GEORGIA

Education Program Curriculum

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Generating Enhanced Oyster Reefs in Georgia's Inshore Areas (GEORGIA) is community-based oyster restoration effort coordinated by the University of Georgia Marine Extension Service. The program goal is to increase oyster reef acreage and to educate the general public on the importance of oyster communities in maintaining a healthy coastal ecosystem. This curriculum details the hands-on, inquiry-based education programs we provide for students in grades five through twelve that focus on oyster reef communities and our restoration efforts.

We would like to acknowledge the following for supporting GEORGIA:
National Marine Fisheries Services Community-Based Restoration Program, Ocean Trust, Tybee Burton 4-H Center, Savannah Presbytery, South Carolina Oyster Restoration and Enhancement Project, Skidaway Institute of Oceanography, the Saltwater Grill, the Oyster Bar, and the Georgia Department of Natural Resources.

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Oyster Reef Habitat Exploration

Instructional Objectives

Students will:

1) explore an oyster reef at one field site by boat;
2) describe the oyster life cycle;
3) identify and describe the important function of oyster reefs in providing a habitat for other organisms;
4) sort and identify organisms that inhabit an oyster reef and;
5) apply a math formula to the data collected and calculate a diversity index for the organisms that inhabit an oyster reef.

Objective 1: Students will explore an oyster reef at one field site by boat.

Students will travel by skiff to a nearby oyster reef site at low tide (e.g. Cabbage Island).

Using one meter quadrants, students will sample and collect data on organisms that occur on an oyster reef

Discuss oyster reefs in general. Retrieve a bag of shells that has been left out on or near a reef for a period of time (Priest Landing) and return it to the dock so that students can open it later for the sorting and identification of associated fauna.

Materials: GEORGIA biological monitoring data sheets, one meter quadrants, clip boards, identification cards, pencils, buckets, sorting trays

Duration: 2 hours

Objective 2: Students will describe the life cycle of an oyster.

Using the life cycle of an oyster poster, guide students through the various stages from spawning adults to the settlement stage of larvae

Oysters are broadcast spawners (release sperm and eggs into the water column for external fertilization) and spawn along the coast of Georgia from May to October. Water temperature plays a critical role in determining the seasonal timing of spawning (trigger is 68 degrees F for spawning). Sperm and eggs are released into the water column, eggs are fertilized and develop into trochophore larvae which drift with the water currents as part of the plankton. The larvae then develop into veliger larvae when they develop "wings" with beating cilia which allow them to feed on other plankton. After a couple of weeks the larvae develop a foot and are then termed "pediveligers". Using this foot they set about exploring various hard substrates (e.g. rocks, pilings and ideally, other oysters) in order to select a suitable site to attach to and begin a sessile existence. Oysters need a hard surface area in order to attach and grow, otherwise they would be quickly covered up with mud and suffocate. Upon settling and attaching, the larvae are referred to as spat. Adult oysters and shells emit chemical cues to attract the larvae. If adults have survived at a location for their lifespan, chances are this will be a suitable site for new oysters to grow. The reduction in oyster reefs and shell over the years has resulted in a reduction in the amount of hard surface area available thus increasing the competition for space among oyster larvae.

Materials: oyster life cycle poster for students, oyster clump

Duration: 10 minutes

Objective 3: Students will identify and describe the important function of oyster reefs in providing a habitat for other organisms.

Oysters are considered a keystone species (i.e. critical to a healthy ecosystem) and serve many important ecological functions. One important function is that oysters provide critical habitat for many organisms that live on, in and around an oyster reef. Oyster reefs are

composed of successive generations of oysters and as older oysters on the bottom die, oyster larvae attach (referred to as spat) on the surface and over time, reefs grow both vertically and horizontally creating space for other organisms to live. The oyster reef is used as a habitat by both transient (organisms that move onto the reef at high tide) and residential organisms (never leave) that use the reef for food, shelter and as a spawning and nursery area. Within the oyster reef, the oysters and those organisms associated with the reef create a food web based on the predator-prey relationships among the organisms inhabiting the reef. Predators of oysters (whelks, oyster drills, blue crab, mud crabs and cownose rays) are at risk of being preyed upon by other organisms (sea turtles, striped bass, oyster toadfish, and bluefish). There are also examples of commercially important species that use oyster reefs as a habitat (brown shrimp, white shrimp, and blue crab).

Have the students construct a food web on the board using a preserved specimen collection and identification cards

Conclude this session with a discussion on natural history of organisms in food web and predator-prey relationships.

Oysters preyed directly upon by: atlantic oyster drill, channeled whelk, knobbed whelk, blue crab, mud crab, cownose ray

Predation on oyster predators by other oyster predators: cownose ray (channeled whelk, knobbed whelk), mud crabs (atlantic oyster drills), blue crabs (oyster drills, whelks)

Upper level predators that consume oyster predators but not oysters: oyster toadfish (blue crabs, mud crabs), bluefish (blue crabs), striped bass (blue crabs), sea turtles (knobbed whelk, channeled whelk)

Materials: clump of oysters, artifacts and preserved specimens for food web (see above list), identification/natural history cards for each specimen.

Duration: 45 minutes

Objective 4: Students will sort and identify organisms that inhabit an oyster reef.

There are many factors which determine oyster recruitment and subsequent colonization of other organism to a particular reef site. Environmental conditions may vary from site to site.

Ask students to think about some of the factors that may influence the types of organisms encountered at a particular reef site and discuss

These factors may include:

- salinity and flow appropriate for sustaining oyster recruitment and growth
- food availability
- substrate (soft mud is not suitable)
- slope of reef site
- sedimentation rates
- zonation (low or high on a reef)
- season
- succession of a reef

Have students open the bag of shells which was earlier collected from Priests Landing (and/or from MECA site). All shells should be sorted through and all organisms found should be retained. A comparison of organisms encountered at two reef sites (MECA and Priest Landing) could also be done depending on size of the group and tides. Discuss the natural history of organisms encountered.

In the lab, have the students identify and count organisms from recovered bags using identification cards and the GEORGIA biological community data sheet

Materials: oyster bags, buckets, sorting trays, dissecting microscopes, tweezers, petri bowls, identification sheets, GEORGIA biological community data sheets, pencils, boots.

Duration: 45 minutes

Objective 5: Students will apply a math formula to the data collected and calculate a diversity index for the organisms encountered at the reef site.

Using the Shannon-Wiener diversity index sheet, have the students apply data to the formula and calculate the index for the organisms encountered at the reef site(s)

Discuss the results and relate to environmental factors that may influence what types of organisms are found on an oyster reef and why. Use previous data to compare the index with seasonal and annual trends and site specific parameters (salinity, sedimentation rates…).

Conclude program with a 5 minute synopsis of overall program.

Materials: calculators, Shannon-Wiener index data sheet, pencils, and prior data.

