Unit 1 Hydrodynamics

On the cutting edge…
Scientists at the University of South Florida's Biology department are on the cutting edge of science studying how water velocity influences the ecology of seagrass communities. They have developed a portable flume system that can be used in natural settings to modify the flow of water and investigate the effects of water velocity and nutrient cycling. Measurements taken with the flume in natural seagrass beds are compared to measurements predicted using simple mathematical models that describe nutrient cycling processes. From the data, scientists are able to determine the efficiency with which seagrass communities remove nutrients from the water column. In addition, models developed from the data will assist in understanding the effects of nutrient loading on the marine and estuarine environment.

Introduction to Seagrasses

Lesson Objectives: Students will be able to do the following:
- Describe a seagrass community
- List three ways seagrass beds are important
- Analyze two reasons for loss of seagrass bed habitat

Key concepts: ecosystems, interdependent communities, seagrass beds, rhizomes, water quality

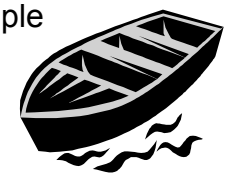
Description of Seagrasses

Ecosystems are composed of living and nonliving components that are interrelated through their energy flow. Our coastlines are characterized by a variety of marine ecosystems. These systems are influenced by oceanographic processes such as **tides**, **waves**, and **currents.** They are also ecologically rich environments that include offshore, **continental shelf**, and beach communities. Within the continental shelf community, we will be exploring the seagrass beds.

Seagrasses are flowering plants that live completely submerged in water. They are similar to **terrestrial** grasses found on land. These plant **producers** are generally located in shallow waters, because they need sunlight to **photosynthesize**. In addition, they utilize **nutrients** from the bottom **sediment** and water column to produce energy. This process also creates oxygen as a byproduct. They reproduce from seeds or send out new plants from

their **rhizomes** or underground stems. (More information on this subject is available in our Spring 1999 Problems and Solutions packet.)

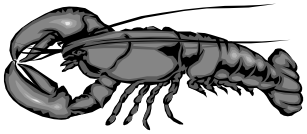
Seagrass beds can be sparsely populated, patchy areas or lush, dense, and green areas. This difference in density depends on the water depth and quality and bottom conditions. Sparsely populated beds can be found in recently colonized areas or areas where the bottom sediment is disturbed. Boat motor propellers are an example of a disturbing force in seagrass beds.



Scarring caused by propellers can injure or destroy the seagrasses. Lush seagrass meadows are found in areas with good water clarity and few disturbance factors. These areas may take decades to grow. Water temperature, sunlight intensity and quality, and water **pollution** are important factors in controlling growth and reproductive rates in seagrasses.

Importance of Seagrass Beds

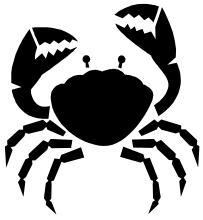
Seagrass beds are **interdependent** communities. They are linked to their surrounding systems by moving water. Water flowing into the system may bring nutrients to nourish it.



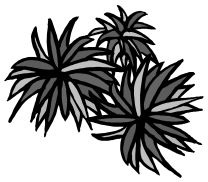
Water flowing out of the system can wash away waste products and pollutants. Animals moving through the seagrass beds add another dimension to this community. Seagrass beds provide food, **habitat**, and protection for many organisms. Their plants also act as sediment stabilizers and influence water quality.

The seagrass beds provide food both directly and indirectly for members of the community. Some animals such as manatees and sea turtles eat seagrass blades or leaves. Other animals eat **algae** and smaller **epiphytic** organisms that live on the leaves of the seagrasses. This microcommunity of **colonial** organisms increases the number of links in many of the **food chains**. These links provide a greater amount of energy flow through the system. This in turn creates a more productive ecosystem. In addition, seagrasses constantly produce new leaves while shedding old ones that become **detritus**. This detritus or dead and decaying plant material is recycled and used as food or fertilizer for the sediment.

