

SECTION 2: Physical Forces

Lab 5: Tides

Introduction

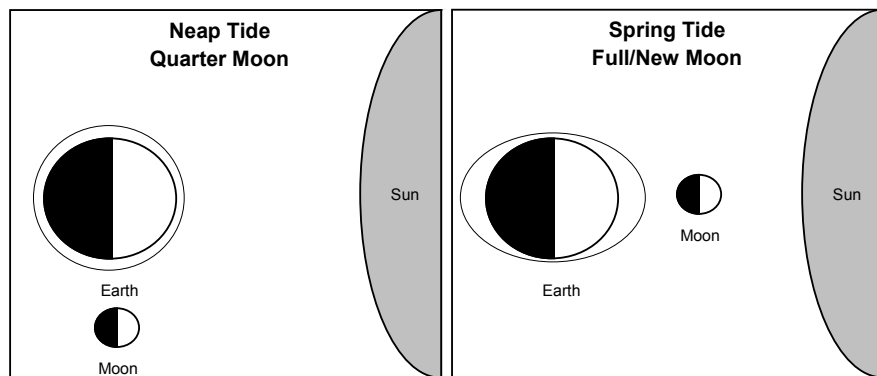
Tides are a major factor affecting life in near shore habitats. The currents created by tides carry food and young animals during critical stages of their life history. Tidal currents carry food to a wide variety of estuarine predators. Some predators follow tidal currents to find prey, while other predators may be sessile and have to rely on the tidal currents to bring the food to them. Tides can carry pollutants and they can also influence where these pollutants settle out in estuaries. Intertidal organisms must adapt to periodic immersion and then exposure according to the tides.

Tides and waves influence the width and shape of barrier islands and the location of inlets. Strong tidal currents can move sediments such as sand and shells and create large flood-tide deltas. Tides also influence salinity levels, presence of oxygen, and temperature in the estuary. Researchers designing near shore studies have to be very aware of the effects of tides on study sites and animals.

What are tides? Tides are the result of a wave created by earth's gravitational forces and the moon pulling on earth. The sun is larger, but the moon is 400 times closer and is, therefore, the stronger force. Although the earth is rotating every 24 hours, the moon is moving as well, orbiting around the earth every 27.5 days. It takes approximately 24 hours and fifty minutes for the moon to circle around earth. The pull which results forces oceans and seas to expand outward, creating a wave that circles the earth every 24 hours and fifty minutes.

Centrifugal force caused by the earth's spinning creates another wave on the opposite side of the earth, equal to the first wave, creating two high tides every 12 hours and 25 minutes. Between these two water bulges or waves are the troughs of the waves that we call low tides. This pattern of two lows and two highs every 24 hours and 50 minutes is called a semi-diurnal tide.

The earth, however, is circling the sun, which is also exerting a smaller, but significant, force on the earth. Twice a month this force is aligned with the moon's gravitational force (full moon) or the centrifugal force on the other side of the earth (new moon). This results in strong tides called spring tides (see graph pg. 23). When the moon and the sun's forces are fighting each other, the result is weaker tides called neap tides (see graph pg. 24).

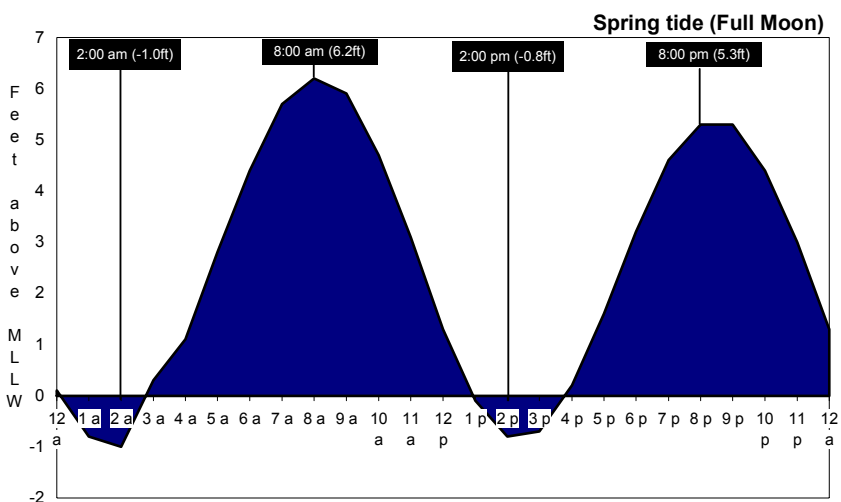


But, wait a minute! Why do some places have only one low and one high tide a day (diurnal tides) and other places have a combination of semi-diurnal tides and diurnal tides throughout the month? Why do tidal heights vary at some locations during the same 24-hour period, or have mixed semi-diurnal tides?