Duration: 15 minutes

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0
3. Biology: 1.1,1.2,1.3
4. Chemistry: 1.0,1.1,1.2
5. Earth Science: 1.1,1.2,2.0
6. Geology: 1.0,1.1,1.2
7. Environmental Science: 1.0,1.1,1.2,2.0
8. Microbiology: 1.0,1.1,1.2
9. Oceanography: 1.0, 1.1,1.2, 2.0
10. Physical science: 1.0,1.1,1.2
11. Zoology: 1.0, 1.1,1.2,2.0

The Amazing Oyster and Water Quality

Instructional Objectives

Students will:

1) recognize why oysters are considered indicator organisms of water quality and understand the importance of monitoring water quality;
2) discuss the role of deteriorating water quality on oyster populations and;
3) sample water at a local oyster reef and collect water quality data.

Objective 1: Students will recognize why oysters are considered indicator organisms of water quality and will understand the importance of monitoring water quality.

Using the life cycle of an oyster poster, guide students through the various stages from spawning adults to the settlement stage of larvae

Oysters are broadcast spawners (release sperm and eggs into the water column for external fertilization) and spawn along the coast of Georgia from May to October. Water temperature plays a critical role in determining the seasonal timing of spawning (68 degrees F trigger for spawning). Sperm and eggs are released into the water column, eggs are fertilized and develop into trochophore larvae which drift with the water currents as part of the plankton. The larvae then develop into veliger larvae when they develop a "wing" with beating cilia which allow them to feed on other plankton. After a couple of weeks the larvae develop a foot and are then termed "pediveligers". Using this foot they set about exploring various hard substrates (e.g. rocks, pilings and ideally, other oysters) in order to select a suitable site to attach to and begin a sessile existence. Oysters need a hard surface area in order to attach and grow, otherwise they would be quickly covered up with mud and suffocate. Upon settling, the larvae are referred to as spat. Adult oysters and shells emit

chemical cues to attract the larvae. If adults have survived at a particular location for their lifespan chances are this will be a suitable site for new oysters to grow. The reduction in oyster reefs and shell over the years has resulted in a reduction in the amount of hard surface area available thus increasing the competition for space among oyster larvae.

Oysters are considered indicators of water quality because they (along with other shellfish) filter large volumes of water from the surrounding aquatic environment to obtain food particles (plankton) and dissolved oxygen. An adult oyster is capable of filtering 60 gallons of water per day or 2.5 gallons of water per hour. In addition to the food source, harmful bacteria, viruses and toxic substances present in the water is filtered and concentrated in the living tissue of the oyster. Oysters are capable of accumulating these pollutants and naturally occurring toxins from the water at considerable distances from the source of pollutants. The bio-accumulation of the pollutants can result in changes in growth rate and other biological processes (reproduction) including potential for death.

Ask the students to give examples of potential sources of pollutants

Discuss the difference between point source and non-point source pollution and give examples of each. Possible pollutant sources include runoff from urban and agricultural areas, sewage discharges, faulty septic fields, and wildlife areas. Non-point source pollution tends to be the largest contributor of pollutants with regard to shellfish bed closings.

Commercial and recreational shellfish beds must be monitored on a regular basis for fecal coliform by resource managers to ensure the safety of shellfish harvesting waters and fresh and marine bathing waters. E. Coli is used as an indicator bacteria and they are relatively easy to test for. The presence of this bacterium in the water is a good indication that pathogenic (disease causing) organisms could also be in the water. Public and commercial shellfish beds are closed by resource managers from the Department of Natural Resources if counts exceed recommended levels. The Georgia Division of Public Health is responsible for closing public bathing areas if fecal coliform levels are too high.

Ask students why monitoring water quality is important

Water quality is monitored:

- for industrial/commercial screening for regulatory compliance (power plants)
- to be able to record chronic or episodic problems (algal blooms)
- to monitor trends or changes (drought)
- to provide scientists with baseline information
- to educate
- to assist with resource management decisions and regulations

Materials: oyster life cycle poster, power point presentation

Duration: 15 minutes

Objective 2: Students will discuss the role of deteriorating water quality on oyster populations.

Georgia's oyster populations were once immense, however over harvesting, habitat degradation, and disease have considerably impacted these estuarine communities.

Over harvesting and Cultch Shortage: During the early part of the 20th century Georgia led the nation in terms of oyster landings. Harvesting was conducted by hand at low tide and from beds that were leased by canneries. At that time approximately 95% of oysters were canned and shells were typically not returned to the water as cultch. Indeed most found their way into road construction, buildings (tabby), driveways and even chicken feed. After the war, labor shortages led to the closure of canneries and the industry essentially collapsed. Today the industry is virtually non-existent, and serves as a supplementary fishery for crabbers and clammers who manually gather clumps, break them up and supply a local roast industry. While annual oyster roasts remain an important part of coastal Georgia's history and culture and continue to be popular with the general public, the lack of oyster shell replenishment following the removal of live oysters is detrimental to the recruitment of juvenile oysters and thus their ability to improve water quality.

Habitat Degradation: Rapid and sustained economic and population growth along the Georgia coastline has led to the loss of wetlands, increased sedimentation rates, increased boat traffic, the large-scale removal of water from coastal aquifers, and inadvertently to an increase in point and non-point source pollution (agriculture, homes, sewage treatment, septic tanks, car exhausts, sediment from construction). All of these factors result in deteriorating water quality which potentially creates a negative feedback loop making oyster populations more susceptible.

Disease: Recent years of drought have adversely affected the salinity regimes of southern estuarine systems, encouraging the spread of diseases including the protozoan pathogens *Haplosporidium nelsoni*, and *Perkinsus marina*. While these diseases are not harmful to humans that ingest infected oysters, they can result in the death of oysters themselves. The biggest disease outbreak in Georgia occurred during the 1980's when many oysters died coast wide due to a massive dermo outbreak.

Materials: power point presentation

Duration: 15 minutes

Objective 3: Students will sample water at a local oyster reef and collect water quality data.

Ask students what parameters or measurements might be important in monitoring water quality, particularly with regard to oyster populations

Salinity, Temperature Dissolved Oxygen, Turbidity or Settable Solids. Discuss how each parameter will be measured in the field.

Have students collect, analyze water samples at the MECA oyster reef site. As a group, interpret the results and relate to oyster recruitment, growth and mortality

Salinity

Salinity is the amount of dissolved solids or salts in seawater. Salinity is stated in units of parts per thousand (ppt, 0/00). Open ocean salinity is 35 ppt (35 grams of dissolved solids in 1000 grams of water). Estuaries (mixture of salt and fresh water) have a range of salinity from 0 ppt (rivers) to 35 ppt (ocean). The salinity determines where plants and animals are found. Estuaries in Georgia are highly mixed having fairly uniform salinity between the surface water and the water at depth.

Salinity can be measured by:

1) chemical: titration of chloride since chloride is fairly constant in seawater. Salinity (ppt) = {1.805 x chlorinity (ppt)} + 0.03
2) conductivity: the more salts in the water, the more conductivity there is in the water.
3) specific density: specific gravity of seawater. Saltwater is denser than fresh water so objects float higher in salt water. The higher the object floats, the higher the salinity. Salinity can be determined by measuring the specific gravity of water using a hydrometer (calibrated glass float or plastic bulb with a calibrated stem that protrudes above the water surface) and temperature. Ask students if they keep a home saltwater aquarium – refer to hydrometer.
4) refractive index: this is the fastest and easiest way to determine salinity. Base on light refraction or the bending of light waves as waves pass from a thinner medium (air) to a thicker medium (seawater). A refractometer is used to determine the salinity.

