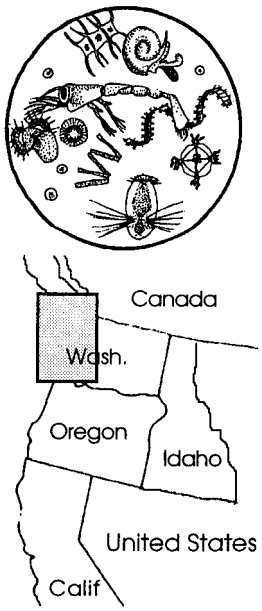
Plankton - A Case Study

Key Concepts

1. Northern waters support enormous plankton growth and sea life in summer, largely as a result of extended hours of daylight.

2. Nutrients, vital to plankton growth, are brought to the surface water by differences in water density, by tidal currents, by freshwater runoff from land, and by wind mixing.

3. Cycles of plankton bloom and demise play a role in the timing of migration and in the abundance of many marine animals.



Background

All of the life in the sea is interrelated through the plankton. Plankton are the basis of all life in the sea in the sense that all other animals depend either directly or indirectly on plankton for the nutrients they require to live.

Northern waters produce enormous amounts of food and sea life in summer. The long summer days in the arctic contribute to the presence of tremendous populations of phytoplankton. Phytoplankton blooms, in turn, support rapid growth of zooplankton and, eventually, growth in the organisms that feed on zooplankton, and so on up the food chain. As the rapidly growing phytoplankton locally depletes the nutrients in the water, the phytoplankton population "crashes", rapidly decreasing in size. In the arctic, as elsewhere, fluctuations in phytoplankton growth are mirrored by fluctuations in zooplankton and other animals.

Much research on plankton population dynamics has occurred in Washington's Puget Sound, one of the Pacific coastal regions where conditions for plankton growth are ideal. Researchers have found that there are four major paths which bring nutrients to the surface waters of Puget Sound are:

a. freshwater runoff from land

b. mixing deep water ocean nutrients by outflow of surface waters and inflow of deep Pacific Ocean waters

c. upwelling by tidal currents

d. wind mixing

It appears from these and other studies, that the interplay between sunlight and nutrient availability is critical in determining the magnitude and duration of plankton "blooms" and "busts".

For more information about plankton studies see the previous activity, "Observing Living Plankton" or any of the following:

Eddy II, John. "Plankton: the basis of life in the sea", The Seattle Aquarium Journal, September/October 1977, Vol. 1, No. 1.

Oxenhorn, Harvey. 1990. Tuning the Rig, a Journey to the Arctic. Harper and Row, New York.

Strickland, Richard M. 1983. The Fertile Fjord, Plankton in Puget Sound. University of Washington Press, Seattle, WA.

Materials

For each student

- "Plankton - A Case Study" student activity sheets

For each group of 3 or 4 students

- 2 beakers or clear jars
- tap water
- food coloring
- salt
- tablespoons
- stir sticks

Teaching Hints

"Plankton - A Case Study" provides your students with a look at the factors which contribute to the abundance of plankton by focusing on a particular location, the Puget Sound, as a microcosm of the world ocean.

This activity is best completed by individual students as a homework or in-class assignment. Provide time for a discussion during which you elicit answers for the study questions.

If you are using the "Voyage of Mimi" in conjunction with this curriculum, "Episode 11: The Feast" correlates with this lesson.

Key Words

bloom - in this case, very rapid growth of phytoplankton due to favorable conditions of light and nutrients

food chain - outline of who eats whom showing path of energy transfer in an ecological community

phytoplankton - plant plankton; the primary producers of the sea

plankton - the mostly microscopic plants and animals that drift in water; singular = plankter

upwelling - the process by which warm, less-dense surface water is drawn away from a shore by offshore currents and replaced by cold, denser water brought up from subsurface

zooplankton - animal plankton

Extensions

1. Make a model of a watershed that drains to an estuary. Have the estuary flow to an oceanic basin. Show how nutrients flow and mix in the water.

