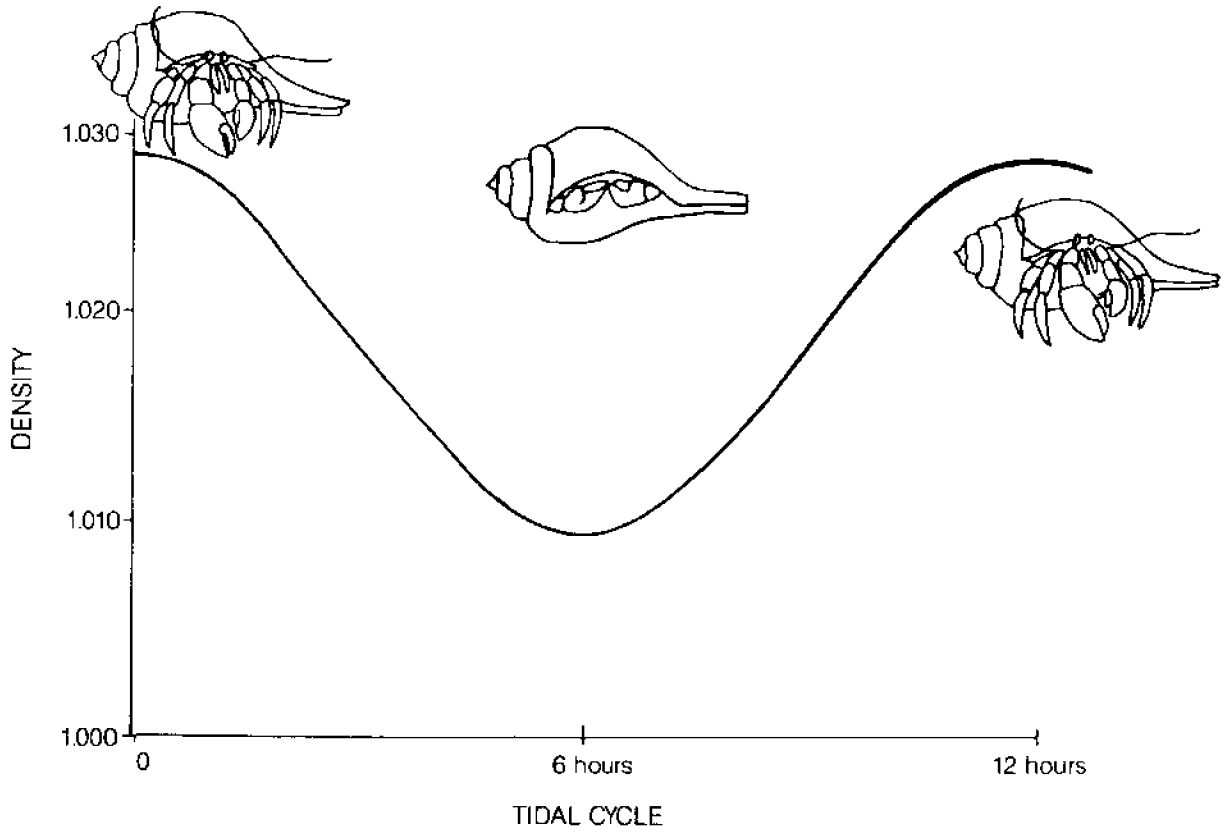
4. A scientist working on a research project in Bogue Sound measures water density at four depths (0 m, 2 m, 4 m, bottom). On the boat ride home, he mixes up the samples. When he returns to the lab, he processes the samples. He gets the following measurements:

	MASS	VOLUME	DENSITY	DEPTH
A	50.150 g	50.00 ml	_____	_____
B	35.910 g	35.00 ml	_____	_____
C	41.820 g	41.00 ml	_____	_____
D	48.432 g	48.00 ml	_____	_____

Calculate the densities for the five samples.

5. Based on your knowledge of density, list the correct depth for each sample in the table above. Using Figures 1 and 2 for site 1, what type of estuary is this?

Figure 6 Hermit crab behavior as density changes during tidal cycle



Competency Factors/References

Competency Indicators

Chemistry-academic/applied and technical—

1.2 know the properties of matter and energy.

Competency Measures

Chemistry-academic—

1.2.2 explain the concepts of density and specific gravity after performing density experiments.

Chemistry-applied/technical—

1.2.2 describe samples of matter in terms of mass, volume, density and physical state.

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