Show students how to use the refractometer

Temperature

Metabolic rates of organisms and the solubility of gases and dissolved solids are affected by water temperature. Water temperature affect not only determines where aquatic organisms will be found but temperature also affects feeding, reproduction and metabolism.
examples of how temperature may affect aquatic organisms:

- fish larvae and eggs may have a narrower temperature range requirement than adult fish.
- thermal stress or shock can occur when temperatures change 1-2 degrees in less than 24 hors.

- many biological processes are triggered by temperatures – oyster feed and spawn at certain temperatures.

Dissolved oxygen

Dissolved oxygen - measure of the level of saturation of free O2 in a sample of water. Levels of DO may be determined by % saturation (the percent of the potential capacity of water to hold oxygen that is present). Salinity and temperature are important. Dissolved oxygen in the water is depends upon temperature and salinity - minerals dissolved in water lower the water's capacity to hold oxygen

Lower salinity = higher potential dissolved oxygen level
Higher salinity = lower potential dissolved oxygen level

Lower temperature = higher potential dissolved oxygen level
Higher temperature = lower potential dissolved oxygen level

Dissolved oxygen in the water is essential to aquatic organisms.

Sources of dissolved oxygen:

- atmosphere – mixing of air and water at the surface (due to wind…).
- phytoplankton
- macroscopic algae
- higher marine plants

Generally ranges in seawater from (5 – 14 ppm or mg/L).
Generally 5.0 mg/L is okay for most fishes.

Oxygen depleted by:

- increase in temperature increases metabolism of organisms thereby decrease do levels.
- higher water temperatures decrease the solubility of atmospheric gases (high temp low do)
- bacterial decomposition consumes d.o. – may lead to anoxia (no oxygen < 0.5 ppm)
- algal blooms to increased bacterial decomposition to decreased oxygen levels

Show students how to use the dissolved oxygen meter

Turbidity or Settable solids

Turbidity refers to the cloudiness of the water due to solid matter scattering light waves passing through the water. What may contribute to the turbidity of water? Plankton, detritus and sediment. Water clarity affects the depth of light penetration. Turbidity defines the photic zone – area or region where phytoplankton will be able to photosynthesize.

Show students how to use the Imhoff cone

Divide students into groups to collect and analyze water samples near the MECA reef using the GEORGIA chemical monitoring data sheet

If low tide, point out the MECA reef site and talk briefly about the GEORGIA program. In a wrap-up session, discuss with the students their results and relate to oyster populations with artifacts (spat sticks, oyster shells). Some examples may include:

- low salinity (< 5ppt results in low recruitment)
- salinity above 15ppt increases risk of dermo and msx
- temperature (68 degrees F for spawning adults)
- low d.o. (death of oysters)
- high sedimentation rates (reduced rates of growth or death)

Materials: spat sticks, shell strings, box oyster, live oyster, sublegal oyster, legal oyster, GEORGIA chemical monitoring data sheet, pencils, white board, marker, eraser, clipboards, d.o. meter, refractometers, thermometers, imhoff cones, buckets Class limit: 15 students

Duration: 1.5 hours

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0

3. Biology: 1.1,1.2,1.3

4. Chemistry: 1.0,1.1,1.2

5. Earth Science: 1.1,1.2,2.0

6. Geology: 1.0,1.1,1.2

7. Environmental Science: 1.0,1.1,1.2,2.0

8. Microbiology: 1.0,1.1,1.2

9. Oceanography: 1.0, 1.1,1.2, 2.0

10.Physical science: 1.0,1.1,1.2

11.Zoology: 1.0, 1.1,1.2,2.0

Oysters – the Fanatic Filterers

Instructional Objectives:

Students will:

1) collect a plankton sample using a plankton net and will be able to describe some of the variables that determine what will be caught;
2) learn how to use a microscope and how to protect it from damage (e.g. spilled water);
3) be able to identify common organisms (e.g. diatoms, copepods) in their collected samples through use of a picture key.
4) identify the relationship between water quality and the distribution/abundance of plankton and the filtration rate of oysters.

Instructor: Set up counting chambers with sample before class starts to allow time for it to settle properly

Objective 1: Students will collect a plankton sample using a plankton net and will be able to describe some of the variables that determine what will be caught.

Introduction to plankton with emphasis on phytoplankton.

- What is the broad definition of plankton?

Organisms that are at the mercy of the currents. Wanderers. They are unable to swim against a current of one knot (nautical mile per hour) for an extended period of time.

- Two plankton groups – phytoplankton and zooplankton.

How do they make their living? What are their nutritional requirements? Autotrophs versus heterotrophs.

- Where would you find phytoplankton?

Photic zone (upper surfaces of water down to 200 meters).

- Factors that might affect primary productivity and types found on seasonal/annual basis. temperature, salinity, nutrients, predation, turbidity (the presence of suspended sediment in the water column reduces light penetration and therefore primary production), trace metals (arsenic, selenium, mercury). Go over some of the equipment that they will use when sampling Skidaway River (refractometer, do meter, Imhoff Cone).

Students divided into groups to collect plankton samples from the Skidaway River using net and buckets. Others will collect selected water quality parameters

Have the students also take a bucket of water back to the laboratory.

Materials: plankton net, buckets, refractometer, do meter, Imhoff Cone

Duration: 30 minutes

Objective 2 & 3: Students will learn how to use a microscope and how to protect it from damage (e.g. spilled water), and students will be able to identify common organisms (e.g. diatoms, copepods) in their collected samples through use of a picture key.

Introduction to oysters as filter feeders. There are many estuarine organisms that are characterized as filter feeders. Filter feeders are aquatic organisms that capture food suspended in water (usually plankton) by using some type of screen or filter.

Have students give some examples (mussels, clams, tunicates)

Talk about filtering experiment (including Isochrysis sp.) which should already be set-up for sampling. Discuss general characteristics (bivalve, sessile, life cycle) of an oyster while passing around shell material including why oysters are important to coastal systems. Throughout the southeastern United States, the eastern oyster, *Crassostrea virginica* (Gmelin),

grows primarily intertidally and is considered a keystone species. Oyster reefs play a functional role in providing hard substrate for other organisms to attach and grow, providing essential fish habitat for a variety of species, filtering water thus significantly improving water clarity and controlling excessive growth of algae resulting from nutrient enrichment, and reducing shoreline erosion. Georgia's oyster resources were once immense, and supported a thriving cannery based industry, however overfishing, wetland loss, pollution and disease have conspired to reduce the fishery to a fragmentary status and to mainly supply local roast events is an oyster and why they are important.

Discuss the amount of water an adult oyster can filter over time. Adult oysters (subtidal) are capable of filtering 60 gallons per day per adult oyster or approximately 2.5 gallons per hour. Oysters at one time in the Chesapeake Bay could filter the entire volume of the bay in 3 days – now it takes over one year.

Oysters will filter algae, bacteria and some detritus however they are most interested in phytoplankton that ranges in sizes from 3-40 microns in diameter.

