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2007: Exploring the Inner Space of the Celebes Sea

Staying Up

Focus
Buoyancy principles as they apply to ocean plankton

Grade Level
7-8 (Life Science/Physical Science))

Focus Question
What are some factors that determine the sinking rate of planktonic organisms?

Learning Objectives
Students will explain Archimedes' Principle.

Students will define plankton, phytoplankton, and zooplankton.

Students will describe at least three factors that can affect the buoyancy of plankton.

Students will apply Archimedes' Principle to construct an object that has a specified buoyancy.

Materials
- ❒ Styrofoam packaging "peanuts," 12 for each student or student group
- ❒ Monofilament fishing line, about 6 lb test; about 1 m for each student or student group
- ❒ Fishing weights or washers, at least 6 pieces with a total mass of about 60 g for each student or student group
- ❒ 100 ml graduated cylinder, one for each student or student group
- ❒ Scissors for each student or student group
- ❒ Triple-beam balance
- ❒ A supply of water

Audio/Visual Materials
- ❒ Overhead projector with transparencies and markers or marker board
- ❒ (Optional) Images of planktonic organisms (see Learning Procedure, Step 1)

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style or groups of 2-3 students

Maximum Number of Students
30

Key Words
Plankton
Phytoplankton
Zooplankton
Archimedes' Principle
Density
Buoyancy
Midwater
Celebes Sea
Hands-on

Background Information
Indonesia is well-known as one of Earth's major centers of biodiversity. Although Indonesia covers only 1.3 percent of Earth's land surface, it includes:
- 10 percent of the world's flowering plant

species;
- 12 percent of the world's mammal species;
- 16 percent of all reptile and amphibian species; and
- 17 percent of the world's bird species.

In addition, together with the Philippines and Great Barrier Reef, this region has more species of fishes, corals, mollusks, and crustaceans than any other location on Earth.

What, exactly, is meant by biodiversity, and why is it important? The term "biodiversity" is usually understood to include variety at several levels:
- variety of ecosystems: high biodiversity suggests many different ecosystems in a given area;
- variety of species: high biodiversity suggests many different species in a given area;
- variety of interactions between species; and
- variety within species (genetic diversity): high biodiversity suggests a relatively high level of genetic variety among individuals of the same species.

A simple definition of biodiversity could be "The variety of all forms of life, ranging in scale from genes to species to ecosystems."

Biodiversity is important to humans because our survival depends upon many other species and ecosystems. Some examples of our dependence on biodiversity include:
- fresh air containing oxygen;
- clean water ;
- productive soils;
- food, medicines and natural products;
- natural resources that provide the basis for human economies; and
- natural beauty that improves our quality of life.

(adapted from the Biodiversity Project, http://www.biodiversityproject.org/bdimportant.htm)

Quite a lot is known about Indonesia's terrestrial and shallow-water ecosystems. But scientific knowledge and understanding of midwater ocean communities is generally sketchy, and many midwater animals have not been studied at all—even though the midwater ocean environment is our planet's largest ecosystem. Midwater animals range from microscopic zooplankton to the largest animals on Earth, provide a major source of nutrition for benthic (bottom) communities, and are an important link in the transfer of energy and materials from the top to the bottom of the ocean. Note that the term "midwater" as used here includes the entire water column, but the same term has also been used to refer to only part of the water column. Scientists often divide the ocean water column into three zones: the "epipelagic zone" (also called the "sunlit" or "euphotic" zone) from the surface to a depth of about 200 m; the "mesopelagic zone" between 200 m and 1100 m; and the "bathypelagic zone," which is deeper than 1100 m.

"Plankton" (from a Greek word meaning "drifters") is a general term for organisms that drift or swim weakly in midwater environments, and includes plants (phytoplankton) as well as animals (zooplankton). Individual planktonic organisms are sometimes referred to as "plankters." Phytoplankton include major primary producers in aquatic food webs, and produce most of the oxygen in Earth's atmosphere. Zooplankton include animals that are planktonic for their entire lives, as well as larvae for whom the planktonic existence is temporary. Many marine animals produce planktonic larvae, regardless of whether the adults are swimmers, bottom-dwellers, or completely immobile as adults. Because they come from many different kinds of animals, zooplankton have many different forms and may resemble jellyfish, worms, shrimps, or extremely bizarre fishes. Many zooplankton are quite small (less than a millimeter long), but the "gelatinous zooplankton" are much larger (1 cm long to as large as 2,000 cm) and include organisms such as jellyfish, shell-less swimming snails, arrow worms, and salps. Many zooplankton (particularly larger ones) move up and down in the water column, migrating to shallower water at night to feed and returning to the safety of deeper waters during the day to avoid predators.