2. Make a post card from a gray whale who stops to feed along the migration route. Draw it on a 5" x 8" unlined index card. Show “a good place to eat” or “fun things to do” or “spectacular sights to see” on your trip to the feeding grounds. On the back of the card, write a descriptive note and address it to another gray whale.

3. Find out what kinds of pollution flows through watersheds into salt water along the migration route. Make a plan to improve the water quality in your watershed to help preserve whale habitat.

4. Visit an estuary. Observe how fresh water brings nutrients from the land and sea. Observe a food chain you find there.

5. Look at a map of your watershed. Trace the path of water that flows from your school to the ocean. Look for tributaries that unite into rivers that flow to the ocean. If you have a wall mural of the gray whale’s migration route and if your watershed connects to the route, draw the nutrient path from your watershed to the Pacific Ocean on the mural. Remember that some water flows in aquifers underground, too.

6. List the ways people affect the food chain from their watersheds and shorelines.

Answer Key

1. The two types of plankton mentioned are phytoplankton (plant plankton) and zooplankton (animal plankton).

2. Phytoplankton require sunlight and nutrients for survival.

3. One would expect to find more fish in areas of high plankton counts because the fish depend either directly or indirectly upon the plankton for their food.

4. Freshwater runoff adds nutrients that the streams and rivers have eroded from the land. These nutrients benefit the plankton populations.

5. The inflow of deep ocean waters helps replenish the nutrients the growing phytoplankton strip from the surface water. The water flowing out at the surface and in at depth make Puget Sound a nutrient trap.

6.a. While the answer depends upon the care with which the experiment is performed, generally the colored, salty water will form a distinct layer at the bottom of the jar.

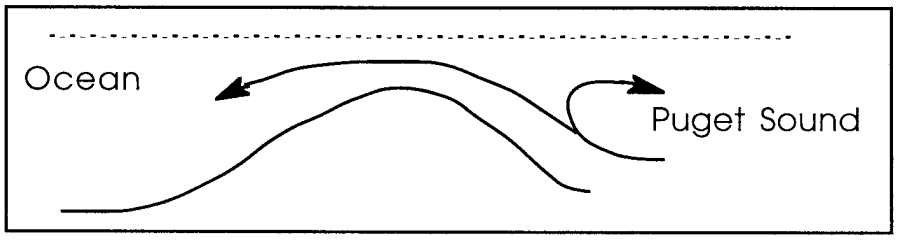
b. The colored salt water is more dense than the clear freshwater.

c. The fact that the salty, colored water sank when slowly added to the clear freshwater is evidence that the colored salt water is more dense than the clear freshwater.

d. The colored salt water represents the nutrient-rich deeper waters.

e. The clear freshwater represents the surface waters.

7. Diagrams will vary but, in general, the diagram should show a tidal current moving over a sill. An arrow should show deep water moving up to get over the sill but since not all of it can flow over the sill, some of the water will return to the basin. This is best shown by a circular arrow showing the nutrient-rich deep water circulating back into the basin. A sample diagram is shown below:



8. Since the zooplankton eat the phytoplankton, the phytoplankton must increase first to provide food to enable the zooplankton to increase. The population growth curves for the phytoplankton and the zooplankton are very similar in shape but they are slightly out of phase. First comes the food, then comes the feeder.

9. The four major paths which bring nutrients to the surface waters of Puget Sound are:
   a. freshwater runoff from land
   b. mixing deep water ocean nutrients by outflow of surface waters and inflow of deep Pacific Ocean waters
   c. upwelling by tidal currents
   d. wind mixing

