

# Whale Sharks Plankton: Ocean Drifters

by Bill Andrake

Science Lesson: Plankton: Ocean Drifters - Based on Webisode 18

Grade Level: 6-8

**Time:** 4 Activities; Each ranges from 1 to 4 (45-50 min) class periods for up to 9 classes total

### Introduction

In the summer along the Northern coast of the Yucatan Penninsula, whale sharks congregate off the small island of Holbox Island. Whale sharks are the largest fish in the world, reaching 50 feet in length. They feed on **plankton** and tiny fish, filtering them from the water as they cruise along the surface. With their mouths open, these giant fish bring in plankton rich water and then close their mouth forcing the water out through their gills, which act like strainers, filtering tiny organisms out the water.

The local economy of Holbox Island is supported by the **ecotourism** generated as visitors come to this tiny island to swim with the whale sharks and thus these creatures are protected and celebrated. But it's the abundance of **plankton** that brings the whale sharks to this area in the summer. So one might say that, in the end, the local economy of Holbox Island is supported by the **plankton**.

This lesson discusses types of plankton, their importance in ocean ecosystems and methods of studying plankton.

### Science Standards

### National Science Education Standards

#### **Life Science:**

- Populations and Ecosystems
- Diversity and Adaptations of Organisms

### Ocean Literacy Principles

- Principle #4: The Ocean makes the Earth habitable. Topic: Oxygen Production
- Principle #5: The ocean supports a great diversity of life and ecosystems. Topic: Primary Productivity, Diversity of Ecosystems, Diversity of Life

### **Objectives**

- To learn about the different types of plankton and the adaptations used by these organisms to survive in the lifestyle of a drifter.
- To understand and appreciate the importance of plankton in productive and healthy ocean ecosystems.
- To learn about the environmental conditions that support plankton in the sea.
- To learn some of the methods and technologies used for studying, collecting, measuring, and working with plankton.



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### **Background Vocabulary**

Algae: mostly aquatic photosynthetic organisms: the seaweeds and microscopic algae

**Chlorophyll:** the green chemical pigment in plants or **algae** responsible for absorbing sunlight for the process of **photosynthesis** 

**Consumer:** grazers or predators, mainly animal life, in ecosystems... they eat or consume plants and other animals.

Copepods: tiny crustaceans that often make up the majority of a zooplankton population

Crustaceans: a large group of mostly aquatic Arthropods which includes lobsters, crabs, and barnacles

**Decomposers:** organisms such as bacteria and fungi whose role in **ecosystems** is to break down complex molecules into in basic nutrients.. they are agents of decay.

**Diatoms:** one of the most common forms of **phytoplankton**, single celled algae, whose cells have cell walls made of a clear silicate glass-like compound

**Dinoflagellates:** a common form of **phytoplankton**, single celled algae, whose cells are propelled by two flagella (whip-like tails). Some species contain toxins and are responsible for harmful algal blooms or "red tides"; so named as their cells have red/brown photosynthetic pigments in addition to chlorophyll

Ecology: the study of the relationship between living things and their surroundings

Ecosystem: a complex community of living things interacting with their physical environment and each other.

**Food Chain:** a series of organisms in an ecosystem in which each organism moving up the chain is dependent on the organisms occupying lower levels for food, rather directly or indirectly.

Example: Diatoms are eaten by Copepods which are eaten by small juvenile fish - which are eaten by Mackerel which are eaten by Tuna... the Tuna depend on the Diatoms, Copepods, and juvenile fish in order to have Mackerel to eat.

**Food Web:** the complex overlapping and connections of the various food chains in an ecosystem.

**Holoplankton:** Animals that are **plankton** for their entire life. ex: Copepods

**Larva:** a juvenile form or stage in the life cycle of certain animals. ex: caterpillar is the larval form of a butterfly. "Larvae" is plural.



barnacle.

**Micron** *or micrometer:* a measurement unit in the metric system used to measure very small distances, equal to one millionth of a meter or one thousandth of a millimeter

**Meroplankton:** animals that are planktonic for only a portion of their life such as the larval forms of crabs and lobsters, or some juvenile fish species.

**Metamorphosis:** a process in the development of an animal from its early stages to adult characterized by distinct and different forms at each stage. *ex: tadpole to adult frog... caterpillar to butterfly...* 

Nutrients: basic elements and simple compounds needed for life.

**Phytoplankton:** Photosynthetic plankton, single celled, microscopic algae. They are major primary producers in aquatic ecosystems and are responsible for a lot of the world's oxygen as a by-product of their photosynthesis.

**Photosynthesis:** The process in plants and algae where they produce their "food" (the sugar glucose  $C_6H_{12}O_6$ ) from Carbon Dioxide ( $CO_2$ ) and Water ( $H_2O_3$ ) using light energy from the Sun. Oxygen ( $O_2$ ) is a by product of this reaction.