Several important factors complicate the progress of the tidal bulge as it travels around the earth. One factor is that the moon does not circle directly around the earth's equator. Instead the position of the moon changes in relation to the earth's equator. The axis of the earth is tilted 23.5 degrees away from the moon; the orbit of the moon is tilted 5 degrees away from the earth. During the course of each lunar month, the moon's orbit varies by up to 28.5 degrees around the earth's equator. This changes where the gravitational forces are acting and, depending upon the location, can result in mixed semi-diurnal tides or diurnal tides. When the moon is in the tropics (28.5 degrees above the equator) mixed semi-diurnal or diurnal tides tend to dominate.

Another important factor is the shape of the ocean basin, shoreline configuration, or near shore slope. Remember, tides are simply two waves that are circling the world. Because wave depth is less than one-half the wavelength, it is a shallow water wave and feels the bottom, causing friction. As a wave feels this friction from the ocean floor, it can be funneled (creating a larger tide) or spread out further (creating smaller tides).

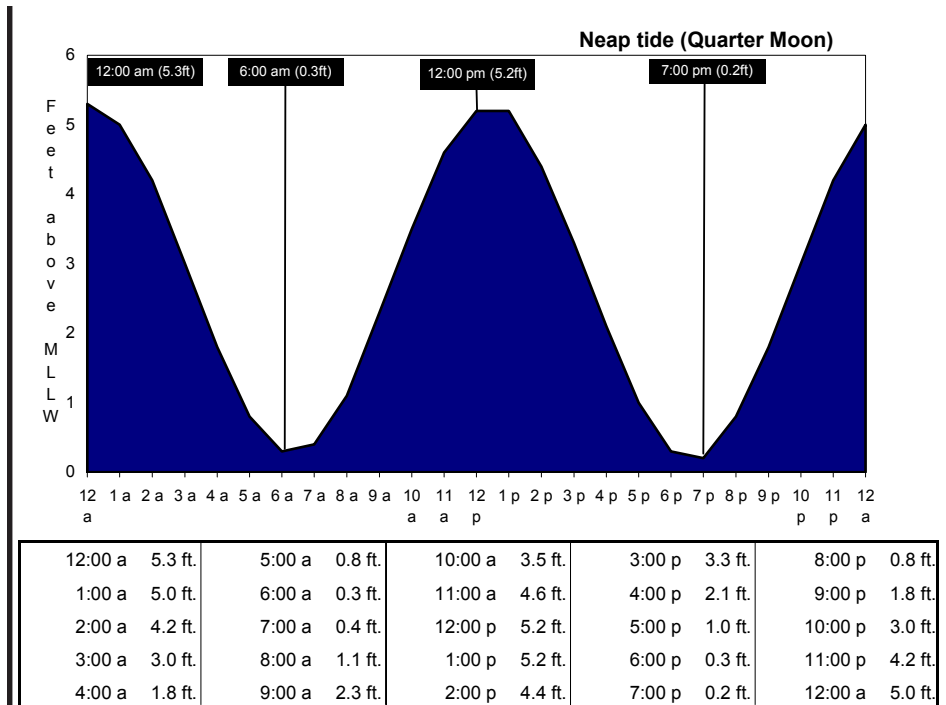
Oceans and gulfs are shaped differently. Waves in enclosed systems such as gulfs or bays tend to form a standing wave called a seiche. The wave rises on one side of the basin and sinks on the other end, then sloshes back to the other side, like a wave in your bathtub. How long it takes this wave to slosh back and forth depends upon the size of the basin. In the Atlantic Ocean this takes 12 hours and 25 minutes, so tides tend to be semi-diurnal. The Gulf of Mexico has a different resonance time and,



12:00 a	0.1 ft.	5:00 a	2.8 ft.	10:00 a	4.7 ft.	3:00 p	-0.7 ft.	8:00 p	5.3 ft.
1:00 a	-0.8 ft.	6:00 a	4.4 ft.	11:00 a	3.1 ft.	4:00 p	0.2 ft.	9:00 p	5.3 ft.
2:00 a	-1.0 ft.	7:00 a	5.7 ft.	12:00 p	1.3 ft.	5:00 p	1.6 ft.	10:00 p	4.4 ft.
3:00 a	0.3 ft.	8:00 a	6.2 ft.	1:00 p	-0.1 ft.	6:00 p	3.2 ft.	11:00 p	3.0 ft.
4:00 a	1.1 ft.	9:00 a	5.9 ft.	2:00 p	-0.8 ft.	7:00 p	4.6 ft.	12:00 a	1.3 ft.

therefore, may have semi-diurnal, mixed, or diurnal tides.