10. b. A completed food chain follows:

sun → phytoplankton → zooplankton → herring → salmon → orca whale

   c. A completed food chain follows:

sun → phytoplankton → zooplankton → ghost shrimp → gray whale

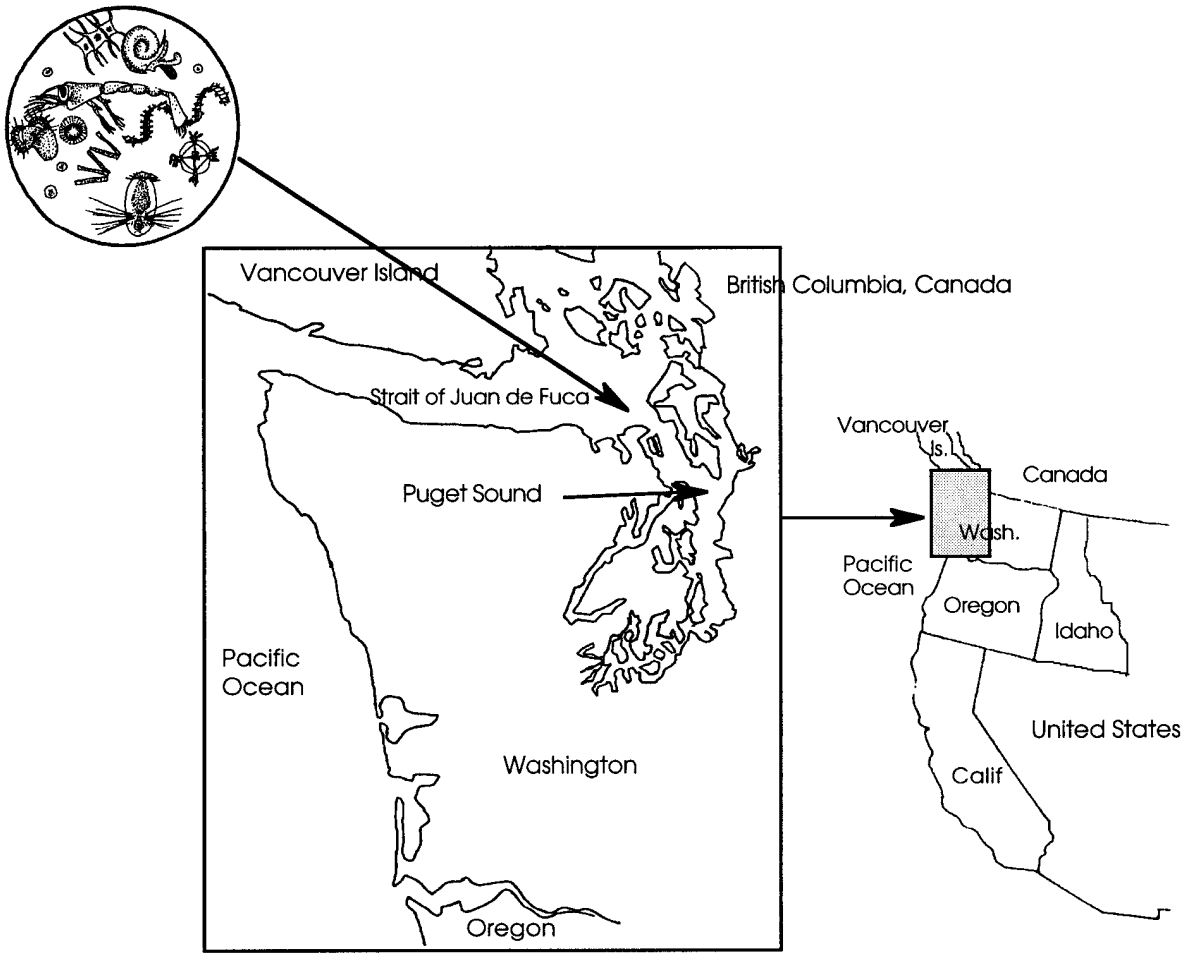
11. Plankton are the basis of all life in the sea in the sense that all other animals depend either directly or indirectly on plankton for the nutrients they require to live. This answer reflects the central concept of this activity: All of the life in the sea is interrelated through the plankton.

12. This question challenges students reasoning skills. The key to one of the two factors that contribute to plankton growth in the arctic is found in the word “summer”. Longer days of summer provide increased sunlight which is vital to plankton growth. Longer days mean more sunlight which grows more plankton. The second contributing factor is nutrient availability.