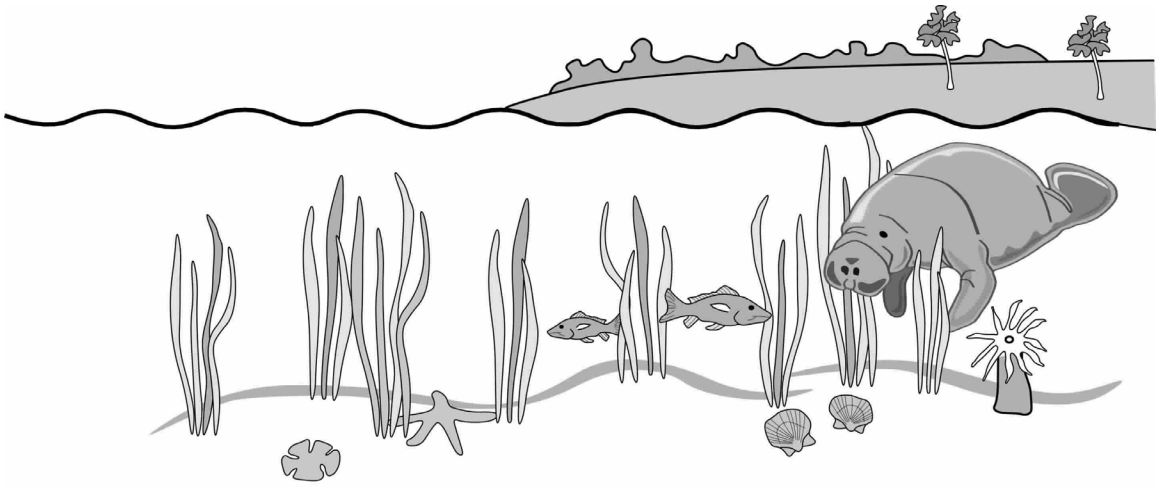
Seagrass beds are home to many **vertebrate** and **invertebrate** organisms such as snook, crabs, and shrimp. They act as nursery areas for commercially and recreationally important species including **crustaceans**, fish, and **shellfish**. Some animals spend part of their life cycle in the seagrass beds and then **migrate** to other environments as



adults. For instance, the lobster begins its life in the seagrass bed and migrates to the coral reef as an adult. Seagrass beds also protect juveniles that hide among the seagrasses **camouflaged** from larger open water **predators**.



In addition, the grasses themselves help maintain the environment in which they live. They influence the water quality and the bottom **topography** as they grow. The root systems of the grasses and their rhizomes hold the bottom sediment in place preventing **erosion** just like land plants. The seagrasses can increase water **clarity** by trapping fine sediments and other particles in their leaves. Sometimes the finer particles become resuspended in the water column as waves, wind, and currents cause water mixing. When this happens, less light is available for photosynthesis. The seagrasses also play an important role in maintaining the water quality of the neighboring **benthic** communities by altering flow rates. Nutrients in the water may be trapped in areas with high plant concentrations providing organisms with food. Pollutants may be incorporated into the plant **biomass** and removed from the water. In effect, these seagrasses act as miniature wastewater treatment plants.

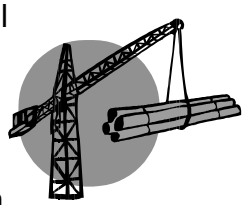


Seagrass Community

Loss of Seagrass Beds

Habitat change and loss in Florida have been studied over the past sixty years using aerial photography and satellite imagery. **Estuaries**, in which seagrass beds are found, are one of the major areas being impacted by environmental changes. Seagrass beds are being lost due to disease, alteration in natural water flow patterns, and degradation of

water quality. As development takes place, fragile upstream ecosystems are impacted. This impact causes a change in the natural flow patterns, cycling processes, and chemical composition of the water in downstream environments. This change in flow and timing interrupts the natural life cycles of many creatures including fish that are caught commercially. By interrupting this cycle, some of the fish species are being reduced at alarming rates. Too little or too much water also affects food available to various species. The change in water quality is most critical for aquatic inhabitants including those found in the seagrass beds. Changes in temperature, nutrient availability, oxygen content, and salinity can severely degrade seagrass communities. For example, repeated water diversion may increase the salinity of water found in marine environments. Salinity levels normally ranging up to 15 parts per thousand could exceed 50 parts per thousand. Animals unable to adjust to these higher salt concentrations could die or be forced to migrate to new areas. This could upset the ecological balance within seagrass communities and neighboring ones



Activity: Ecosystems for All

Our world contains many interrelated natural communities. These communities contain both living and nonliving parts. All the parts of these communities are connected together to form a system. These natural systems or ecosystems provide energy for the living components.