Wind can also overpower gravitational tides, especially in wide open, shallow basins. This can be true during periods of strong winds in southwest Florida. When conducting research on shallow sites, it is often critical to be there at the right tide. Mud flats are only exposed at low tides. Conversely, some locations can be reached by boat only when the tide is high.



Objective

To understand how, why, and when tides occur. How estuary life, inlets, and barrier islands are influenced by tides. To use tidal charts to plan field trips to mud flats, oyster reefs, and seagrass beds.

Materials Required

- Tidemaster charts from different areas in Florida and local tide charts for the next school year.
- Earth-Sun-Moon model
- Nautical maps or charts of Collier County

Procedure

Using the Tidemaster tide charts, find the best date, times, and tides for field trips to mudflats, grass flats and oyster bars. Check for the lowest tide possible for these field trips.

Critical Thinking

The tides at Rookery bay are approximately one hour later than at Big Marco Pass. Why? Study the tide charts from Gordon Pass and Big Marco Pass and try to determine the tides at Hurricane Pass. Is the tide later or earlier than at Big Marco Pass? If you were planning a visit at low tide to the restoration site on upper Henderson Creek, would low tide occur earlier or later than at Big Marco Pass? How much earlier or later?

References

Ball, John. (1998). Catapulting Students into Real World Problems. *Coastal Journal*. p 10-13.

Biscom, W. 1980. *Waves and Beaches*. Anchor Press/Doubleday. Garden City, NY.

Ford, Brent., Smith, Sean. (1995). Physical Oceanography: Project Earth Science. *Material for middle school teachers in earth science*. BP America, Cleveland, OH.

Kempton, Drew. (1998). *The Book of Waves, Rinehart Reader*. New York. N.Y.

Montvilo, Jerome. (1998). Applied Coastal Oceanography. A Course that Integrates Science and Business. *Journal of College Science Teaching*. v27 n25 p329-33.

Summich, J.L. (1996). *An Introduction to the Biology of Marine Life*. Sixth Edition. W. Brown Publishing.

<http://www.stormy.ca/tides/tides.html>

<http://www/ems.psu.edu/info/explore/tidesocean.html>

<http://explorezone.com/earth/tides.htm>

<http://www.opsd.nos.noaa.gov/about2.html>

Sunshine State Standards

SC.D.1.4. The student recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the earth.

SC.E.1.4. The student understands the interaction and organization in the solar system and the universe and how this affects life on earth.

SC.H.2.4. The student understands that most natural events occur in comprehensible, consistent patterns.



Lab 6: Barrier Islands

Introduction:

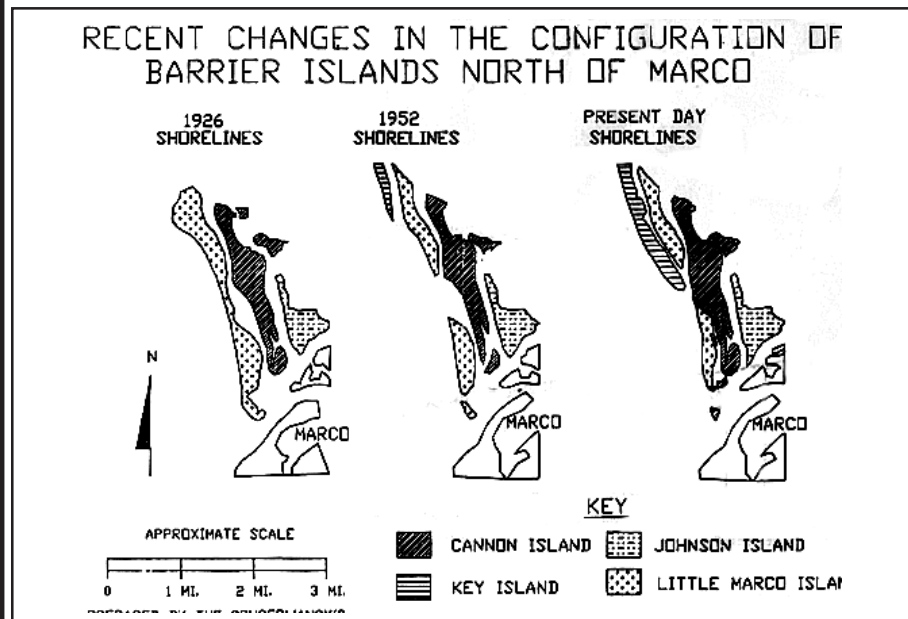
Barrier Island Dynamics

Barrier islands are composed of sand and are constantly shifting in response to the physical forces of wind, waves, and tides. These islands form important barriers that protect the productive estuaries, mangroves, and fresh and salt water marshes that are found behind them (see appendix Lab 6). Barrier islands respond to long-term sea level rise by gradually retreating landward. Coastal storms create waves and inlets that typically carry the sand to the southern portion of the island beach. Structures built on the beaches of barrier islands are often destroyed as the beach erodes. Waves tend to strike the beach at an angle which allows sand to be carried along the beach by the backwash of the wave. Strong, turbulent waves transport the sand off the beach and deposits it on offshore bars, while smaller waves usually transport sand from the bars back onto the beach. Wind blows the lighter sand back into the water or landward to the interior of the island, where dune building plants such as sea-oats capture the sand. These important pioneer plants help stabilize the island by holding the sand in place building up sand dunes. Dunes reduce the amount of salt spray that reaches the interior of the island, resulting in more diverse plant communities

Australian pine, an introduced invasive tree, crowds out native plants and does little to hold the sand in place during storms. These trees spread quickly and out-compete the native plants for sunlight and space. They have little to offer the native wildlife. Their shallow root systems do not support them during high winds and storms, and when they fall, they often accelerate beach erosion. The roots and limbs of the fallen trees are a hazard to nesting sea turtles.

Although beachfront land is very expensive, barrier islands are popular areas for recreation and, as such, are heavily developed with hotels, condominiums and houses. This creates a problem when the sand on the beach moves and the island migrates. Buildings are often damaged and

many houses have fallen into the ocean as the beach shifts. To combat this, landowners often build structures such as seawalls to protect shorefront property. Seawalls do protect the property, but will usually increase wave turbulence, which in turn increases the erosion of the beach. The final result is that the beach completely disappears. Another method used to protect buildings along a barrier beach front is “beach re-nourishment.” This involves dredging sand from offshore and depositing it onto the beach to make the beach wider. This method is not always effective, however, as the new sand is often washed away in the first real storm of the season.



Objectives

- To better understand how barrier islands respond to coastal geomorphic forces such as storms, waves, tides, and rising sea levels.
- To sample plant life and learn their adaptations to the harsh environment of a barrier island.
- To study and compare the animal life of the ocean side surf zone and the lagoon area on the back of the island.

Materials Required

- food coloring
- grapefruit
- two meter sticks
- string
- two levelers
- data sheets for beach profiles (see Appendix)
- compass
- sand sieves
- thermometers
- petroleum jelly
- glass sheet
- anemometers
- shell guides and field guides
- quadrants
- marker pole
- YSI probe
- secchi disk

Procedure

Using the equipment provided, sample the surf and lagoon side of the island for nearshore marine organisms. Design a data sheet that will help you compare the two habitats (see appendix). How do the catches differ? How do the animals differ? How do the locations differ?

Examine the beach habitat. Are there many living creatures using it? Is it being used for resting, nesting, or feeding? Physically describe the habitat, paying particular attention to the temperature, wind speed, and cloud cover. Is the wind moving sand along the beach? Using the petroleum jelly and glass sheet, try to determine if the wind is strong enough to move sand today. Also, use the grapefruit or food coloring to determine if there is a longshore current moving sand and water along the beach. Measure the rate of the current. At two different locations, do a beach profile.

With very tall poles, string, line level, and meter sticks, measure the change in height of the beach from mean tide (sea level) up to the beginning of the dune vegetation (see illustration). One pole should be set

at the base of the primary dune; the other pole should be placed at the water's edge. Connect a line from pole to pole and then level it. Using the data sheet in the Appendix, record the distance periodically from the line to the ground (C). Subtract the distance (C) from the height of the line at the water's edge (A). The result (D) is the height above sea level at that particular distance from the water's edge. Record the distance from the water's edge (B) for each height measurement (D). To graph the data, put the measurements for the distance from the water's edge (B) on the "x" axis and the height above sea level (D) on the "y" axis of your graph. After the data is graphed, discuss why the beach is shaped like it is and whether the shape changes with the seasons.

Mark the locations, so that the classes that follow can repeat the experiment and see if the beach profile has changed. You may also want to photo-document the beach at different fixed locations to get a visual documentation of changes in island geomorphology.