13. The timing of the gray whale’s southern migration is signaled by the decline in plankton numbers as the bloom period ends with shortened day length. Their northern migration is such that they arrive in the arctic after phytoplankton blooms have started. How these events in the arctic could directly affect the northern migration is unclear. Since the plankton blooms are followed by an increase in many types of sea life, a great amount of food is available in the arctic in summer. Although the exact trigger is unclear, migration to where the food is most plentiful clearly could have a selective advantage. In discussion, you may explore questions concerning migration with your students as it relates to migrating animals

who move through less hospitable areas to more hospitable areas for feeding and breeding - what was the advantage to the first gray whale to leave either the arctic or the lagoons to head across 7,000 miles of uncharted sea for the other?

Plankton - A Case Study

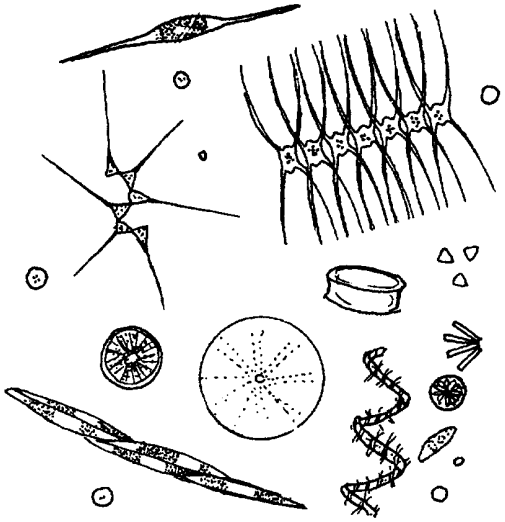


Northern waters produce enormous amounts of food and sea life in summer. Is there a single reason which explains the abundance of life? If one had to choose a single reason, it would be the presence of tremendous populations of plankton. Plankton is the basis of marine life the world over. The long summer days in the arctic contribute to the large number of plankton. We don't know all the other contributing factors. The arctic ocean is complex. Perhaps we can learn something about plankton growth by looking at a smaller body of water.

The Puget Sound is one of the Pacific coastal regions where conditions for plankton are ideal. Washington's Puget Sound is the home for a remarkable assortment of marine life.

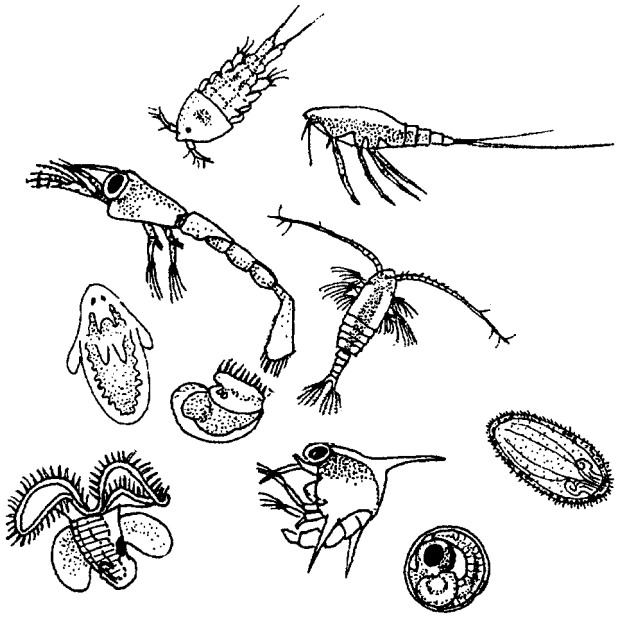
Most plankton are microscopic plants and animals that drift along at the mercy of currents. Plant plankton are called phytoplankton. Like land plants, the tiny phytoplankton need sunlight and nutrients to survive. (Nutrients are minerals and other chemicals that are a plant's "food".) Summer days are long

in the Puget Sound. Even so, sunlight does not penetrate very deeply into the water. To capture sunlight, phytoplankton must live near the surface.



Phytoplankton
.001 mm to 0.1 mm

Animal plankton are called zooplankton. For the most part, they require phytoplankton for food. The zooplankton depend upon the phytoplankton. Remember, phytoplankton live near the surface because they need sunlight and nutrients. Since phytoplankton live near the surface, zooplankton need to live there, also.