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Zooplankton includes many primary consumers that are a key link in transferring energy to other consumers in ocean food webs. Despite their importance, many types of zooplankton are not well-understood. This is partially because many species are fragile, jelly-like creatures that are easily damaged by nets and other devices that are traditionally used to collect midwater animals for study. Scientists participating in the 2007: Exploring the Inner Space of the Celebes Sea Expedition plan to use techniques known as "blue-water diving" to observe and collect fragile midwater animals, some of which will probably be new to science.

Because they require sunlight for photosynthesis, phytoplankton need to stay relatively close to the ocean surface. Most phytoplankton are very small, and their body composition makes them nearly neutrally buoyant, so the viscosity ("stickiness") of seawater is often enough to counteract any tendency to sink. Some phytoplankton have flagella which are tail-like appendages that give the cells a limited ability to move themselves. Another adaptation to avoid sinking is the production of low-density oils that increase the cells' buoyancy.

In this lesson, students will compete with each other using the principles of buoyancy to design a model plankter with the slowest sinking rate.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the 2007: Exploring the Inner Space of the Celebes Sea Expedition at http://oceanexplorer.noaa.gov/explorations/07philippines/. You can view many images of planktonic organisms at http://www.imagequest3d.com/catalogue/larvalforms/, but be aware of copyright restrictions posted on the Web site.

   Prepare a "model kit" for each student group containing a dozen styrofoam peanuts, monofilament fishing line, and fishing weights or washers. Be sure the peanuts will have sufficient displacement to balance the weights. The easiest way to check this is to put a handful of peanuts and at least six weights into a plastic zip-top bag, squeeze as much air as possible out of the bag, and seal the top. Drop the bag into a container of water. If the bag floats, all is well. If the bag sinks, use smaller weights.

2. Briefly introduce the 2007: Exploring the Inner Space of the Celebes Sea Expedition, highlighting the Expedition's emphasis on midwater communities and the fact that these communities have not been well-explored, even though they are part of Earth's largest ecosystem. Discuss the role of plankton in ocean ecosystems (you may want to tell students that "plankton" comes from a Greek word meaning "drifters"). Be sure

students understand the distinction between phytoplankton (plant plankton) and zooplankton (animal plankton), and that zooplankton may be planktonic for all of their lives or only part of their lives (as is the case with larvae of many marine animals). Point out that phytoplankton are responsible for the majority of primary production in the ocean, and produce at least half of the oxygen we breathe. Discuss the importance of buoyancy to the planktonic way of life. If students are not familiar with Archimedes' Principle, discuss this as well. The following instructions assume that students are familiar with concepts of volume and density, and how these properties can be measured in solid objects.

3. Provide each student group with a supply of styrofoam peanuts, monofilament fishing line, and fishing weights or washers. Each group should also have access to a 100-ml graduated cylinder, a supply of water, and a balance. Tell students that their assignment is to design a model plankter using materials provided, and compete with other student groups to determine which plankter has the slowest rate of sinking. Instruct each group to write a description of their design, including appropriate measurements and calculations that predict a slow sinking rate for their model. Say that when each group has completed their model and written description, they will compete to see which group has been most successful. There will be no opportunity for testing the models prior to the competition, so good calculations are essential!

   For example, if three peanuts displace a volume of 17 ml in the graduated cylinder, then the buoyant force acting on the peanuts will be equal to the weight of 17 ml of water, which is 17 grams. If the students have six fishing weights, each of which weighs 7.5 grams (1/4 ounce), then two weights would weigh 15 grams (not quite enough to sink three

Archimedes' Principle

The idea of buoyancy was summed up by a Greek mathematician named Archimedes: any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. Today, this definition is called the Archimedes Principle.

Archimedes is considered one of the three greatest mathematicians of all time (the other two are Newton and Gauss). Archimedes was born in 287 B.C., in Syracuse, Greece. He was a master at mathematics and spent most of his time thinking about new problems to solve.

