A Matter of Density

FOCUS QUESTION: What is the relationship between temperature, salinity, pressure, and the density of seawater, and why is this important to life in the ocean?

GRADE LEVEL: 7-8 (Physical Science)

LEARNING OBJECTIVES

Students will be able to explain the relationship between temperature, salinity, pressure, and density.
Given CTD data, students will be able to calculate density and construct density profiles of a water column.
Students will be able to explain the concept of sigma-t, and explain how density differences may affect the distribution of organisms in a deep-sea environment.

MATERIALS

Copies of "CTD Data Collected on Alvin Dive No. 3904," (Student Handout Sheet)

TEACHING TIME: One 45-minute class period

KEY WORDS PROCEDURE

Georges Bank
New England Seamounts
CTD
Density
Sigma t
Seamount
Biodiversity
Endemic
Buoyant

BACKGROUND INFORMATION

Seamounts (also called "guyots") are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Seamounts are formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long. In the Atlantic Ocean, the New England Seamounts form a chain of more than 30 peaks that begins on the southern side of George's Bank near the coast of New England and extends 1,600 km to the southeast. Some of the peaks are more than 4,000 m above the deep-sea floor—similar to the heights of major peaks in the Alps.

While several of the New England seamounts were visited by geologists in 1974, until recently there has been little biological exploration of these habitats. Preliminary investigations in 2002 found numerous invertebrates, including cephalopods, crustaceans, and more than a hundred other species in 10 different phyla. These investigations also found more than 100 species of fishes, some of which are commercially important. Several species were previously unknown to science. In the summer of 2003, a team of scientists, educators, artists, and oceanographers participated in a cruise on the R/V *Atlantis* to explore some of these seamounts. The submersible Alvin was used to visit areas whose depths ranged from 1,100 m to 2,200 m. Photographic images as well as samples of living organisms were collected.

Biological communities in the vicinity of seamounts are important for several reasons. High biological productivity has been documented in seamount communities, and these communities are directly associated with important commercial fisheries. Unfortunately, some of these fisheries cause severe damage to seamount habitats through the use of commercial fishing trawls. Scientists at the First International Symposium on Deep Sea Corals (August, 2000) warned that more than half of the world's deep-sea coral reefs have been destroyed. Ironically, some scientists believe that destruction of deep-sea corals by bottom trawlers is responsible for the decline of major fisheries such as cod. Besides their importance to commercial fisheries, seamount communities are likely to contain significant numbers of species that may provide drugs that can directly benefit human beings.

Because seamounts are relatively isolated from each other, they can vary greatly in their biodiversity (the number of different species present) and may also have a high degree of endemism (species endemic to seamounts are species that are only found around seamounts). Biodiversity and endemism are both affected by the reproductive strategy used by benthic seamount species. Most benthic marine invertebrates produce free-swimming or floating planktonic larvae that can be carried for many miles by ocean currents until the larvae settle to the bottom and change (metamorphose) into juvenile animals that usually resemble adults of the species. The advantage of a longer larval phase is that it allows for greater dispersal, which gives the species a wider geographic range. On the other hand, although species with shorter larval stages do not have the advantage of broad dispersal, they are more likely to remain in favorable local environments. Some species do not have a free larval stage at all, but brood their larvae inside the adult animal or in egg cases until metamorphosis.

Other forces may also tend to keep larvae from drifting away. Eddies known as Taylor columns can effectively trap larvae that would otherwise be carried away. Variations in density are one of the most important processes that affect larval transport, as well as motion of the entire ocean. Small density differences that might result from differences in surface heating or cooling can produce very strong currents that can carry larvae over long distances. In addition, changes in seawater density can affect the buoyancy of larvae and may limit the range over which larvae can be transported before they sink.

The density of sea water depends on temperature, salinity, and pressure. The mathematical relationship between these factors in somewhat complicated, and is known as the “equation of state” of seawater. There are several online calculators, though, that compute density of seawater from input values of temperature, salinity, and pressure. The density of seawater is always greater than 1.000 g/cm^3 and less than 2.000 g/cm^3, so oceanographers often express density as sigma, which is

[(Sea water density - 1) x 1000]

This way, oceanographers do not have to write 1 or the decimal places every time they want to record a density measurement. Oceanographers also use a quantity known as sigma-t, which is sigma calculated as described above, for a water sample whose density is adjusted to the density that would exist if the absolute pressure were 1 (that is, if the water sample were brought to the ocean surface without changing its temperature or salinity).
Oceanographers often use an instrument package called a CTD to measure conductivity (which indicates sea water salinity), temperature, and depth. In this lesson, you will convert CTD data from the 2003 Mountains in the Sea Expedition to density measurements, and draw inferences about how density may affect the transport of larvae on the New England seamounts.

PROCEDURE

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment. Although seamounts have not been extensively explored, expeditions to seamounts often report many species that are new to science and many that appear to be endemic to a particular group of seamounts.
Point out that seamounts are relatively isolated, and explain the meaning of endemic species. Discuss ways in which planktonic larvae may affect the distribution of species, and ask students to infer advantages and disadvantages that might be associated with a long or short larval phase. Ask students what other factors might affect transport of planktonic larvae. Review the meaning of density, and be sure students understand how the density of seawater varies with an increase or decrease of temperature, salinity, and pressure.