Zooplankton
0.5 mm to 20 mm

1. What are the two types of plankton?

2. What do phytoplankton require for survival?

The Puget Sound is a storehouse of nutrients. Phytoplankton use the foods and minerals from near the water surface. These nutrients enable the phytoplankton to grow, and live. As the plankton eat, are eaten, and die, they slowly sink. As they sink, their nutrients are carried to deeper waters. Nutrients in the dark, deep waters are of little use to plankton. (They are, however, of use to the detritus feeders which are food for gray whales. But, that's another story.)

In most of the world's oceans, the nutrients never return to the surface waters. Without these nutrients the waters have little life. In the Puget Sound these nutrients are being constantly returned to the sunlit surface waters.

3. As skipper of the **Margaret D.**, you are searching for herring. Herring are small fish that are eaten by larger fish and some whales. You are using your plankton net to capture plankton. You count the number of plankton in the water. Would you expect to find more fish in areas of high plankton counts or low counts? Explain your reasoning.

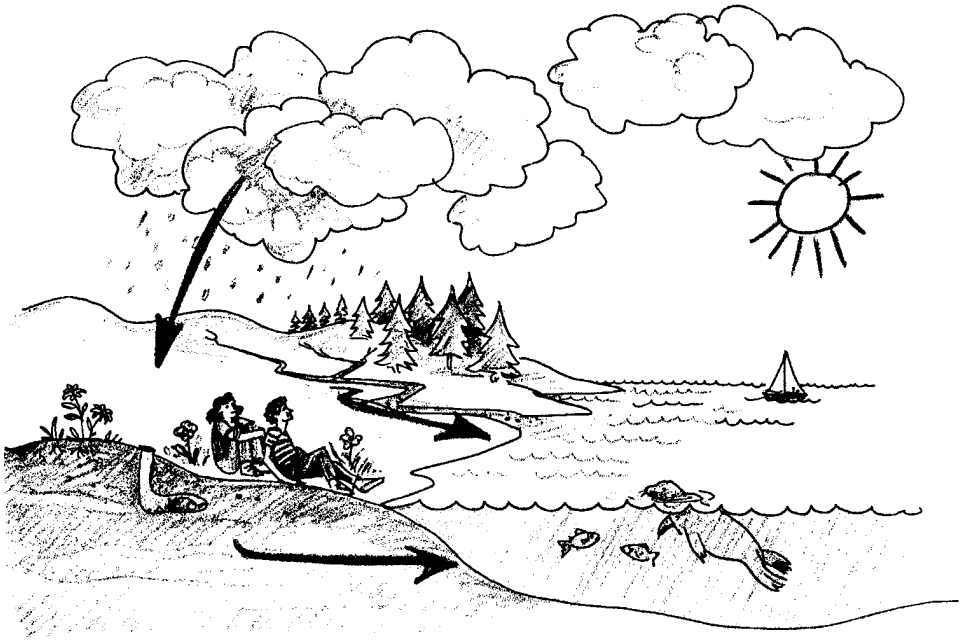
Four Major Nutrient Paths

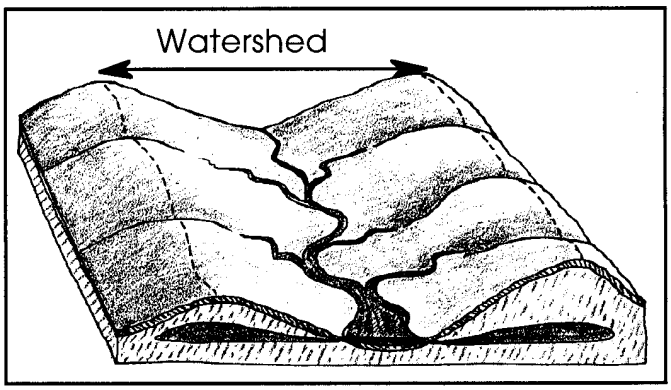
In the Puget Sound, four major paths bring nutrients to the surface water.