Many of these problems came from Hiero, the king of Syracuse. Archimedes came up with his famous principle while trying to solve this problem: The king ordered a gold crown and gave the goldsmith the exact amount of metal to make it. When Hiero received it, the crown had the correct weight but the king suspected that some silver had been substituted for the gold. He did not know how to prove it, so he asked Archimedes for help.

One day while thinking this over, Archimedes went for a bath and water overflowed the tub. He recognized that there was a relationship between the amount of water that overflowed the tub and the amount of his body that was submerged. This observation gave him the means to solve the problem. He was so excited that he ran naked through the streets of Syracuse shouting "I have found it!". The goldsmith was brought to justice and Archimedes never took another bath...(just kidding!).

(from "Discover Your World with NOAA: An Activity Book;" http://celebrating200years.noaa.gov/edufun/book/welcome.html) peanuts) and three weight would weigh 22.5 grams (which would cause the peanuts to sink rapidly). So, a design using three peanuts plus a whole number of weights will not meet the requirement of designing a model that sinks slowly. A better design solution would be to adjust the buoyancy of the peanuts by picking off small pieces of styrofoam until the displaced volume is just slightly below 15 ml. Now, two weights should make the model slightly negatively buoyant, so it will slowly sink. Students should record their measurements of peanut volume and weight mass in their report, and say how they combined this information to produce a "slow sinker."

4. When each group has completed their model, test the sinking rate of two or three models at a time, using an aquarium filled with water. Students should hold their model just above the water, and when given the "Go" signal should drop their models, and at the same time a timekeeper will begin timing with a stopwatch or watch with a sweep second hand. The time required for each model to sink to the bottom should be recorded, and the competition repeated until the winner is determined. If desired, students may be given an opportunity to fine-tune their models for a return engagement.

5. Lead a discussion of the design calculations that produced the most successful model. Students should realize that key parameters are:
   - the total volume of the plankter model, which will determine the volume of water displaced;
   - the mass of the volume of water displaced, which will determine the buoyant force acting on the model (since this is fresh water, a volume of 1 cm3 can be assumed to have a mass of 1 gram); and
   - the mass of the weights attached to the model.

The volume of the model can be determined by immersing the styrofoam peanuts in a partially-filled graduated cylinder (by stacking the peanuts inside the cylinder, then pushing on the top-most peanut with a pencil until all of the styrofoam is just submerged) and noting the change in volume within the cylinder. It isn't necessary to use all of the peanuts in a model. Once the volume (and hence the buoyant force) is determined, an appropriate combination of weights can be selected. If necessary, peanuts could be broken into smaller pieces to bring the buoyant force closer to the mass of the weights. Once the appropriate combination of peanuts and weights has been determined, the components can be tied together with the monofilament line. The line should be kept as short as possible to minimize its effect on the buoyancy of the model.

Ask whether the overall size of the model matters, as long as the mass of the weights is just slightly more than the buoyant force acting on the styrofoam peanuts. In fact, overall size does have an effect on the sinking rate of the model because of the viscosity ("stickiness") of the water: a model with a larger surface area will experience greater resistance from the water, and hence will sink more slowly (if you try to force your hand palm-down through water you will feel more resistance than if you push your hand through the water fingers-first).

Ask students how they would modify their models for a competition in salt water. Students should recognize that the density of salt water is greater than the density of fresh water, so the volume of water displaced will have a greater mass, and hence the buoyant force on the model will be greater; so they would need to add additional weight to cause the model to sink.

Finally, briefly discuss the relevance of students' models to the behavior of ocean plankton. In addition to the mass and volume of planktonic organisms, buoyancy can be affected by an organism's internal composition; if an organism produces lightweight oils or gas bubbles, its buoyancy can be increased. In addition, many planktonic organisms have a limited degree of mobility (even though they are called "drifters"), and this may be enough to counteract sinking if an organism's buoyancy is only slightly negative.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Biology," then "Plankton" for information and activities involving phytoplankton, zooplankton, and bioluminescence.

The "Me" Connection

Have students write a short essay in which they describe at least three ways in which Archimedes' Principle is relevant to their own lives.

Connections to Other Subjects

English Language Arts, Physical Science

Assessment

Models and written design reports provide opportunities for assessment.