**Plankton:** organisms in aquatic environments that drift with currents.. a.k.a. plankters

**Producer:** photosynthetic organisms such as plants and **algae** that carry out **photosynthesis** and *produce* the material needed to begin the food chain in an **ecosystem.** 

**Upwelling:** rising water from deeper regions that is cooler and more rich in **nutrients** than the surface water it displaces



### **Introduction & Activity: What is Plankton?**

Time: 2-3 class periods

Materials: Photographs or samples of plankton; Jonathan Bird's Blue World Whale Shark webisode 18

Photographs by Bill Andrake

Plankton are organisms in aquatic environments that drift with currents. Plankton comes from the Greek word *planktos* which means "drifter." These are living things that are adapted for and rely on a lifestyle in the water column where they are unable to swim against prevailing currents; so they drift. A piece of dislodged seaweed or barnacles attached to floating piece of driftwood are not considered **plankters.** Most plankton are tiny microscopic creatures, however there are many larger forms of plankton such as jellyfish that are adapted for this lifestyle. There are two major groups of plankton, **phytoplankton** ("plant"-plankton) and **zooplankton** ("animal"-plankton).

### **Phytoplankton**

Phytoplankton are tiny single celled algae, which are photosynthetic organisms.

Examples of Diatoms, which may be the most common group of phytoplankton and are characterized by their golden brown color and cell walls made of a silicate glass-like compound. Some are solitary cells others form chains of cells. (magnified 430 times)

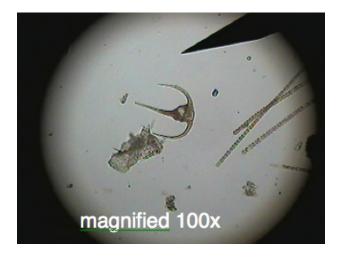


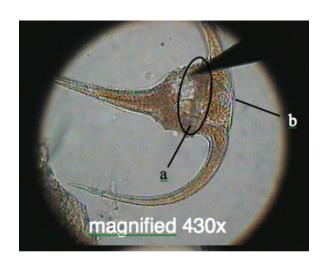






Pictured below is the Dinoflagellate, Ceratium longipes. Dinoflagellates are common marine phytoplankton characterized by their reddish brown pigments and their ability to propel themeselves with two whip like tails or flagella (The flagella, located at "a" and "b" are not visible from the cells in these photos).



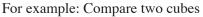




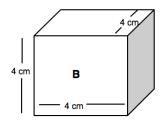
### Staying Afloat: Math Connection...surface area to volume ratio

**Phytoplankton** are photosynthetic and need to be near the surface to get sunlight. They account for 50% of the photosynthetic activity on Earth. Some phytoplankters, such as Dinoflagellates, can propel themselves to the surface using their flagella, while others rely on currents to lift their cells to the surface. Phytoplankton often contain oil in their cells which will help them float as it is less dense than water, but the most effective strategy for staying afloat is that they're really small.

Tiny particles will have an easier time staying up in the water column BUT NOT because they're lighter or more buoyant. It is actually due to the <u>ratio of their surface area to their volume</u>. As an organism increases in size its volume increases at a greater rate than its surface area the result is less units of surface per unit of volume.







For cube "A" each side is 1 cm in length and in cube "B" each side is 4 cm long.

• Each square side in cube "A" has an area of 1 cm<sup>2</sup>, so its <u>Total Surface Area = 6 cm<sup>2</sup></u>. The <u>Volume</u> of cube "A" (L x W x H) =  $1 \text{cm}^3$ .

The surface area to volume ratio is 6 to 1.... 6 units of area for every unit of volume.

• Each square side in cube "B" has an area of 16 cm<sup>2</sup>, so its total surface area is 96 cm<sup>2</sup>.

The <u>volume</u> of cube "A"  $(L \times W \times H) = 64 \text{ cm}^3$ .

The surface area to volume ratio is 96 to 64.... just 1.5 units of area for every unit of volume.

#### Being smaller increases the surface area to volume ratio.

So what does mean for plankton cells? By being tiny they have more surface relative to their volume. This helps them stay up in the water column because as gravity pulls them down, friction between their cell surface and the surrounding water slows their descent. The more surface contact with water relative to their size means more friction per unit of volume, which slows their fall to the bottom.

When looking at the photos of phytoplankton (page 3) you may have also noticed several have spines and spikes. When cells have these features, this also increases their surface area without a significant increase to their overall volume, thus increasing friction and slowing their descent.

Phytoplankton are among the tiniest creatures in the sea and yet they can be seen from outer space... well sort of. Being "plants," phytoplankton have chlorophyll in their cells. Some satellites are equipped with sensors that can detect chlorophyll concentrations on the surface of the Earth or in the ocean. With this data, vegetation and phytoplankton can be mapped, allowing scientists to study changing patterns in forestation on land or gain a better understanding of phytoplankton in the sea.



Shown below is a satellite map of chlorophyll concentration showing phytoplankton in the Gulf of Maine. Highest

concentrations are in red.