Use a live oyster demonstration to show how an oyster filter feeds

Oysters filter plankton out of the water by setting up currents using small hair-like structures called cilia that are located on the gills. The cilia create water currents that supply oxygen to the gills and remove carbon dioxide. The currents also carry food particles and other small pieces of material to the gills. The particles are sorted and food particles are carried to the mouth while the other material collects on the mucus of the gills. A suspension feeding organism like an oyster makes its living by ingesting particles from the water column however how can the oyster selectively filter the particles so that it is ingesting only the particles that have nutritive value? Talk about examples of experiments that showed the gills sorting the food stuff with high value and passing it along the labial palps. The labial palps are found attached near the mouth and function as the major conduit conducting food to the corners of the mouth.

Incoming food is sorted and accepted particles are passed along to the mouth down to a pouch-shaped stomach surrounded by a digestive gland. Waste passes through a long, coiled intestine to be emptied by the rectum as feces. Inedible particles are often "blown-out" which are stuck together with mucus. The expelled material is called pseudofeces.

Have students take a look at their river water sample under a microscope and try to identify any plankton which might be present.

Instructions on the correct use of a microscope should first be given (e.g. not spilling water, always checking where the platform is in relation to the lens before turning the focusing knob, always turning the focusing knob so that the platform is moving away from the lens so as not to break the slide or damage the lens). Pass out simple waterproofed plankton identification keys and have the students match up the shapes they see in their sample to those on the key.

Materials: microscopes, slides, live oysters, plankton samples, plankton identification keys.

Duration: 45 minutes

Objective 4: Students will identify the relationship between water quality and the distribution/abundance of plankton and the filtration rate of oysters.

Get back to topic of filtering rates of oysters.

Ask students how they might measure in a controlled experiment how many cells the oyster is filtering over time?

One way is to count the number of cells in a water sample, then add oysters and allow feed for a predetermined time and then again to determine the number of cells present. Describe how counting chambers are used and a formula applied to determine the number of plankton cells in a water sample. If actually determining the filtration rate of oysters over the course of the class period, start with a water sample which has been prepared to a known

concentration. Start a timer once the oysters are added. Then towards the end of the class mix the water up well and take another sample which the students will use to determine the cells/ml. By subtracting this cell concentration from the prepared concentration and knowing the number of oysters present and the amount of time available for feeding, a feeding rate can be calculated =

$$\frac{\text{Initial Concentration} - \text{Final Concentration}}{(\text{Number of Oyster}) \times (\text{Time})}$$

Have students determine the filtration rate of live oysters – how many cells/ml/hour

Alternatively, explain how the above experiment would be conducted and have the students practice doing cell counts.

Analyze and interpret water quality data collected. Discuss the need for replicates when sampling. Discuss what might affect oyster feeding rates (season, food availability, tides. trace metals).

Materials: live oysters, algae culture, prepared concentration of algal cells, container to hold feeding oysters, counting chambers, calculators, timer.

Duration: 45 minutes

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0
3. Biology: 1.1,1.2,1.3
4. Chemistry: 1.0,1.1,1.2
5. Earth Science: 1.1,1.2,2.0
6. Geology: 1.0,1.1,1.2
7. Environmental Science: 1.0,1.1,1.2,2.0
8. Microbiology: 1.0,1.1,1.2

9. Oceanography: 1.0, 1.1,1.2, 2.0

10.Physical science: 1.0,1.1,1.2

11.Zoology: 1.0, 1.1,1.2,2.0

Oyster Populations

Instructional Objectives:

Students will:

1) describe the external features of an oyster, its life cycle and express why oysters are important to coastal systems;
2) recognize that various environmental factors (sedimentation, salinity, over-harvesting, and disease) affect oyster recruitment, growth and reproduction.

Objective 1: Students will describe the external features of an oyster, its life cycle and express why oysters are important to coastal systems.

Introduce the following concepts to the students.

- What is an oyster?

Briefly describe what an oyster is using various sized oyster shells. The discussion should include that it is: a bivalve mollusk that secretes a shell; a filter feeder; filters plankton from the water (60 gallons per day per adult oyster (subtidal) 2.5 gallons per hour; are intertidal and found along the coast of Georgia creating reefs. Have examples of major predators: rays, crabs, whelk, oyster drills, moon snails, sea stars, drums, marine worms, birds, humans.

- Why are oysters important to the coast?
  - oysters obtain their food by filtering plankton from the water. They are capable of removing and concentrating materials (i.e.: toxins) in their tissues so that they can be used as living indicators of water quality.
  - oysters provide a food source for many other organisms.
  - oyster reefs provide a habitat for many other organisms.

- oysters – protect against shoreline erosion, act as natural breakwaters to protect the shoreline against boat wakes, and waves, absorb energy before reaches salt marsh

- Oyster life cycle, size classes and dead vs. live

Using the life cycle of an oyster poster, guide students through the various stages from spawning adults to the settlement stage of larvae

Oysters are broadcast spawners (release sperm and eggs into the water column for external fertilization) and spawn along the coast of Georgia from May to October. Water temperature plays a critical role in determining the seasonal timing of spawning. Adult oysters require water temperatures to be approximately 68 degrees F for spawning. Sperm and eggs are released into the water column, eggs are fertilized and develop into trochophore larvae which drift with the water currents as part of the plankton. The larvae then develop into veliger larvae when they develop beating cilia which allow them to feed on other plankton. After a couple of weeks the larvae develop a foot and are then termed "pediveligers". Using this foot they set about exploring various hard substrates (e.g. rocks, pilings and ideally, other oysters) in order to select a suitable site to attach to and begin a sessile existence. Oysters need a hard surface area in order to attach and grow, otherwise they would be quickly covered up with mud and suffocate. Upon settling and attaching to a surface, the larvae are referred to as spat. Adult oysters and shells emit chemical cues to attract the larvae. Obviously if adults have survived at this location for their lifespan chances are this will be a suitable site for new oysters to grow. The reduction in oyster reefs and shell over the years has resulted in a reduction in the amount of hard surface area available thus increasing the competition for space among oyster larvae.

Briefly describe the size classes of the oyster and show how to measure oyster length (umbo to the beak)

Spat- recently settled larvae, need a hard substrate in order to grow.
Sublegal- less than 3 inches in length, cannot harvest
Legal – 3 inches or greater in length, harvestable

Briefly describe what a dead oyster (box oyster) looks like (open shell) and what a live oyster looks like (closed shell) using examples.

Materials: oyster shell, clump of oysters, oyster drill, whelk shells, moon snails, sea stars, life cycle posters, rulers, sublegal shell, legal shell, spat sticks with various sized oysters

Duration: 30 minutes

Objective 2: Students will recognize that various environmental factors (sedimentation, salinity, over-harvesting, and disease) affect oyster recruitment, growth and reproduction.

Ask the students what they know about oyster populations along the Georgia coast. What are some factors occurring along the Georgia Coast that may affect oyster growth and reproduction?

Remind students how oyster populations been impacted over the years (sedimentation, poor water quality, disease). Students will investigate possible reasons for how oyster populations have been affected and why they have declined over the years. Discuss salinity with students. What is salinity? How is it measured?

Briefly go over quadrants and worksheets. The students will be "scientific researchers" responsible for collecting data on oysters at various sites along the coast of Georgia to explore possible reasons for the negative effects to oyster populations (decline).