Examine the mollusk population on the beach. Are they mostly bivalves or univalves? Use your shell book to determine what they feed on. Are there more filter feeders or predators on the beach? Can you find evidence of predation by looking at the shells? Identify the shells.

Sample life in the different habitat zones of the barrier island. Use a quadrant and meter tape to get a random sample of the available plant life. Examine the plants from the different zones. How do they differ? How do their adaptations allow them to live in the environment where they are found?

Critical Thinking

Why do beach profiles and barrier islands change? Are the profiles different for different sections of the beach? Use sieves to analyze the sand at the different zones on the beach. Hypothesize why sand changes in grain size at different locations of the beach. Hypothesize how plant adaptations allow them to live in the barrier island environment.

Environmental Application

Barrier islands are beautiful places that are constantly moving and changing. They provide important nesting habitat for shore birds and sea turtles. Some environmentally-friendly actions that you could do for barrier islands include:

- Avoid disturbing birds whenever possible. Barrier beaches are important nesting and resting sites for shore birds.

- Turn off lights at night during turtle nesting season. Lights confuse hatchlings and lead them toward land instead of the sea.
- Keep off dunes and avoid trampling native vegetation. Native plants, especially sea oats, help stabilize the sand on barrier islands.
- Do not leave food or trash on the beaches. Food and trash attract predators, such as raccoons, that prey on eggs and young of turtles and shore birds.
- Avoid building too close to the beach or you may end up in the sea.
- When building on barrier islands, take into account their instability and constantly changing geology.
- Support efforts to preserve and protect barrier islands.

References

Biscom, W. (1984). *Waves and Beaches*. Anchor Press/Doubleday, Garden City, New Jersey.

Hopkins, W., Amos, Stephen, (1995). *Atlantic and Gulf Coasts*. Knopf Alfred Publishers. New York, NY..

Ford, Brent., Smith, Sean. *Physical Oceanography: Project Earth Science*. B.P. America. Cleveland, OH.

Leatherman, S.P. (1982). *The Barrier Island Handbook. Second Edition*. University of Maryland, College Park, MD.

The Fragile Fringe: A Guide for Teaching About Coastal Wetlands. 1999

<http://www.simmons.edu/~madsend/barrier/resources.html>

<http://161.99.21/homepg/whatsnew/publicat/gomr/barrier.html>

http://www.fsu.edu/~cpm/FACT/sec_A/barrier.html

<http://www.nwrc.gov/fringe/barriers.html>

Sunshine State Standards

S.C.G.2.4. The student knows that the world ecosystems are shaped by physical processes that limit their productivity.



Lab 7: Water Quality Monitoring

Introduction

Why do researchers sample water to ascertain its quality? Why is water quality monitoring so important? Water is the life blood of the estuary. It contains nutrients, essential salts, and minerals. It supplies oxygen to aquatic life, supports large animals, and serves as a means of transport for many marine organisms.

Poor water quality can lead to disease, and even death, of plants and animals. Even minor changes in the physical and chemical characteristics can have a profound impact on marine habitats and organisms.

Important Water Quality Parameters:

Temperature

Sudden changes in temperature or extremes of temperatures can be lethal to estuarine animals. All animals have a set of ranges that they can tolerate. Snook and manatees can die from prolonged exposure to temperatures below 15° Celsius. Temperatures around the world can range from 0° to 45° Celsius. In Southwest Florida estuaries, the temperature ranges from 10° to 35° Celsius.

Dissolved Oxygen

Most animals need a certain amount of dissolved oxygen in the water in order to breathe. Dissolved oxygen (DO) is measured in units of milligrams per liter (mg/L). The DO range for estuaries is between 0 and 12 mg/L. Low DO readings can be lethal to estuarine animals. In temperate estuaries, readings below 4 are considered unhealthy. Sub-tropical estuaries can tolerate dissolved oxygen levels as low as 2 mg/L for short periods of time.

pH

pH is a measurement of the amount of hydrogen ions in the water. This indicates how basic or acidic the water is. High acidity can be lethal to marine organisms, and rapid changes in pH can affect other water chemistry. The pH scale is from 0 to 14 with 7 being neutral. It is a

logarithmic scale, so water with a reading of 5 would be 10 times more acidic than water with a pH of 6. A pH reading below 6 can cause serious problems in ponds and lakes. Salt water is slightly basic and usually reads between 7.6 and 8.6.