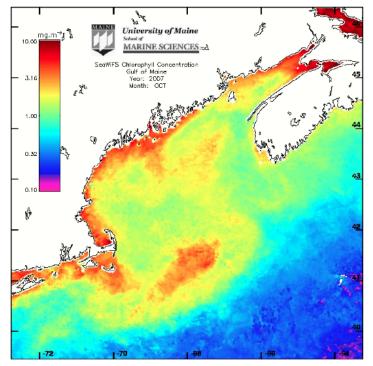


Image provided by Satellite Oceanography Data Laboratory, University of Maine through Northeast Regional Association of Coastal Ocean Observing Systems: neracoos.org

Ocean scientists are very interested in phytoplankton populations as they are the <u>base</u> or beginning of **food chains** in the sea. It is the phytoplankton that becomes food for the next step in the chain, the **zooplankton**. Zooplankton is the food source for many other animals from small fish to whales and whale sharks.

As photosynthetic organisms, phytoplankton release oxygen. In fact they are responsible for at least half (probably more) of the oxygen that we breathe.

### Refer back to the Webisode on Whale Sharks...

In the webisode on whale sharks, Jonathan often commented on how cloudy the plankton made the water. As you watch the underwater scenes you will see the green color or tint to the water, indicating the presence of phytoplankton. Usually, where there is phytoplankton there is zooplankton, and where there is zooplankton you have in this case, whale sharks.

#### Zooplankton

Zooplankton or "animal plankton" are the next step in the food chain feeding on phytoplankton. There are also some larger forms of zooplankton such as some jellyfish or fish larvae feed on smaller species of zooplankton.

There are two forms of zooplankton: **meroplankton** and **holoplankton**. **Holoplankton** are species that spend their entire lives in the plankton community whereas **meroplankton species** only spend a portion of their lives drifting with the ocean currents. Many familiar marine animals, especially invertebrates have larval stages that are found in the plankton community.



### Meroplankton

Some marine creatures go through an interesting **metamorphosis** as they go through their life cycle, and along the way they may become part of the zooplankton community.

For example crabs go through different stages after hatching from eggs. They begin as "zoea" followed by a "megalops" stage, as plankton, before settling to the seafloor and maturing into their familiar form. Photos by Bill Andrake.

Note the spines on the body of the zoea, perhaps they help keep it up in the water column; an adaptation seen in phytoplankton.



Crab "Zoea" Stage



Crab "Megalops" Stage

### What's the advantage for spending part of your life cycle as plankton?

As plankters drift, they are able to spread their populations; it's a reproductive strategy. We see this on land where plants take advantage of the wind to spread their seeds. Consider the barnacle. Once a barnacle reaches maturity, its attached to a surface and there it will remain. If it's in an area where conditions are not healthy it may struggle to survive. However, barnacle eggs and the larval stages that follow become part of the plankton community and may drift to occupy more favorable habitats to ensure their survival. Photos by Bill Andrake.

The early stage or "Nauplius" larva of a barnacle



The later stage or "Cypris" larva of a barnacle



Many other animals begin their lives in the plankton community.

The larva of a seaworm



The larva of a snail





#### **Zooplankton** (continued)

Unlike phytoplankton, zooplankton are multicellular. They are animals and need to find food and if possible keep from becoming food. They have features and adaptations for moving vertically in the water column. A good example is the **Copepod**, (pictured below, photo by Bill Andrake) the most common zooplankter in the sea and highlighted in the episode on whale sharks, (refer to the 4:40 mark in the Whale Shark episode).

We can see many of the features that make this animal so well suited for life as a plankter. What purpose does the eye spot serve? What is the function of those large antennae?



The eyespot allows copepods to sense light which helps them to navigate up or down in the water column. They migrate up in the water column (toward light) to get at phytoplankton near the surface, however they migrate down (toward dark) as they are less likely to be seen by visual predators such as fish. It is common for populations of copepods to come up near the surface at night to feed on phytoplankton, and return to the dark deeper waters during daylight hours, thus using their eye spot to avoid light.

The most distinctive feature of these animals is their large antennae. Antennae can detect vibrations in the water as well as changes in chemistry. This allows them to find food or even detect predators. The antennae along with their feet act as oars pushing them through the water with <u>very quick</u> "hops" which you can see in the video.

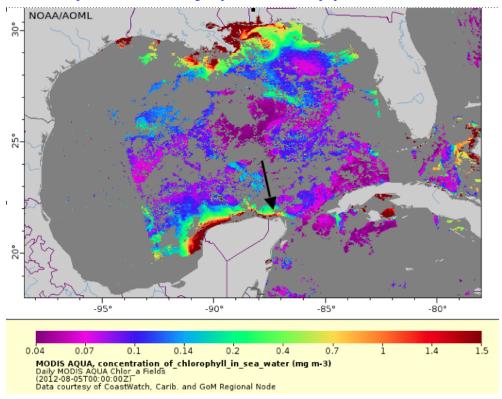
As they feed on phytoplankton their bodies become rich in oil. Oil contains a lot of energy, thus copepods are a highly sought after food item by large creatures such as whales and whale sharks.. copepods are a high energy food source.