Extensions

1. Visit oceanexplorer.noaa.gov to keep up to date with the latest 2007: Exploring the Inner Space of the Celebes Sea Expedition discoveries, and to find out what researchers are learning.
2. See the following activity packages for additional activity ideas involving plankton:
   - http://www.msc.ucla.edu/oceanglobe/pdf/PlanktonPDFs/PlanktonEntirePackage.pdf – Plankton lesson plans from the University of California, Los Angeles Marine Science Center
   - http://www.msc.ucla.edu/oceanglobe/pdf/guide_plankton1.pdf – "A Guide to the Marine Plankton of Southern California" by Robert Perry
   - http://www.marine.usf.edu/pjocean/packets/f01/f01u6p2.pdf – Plankton unit from UCLA's Project Oceanography Science Standards with Integrative Marine Science (SSWIMS)
   - http://sealevel.jpl.nasa.gov/education/activities/ts3ssac3.pdf – plankton identification activity from NASA's "Visit to an Ocean Planet" CD-ROM
   - http://www.oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_drifting.pdf – "Drifting Downward," lesson plan from the Ocean Explorer 2002 Islands in the Stream Expedition

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 8 and 12 for interactive multimedia presentations and Learning Activities on Ocean Currents and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from the Ocean Exploration Program

Come on Down! [http://www.oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf] (6 pages, 464k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; students will calculate the density of objects by determining the mass and volume; students will construct a device that exhibits neutral buoyancy.

A Matter of Density [http://www.oceanexplorer.noaa.gov/explorations/04mountains/background/edu/media/MTS04.density.pdf] (6 pages, 416k) (from the 2004 Mountains in the Sea Expedition)

Focus: Temperature, density, and salinity in the deep sea (Physical Science)

In this activity, students will be able to explain the relationship among temperature, salinity, and density; and, given CTD (conductivity, temperature, and density) data, students will be able to calculate density and construct density profiles of a water column. Students will also 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.

Who Has the Light? [http://www.oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/media/WhoHasLight.pdf] (PDF, 200Kb) (from the 2004 Operation Deep Scope Expedition)

Focus: Bioluminescence in deep-sea organisms

In this activity, students compare and contrast chemiluminescence, bioluminescence, fluorescence, and phosphorescence. Students also explain at least three ways in which the ability to produce light may be useful to deep-sea organisms and explain how scientists may be able to use light-producing processes in deep-sea organisms to obtain new observations of these organisms.

It's a Gas! Or Is It? [http://www.oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_gas.pdf] (9 pages, 270Kb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Effects of temperature and pressure on solubility and phase state (Physical Science/Earth Science)

In this lesson, students will be able to describe the effect of temperature and pressure on solubility of gases and solid materials; describe the effect of temperature and pressure on the phase state of gases; and infer explanations for observed chemical phenomena around deep-sea volcanoes that are consistent with principles of solubility and phase state.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://www.st.nmfs.gov/plankton/ – NOAA's Coastal & Oceanic Plankton Ecology, Production & Observation Database (COPEPOD)

http://www.oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_drifting.pdf – "Drifting Downward," lesson plan from the Ocean Explorer 2002 Islands in the Stream Expedition

http://www.msc.ucla.edu/oceanglobe/pdf/PlanktonPDFs/PlanktonEntirePackage.pdf – Plankton lesson plans from the University of California, Los Angeles Marine Science Center

http://www.msc.ucla.edu/oceanglobe/pdf/guide_plankton1.pdf – "A Guide to the Marine Plankton of Southern California" by Robert Perry

http://www.marine.usf.edu/pjocean/packets/f01/f01u6p2.pdf – Plankton unit from UCLA's Project Oceanography Science Standards with Integrative Marine Science (SSWIMS)

http://sealevel.jpl.nasa.gov/education/activities/ts3ssac3.pdf – plankton identification activity from NASA's "Visit to an Ocean Planet" CD-ROM

http://www.imagequest3d.com/catalogue/larvalforms/ – Image Quest 3-D Web site, featuring images of numerous marine organisms; all images are copyrighted, but are still great to look at

http://www.pbs.org/wgbh/nova/lasalle/buoybasics.html

– "Buoyancy Basics" Web site from NOVA

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
- Motions and forces

Content Standard C: Life Science

- Structure and function in living systems
- Diversity and adaptations of organisms

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Ocean Exploration Program
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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