Salinity

Many organisms can be quite sensitive to rapid changes in salinity. Salinity is measured in parts per thousand (ppt). Juvenile animals are often more sensitive to salinity changes. For instance, juvenile redfish need a salinity between 10 and 20 ppt to survive, whereas an adult can live in fresh (0 ppt) water or salt (35 ppt) water, as long as it experiences gradual changes in the salinity levels. Salinity that is too high can kill plants. Fresh water has a salinity near 0 ppt and the Gulf of Mexico has a salinity of around 35 ppt. During dry times of year, estuaries can often become hypersaline, with salinity readings much higher than the Gulf.

Turbidity

Plants need sunlight to survive. Lack of sunlight can adversely affect seagrass beds and other submerged plant communities. When an area of water being sampled is “cloudy” it stops the sunlight from penetrating into the water. This is known as turbidity. Turbidity is commonly read using a black and white disk called a secchi disk. The disk is lowered into the water until it is no longer seen. The average depth in meters at which it disappears is recorded as the turbidity.

Nutrients

Excess nutrients can cause algal blooms, which can reduce visibility (increase turbidity) or cause fish kills by lowering dissolved oxygen levels. When algae die they decompose, and bacteria decomposing the algae use all the available oxygen. Lack of adequate nutrients can often result in low productivity, which, in turn, results in reduced plant and animal life.

Objective

To learn how water quality affects estuarine organisms. To understand the objectives of water sampling programs in estuary systems. To analyze data from telemetry stations in Blackwater River and Henderson Creek.

Materials Required

- DO meter: measures dissolved oxygen in water
- Refractometer: measures salinity by measuring how much light the water refracts

- YSI unit: measures physical factors such as salinity, DO, temperature, and pH
- Hach kits: chemical kits to measure nitrates and phosphates
- Map of Rookery Bay
- Clipboard
- Secchi disk: measures turbidity. Drop it into the water until it disappears, record the depth, record the depth at which it reappears, then take the average.
- Nansen bottle: used to collect water samples from a variety of depths
- Marking pen
- Data sheet
- Masking tape
- Water sampling bottles
- YSI telemetry station and data

Procedure

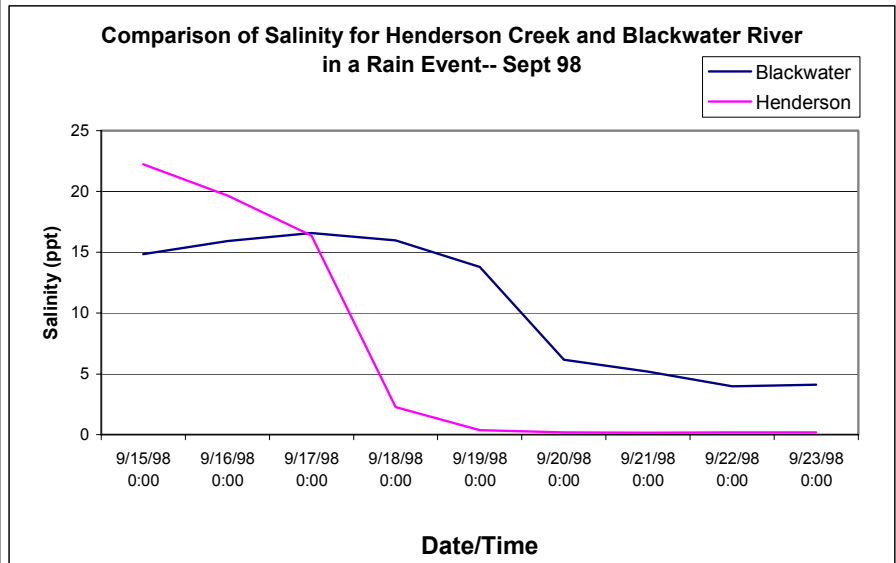
Look at maps of Rookery Bay, Blackwater River, and the canal systems of Collier County. Before Collier County was developed, most of the fresh water in the county flowed in a shallow sheet just above or just below the surface of the soil into nearshore marine habitats. Now it flows mostly through a recently constructed canal system into nearshore habitats. A weir controls the amount of water entering Henderson Creek. The weir is kept closed until water levels reach the point at which local residences are threatened with flooding. There are no weirs or dams controlling the water flowing into the Blackwater River. How might the canal and weir system affect water conditions in Rookery Bay?

You have been provided with salinity data from two telemetry probes in Henderson Creek and Blackwater River (see Appendix). The Collier County canal system feeds into Henderson Creek, and that the upper end of the creek is heavily developed. A weir controls the water flow into the Creek from the canal. The Blackwater River, however, is in a close-to-natural condition (see Appendix).