Path 1 - Freshwater runoff from land

One major path of nutrients is in freshwater runoff. Freshwater runoff is what we call the water that drains from land. Rain and snow fall on the land surrounding the Sound. Streams and rivers drain the land between higher ridges. The ridges form the boundaries of the area from which the rain and snow "sheds" and flows to the sea. All the land that drains into the Sound is called the "Puget Sound watershed".

The water from precipitation (rain and snow) in the watershed eventually flows into the Puget Sound. Along the way it collects decaying plants and animals. The water also gathers minerals from rocks as it erodes riverbeds. The decaying materials and minerals become nutrients, or food, for plankton.



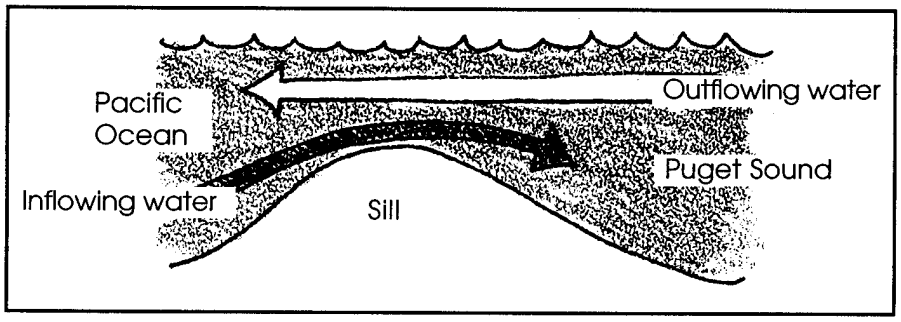


The watershed drains nearly 11,000 square miles of land area into Puget Sound's 1000 square miles of surface area. Compare this 11 to 1 ratio with the Baltic Sea's 4 to 1 or the Great Lake's 2 to 1 ratio. If Puget Sound were drained completely, it would take less than four years to refill it with freshwater runoff from its watershed! Other bodies of water might take over a hundred years. All of this freshwater flowing into the Sound carries nutrients that the streams and rivers have gathered or eroded from the land.

4. How does freshwater runoff add nutrients for Puget Sound plankton?

Path 2 - Mixing Deep Water Ocean Nutrients

A second source of nutrients in Puget Sound is the nutrient-rich deep waters of the Pacific Ocean. Freshwater is less dense than saltwater. This means that fresh water will float on top of saltwater. In estuaries, freshwater runoff from rivers and streams mixes with the Sound's surface waters. These mixed waters are lighter than the layers of saltier water below. This lighter surface layer gradually flows out of Puget Sound and into the Pacific Ocean. This outflowing surface water is constantly replaced by the inflow of nutrient-rich deeper waters from the Pacific Ocean. In the Puget Sound, water flows out at the surface and in at depth.



Nutrients Trapped in Puget Sound

Plankton in the Sound use nutrients from the surface water flowing out. As oceanic plankton die and sink, they pass their nutrients to deeper oceanic waters. These nutrient-rich deep oceanic waters are the waters pulled into the Sound. The plankton in the Sound can also use these oceanic nutrients for growth. The bottom of Puget Sound has several ridges or "sills". The sills act like a wall to keep water in the Sound. The flow pattern and sills let Puget Sound trap nutrients. The trapped nutrients are just what is needed for lots of plankton growth.

5. How does the inflow of deep ocean waters help explain the large numbers of plankton in Puget Sound?

6. The nutrient-rich deeper waters and the surface waters have different densities. Try the following experiment to see what this means.

Here's what you'll need:

- 2 beakers or jars, half full of tap water
- food coloring
- salt
- tablespoon
- stir stick

Here's what to do:

Obtain two beakers or jars half full of tap water.

Add three drops of food coloring and three tablespoons of salt to one of the jars.

Stir the water until the salt dissolves.

Now very slowly pour the colored, salty water down the inside wall of the other jar.

a. What happens?

b. Which water is more dense: salt water or fresh water? (Circle one.)