The students will be grouped and will rotate periodically from one station to the next within one parameter and will collect data on the worksheets

Students will then place results on the board for discussion. There may also be time for students at table one, parameter 1 (i.e.: salinity) to compare data with students at table two parameter 1 (i.e.: salinity). Collect, interpret and discuss the data with the students.

FOUR PARAMETERS

1.) SALINITY

This station is a comparison of two quadrants within an oyster reef that were taken during two different years. One salinity sample represents a dry year (high salinity) and the other salinity sample represents a wet year (low salinity). The two samples could also represent two different sites, one with high salinity (further down river or not near outflow), and the other with a low salinity (site located upriver or near outflow). The students are responsible for determining the salinity of their unknown sample collected from their quadrant. The water samples were taken in the summer months during spawning season. The students should count the number of spat that have settled on the spat sticks within their quadrant.

Ask students what conclusions can be made regarding salinity and spat settlement. "Which quadrant represents a dry year and which quadrant represents a wet year?"

Oysters that are mature (~ 2 years) are able to reproduce but the larvae in lower salinity (5 ppt) waters generally have low survivability.

a.) Salinity Quadrant 1 Materials:

- unknown salinity sample
- refractometer
- waste bucket
- tray to catch water
- worksheet, marker
- spat sticks with few spat
- quadrant
- extra shell

b.) Salinity Quadrant 2 Materials:

- unknown salinity sample (20 ppt)

- refractometer
- waste bucket
- tray to catch water
- worksheet, marker
- spat sticks with many spat
- quadrant
- extra shell

2.) SEDIMENTATION:

This station compares two locations, one area with less sedimentation than the other. The oysters in both quadrants are the same age.

Students are to measure the oysters and determine whether they are live or dead and then to compare both quadrants to determine the effect of sedimentation on the growth rates of oysters

Although they are approximately the same age, it should be concluded that there are more dead, and smaller oysters in one quadrant and more live, larger oysters in the other quadrant. Sedimentation reduces the filtering capability and the growth rate of oysters and may lead to death.

Sediment from rivers, shoreline erosion, unsound agriculture practices and urbanization increases sediment loads along the coast (GIS maps?). Oysters need a hard substrate like other oyster shell, rock, cement, rock or wood to settle attach and grow. Oyster larvae will not set on soft mud or unstable sandy bottoms because ultimately the oysters will be covered. Also, an increase in sedimentation increases turbidity and decreases available sunlight for primary production of phytoplankton. Nutrients (N+P) associated with sediments may result in algal blooms. This could potentially cause a shift in preferable food items of oysters to unpreferable food items (chlorella and dinoflagellates).

a.) Sedimentation Quadrant 1 Materials:

- vials with sediment
- rulers
- worksheet, markers
- 2 live oysters that are the same size and measure at least 3 inches
- 4 dead oysters that measure between 2.5 inches and 3 inches.
- Quadrant

b.) Sedimentation Quadrant 2 Materials:

- vials without sediment or low sediment levels
- rulers (calipers)
- 4 live oysters that are the same size and measure at least 3 inches
- 2 dead oysters that measure between 2.5 inches and 3 inches
- quadrant

3.) DISEASE (Dermo and MSX):

This station has three components: quadrant with no Dermo, quadrant with Dermo, and quadrant with Dermo and percent of class size affected with Dermo. Dermo presence/absence is illustrated by dead/living oysters.

One table has two quadrants comparing an area affected with Dermo and areas not affected by Dermo. Temperature measurements are given and a water sample provided to determine salinity..

Students are to determine the salinity of each area and determine the number of live versus the number of dead oysters in each quadrant

At another table, students are to count and measure the length of each oyster in the quadrant and determine which size class seems to be more affected by Dermo

Young oysters (1yr) are generally less likely to be infected with Dermo and are more likely to have lower mortality rates than older oysters (2 and 3 years old). Dermo spreads between and kills oysters faster at temperatures greater than 25 degrees C (metabolic rate of Dermo decreases at lower temperatures; threshold is between 15-20 degrees C). Also, Dermo seems intolerant of salinities below 8-9 ppt).

Coastal development (increasing population growth, wetland loss (7000 acres pa in GA), increased boat traffic, and increased non-point source pollution (agriculture, homes, sewage treatment, septic tanks, car exhausts, sediment from construction) all result in deteriorating water quality which causes stress.

a.) Disease Quadrant 1 Materials (table 1): (low salinity, low temperature, no Dermo)

- salinity sample (5ppt at 18 degrees C)
- waste bucket
- tray
- refractometer
- worksheet, marker
- 8 live osiers (2-3 inches)
- 2 dead oysters (2-3 inches)
- quadrant

b.) Disease Quadrant 2 Materials (table 1): high salinity, high temperature, Dermo)

- Salinity sample (20 ppt at 25 degrees C)
- Waste bucket
- Tray
- Refractometer
- Worksheet, marker
- 2 live oysters (2-3 inches)
- 8 dead oysters (2-3 inches)
- quadrant

c.) Disease Quadrant 1 (table 2):

- quadrant
- rulers
- worksheet, markers
- 1, < 1 inch dead oyster
- 2, 2 inch dead oysters
- 7, 3 inch dead oysters

4.) HARVESTING:

This station compares two oyster reefs; one that is harvestable and one that is not (based on size of oyster).

Students will determine the length of each oyster in their quadrants and determine which quadrant would be harvestable based on oyster size regulation (market size of three inches or greater)

The harvestable table will also have loose oyster shell in a couple of baskets or containers that represent the amount of shell required by watermen to return to beds dependent upon the amount harvested at any given time (=1/3).

Possible discussions of this station could involve:

1.) where in Chatham county is their a public oyster bed? Do you know if your county has a public oyster bed and how would you go about finding this information?
2.) discuss historical information/change in harvest amounts and trend that shifted from canned industry to local oyster roasts and why.
3.) would it be beneficial for oyster populations to increase the regulation size of harvestable oysters from three inches to four or more? Possible discussion: Oysters change sex based on environmental factors. It is more advantageous to populations to have older, larger reproducing females (more productive) son in the case of increasing market size, this might be more advantageous to the overall population.

Dermo however, tends to affect the older oysters (greater than two years old) so you would want to harvest them as soon as they reach market size (3 inches) before they risk infection or prolonged affects of Dermo.

4.) for those at quadrant one with more sublegal sized oysters, what might have the waterman done in the past to supplement their oyster catch?

a.) Harvesting Quadrant 1 Materials:

- 5 sublegal oysters
- 1 legal oyster
- quadrant
- calipers
- data sheets, markers

b.) Harvesting Quadrant 2 Materials:

- 1 sublegal oysters
- 5 legal oysters
- quadrant
- calipers
- data sheets, markers

SUMMARY/WRAP-UP

1. Go over the results from each station. Make sure that the students give results using the evidence that they have collected. Oyster populations may be affected by salinity, sedimentation, disease, over-harvesting, loss of suitable substrate or habitat, predation and low dissolved oxygen.

2. Review the optimum conditions necessary for recruitment, growth and reproduction of an oyster:

- abundant population of spawning adults
- good water quality

- clean, hard substrate to settle
- good water flow/movement
- adequate food supply
- proper management regulations

3. What are some ways in which you can help protect, restore and enhance oyster populations no matter where you live in Georgia:

- seed beds
- plant shell
- reduce the amount of nutrients entering waterways (non-point and point source pollution)
- reduce soil erosion by creating riparian buffers along tidal creeks and homes
- recycle oyster shell and cure
- abide by the oyster harvesting regulations

Materials: See above.