Design a data sheet to record your information. Using the above equipment and the maps that you have been provided with; design a water quality sampling program for Rookery Bay. What would you sample for, where, how often, and when? Do remember that time is a factor. It is not possible to sample everywhere and all of the time.

Compare the water quality data collected from the two sites for the rainy season (September 15-23) of 1998 (see Appendix).

Graph the data that was collected every three hours. Compare the graph to the data that was collected once a day. How do the graphs compare? What seem to be the advantages to collecting data more frequently? Are there any advantages to less frequent sampling? How do the two sites respond to influxes of fresh water? Do you think that tides are affecting the probes? If so, are both sites influenced to the same degree by tides?



During this particular week, the weir was open due to the influence of Hurricane Georges. How did this affect the Henderson Creek site? Hypothesize the impact this may have had on animals living in Henderson Creek as opposed to animals living in the Blackwater River.

Graph the data collected during the dry season (April 1-6). Compare the data that was collected daily with the data that was collected every three hours. How do the dry season graphs differ from the wet season graphs?

Critical Thinking

An important aspect to remember when designing a water quality program is to define your goals. Do you have questions that you would like to answer through your monitoring program? It is important to answer specific questions rather than randomly collect data and hope that the results will fit a pattern.

Environmental Application

Here are some important questions that you should ask when designing a water sampling program: Why do you need the data? Is there a hypothesis that you want to test? Where do you want to sample, and how many locations do you need? How often do you need to sample and at what time or tide?

To make the sampling relevant, connect the water sampling results to the animals and habitats present in the sampling area. Try to answer the questions: What affect would the changes in physical and chemical water quality parameters have on the animals, plants and habitats in the area monitored?

Clean water is the lifeblood of an estuary. As a citizen, there are certain actions that you can take to help improve the quality of estuarine water.

- Practice water conservation: water is a valuable resource, so try not to waste it
- Dispose of hazardous material properly
- Avoid using excess fertilizers on lawns and gardens
- Practice responsible boating: do not dump oil, fuel or human waste into an estuary
- Limit the use of hazardous chemicals: always use nontoxic substances when available, and dispose of chemicals properly
- Support conservation of watershed recharge areas

References

Kappmeyer, C. (1992). *Keep it Clean: A Citizens Guide to Protecting Our Estuary*. Rookery Bay NERR. Naples, FL.

Mitchell, M.K., and W.B. Stapp. (1993). *Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools*. Thomson-Shore Printers, Dexter, MI

Sunshine State Standards

S.C.H.1.4. The student uses the scientific process and habits of mind to solve problems.

S.C.H.3.4 The student understands that science technology and society are interwoven and interdependent.



Lab 8: Osmoregulation

Introduction

Temperature and salinity are two physical factors that can influence the behavior and survival rate of marine organisms. Severe drops in temperature have caused mortality of snook and manatees in Florida. This is not unusual for animals living in the northern limits of their geographical range. Salinity is another factor that influences behavior and survival in estuaries. Several fish kills on the east coast of Florida have been associated with rapid drops in salinity brought about by heavy rains and alterations in natural drainage patterns. Estuarine animals tend to be somewhat tolerant of changes in salinity and temperature, but often show signs of stress if the changes are too large or occur too quickly.

Cassiopeia xamachana is a common inshore jellyfish found in the calm shallow waters of southwest Florida. It is often called the “upside down jellyfish” because of its habit of lying upside down on the bottom. Tiny plant-like dinoflagellates called a zooxanthellae reside in the jellyfish’s lacy oral arms. The zooxanthellae have a mutualistic relationship with the jellyfish. Because the jellyfish lies upside down on the bottom, the zooxanthellae are able to benefit from sunlight.



Through the process of photosynthesis, the zooxanthellae makes food for the jellyfish. The stinging structures of the jellyfish protect the zooxanthellae. *Cassiopeia*’s stinging cells (called nematocysts) are too small to penetrate the thick skin of your palms. It can, however, penetrate the skin in more delicate areas where the skin is thinner (please, don’t kiss this jellyfish!)

Cassiopeia's behavior consists mainly of lying on its back and pulsating. This pulsating probably brings new water and food over its stinging cells and zooxanthellae. Stress may cause *Cassiopeia* to pulsate more rapidly, to pulsate slowly, or to swim away from the stressful condition or temperature.

The Sheepshead minnow, *Cyprinodon variegatus*, is a common minnow found in estuaries from New England through south Florida and Texas. It is an

opportunistic omnivore with a high tolerance for a wide range of salinities and temperatures.