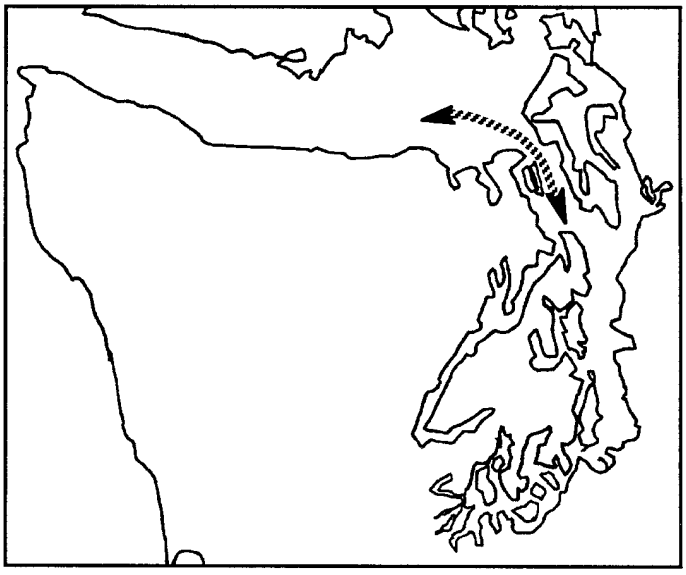
c. How can you tell?

d. Which water represents the nutrient-rich deeper waters?

e. Which water represents the surface waters?

Path 3 - Upwelling by Tidal Currents

The third path bringing nutrients to the plankton is driven by tidal currents. We've seen that Puget Sound waters move due to different densities. The tides also move Puget Sound waters twice a day. These tides cause tidal currents. The arrows in the drawing below show water moving into and out of the Sound.

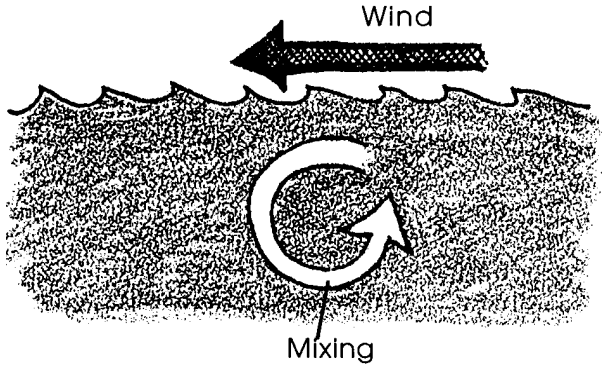


Islands, undersea mountains, canyons, and basins direct the flow of currents. As the currents rush from deep basins up through narrow, shallow passages, nutrient-rich deep water is carried to the surface.

7. Draw a diagram that shows tidal currents causing nutrient-rich water to rise to the surface.

Path 4 - Wind Mixing

The fourth path that carries nutrients to the water surface is wind mixing. In early fall, wind storms alternate with warm sunny weather. The wind produces waves. The waves cause enough mixing to bring nutrients to the surface.



In early fall, the water temperatures are still warm and the days are long. The phytoplankton begin reproducing by dividing furiously until the population explodes. The zooplankton suddenly have lots to eat. Their population also explodes. These population explosions are called blooms.

The blooms continue until the phytoplankton have stripped the nutrients from the surface waters. With no nutrients, most of the phytoplankton die. With no phytoplankton many zooplankton also die.

8. Scientists have noticed that the increase in zooplankton occurs **after** the increase in phytoplankton. How does the diet of these animals explain the observation made by scientists?