Whale sharks congregate around Holbox Island during the summer months to feed on the copepods. The copepods are feeding in the green, phytoplankton rich waters. So why are the phytoplankton blooming off Holbox Island?



### **Nutrients and Upwelling (one class period)**

This is a map of chlorophyll concentration in the Gulf of Mexico from satellite data collected from NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) satellite in August 2012. Highest phytoplankton (chlorophyll) concentrations are in red. (<a href="http://www.aoml.noaa.gov/phod/dhos/color.php">http://www.aoml.noaa.gov/phod/dhos/color.php</a>).



From this map, the Northern coast of the Yucatan (location of Holbox Island) is rich in phytoplankton. So why is the phytoplankton so abundant in this area? Across the Gulf of Mexico where the Mississippi River enters the sea, we see high concentrations of phytoplankton as well.

In addition sunlight, what else would phytoplankton need to thrive? Like all plants, they need basic nutrients as well as water and sunlight in order to survive; they need fertilizer or plant food. The Mississippi River system carries much of the water that runs off the land between the Rocky Mountains and Appalachian Mountain Range. This water carries with it tons of sediment and dissolved materials. Many of these dissolved materials are basic compounds or nutrients that are absorbed by phytoplankton allowing their populations to multiply.

#### Upwelling...

The waters off the Yucatan do not have the huge volume of nutrient rich water coming off the land as seen in the area near the mouth of the Mississippi. So what might be the source of nutrients for phytoplankton along the northern coast of the Yucatan?

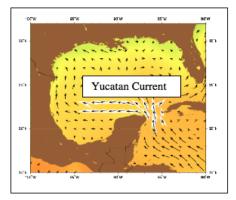
In many areas of the ocean, nutrients from the deep are brought to the surface through **upwelling**. Upwelling is a process where water from deeper regions of the sea is brought up as surface waters are pushed away. Deeper water often is colder and rich in nutrients. When life in the sea dies it sinks to the seafloor where it will decay and decompose into basic nutrients which can "fertilize" phytoplankton when brought to the surface by upwelling.



# **Nutrients and Upwelling (continued)**

#### How does upwelling occur off the northern coast of the Yucatan?

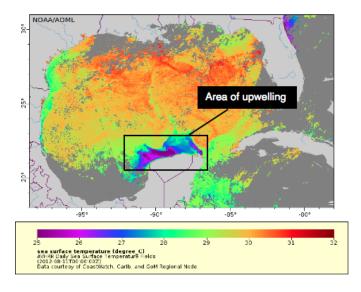
Through the passage between the Cuba and the Yucatan flows the Yucatan Current. The current pushes against the slope on the eastern edge of the Yucatan Shelf bringing colder water up from the deeper regions to the surface. The research and mechanisms for the Yucatan upwelling are summarized in *The Yucatan Current* by Joanna Gyory, Arthur J. Mariano, and Edward H. Ryan. Map below from <a href="http://oceancurrents.rsmas.miami.edu/caribbean/yucatan.html">http://oceancurrents.rsmas.miami.edu/caribbean/yucatan.html</a>

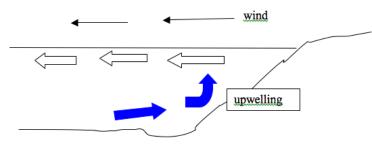


Map shows surface current velocity in the Gulf of Mexico.



From this satellite color map of sea surface temperature in the Gulf of Mexico one can see an area of colder water on the Northern side of the Yucatan, indicating an area of upwelling, which brought up cooler, nutrient-rich waters from the deep. From NOAA, Gulf of Mexico Monitoring, http://www.aoml.noaa.gov/phod/dhos/color.php





There are a variety of ways that deep water can be brought up to the surface. Winds can drive surface waters away from an area, drawing deeper waters to the surface. Also the cooling of water during colder months can cause surface water to sink and force bottom water to the surface; a process often found in lakes as well as in semi-enclosed bodies of water in the oceans.



### **Demonstration: Seasonal Upwelling**

Time: One to Two Class Periods

**Materials:** Food coloring, ice, water, dropper, aquarium airline tubing, tall clear plastic/glass cylinder, (ex: 1000 ml graduated cylinder).

#### **Introduction:**

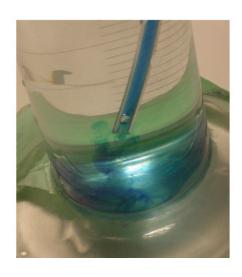
Upwelling in large semi-enclosed bodies of water can occur during the fall and winter in temperate climates. Surface water becomes colder which makes it more dense. This dense water sinks and nutrient-rich deeper water rises as it is displaced by the sinking water from the surface.