Sheepshead minnows are animals that keep their body fluids at a constant salinity level.

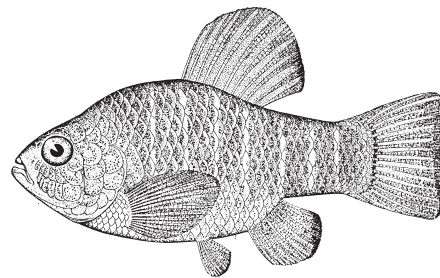


FIGURE 78.—Sheepshead minnow (*Cyprinodon variegatus*), Maryland. From Jordan and Evermann. Drawing by A. H. Baldwin.

They do this either by excreting salts or liquids, or by excluding salt or water from entering into their internal tissues. This type of animal is called an osmoregulator. If they are unsuccessful in maintaining this constant ion level, they show signs of stress and quickly die.

Simpler animals are often osmoconformers. They do not regulate their internal tissues but, instead, have the same ion concentration as the medium in which they are found.

Objective

To measure stress and the effects of salinity and temperature on marine organisms utilizing a methodology that measures the tissue response of animals and plants.

Materials Required

- Sheepshead minnow, *Cyprinodon variegatus*
- Potatoes
- Live sponges
- Upside down jellyfish, *Cassiopeia xamachana*
- Aquarium
- Scales
- Large tubs
- Instant Ocean

Procedure

Measuring stress or the affects of changing salinity and temperature is not always easy. One method is to measure the tissue response of the animals or plants. A simple example is to use pieces of potato by placing them in different salinities and weighing them afterwards. In sessile animals, such as sponges, the same approach can be used with the whole animal.

Compare the response of a sheepshead minnow, a sponge, and a piece of potato, by placing them in water of different salinities and then weighing them.

Another method to measure stress is to measure movements such as pulses and breathing rates. In fish, breathing rates (gill opening rates) and swimming activity can be monitored. *Cassiopeia* pulsates as it sits on the bottom. Starting at the simplist level, measure the response of a piece of potato, a sponge, a *Cassiopeia*, and a sheepshead minnow to different salinities and temperatures.

For the safety of the animals, keep the temperatures between 69 and 90 degrees and the salinities between 0 and 40 ppt. Do not keep them in these extreme conditions for more than five minutes. Make sure the water has been treated for the removal of chlorine if you are using tap water. Remember to replicate the experiment several more times in order to obtain the most valid results. Use a scattergraph to compare the metabolic responses of the two animals to changes in temperature and salinity.

Critical Thinking

Construct an experiment to study the responses to stress. In this experiment we have used salinities and temperatures as the stressors. Can you think of anything else that you could measure as a stressor? What might that be, and how would you record them? How could human alteration of sheet flow, marshes, and mangrove areas affect the salinity and temperature in an estuary? What can you do to help return estuaries to a more normal mix of fresh and salt water?

Environmental Application

- Support efforts to restore sheet flow by protecting watershed recharge areas and re-engineering the canals
- Conserve water at home and at work
- Landscape with native plants that require little watering
- Volunteer with efforts to restore mangrove and marsh habitat
- Support conservation of watershed recharge areas

References:

Sumich, J.L. (1996). *An introduction to the Biology of Marine Life. Sixth Edititon.* Wm.C. Brown Publishers

Mauro, N., Buck-Bernard, J. (1998). Aquatic Analysis. *Science Teacher.* v65 n5 p38-39 May.

Dobson, Stephen., Whithall, Russell. (1996). It's Something in the Water! *School Science Review.* v78 n283 p37-40 December.

Kappmeyer, C. (1992). *Keep it Clean: A Citizens Guide to Protecting Our Estuary.* Rookery Bay NERR. Naples, FL.

Mitchell, M.K. and W.B. Stapp. (1993). *Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools.* Thomson-Shore Printers, Dexter, MI

<http://meteora.ucsd.edu/~knowles/htm/estuary/salinitypaperi.htm>

<http://chi.wesarmy.mil/research/estuaries>

http://ns.noaa.gov/atlas/htm/mov/movsal_1.htm

Sunshine State Standards

- S.C.H.1.4. The student uses the scientific process and habits of mind to solve problems.
- S.C.H.3.4 The student understands that science technology and society are interwoven and interdependent.
- S.C.G.2.4 The student knows that the world ecosystems are shaped by physical processes that limit their productivity.
- S.C.H.1.4. The student uses the scientific process and habits of mind to solve problems.