Objectives: Students will be able to do the following:
1. Identify an ecosystem.
2. Describe the components of an ecosystem.
3. Analyze the components of a successful ecosystem.

Materials:
- Items necessary to create ecosystem stations (Suggestions include: glass of water, sponge containing germinated seeds**,** moldy bread**,** aquarium with fish**,** soil**,** empty container, etc.)
- Labels for each station (Number or letter the stations, so students will be able to follow a sequence to visit each station.)
- Paper
- Pencil

Prior Set-up:
Before class, create stations with collected items. Be sure some stations represent ecosystems and others do not. Label each station with a letter or number.

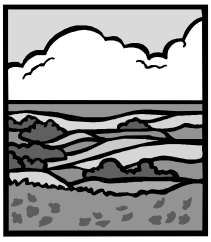
Procedure:
1. Discuss characteristics that all ecosystems have in common.
2. Brainstorm with students about the interconnectedness of the biological and physical components in an ecosystem. List ideas of needs that must be met by living organisms within their environment.
3. Tell students that they will become scientific investigators as they travel from station to station identifying ecosystems and answering questions about them.
4. Make a list of questions that students need to answer at each station. Include the following:
   Does this station contain an ecosystem?
   If the answer is no, explain what is missing.
   If the answer is yes, explain how each need is met within this ecosystem.
5. Divide students into groups. Have each group choose a station. (This activity may also be completed individually.)
6. Give students time at each station to observe and record their answers.
7. Have students rotate sequentially through the stations.
8. After students have visited all the stations, discuss their observations and answers. Discussion could include the importance of biotic and abiotic factors

in an ecosystem, identification of the producers and consumers in the ecosystem, or ecological energy flow through the ecosystem.

Possible Extensions:

1. Have students go outside and identify ecosystems. Discuss the idea of size with relation to an ecosystem.
2. Have students create ecosystems. These could be created according to particular criteria such as woodland ecosystems or marine ecosystems.
3. Research various types of ecosystems such as pond ecosystems and rocky shores. Have students explain the importance of each component of the ecosystem.

Student Information: Seagrass Beds



Natural **communities** include a wide variety of organisms. These organisms and the nonliving parts of their environments form **ecosystems**. Along our coastal areas we find aquatic ecosystems. These areas change frequently as water flows through them. This water can nourish the aquatic ecosystem bringing food and oxygen to the organisms that live there. In some instances, this water can poison the ecosystem, as it transports **pollution** in the form of chemicals or discarded rubbish. This pollution can harm or kill the organisms that live in this environment. The seagrass beds are one of these aquatic transition communities.

Seagrass beds are similar to meadows or fields that we find on land. They are shallow, near shore, water environments. The seagrasses are the producers. These flowering underwater plants make energy through **photosynthesis**. They provide food, homes, and protection for animals. Seagrass beds and the communities they form act as filters, removing **nutrients** and **sediment** from the water column. The seagrass plants also use their root systems as anchors to help stabilize the ocean floor.

Over time, humans built in areas that were affected by water flow. We destroyed many natural drainage areas and changed water flow patterns. This has caused flooding in areas that have never flooded before. It has also changed the water levels in the ecosystems downstream. Animals that live in these areas can no longer tolerate the conditions. We have destroyed some of the seagrass beds by altering the environments upstream. Because we have changed drainage patterns and water quality, we have upset the delicate balance found in nature. As we learn more about these environments, perhaps we can learn to appreciate and protect these natural systems rather than destroy what is so vitally important to our survival.