#### **Procedure:**

- 1. Fill the tall clear cylinder with water.
- 2. Fashion a long pipette by connecting a 6 to 8 inch piece of aquarium airline tubing to the end of a dropper.
- 3. Draw food dye up into the pipette and slowly deliver the dye to the bottom of the tube of water. Slowly remove the pipette leaving a layer of blue dye on the bottom of the cylinder.
- 4. The food dye represents nutrients at the bottom of sea.



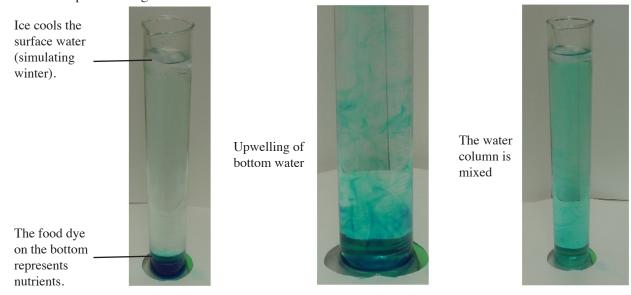






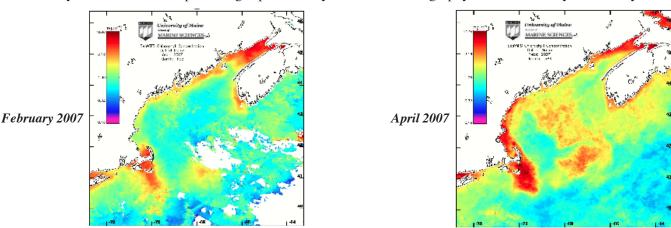
### **Demonstration: Seasonal Upwelling (continued)**

Next, add a few ice cubes to the top the water column and observe what happens. The ice represents the cooling of surface water that takes place during the winter months.



### Follow-up Discussion: Seasons in the Gulf of Maine

As in ecosystems on land, there are seasons in the sea. Phytoplankton blooms in the sea and increases in zooplankton are controlled by factors such as seasonal upwelling and the availability of sunlight. The timing of these events is extremely important, as many creatures depend on plankton directly or indirectly for food. The following are satellite maps of chlorophyll concentration in the Gulf of Maine, showing in red the highest phytoplankton populations. These maps show a comparison between the phytoplankton population in February and April 2007 in the Gulf of Maine. The spring phytoplankton bloom occurs normally in late March or April. Images provided by Satellite Oceanography Data Laboratory, University of Maine.



*Explanation:* During the fall and winter upwelling occurs in the Gulf of Maine and nutrient-rich water has reached the surface by February. However, the phytoplankton bloom does not happen until Spring, when the Sun's energy is more abundant for the process of photosynthesis. This phytoplankton bloom is followed by an increase in the zooplankton population.

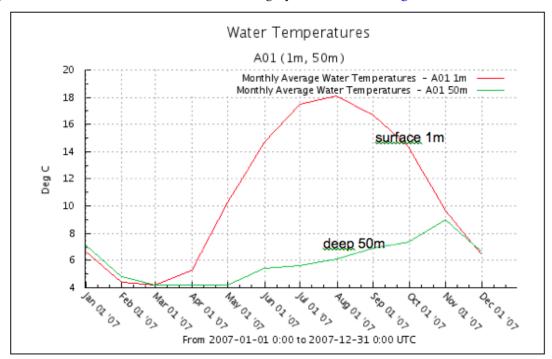
*Timing is Everything:* Whale species migrate to these waters to feed on copepods and small fish in late spring and remain until early fall when they migrate to tropical and subtropical waters over the winter.

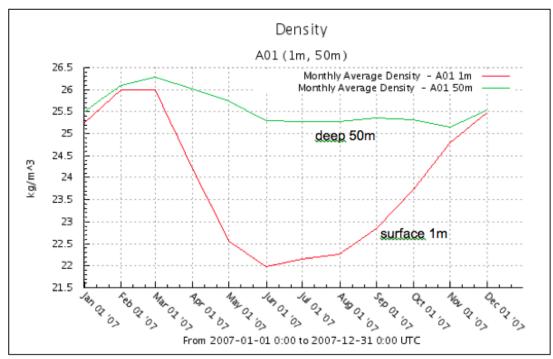


### **Seasonal Upwelling (continued)**

### Connecting buoy data to upwelling...temperature, density, and upwelling.

Shown below are graphs of water temperature and density from surface measurements and deep water for Massachusetts Bay in 2007. The data was recorded from the Gulf of Maine Ocean Observing System Buoy A01 and accessed from the Northeast Regional Association of Coastal Ocean Observing Systems: <a href="maintenancements">neracoos.org</a>







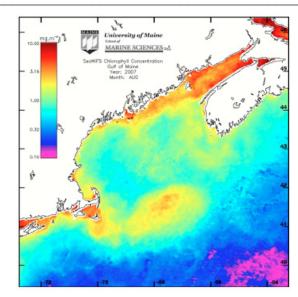
# Seasonal Upwelling (continued)

After studying the graphs of temperature and density data on the previous page, answer the following questions.