Duration: 1.5 hours

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0
3. Biology: 1.1,1.2,1.3
4. Chemistry: 1.0,1.1,1.2
5. Earth Science: 1.1,1.2,2.0
6. Geology: 1.0,1.1,1.2
7. Environmental Science: 1.0,1.1,1.2,2.0
8. Microbiology: 1.0,1.1,1.2
9. Oceanography: 1.0, 1.1,1.2, 2.0
10. Physical science: 1.0,1.1,1.2
11. Zoology: 1.0, 1.1,1.2,2.0

Oyster Restoration in Georgia

Instructional Objectives

Students will:

1) describe general characteristics of an oyster;
2) express why oysters are important to coastal systems;
3) understand the importance of restoration efforts that are being implemented along the coast of Georgia to enhance oyster reef populations and;
4) participate in one component of the GEORGIA program (oyster shell bagging) for community service hours.

Introduction: Students will be provided an introduction to oysters and why they are important to coastal systems and a brief overview of the GEORGIA program. This portion of the program covers Objectives 1-3 and will take approximately 45 minutes.

Objective 1: Students will be able to describe general characteristics of an oyster.

Using the power point presentation entitled, GEORGIA: Generating Enhanced Oyster reefs in Georgia's Inshore Areas and artifacts, provide students with a general introduction of what makes an oyster an oyster. Oysters are bivalves related to other mollusks such as squid, mussels and clams.

Provide molluscan examples that can be passed around to the students

Discuss external features of an oyster (umbo, beak, right valve vs. left valve, evidence of spat and fouling organisms) and internal features (adductor muscle scar, traces of tubes worms).

Have students measure an oyster to determine whether the oyster is sublegal or legal, and whether it is a box oyster (dead) or a live oyster?

Briefly discuss the internal anatomy (gills, mantle, labial palps, and mouth) and its ability to filter sediment, plankton and pollutants.

Materials: power point presentation – GEORGIA: Generating Enhanced Oyster Reefs in Georgia's Inshore Areas, glued oysters, oyster valves, rulers, clam shell, mussel shells, oyster drills, moon snails, preserved sea stars, whelk shells, box oyster, and "live" oyster.

Objective 2: Students will express why oysters are important to coastal systems.

Discuss with students why oysters are important to coastal systems. Oysters are considered a keystone species critical to a healthy ecosystem and serve many important ecological functions:

1.) Oysters are **filter** feeders capable of filtering 60 gallons of water per day per adult oyster (sub tidal) or 2.5 gallons of water per hour. Oysters improve water clarity by removing suspended sediments that could potentially interfere with primary productivity. Oysters also filter pollutants and control excessive algal blooms.

2.) Oysters are capable of **reducing shoreline erosion**. Oyster reefs reduce the energy of breakwaters by absorbing wave energy before it reaches the salt marsh thus protecting the shoreline against boat wakes and waves.

3.) Oysters provide essential **habitat** for transient and residential organisms that use the reef for food and shelter. Oyster reefs provide organisms with a spawning and nursery habitat. There are examples of commercially important species that use oyster reefs as a habitat (brown shrimp, white shrimp, and blue crab).

4.) Oysters were at one time, an important **commercial industry** along the coast of Georgia. Prior to the 1940's, oysters were harvested manually by gathering the intertidal oysters and breaking the legal sized oysters (3 inches) from the large clumps. This method of harvesting oysters was labor intensive for the low meat yield generated from collecting the oysters. There was a shift from the commercial harvesting oysters to traditional local oyster roasts stemmed from the low meat yield that was acquired from coastal GA oysters and today, the commercial oyster industry is virtually non-existent.

Ask students to provide examples of why oyster populations along the Atlantic coast have declined over the last century

Discuss in general over harvesting, habitat degradation, disease and oyster shell shortages:

habitat degradation – coastal development results in increased population growth, wetland loss, increased boat traffic, large scale removal of water from coastal aquifers, increased non-point source pollution (agriculture, homes, sewage treatment, septic tanks, car exhausts, and sediment from construction). These factors result in deteriorating water quality which potentially creates a negative feedback loop.

disease - Dermo (*Perkinsus marinus*): protozoan parasite, found in GA in 1960's, mass mortalities in the 1980's, attacks digestive tissues and is harmless to humans. MSX (*Haplosporidium nelsoni*): protozoan parasite, found in GA in late 1980's, attacks gills, and is harmless to humans.

shell shortage - during early part of last century oysters were over harvested and there existed a lack of oyster shell replenishment to water in low quantities even though by law, a third of the oyster shell was required to be returned to the water. Oyster shell was commonly used in road construction, driveways, buildings (tabby), and in the production of chicken feed.

Why is returning recycled oyster shell to the water so important for future generations of oysters? Use the life cycle poster to discuss with students the general life cycle of an oyster

Oysters are broadcast spawners and spawn along the coast of Georgia from May to October. Sperm and eggs are released into the water column and develop into trochophore larvae which drift as part of the plankton for a couple of weeks. The larvae then develop into veliger larvae where they then will settle on a hard substrate (oyster reefs), attach and begin a sessile existence. Oysters need a hard surface area in order to settle, attach and grow. The reduction in oyster shell replenishment over the years has resulted in a reduction of hard

surface area to settle, attach and grow thus increasing the competition for space among oyster larvae.

Materials: carboy, jar of sediment, clump of oysters, posters of oyster life cycle for students

Objective 3: Students will understand the importance of restoration efforts that are being implemented along the coast of Georgia to enhance oyster reef populations.

Continue with the power point presentation to provide students with an overview of the GEORGIA program. Introduce the goals of the GEORGIA program (to create ecologically functional and sustainable oyster reefs and to provide action-based conservation program for the local community).

Discuss in general the three components of the GEORGIA program (oyster shell procurement, oyster reef building and oyster reef monitoring).

Materials: spat sticks, bagged oyster shell, shell strings, oyster valves with spat, spat sticks with oysters (spat, 6, month, 1 year).

Duration: Objectives 1-3 should take 45 minutes

Objective 4: Students will participate in one component of the GEORGIA program (oyster shell bagging) for community service hours.

Allow students to bag oyster shell at the Skidaway shell recycling center for community service hours

Materials: gloves, baskets, shovels, buckets, tubes, bag material, scissors, first aid kit, water cooler and cups.

Duration: 1.5 hours including travel time to and from the recycling center site.

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0
3. Biology: 1.1,1.2,1.3
4. Chemistry: 1.0,1.1,1.2
5. Earth Science: 1.1,1.2,2.0
6. Geology: 1.0,1.1,1.2
7. Environmental Science: 1.0,1.1,1.2,2.0
8. Microbiology: 1.0,1.1,1.2
9. Oceanography: 1.0, 1.1,1.2, 2.0
10 Physical science: 1.0,1.1,1.2
11. Zoology: 1.0, 1.1,1.2,2.0

All About Whelks and Oysters

Instructional Objectives

Students will:

1) describe the characteristics of the phylum Mollusca and the external differences between bivalves (oyster) and gastropods (whelk);
2) compare and contrast their reproductive systems, life cycles, digestive systems, and feeding behaviors through dissections;
3) recognize their commercial importance in Georgia.