Fun with Flumes

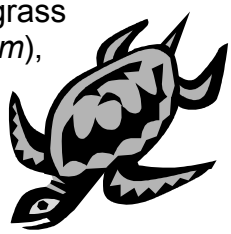
Lesson Objectives: Students will be able to do the following:

- Name the three main grasses found in Florida seagrass beds
- Describe tidal action
- Describe how a flow lab works and what it measures

Key Concepts: diurnal tide, semi-diurnal tide, tidal current, flow rate, boundary layer, no slip condition, viscosity, turbulence

Florida Seagrasses

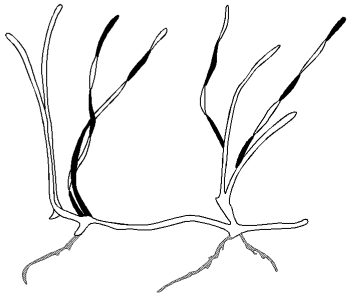
Florida **seagrass** beds are found from the northern peninsula to the Florida Keys National Marine Sanctuary. The beds found in the northern areas such as Apalachicola and St. Joseph Bay have hard bottoms constructed of **calcium carbonate**. Those in the southern Keys are formed on softer sand bottoms. This bottom **topography** and composition has a direct effect on the types and density of seagrasses found in these areas. Although there are over fifty species of seagrasses found worldwide only seven species are found in Florida. The three species of seagrasses found most often in Florida seagrass beds include: turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*).



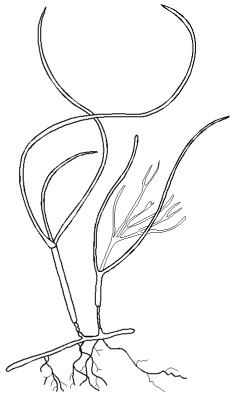
Turtle grass is the most common species found in Florida. This grass is the largest of the Florida species and is characterized by wide flat leaves with rounded tips. It has the deepest root structure of all the Florida species with **rhizomes** and roots extending five feet into the **sediment**. The rhizomes or underground stems help to hold the grasses in the sediment. This grass is also the most susceptible to stress. It takes a long time to recover from prop scarring due to its slow branching and vertical growth. Shoal grass tolerates extremes in environmental conditions such as changes in salinity. This grass, identified by its flat blades ending in forked tips, is usually the first grass to colonize a disturbed area. It can grow in shallow water that leaves it exposed to the air at low tide. It recovers more quickly from prop scars, because its rhizomes are shallower and carry more nodes or areas where branching can take place. Manatee grass is distinguished by its cylindrical, wiry leaves. This plant can tolerate strong **currents** and can be found mixed

with turtle grass in areas not exposed at low tide. The flow of water is greatly affected by the seagrass plants and other members of the community as water flows over and through the canopy. The characteristics of water flow in turn influences the ecology of the seagrass community, including the transport of **nutrients** and larval organisms.