- 1. During what time period during the year is deep water upwelling and mixing with surface water?
- 2. What do you observe in the density data that indicates this mixing?
- 3. From the temperature data explain why mixing of deep water and surface water is occurring at this time.
- 4. This map shows phytoplankton in the Gulf of Maine for the month of August 2007. How does it compare to the phytoplankton map from April? (p.10)

So how do we explain this change in phytoplankton population over the summer? It's certainly not a lack of sunlight. Hint: the answer might lie in the temperature and density data.

Explain how this would happen.



6. What do you suppose has happened to the nutrient levels in the surface waters during the summer months?

Is there upwelling at this time? \_\_\_\_\_ Explain \_\_\_\_\_

- 7. What must happen in order to start the process of upwelling once again? \_\_\_\_\_
- 8. This map shows another phytoplankton bloom in October of 2007 in the Gulf of Maine. How might we explain this one last bloom of phytoplankton before the approaching winter?

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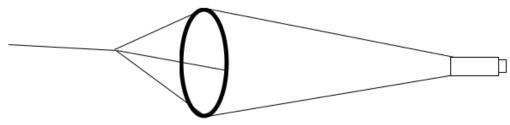
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An answer key is located on p. 20



### **Collecting and Working with Plankton**

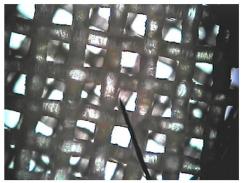
#### The Plankton Net



A plankton net is basically a very fine mesh net shaped into a cone held open by a metal ring. As the net is dragged or towed through the water, plankton is concentrated into a collecting bottle at the end of the net.

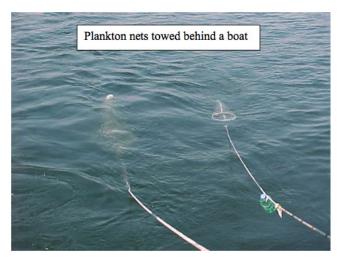
There are different net diameters and different mesh sizes, depending on what size plankters you would like to collect. A plankton net with a mesh size of about 100 **microns** is a good size for collecting phytoplankton as well as zooplankton.

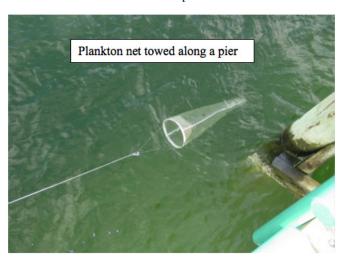
Here is a picture of a 100 micron mesh plankton net seen through a microscope magnified 100 times.



Commercial nets are widely available, but homemade nets are easily made from material such as curtain shears or nylon stockings. A wire coat hanger can be used to form the wire opening and a small plastic bottle with its bottom cut away can serve as the collecting vessel at the end of the net.

There are many ways to collect plankton. Plankton nets are typically towed behind a boat traveling at a very slow speed. However, they can be towed along a pier with a pole and a line or they can be hung off a bridge, collecting plankton in the current of a river or on an outgoing or incoming tide. Students can wade in a stream to collect plankton as well.







### **Collecting and Working with Plankton (continued)**

### **Working with Plankton**

**Keeping a plankton sample alive.... dilute it.** After collecting a plankton sample, the plankters are concentrated in a small collection vessel at the end of the net. If left in that vessel or even poured into a small jar, the creatures will soon use up all the available dissolved oxygen in the water and die.

Diluting your plankton sample with seawater in a large plastic jar (1-2 gal.) will keep the plankton alive for several days, especially if it's stored in a refrigerator. Using an aquarium air pump to add a low flow of air bubbled into the jar will also help maintain your sample.

**Observing plankton....concentrate it.** When it comes time to observe plankton in the classroom, your diluted sample will not be very useful. Trying to get an adequate number of plankters with a dropper for viewing through a scope is very difficult unless you concentrate the plankton. Pouring your sample through a mesh coffee filter can quickly and easily do this. The mesh is very fine and traps zooplankton however some phytoplankton species are too tiny and pass through this filter. (See photo).

### Zooplankton cage

Adding small floats (pieces of pipe insulation) to a mesh coffee filter allows a concentrated sample of plankton to float in a saltwater aquarium to keep it alive. (See photo below).

Concentrating a plankton sample by pouring it through a mesh coffee filter

Coffee filter "plankton cage" floating in an aquarium.



#### Observing and Identifying Plankton.

Most zooplankton is best observed in a small dish using a stereo or dissecting microscope as the creatures are typically moving around too quickly to follow it around on a microscope slide through a compound microscope. Phytoplankton cells are smaller and need to be observed using a compound microscope.



