Neutrally Buoyant No More

Intended Class: Marine Science

Intended Grade Level: 11-12

Time Allotment:

Two, 55-minute periods. Day one should be lecture, background information and giving the students time to sketch their plankton designs. Day two should be used for construction, testing and revising plankton models.

Materials Needed:

- 2, 10-gallon fish tanks one filled with ambient water (~24°C) and one filled with warmer water (~30°C)
- Modeling clay (that won't air dry or fall apart in water)
- Feathers
- Toothpicks
- Scale
- Stopwatch (1 for each group of students)
- Plankton adaptations PowerPoint lesson – Neutrally Buoyant No More
- Plankton drop data sheet

Background Information:

The term "plankton" is used to describe organisms that are unable to move against a current and are therefore considered drifters. There are many different types of plankton including macroplankton, plankton big enough to see with the naked eye like jellies (2-20cm). There are also microplankton, nannoplankton and even picoplankton, all of which are categorized based on their size and some of which are mere micrometers in size. Plankton can also be divided into plant-like plankton called phytoplankton, and animal-like plankton called zooplankton. For the purposes of the rest of this lesson, we will focus on the plant-like phytoplankton.

Plankton are one of the most abundant organisms on Earth and actually make up the majority of Earth's biomass (or weight of living tissue). In performing photosynthesis, plankton also help balance the Earth's carbon cycle. Given the equation for photosynthesis;

$$6CO_2 + 6H_20 \text{ (in the presence of light)} \rightarrow C_6H_{12}O_6 + 6O_2$$

it is easy to see that carbon dioxide, water and sunlight are vital components to oxygen and organic molecule production. Like land plants, plankton also need nutrients such as nitrates and phosphates, that are dissolved in their surrounding waters. Roughly half of Earth's oxygen production is actually done in the ocean by phytoplankton and the other half by land plants. The boundary between the ocean and the atmosphere allows gases to diffuse across it quite easily. This air-sea interface will allow carbon dioxide, oxygen and even nitrogen gases to move from the location of higher concentration, to the location of lower concentration, in an effort to reach equilibrium. Plankton readily remove this CO_2 from the atmosphere which becomes dissolved carbon dioxide in the ocean, and produce oxygen. This oxygen not only becomes the dissolved oxygen in the ocean water that fish and other organisms are going to use for respiration, it also readily diffuses across the air-sea interface and becomes much of the oxygen we breathe daily. Currently, the oceans are taking up 20-25 million tons of carbon dioxide each day and atmospheric CO_2 levels are continuing to rise. The ability of the ocean to take in atmospheric carbon dioxide and utilize it is the reason it is called a "carbon sink", or a source of minimizing atmospheric carbon dioxide levels.

Plankton are generally used as an indicator for the health of the ocean ecosystem. They fill a crucial role in the food web as they are not only the major primary producers of the ocean, but also are the bottom of the food chain. Without an abundance of plankton and therefore productivity, the food webs are greatly affected. If waters continue to warm, nutrients that plankton need to perform photosynthesis might not be able to reach the plankton at the surface (colder waters generally hold more nutrients than warmer waters). This means the plankton would not get the fertilizers they need to complete the photosynthesis process and therefore would not be able to survive in abundance. Without the masses of phytoplankton, fewer individuals at each trophic level would be able to feed enough to survive to reproduce. We would see large die-offs in the numbers of zooplankton, which would mean less food for whales, fishes and many invertebrates, all the way to the top level carnivores. The removal of the bottom of the food chain (plankton) would have dire implications all the way up. Climate change has already been seen to warm the ocean's surface waters and affect the distribution of plankton globally. Between the years of 1999 and 2004, sea surface temperatures rose approximately ± 0.15°C in roughly 74% of the world's oceans. Also observed during this time was a decrease in plankton productivity which decreased the amount of energy available to be distributed through the food chain.

<u>Objective:</u>

Students will be able to describe the major adaptations of plankton to keep them neutrally buoyant.

Students will compare and contrast these adaptations in warm and cold water systems.

Students will be able to describe the possible negative effects of a warming ocean climate on plankton and therefore on global oxygen production.

Anticipatory Set: (about 6 minutes)

Show the NASA video which is about 5 minutes long. This video introduces the concepts that will be covered in this lesson. The video can be found at; http://www.youtube.com/watch?v=H7sACT0Dx0Q. The link to this video can be found on the first slide of the PowerPoint presentation

Teaching Input: (20 minutes)

Through the use of the "Neutrally Buoyant No More presentation, lab activity and discussion, students will be introduced to plankton, their form and function, behavior, and importance in the marine ecosystem as primary producer and regulator of Earth's carbon cycle. Students are expected to take notes during the presentation and ask relevant questions to build on their knowledge of plankton adaptations and how these adaptations will work in a changing environment. Students will also work to create a hypothesis for sinking rates of plankton they design in warmer and colder waters.

Start the Plankton adaptations PowerPoint lesson entitled, "Neutrally Buoyant No More". Notes for the instructor are included at the bottom of each slide.

Slide 1 – Title and link to video for Anticipatory Set

Slide 2 – Introduce the 3 main forms of plankton but tell students that the focus will be on phytoplankton

Slide 3 – Introduce the importance of plankton in the marine ecosystem. Be sure to emphasize the plankton-human connection through the intake of carbon dioxide and production of oxygen.

Slide 4 – Visually walk students through the various roles of plankton both in the food web and carbon cycle

Slide 5 – Explain that two very important adaptations to be employed by plankton are to maintain a small body size and also find ways to delay their sinking. Ask students why phytoplankton would not want to sink to the bottom, but what must come up from the bottom in order for photosynthesis to happen.