2. Provide students or student groups with copies of “CTD Data Collected on Alvin Dive No. 3904.” (Student Handout Sheet) Tell students that their assignment is to:

a. Graph salinity as a function of depth (salinity on the y-axis)
b. Graph temperature as a function of depth (temperature on the y-axis)
c. Find the density at each depth using seawater density calculators at
http://www.es.flinders.edu.au/~mattom/Utilities/density.html or
http://freespace.virgin.net/mark.davidson3/OSC272/density.html. These calculators require users to input values of pressure as well as temperature and salinity. Tell students that pressure in the ocean (in bars) is nearly equal to the depth in meters divided by 10 (in other words, for every 1 m increase in depth, pressure increases 0.1 bar). Be sure

students understand that pressure at the ocean surface (depth = 0 m) is equal to 1 bar, so pressure underwater is equal to

[(depth in meters) ÷ 10] + 1.0

d. Calculate sigma for each depth by subtracting 1.0 using the formula

[(Sea water density in g/cm^3) - 1] x 1000

e. Graph sigma as a function of depth (sigma on the y-axis)

3. **Discuss students' results. The following points should emerge during this discussion:**

(1) Where did density change most rapidly? *<near the surface>*

(2) In general, what happens to density as depth increases? *<density increases>*

(3) How do changes in density with increasing depth differ from changes in temperature and salinity with increasing depth? *<temperature and salinity tend to level out, while density continues to increase because pressure continues to increase with increasing depth>*

(4) If a larva is neutrally buoyant (that is, it does not rise or sink in the water column) at a certain depth, what will happen if a current carries the larva into a water mass that has a lower density? *<the larva will sink>*

(5) What will happen if the water mass has a greater density? *<the larva will rise until it encounters a water mass whose density equals that of the larva>*

(6) If a larva is released from a parent animal and is neutrally buoyant when it is released, what will happen if the larva matures and its density increases *<the larva will become more dense and will sink to the bottom>*

(7) If a species' survival strategy depends upon establishing many new individuals near the parent organism, should the density of the larvae be less than, equal to, or greater than the density of the surrounding seawater? *<less than the surrounding seawater, as this will cause the larvae to settle to the bottom quickly, and thus settle near the parent organisms>*

(8) If a species' survival strategy depends upon establishing new individuals in areas away from the parent organism, should the density of the larvae be less than, equal to, or greater than the density of the surrounding seawater? *<equal to the surrounding seawater, as this will allow the larvae to be carried by horizontal currents to the areas away from the parent organisms>*

THE BRIDGE CONNECTION

www.vims.edu/bridge/ – Enter "density" in the Search box to retrieve activities including seawater density

THE "ME" CONNECTION

Have students write a brief essay describing how density of fluids on Earth affect their own lives. Students may struggle with this initially, depending upon their understanding of what can be included in the term "fluids." You may need to suggest that this term includes gases as well as liquids, which may help students think in terms of atmospheric fluids (air) and issues concerning the density of these fluids (barometric pressure, which affects weather patterns, storms, etc.).

EVALUATION

Graphs prepared in Step 2 and responses to questions in Step 3 offer opportunities for evaluation. You may want to have students prepare individual written responses to the questions in Step 3 prior to group discussion.

EXTENSIONS

Have students visit http://oceanexplorer.noaa.gov to find out more about the 2004 Mountains in the Sea Expedition and about opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.

RESOURCES

http://www.es.flinders.edu.au/~mattom/Utilities/density.html — seawater density calculator

http://freespace.virgin.net/mark.davidson3/OSC272/density.html. — another on-line calculator that computes density and many other things

http://www.nature.com/nature/journal/v411/n6833/abs/411077a0.html — Marsh, A. G., L. S. Mullineaux, C. M. Young, D. T. Manahan. 2001. Larval dispersal potential of the tubeworm *Riftia pachyptila* at deep-sea hydrothermal vents. Nature 411:77-80. A technical journal article about the influence of density on larval disperal of a deep-sea organism

MASSACHUSETTS SCIENCE EDUCATION STANDARDS

Physical Sciences Grades 6-8: Properties of Matter

- Differentiate between changes of properties in matter
- Differentiate between volume and mass. Define density.

Life sciences Grades 6-8: Changes in Ecosystems over time

- Identify ways in which ecosystems changed in response to physical conditions.
-

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes of properties in matter

Content Standard C: Life Science

- Populations and ecosystems

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Mathematics, Earth Science

ACKNOWLEDGEMENTS

This lesson plan is adapted from a NOAA Ocean Explorer activity identified below.

The original lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov

STUDENT HANDOUT

CTD Data Collected on Alvin Dive No. 3904

Depth (m)	Temp (°C)	Salinity (ppt)	Density (g/cm^3)	Sigma (g/cm^3)
0	26.88	35.28		
25	21.17	34.80		
50	17.07	36.06		
100	16.43	35.79		
200	13.27	35.59		
300	11.59	35.43		
400	9.26	35.15		
500	7.80	35.05		
600	6.40	35.01		
700	5.38	34.97		
800	5.05	34.98		
900	4.69	34.98		
1000	4.53	34.97		
1100	4.40	34.98		
1200	4.25	34.97		
1300	4.08	34.97		
1400	3.95	34.95		
1500	3.76	34.94		
1600	3.65	34.93		
1700	3.59	34.94		
1800	3.58	34.94		
1900	3.58	34.95		
2000	3.46	34.94		
2100	3.35	34.94		
2200	3.40	34.94		