### **Collecting and Working with Plankton (continued)**

### Resources for identification of marine plankton

#### **Phytoplankton:**

"Great Bay Coast Watch Guide to Common Gulf of Maine Phytoplankton." New Hampshire Sea Grant and the University of New Hampshire Cooperative Extension.

http://nsgl.gso.uri.edu/nhu/nhuh06003.pdf

Color Guide to Identifying Dinoflagellates" Ocean Globe Program from UCLA Marine Science Center. http://www.msc.ucla.edu/oceanglobe/pdf/guide\_dinoflag.pdf

#### **Zooplankton:**

"Zooplankton Identification Guide." The University of Georgia Marine Education Center and Aquarium . <a href="http://www.marex.uga.edu/aquarium/docs/ID\_sheets/Zooplankton%20key.pdf">http://www.marex.uga.edu/aquarium/docs/ID\_sheets/Zooplankton%20key.pdf</a>

"A Guide to the Marine Plankton of Southern California." Ocean Globe Program from UCLA Marine Science Center. <a href="http://www.msc.ucla.edu/oceanglobe/pdf/guide\_plankton1.pdf">http://www.msc.ucla.edu/oceanglobe/pdf/guide\_plankton1.pdf</a>

"Plankton Identification Activity." Massachusetts Marine Educators.

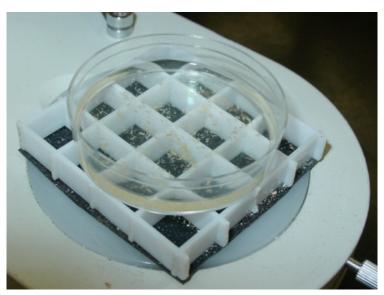
http://www.massmarineeducators.org/curriculum/pdf/Plankton\_Id\_Activity.pdf

"Visit to an Ocean Planet. Plankton Activity." NASA.

http://er.jsc.nasa.gov/seh/Ocean Planet/activities/ts3ssac3.pdf

### Counting plankters in a grid.

If you wanted to quantify plankton and actually wish to count individuals in a preserved sample, you'll need a grid. You can make grids using plastic "egg crate" material, which is used to cover light fixtures and found in most home centers. Place the grid on a black background. (attach black contact paper to the bottom of the grid). Next, center a small Petri dish with your plankters on to the grid. Then systematically move the grid (not the dish) as you count and record the individuals per square using a stereomicroscope or magnifying glass.



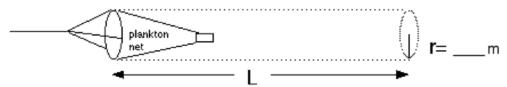
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## Quantitative Analysis: How Much Plankton is in a Cubic Meter of the Sea?

The amount of plankton in a sample doesn't mean much unless you consider the volume of water that you filter with the plankton net to get those plankters. So how do we do that????



Distance that the net was towed

Volume of water filtered	= Area of Net Opening x Distance	the net was towed
Step 1. Find the Area of the net opening bel	ow: $r = radius of the net$	
Area = $\pi r^2$		
Area = $3.14 \times r \times r$ (so	how your work below)	radius =m
Area of Net Opening =	<b>m</b> <sup>2</sup> square meters	
Step 2. Find the distance that the net was towed if from a boat Distance = Speed x Time		
Speed of the boat:meters per	r min.	
Time of the Tow: minutes.		
Distance the net was towed = Speed x Tin	ne (show your work below)	
•Distance of Net Tow =	m	
Step 3. Calculate the Volume of water filtered		
Volume of water filtered = Area of Net Op	ening x Distance of the Tow	
Volume of water filtered =	m² x =	m <sup>3</sup>
SoHow Mucl	h Plankton is in a Cubic Meter o	f the Sea?
Donulation Density	Number (or mass) of Plankters (g)	
Population Density =	Number of m <sup>3</sup> of water filtered	(Snow your work below)



### Quantitative Analysis: How Much Plankton is in a Cubic Meter of the Sea? (continued)

### **Plankton Population Density Worksheet**

1.	Date of Sample	
2.	Speed of Tow = m per min.	
3.	Time of the Tow minutes	
4.	<b>Distance of Tow</b> $(speed \ x \ time) = \underline{\qquad} meters$	
5.	. Area of Net Opening = square meters	
6.	<b>Volume of the Water Filtered</b> m³ orliters There are 1000 liters in a cubic meter (m3) .	
7.	• Population Density = number or mass of plankters ÷ Volume of water filtered	
	Population Density = ÷	
	Population Density = per m <sup>3</sup>	
	or per liter	

### **Sample Problems from Actual Data**

1) Calculate the biomass of copepods per cubic meter of water filtered. Plankton Data from a September Oceanography Cruise in Nahant Bay, Massachusetts.

• Duration of the plankton tow: 5 minutes

• Boat speed: 5 meters in 3 seconds

• Biomass of copepods in sample: 78.8 grams

(Collection was nearly all copepods with a few crab megalops larvae in sample)

- 2) Calculate the number of copepods per cubic meter of water filtered. Plankton data from a spring time collection along pier in Nahant Bay, Massachusetts
  - Plankton net diameter = 30 cm (0.3 m)
  - Net was towed along pier a distance of 50 meters
  - 14,860 copepods were counted in the sample.