Slide 6 – Explain the concept of the surface are to volume ratio using example of cubed cells of three different sizes

Slide 7 – What a larger surface are to volume ratio means for a cell and its requirements

Slide 8 – Explain some of the various adaptations that plankton use to delay their sinking rate

Slide 9 – Preferences of plankton are generally colder waters as they retain more gases and nutrients for photosynthesis.

Slide 10 – The sea surface temperature graph shows a general rise in sea surface temperatures over the last 60 years. El Nino and La Nina dates are shown below to account for large anomalies in the data.

Slide 11 – Image showing change (anomaly) in sea surface temperatures for 2006.

Slide 12 – Shows the statistics for how much temperatures have changed thus far. Changes may seem miniscule but are important given that we have never seen greenhouse gas emissions this large.

Slide 13 – Discuss the different adaptations employed by cold and warm water species due to water viscosity differences between temperatures.

Slide 14 – Since plankton are so important to ocean and land dwellers, what will these increasing ocean temperatures mean for them? Have students create a hypothesis that they will then test regarding the sinking rates of plankton in different temperatures of water. Students should see that the same design will sink faster in warmer, less viscous waters. The most successful designs in warm water will be those which have large surface areas and lots of ornate plumage (horns, thorns, spikes, etc) to increase the drag on the body. Students should note that these protrusions are not as necessary in colder, more viscous waters.

<Do the lab activity here>

Slide 15 – Summarizes some of the implications for increased sinking rates in plankton

Guided Practice: (25 minutes)

After the "Neutrally Buoyant No More" presentation, students will demonstrate their understanding of the concepts by designing and building two identical plankton models using clay, feathers and toothpicks, to test and compare the sinking rates of each plankton in warm and cold waters.

Give students the following materials; clay, feathers, toothpicks, a digital scale, and stopwatch. Have them design two identical plankton (both must use the same amount of clay that they measured on the scale). One will be dropped in a large aquarium (10 gallons or more) with the water temperature at roughly room temperature (~24°C), and the other will be dropped in a tank filled with warmer water (~30°C). Both plankton should be designed with a slow sinking rate in mind (and the adaptations discussed in class earlier). Record the times to sink on the data sheet where their hypotheses were recorded.

Closing: (4 minutes)

With students back in their seats, discuss some of their findings. What types of adaptations worked? What didn't work? Did they come across anything that worked in cold water but not warm water or vice versa? Did their plankton have the same sinking rate? Why or why not? Guide students into discussing the implications that warmer sea surface waters have on plankton. If waters continue to warm, plankton will not receive the nutrients they usually get from colder, nutrient-rich waters. This will stunt plankton growth and reproduction and mean less food for the ecosystem's other organisms. In addition, warmer, less-viscous waters, may cause plankton to sink to depths that will remove them from the sunlight surface waters, which will also decrease oxygen production and mean less food available for other trophic levels.

Independent Practice:

Students will complete the included worksheet during the course of their lab activity and answer the questions.

Assessment:

In addition to the lab worksheet, students could make posters/sketches of their plankton designs along with their data and present to the class. This could spark a discussion about what characteristics proved to be more conducive to slower sinking rates. They will probably see similar trends within the successful designs. Students could then research types of marine phytoplankton which use similar characteristics.

Expansion:

In a lab encompassing multiple days, students could grow phytoplankton under different environmental conditions such as varying temperatures and observe plankton at various times to record data on productivity levels. Students could measure dissolved oxygen concentrations at each of these conditions as an indicator of productivity levels.

Resources:

Organic decomposition in ocean image U.S.JGOFS - ems.psu.edu
Bacterioplankton image - st.nmfs.noaa.gov
Zooplankton photo from flmnh.ufl.edu
Phytoplankton image from toothfish.org
Surface area to volume ratio image – www.open.jorum.ac.uk

Sea surface temperature anomaly-
http://www.giss.nasa.gov/research/news/20060925

Phytoplankton diversity image -
https://web.duke.edu/nicholas/bio217/jrc25/impacts.html

Bamfield Marine Science Centre Newsletter–Plankton Article:
http://oceanlink.island.net/ONews/ONews7/plankton.html

Plankton types and species - http://life.bio.sunysb.edu/marinebio/plankton.html

Plankton’s role in climate regulation -
http://www.sciencedaily.com/releases/2002/11/021107074203.htm

Perspectives on Science lecture, Peter Franks, Plankton:
http://www.youtube.com/watch?v=lQPh61upbTs

Basic introduction to phytoplankton -
http://earthobservatory.nasa.gov/Features/Phytoplankton/
http://oceanservice.noaa.gov/facts/phyto.html

Role of plankton in the carbon cycle -
http://kids.earth.nasa.gov/seawifs/carbon2.htm

Reflection:

This lesson works much better as a two day lesson. I tried to squeeze it into one day but the students get really into the design of the plankton and want to test the buoyancy of all the materials first. I allowed them to do this in a beaker at their lab station. Encouraging the students to sketch their design is critical to their success in the lab. There are really two goals in the lab; 1) to show that the same design should sink faster in warm water than colder water and 2) to make a neutrally buoyant (or close to it) model. I encouraged the students to try to neutral buoyancy on their first design (the one they made two of) and then test the sinking rates. Once they saw that warm water caused the plankton to sink faster, I encouraged them to take one of their models back, make some revisions and test (in cold water because it's easier to obtain neutral buoyancy) again. They can continue revising their models for the remainder of the period. If they get a model that works, that then can also be tested in the warm water to see if it remains neutrally buoyant. My students also did not want to use the scales to measure their clay, which is important to ensuring their warm and cold water plankton are similar enough to draw conclusions from.