Objective 1: Describe the characteristics of Phylum Mollusca and explain the differences between bivalves (oysters) and gastropods (whelk).

- Introduce classification (the general scheme of how scientists/biologists organize animals according to certain characteristics). Go through the classification scheme-

Phylum
Class
Order
Family
Genus
Species

- Discuss the major characteristics of the phylum Mollusca.

Characteristics include the presence of a mantle and a mantle cavity. The mantle tissue is an outer layer of tissue that encompasses the organs and also secretes the shell. Mollusks also have a head, foot (muscle) and a visceral mass (organ systems). Mollusks also have a radula (to aid in feeding). Sexes are separate (dioecious). Two important classes in the phylum include Gastropoda and Bivalvia, which we will talk about today.

- Gastropoda: These include snails, abalone, sea slugs, and limpets. This is the second largest class after the Insecta. Very diverse forms. In Georgia our state shell is a gastropod, the knobbed whelk. The knobbed whelk *Busycon carica* is quite common in our waters and can grow to 10 inches. Three other species of whelk also occur here: the lightening whelk *Busycon sinistrum*, is the largest whelk growing to a maximum length of 16 inches. This species shell opens on the left hand side, it is a mirror image of a knobbed whelk. The channeled whelk *Busycotypus canaliculiatus*, has a thinner shell which grows to 7 inches. The pear whelk *Busycotypus spiratu*s is the smallest whelk at 4 inches maximum size. Channeled and knobbed whelks have much thinner shells. You can see live whelks crawling or burrowing on intertidal mud flats at low tide, particularly during the cooler months of fall, winter, and spring. Whelks become active and feed on burrowed clams and oysters during these cooler months. During the warmer weather they tend to burrow into sediment or stay in deeper water in the subtidal zone.

- Bivalvia: The most common oyster in coastal Georgia is the Eastern Oystern (*Crassostrea virginica*). They live in the intertidal zone in clumps or in large oyster reefs. Can live for up to 10 years and reach >6" in length.

- Gastropod external anatomy: Gastropoda characteristics include a single shell that coils and has whorls. Other external characteristics include the siphonal canal, operculum, knobs, protoconch, columella, inner and outer lips, spire. Show labeled features on the board.

Have students identify external shell features and check outer lip for chips or cracks

Discuss what may have caused these chips (predating on clams). If a channeled whelk is available discuss the periostracum and explain the function (aids burrowing)

Materials: Labeled whelk illustrations, whelk shells.

Duration: 20 minutes.

- Oyster external anatomy: Bivalve characteristics include two shells that are attached together along a hinge line. Other external characteristics include the umbo, and muscle scars. Show a labeled oyster shell on the board.

Have students identify external shell features

Discuss valve orientation, and growth lines showing the oldest and newest parts of the shell. Why are these lines produced. Are there any other organisms attached to the shell?

Materials:
Labeled oyster illustration, oyster shells.

Duration: 10 minutes.

Objective 2: compare and contrast their reproductive systems, life cycles, digestive systems, and feeding behaviors through dissections.

Reproduction & Life Cycle

Whelks: Separate sexes. Show labeled anatomical diagram (male = penis, vas deferens, testes; female= ovary, oviduct, capsule gland). Have internal fertilization. Whelks visit the mud flats to mate and spawn eggs during the spring and also during the fall. Males attracted to females with pheromones. Males typically smaller than females. This size variation for the male and female is an example of dimorphism. Dimorphism is a difference in the morphology (shape), color, or size in a given species. The female can store sperm for a period of time. Females lay embryos in capsules arranged in long strings. One end of the egg string is anchored into the sediment by the female digging down. When scientists examined the egg capsules from a number of egg strings, they found that the male to female sex ratio of developing embryos was nearly 50 males to 50 females (typical in a species with separate male and female sexes). Also multiple fathers are evident both within each capsule and along the egg string. After approx 6 weeks (depending on the water temperature) the embryos develop and hatch. Hatchlings are generally 5-7 mm in length. They look just like an adult whelk.

Have students identify the sex of a whelk. If female check the oviduct size to see whether it is swollen with eggs. If available have students open an egg capsule so they can observe the size of the whelks prior to hatching.

Materials: Whelk specimens, dissection kits, whelk egg capsules, dissection trays.

Duration: 30 minutes.

Oysters: Oysters spawn in coastal Georgia from May until October in temperatures 60 to 68 degrees F or 15.5 – 20 degrees C. They release sperm and egg into the water where fertilization takes place. This is known as external fertilization.

Introduce the life cycle diagram (oyster) and point out the stages of development.

A fertilized egg develops into a trochophore stage which swims in the open water. After 24 to 48 hrs the trochophore develops into a veliger stage which has a thin shell and feeds on microsopic algae. After 12-20 days the larva develops a foot and eye spots and is called pediveliger (meaning eyed larva). Pediveligers can settle and crawl to short distances seeking suitable sites for setting. The oyster sets when the larva cements or glues itself to a hard substrate and metamorphoses into a tiny oyster which at this point is called spat or a miniature oyster. Spat are mostly male reaching sexual maturity in 4 months. Some of the males will change to females and some females can change back to males. Oysters can take 12 – 36 months to grow to the harvestable size of 3 inches. Growth depends on the temperature, salinity, and food supply. Oysters grow when they are on a firm substrate, and when salinities are from 10 to 30 ppt. but 15 to 18 ppt is considered the optimum salinity. Other factors that effect growth are water flow, sediment load, and oxygen concentration (must be 3 ppm to 5 ppm).

The following activity is seasonal and depends on the stage of reproductive development. If the class occurs when oysters are outside the spawning season then use previously prepared stained slides.

Have the students take a scraping from the surface of the oyster, which is the gonad area. Dip the scrapings into a few drops of salt water on a slide and cover with a cover slip. Using a microscope see if they can determine the sex of the oyster.

Materials: Oyster specimens, dissection kits, dissection trays, microscopes, slides and cover slips, prepared stained slides.

Duration: 30 minutes

Feeding Behavior & Digestive System

Whelks: Carnivorous, eating bivalves including oysters by using the edge of their shell and their strong foot (muscle). The foot and shell edge work together by prying open the 2 valves of an oyster clam or mussel. The way this works is that the whelk actually causes the muscles of the oyster/clam to tire until the oyster/clam cannot hold the shells together any longer. Once the valves are open, the whelk inserts a straw like proboscis with a radula or teeth on one end. This "straw shaped mouth" can consume a bivalve in 1-2 days depending on the size and strength of the whelk. A large whelk can also rub the oyster shell against the outer lip of its own shell and wear away a hole large enough through which a proboscis can be inserted. The proboscis leads to an esophagus, which leads to a stomach which sits upon a large digestive gland at the posterior end of the body, the intestine turns around 180 degrees to end at a rectum in the mantle cavity at the anterior end of the body. Show a labeled diagram.

Pull the proboscis out of a whelk's mouth and using a forceps, pull the radula out of the anterior end of this tube-like structure. Using a dissecting microscope and the TV monitor students should observe the rows of teeth and count how many teeth are present in a single row.