An answer key is located on p. 21



### Quantitative Analysis: How Much Plankton is in a Cubic Meter of the Sea? (continued)

#### Follow up:

- 1. At the time of its collection a lot of plankton has been concentrated in the jar or bottle at the end of the net. This observation often misleads students into believing that the ocean is densely populated with plankters when in reality a lot of water may have been filtered to capture just a few grams of plankton.
  - It's useful to have a model of a cubic meter in the classroom as a visual so students get a real sense of how much plankton one might find in that volume of seawater.
  - Students may begin to appreciate just how much water must be filtered by a baleen whale, whale shark (or other plankton feeders) in order to be adequately nourished.
- 2. From the population density per m<sup>3</sup>

What are the chances of a little barnacle capturing a few zooplankter each time it scrapes the water with its legs (*cirri*) or that a swimmer might swallow a copepod in a mouthful of water?

- 3. Determining the distance of that very long cylinder of water filtered by your plankton net can be a nice math lesson.
  - Measuring the distance of a plankton tow is straightforward if you walk the net along a dock or pier; or if you do a vertical tow and know the water's depth.
  - It becomes a bit more challenging when towing the net behind a boat as you need to calculate the boat's speed in meters per minute and record the number of minutes for your tow.

#### Boat Speed....

If you estimate the length of the boat in meters and time how long it takes to pass a floating object in the water (like an apple), you can get a speed in meters/ second which can then be converted to meters per minute.

For a <u>plankton net sitting in a current</u>, deployed from a bridge or dock, you would need to estimate the current's speed by timing a floating object drifting a measured distance. You also need to record the time that the net is in the water.

For example: A plankton net sitting in a current traveling at about 0.5 meters/sec., filters a cylinder of water (with the diameter of your net opening) that is 30 meters long for every minute that the net is in the water.



### **Answers to Seasonal Upwelling Questions**

- 1. During what time period during the year is deep water upwelling and mixing with surface water? Fall through Winter
- 2. What do you observe in the density data that indicates this mixing. *The density of the surface water is the same as the density of the deeper water.*
- 3. From the temperature data explain why mixing of deep water and surface water is occurring at this time. During the fall and winter, the surface water becomes colder and becomes more dense and sinks. This displaces the bottom water, bringing it to the surface. This process or upwelling mixes the surface water and deep water.
- 4. This map shows phytoplankton in the Gulf of Maine for the month of August 2007. How does it compare to the phytoplankton map from April? (p.10) *There's less plankton than in April*.
- 5. What happens to the temperature of the surface vs. deep water during the summer? Is there mixing of the surface and deep water or are there layers? *There are layers*.

Explain how this would happen. The surface water becomes heated in the summer, making it less dense than deeper water. This forms a warm layer of water on top of the colder deeper water. We can see this in the graphs as the density of the surface water is much less than that of the colder deeper water during the summer.

6. What do you suppose has happened to the nutrient levels in the surface waters during the summer months? *They've been used up*.

Is there upwelling at this time? No

Explain Warm water rests on top of the colder deeper water and there is no mixing of the two layers.

- 7. What must happen in order to start the process of upwelling once again? *Colder temperatures of fall and winter need to chill the surface water.*
- 8. This map shows another phytoplankton bloom in October of 2007 in the Gulf of Maine. How might we explain this one last bloom of phytoplankton before the approaching winter? Surface water is cooling and sinking as the air temperature gets cooler. This causes upwelling and brings nutrient to the surface waters. Also there is still a lot of sunlight available for photosynthesis and phytoplankton can multiply.



### Answers to: How Much Plankton is in a Cubic Meter of the Sea?

### **Answer Key to Sample Problems**

#### Problem 1:

Distance of net tow = Boat speed x minutes towed

(Speed = 5m/3 sec or 100 m per minute)

Distance of net tow = 100m per min. x 5 min. = 500 meters

Volume of Water Filtered by Net in Cubic Meters ... (radius of net = 0.25 m)

V = area of net opening x distance it was towed

 $V = \pi \times r^2 \times distance of tow$ 

 $V = 3.14 \times 0.25 \text{ m} \times 0.25 \text{ m} \times 500 \text{ m}$ 

V = 98 cubic meters of water filtered

Biomass of copepods per cubic meter.

78.8 grams  $\div$  98 cubic meters =  $0.8 \text{ g} / \text{m}^2$  (or 0.8 mg per liter)

#### Problem 2:

Volume of Water Filtered by Net in Cubic Meters ... (radius of net = 0.25 m)

V =area of net opening x distance it was towed

 $V = \pi \times r^2 \times distance of tow$ 

 $V = 3.14 \times 0.15 \text{ m} \times 0.15 \text{ m} \times 50 \text{ m}$ 

V = 3.53 cubic meters of water filtered

Number of copepods per cubic meter.

 $14860 \div 3.53$  cubic meters = 4210 copepods /  $m^3$  (or about 4 copepods per liter)