9. What four paths bring nutrients to the surface waters of Puget Sound?

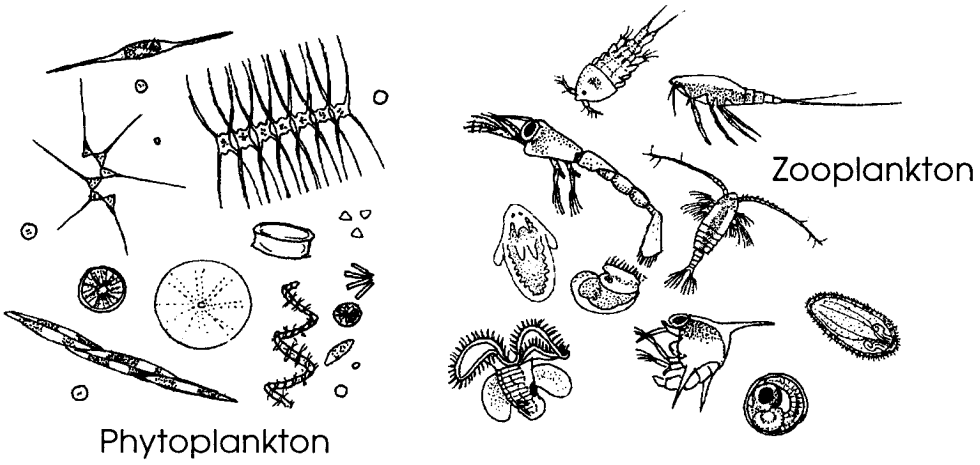
   a.

   b.

   c.

   d.

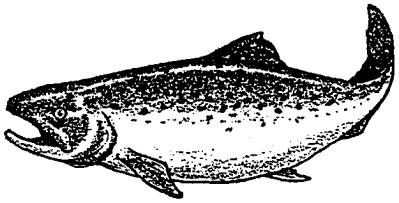
It's a Whale of a Food Chain



How does this tremendous population of microscopic plants and animals affect the lives of animals we can see?

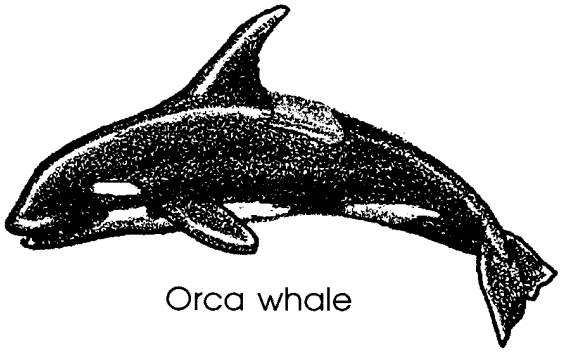

Herring

Herring are slender, silvery fish. Herring eat plankton. Large numbers of plankton mean large numbers of herring.



Salmon

Salmon eat herring. Large numbers of herring mean large numbers of salmon.



Orca whale

Salmon are eaten by orcas whales. Large numbers of salmon mean large numbers of orcas.

So, one of the most impressive animals, the orca, depends upon the microscopic plankton. All life is tied together through these feeding relationships. Plankton are the basis of life in the sea.

10. A description of who eats whom is called a food chain. Food chains are easy to draw:

    a. Start with the sun nourishing phytoplankton.

    b. Connect the eaten with the eater. Do this by drawing an arrow pointing from the eaten to the eater. For example:

    sun → phytoplankton → zooplankton

    The arrows show where the nutrients go.

    c. In the space below make a food chain from the sun to the orca whale.

d. Gray whales have been observed in Puget Sound in 12 feet of water at high tide. They are eating Ghost Shrimp that live in the mud and sand. From each mouthful, the gray whale strains 11 pounds of shrimp. Ghost Shrimp eat zooplankton.

In the space below make a food chain from the sun to the gray whale.

11. What does it mean when we say that plankton are the basis of all life in the sea?

Meanwhile, back in the Arctic...

Nutrients and long day length in the arctic have also caused plankton blooms. With the shorter days of early fall, the sun provides less energy for plankton growth. Phytoplankton die. With less plankton in the water, animals die or migrate in search of food. Gray whales stop feeding and migrate south where they will breed and bear their young. Some will feed along the migration route. Most will not eat again until the next summer's plankton blooms produce more sea food in the northern waters.

12. Think about the enormous amount of plankton produced in arctic waters in the summer. What are two things that contribute to this growth?

13. Think about arctic food chains and plankton blooms. How might plankton "blooms" in the arctic waters affect the timing of the gray whales' migration?