Thalassia testudinum
Turtle-grass



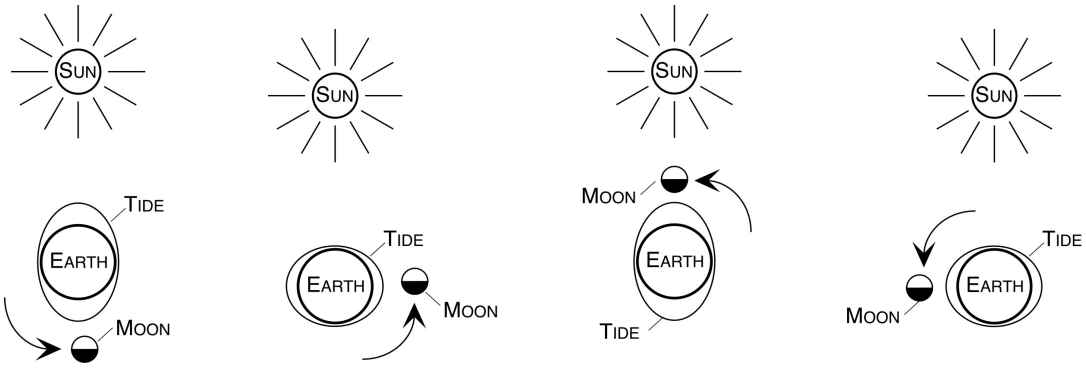
Halodule wrightii
Shoal-grass



Syringodium filiforme
Manatee-grass

Tidal Flow

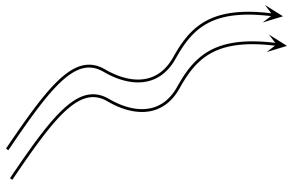
Water flow through a seagrass bed community is due to tidal action and **wave** action. **Tides** are the slow periodic rise and fall of the surface level of **bays**, **gulfs**, **inlets**, and **estuaries**. Tides can be described as **diurnal** or **semi-diurnal**. Diurnal tides have one high water level and one low water level every lunar day or about 24.8 hours. Semi-diurnal tides have two highs and two lows in a lunar day. For instance, in the Florida Keys, the tides are semi-diurnal completely changing direction every six hours. This vertical change in the level of the sea surface is caused by the gravitational pull of the sun and moon on the rotating earth. The position of these three celestial bodies in relation to each other is what causes the variations in the tidal ranges. As the water level rises and falls, a horizontal flow of water is created.

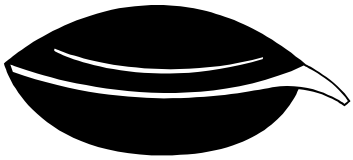


This horizontal flow is called a **tidal current**. This tidal current washes new water through the seagrass system providing nutrients and carrying with it pollutants. As the current flows away from the coast an **ebb curren**t is created. When the water reverses direction and moves toward the coast a **flood current** occurs. Waves also cause water to flow through the seagrass beds. The waves are primarily caused as wind moves over the water. The **friction** between the water surface and the moving air creates ridges of water. These waves sometimes enhance or change the direction of the water flow. For instance, in St. Joseph Bay waves and tides affect the flow rate causing a bi-directional flow.

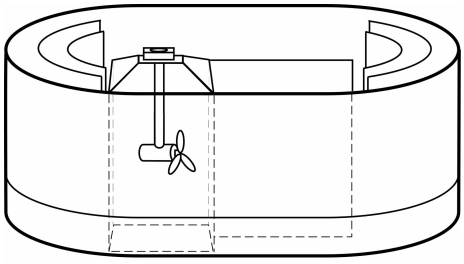
As water moves through the seagrass beds, it comes in contact with the sediment and the canopy. The **velocity** and direction of water flow may change due to the shape and dimension of coastal areas, the composition of bottom sediment, the bottom topography, and the composition and density of the canopy. The canopy includes the plants and the organisms that live around and on the plants.

As we look at water flowing over a surface, we witness the “no slip” condition. This simply means that the layer of water in contact with the bottom does not move. This is the same reason that we see dust on fan blades. If you run the fan and then turn it off, the thin layer of dust still clings to the blades. This no slip condition and the water’s viscosity or how easily it flows causes a boundary layer to develop. Boundary layers form wherever solids come in contact with flowing water. Imagine the water in the system as a layer of playing cards. The card on the bottom, in contact with the sediment, does not move. The cards above the bottom one do move. They move at different speeds and in different directions as they respond to tidal currents, etc. As more organisms are added to the environment, water velocity will change as it moves over, under, and around objects. Nutrients in the system will have to cross boundary layers in order to be utilized by the organisms. As a result of the various movements in the water layers, the water velocity will fluctuate in a horizontal as well as a vertical direction. Fluctuations in water velocity are what create water **turbulence**.



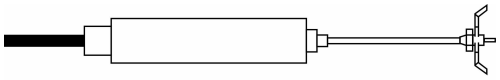


Field Flume



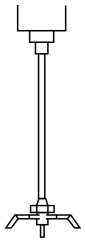
Field Flume

A portable field **flume** (see diagram) sometimes called a “flow” lab can help researchers measure water velocity and boundary layers in the natural environment. Furthermore the effects of water velocity on nutrient cycling in seagrass beds can be investigated. In order to measure the uptake of nutrients by a natural seagrass community, a field flume is used to isolate a section of the bottom from the surrounding water. Nutrient uptake rates for seagrass communities can then be measured over a range of water velocity. Nutrients are added to the flume and an electric motor is used to vary the velocity of water as it flows over the community. The decline in nutrients in the water column is then measured over time as the community is removing the nutrients.



Velocimeter

Researchers can measure flow velocities in the test area using an acoustic doppler **velocimeter** (ADV). The technology demonstrated by an ADV is similar to **echolocation** used by dolphins and whales to locate food. A probe at the tip of the ADV emits rapid pulses of sound. These sound pulses bounce off moving particles in the water and the signals are returned to the probe. The velocity of these moving particles is then determined. The signals are then transmitted through the probe where the information is converted into numerical data in the computer. Scientists can measure the flow rate at various depths in the target area to determine boundary layers and discover how members of the seagrass community affect flow.



Velocimeter Probe

Why are scientists interested in finding out how water flow influences nutrient cycling in seagrass beds? Scientists know that the amount of food or nutrients available for living organisms in aquatic environments is limited by biological and physical factors. If scientists assume that all the nutrients in the system can be used in living processes such as growing or photosynthesizing, then they can study the physical processes that influence the system. Water velocity is one of the major physical processes that scientists study. Using data collected in the field flume, scientists are able to determine how water velocity affects nutrient uptake by seagrass communities. Using data on natural water velocities during tides, they are then able to formulate models that assist in understanding the ecology of seagrass communities.

Activity: No Slipping Allowed

In the seagrass beds, water flows through the system as a result of wind and tidal action. This moving water interacts with the solid surfaces it contacts according to the principles of hydrodynamics. One of these principles states that when a fluid comes in contact with a solid surface the "no slip condition" occurs. This means that the fluid in contact with the surface forms a layer that will not move.

Objectives: Students will be able to demonstrate the "no slip condition" in an artificial environment and make predictions concerning water flow in real environments.

Materials: The following items are needed for each student group.

- Shallow glass container approximately three inches deep (a 9x13 inch white glass container works best)
- Water (enough to fill the container three times)
- Liquid food coloring (one container for each group)
- Eyedropper (one for each group)
- A variety of containers made of various materials such as plastic and metal
- Paper
- Pencil

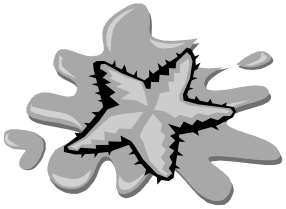
Procedure:

1. Have students divide into groups of three or four.
2. Provide each group with a container, water, eyedropper, and food coloring.
3. Have students fill the container two-thirds full of water.
4. Have students fill the dropper with food coloring and slowly release food coloring into the container by running the coloring down the side of the container. Watch for the dye to adhere to the side of the container. Have students illustrate their results.
5. Have students repeat the procedure with the end of the dropper in contact with the bottom of the container. Watch for the dye to adhere to the bottom. Have students illustrate their results.
6. Have students repeat steps four and five while the water is being stirred with a straw. Compare the results of the two tests.
7. Have students repeat the experiment using containers of various sizes, shapes, and materials.
8. Discuss the results.

Possible Extensions:

1. Have students repeat the experiment using a container that contains sand or other material. Does bottom texture influence the "no slip condition"?

Student Information: Water Velocity



Seagrass beds are dynamic communities. This means that they are constantly changing. One reason they change so frequently is because water flows through them. The water flowing through the seagrass beds is mainly the result of tidal action. **Tides** are the change in the surface level of the ocean. As the earth moves it is influenced by the gravitational pull of the sun and the moon. The relationship between these three bodies determines how much the tide changes. This causes high and low tides. Some places on earth have two high tides and two low tides in one day. Other places have only one high tide and one low tide daily. A horizontal flow of water is created as the water level rises and falls. Think of this as a river of water moving through the ocean. This river of water is called a **tidal current**. This tidal current washes water through the seagrass bed community. When the tide reverses, the water is washed in the other direction.

As water moves through the seagrass bed, it comes in contact with plants and animals. These organisms may stop the water flow in certain places or they may change the water movement. Think of a big boulder sitting in the water. As the current moves toward the boulder, its flow pattern changes, causing the water to move in many directions. This is what happens with every organism that the water contacts. Either the water moves the organism or the organism moves the water. As all this water starts moving about, **turbulence** is created. This water mixing helps some organisms by bringing them food, but may hurt others by injuring them.

Scientists are studying water flow in seagrass communities. They use a specially designed field flume and mathematical models to describe how water flow influences organisms living in seagrass communities. Why do we care? So we can study the effects that certain changes will have on our **food web**, and then we can tell how these changes will affect us.