Discuss that the proboscis is like a human esophagus, so the musculature is very similar. Explain how teeth are continually being worn away as the whelk feeds and these are being replaced by new ones which form on the other end and are continually moving forward.

Arrange the students into small groups and during the next stage (i.e. oyster dissections) take a prepared dissected and labeled whelk to each group.

The marine educator will give each group a guided tour of whelk anatomy using the prepared specimen

Point out the water coming into the siphon over the osphradium and the gills and which then goes out the other side of the mantle cavity after it passes by the anus to carry wastes away. Also explain the digestive system and demonstrate the flow of food through the whelk. Point out the radula, proboscis, esophagus, stomach and anus.

Materials: whelk specimens, dissection kits, whelk anatomical illustration (labeled), dissecting trays, labeled and dissected whelk.

Duration: 20 minutes

Oysters: Oysters are filter feeders. The only time when oysters are mobile is during their earlier stages of life during the larval period. After they settle as spat and mature into a larger oyster they become sessile. Grouped together in clumps or in large mounds they eventually form oyster reefs. The oysters rely heavily on the phytoplankton or zooplankton that flows to them with the currents of the estuaries and rivers. Oysters cannot selectively feed so they draw from the water whatever particles or food items come to them. More specifically, water passes through the mantle with a network of tentacles. This is where large sand, non-food and food items are sorted before flowing to the gills. Food comes in thru the tentacles of the mantle to the gills where it sticks to mucus. The gills and mucus will form a string with food particles which are then passed to the mouth for digestion. Show labeled diagram of digestive system.

Have the students observe eggs, sperm, gills, digestive tissue, food particles the foot and muscle layers using prepared histological slides

Discuss briefly the process of histology (dissecting the tissue and how it is processed and embedded in a paraffin block; show an example of a paraffin block, describe how the tissue is sectioned and that they are looking at a 6-7um section). Something to mention here is that when the particles are too small they can clog the gills by passing through the mantle tentacles. Silt particles are very tiny (smaller than sand) so it can pass through and travel to the gills and cause clogging. One way that oysters deal with this problem is by closing the valves as they feed however since they need current and water for respiration they cannot keep their valves closed very long (e.g. if you held your breath for a long time that would be similar to an oyster closing its valves.

Materials: stained oyster slides, dissecting and stereo microscopes, TV monitor, oyster anatomy diagram.

Duration: 15 minutes.

Then put students into groups of 2-3 and provide with fresh oyster specimens for dissection.

Students should label the following parts: gills, foot, gonad, digestive tissue, adductor, abductor muscle, and mantle. A scraping of the stomach should also be placed onto a slide with water and the shapes of contents drawn.

Ask the students if they can guess what the stomach contents might be. Discuss the various types of plankton found in the oyster's stomachs.

Materials: oyster specimens, pins, labels, oyster anatomy illustration, dissection kits, dissection trays, microscope slides, cover slips

Duration: 45 minutes

Objective 3: recognize their commercial importance in Georgia.

Whelk fisheries occur throughout the Eastern seaboard. The most important fishery in Georgia is shrimping. When the shrimping season is over many shrimpers will install a whelk trawl net and fish for whelk. In coastal Georgia, you often see whelk advertised on the menu as "Conch" rather than the correct biological name "whelk". Conch are actually vegetarian sea snails and occur in the warm and clear waters of the Caribbean. Native Americans used whelk and oysters as food, tools, and for ornamentation. There is evidence of how the Native Americans utilized oysters by the remains left in shell middens and shell rings along the coastal Georgia areas. Shell rings are believed to have been used for ceremonial purposes. Oyster culture began taking place as early as 1830 in the Southeastern part of the United States. In 1880 it was estimated that 290,000 bushels of oysters were harvested and were valued at $115,000. Early in the 1900's steam canneries grew in Georgia and South Carolina and by 1902 nearly 95% of the oyster catch was canned in Georgia and South Carolina. Oysters were gathered by pickers in the intertidal zones of S.C and GA and taken to canneries. At the canneries the oysters shells were opened by steam and picked by hand. Oysters were placed in a tin can and sealed. This hard labor made it difficult to maintain employees over an extended period of time. By World War II many canneries closed due to labor shortages. Poor yields, cheap imports, and labor shortages all led to the demise of the oyster canneries in the late 1980's. At present time, the oyster production is at an all time low because of:
Closures of productive grounds due to pollution, lack of markets, labor shortages, coastal development, non point source pollution, and run off from golf courses and residential areas. The whelk fishery is also at an all time low due to overfishing of the resource.

Materials: powerpoint slides.

Duration: 10 minutes.

Quality Core Curriculum Addressed:
1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0

3. Biology: 1.1,1.2,1.3

4. Chemistry: 1.0,1.1,1.2

5. Earth Science: 1.1,1.2,2.0

6. Geology: 1.0,1.1,1.2

7. Environmental Science: 1.0,1.1,1.2,2.0

8. Microbiology: 1.0,1.1,1.2

9. Oceanography: 1.0, 1.1,1.2, 2.0

10.Physical science: 1.0,1.1,1.2

11.Zoology: 1.0, 1.1,1.2,2.0

Guided Oyster Disease Study

Instructional Objectives

Students will:

1) define a major disease (MSX) of oysters in coastal Georgia;
2) describe what environmental effects cause MSX and how it adds to the decline of oysters;
3) observe a working histology laboratory and see how slides are prepared;
4) identify tissues & MSX on a prepared slide
5) determine MSX intensity
6) determine disease prevalence and investigate why it is more prevalent at some locations

Objective 1 & 2: Define a major disease (MSX) of oysters in coastal Georgia and describe what environmental effects cause MSX and how it has decreased oyster populations.

Oysters have declined in population over the last century. The reasons are a combination of environmental factors and over fishing. The environmental factors include increased development on the coast. More coastal construction leads to sediment loading in the water. The increase of sediment in the water causes oyster gills to clog with material causing suffocation. In addition to the development we also have had an increase of non point source pollution also related to the increased development. The increased human inhabitation brings along with it golf courses, septic tank leaks, garden and lawn fertilizing and other numerous land use practices that add to poor water quality and the demise of the oyster population. Another problem resulting in the oyster population decline has to do with the over fishing and lack of replacement of shell to the creeks and riverbanks. The substrate in which an oyster settles is often referred to as cultch. Over time, when oysters

were harvested the fishermen used to replace whatever shell they took from the creeks and rivers. However, oyster shell replacement is no longer done in tidal creeks and rivers. Over the years periodic drought conditions have caused problems by increasing salinity in the coastal waterways causing ecosystems to stress. In addition, we also have pathogens that lie dormant in sediment. When the right conditions occur pathogens will hatch becoming prevalent in the water, resulting in oyster disease. One of these diseases we will talk about today is MSX.

MSX was discovered in 1957 in the Delaware Bay area. Scientist were confused by the mysterious microbe that they found in the sick oyster cells. They decided to call it MSX which stands for Multinucleate Sphere Unknown. Later the MSX microbe ended up being a protozoan that thrived in areas higher than 15 ppt salinity now called *Haplospordium nelsoni*. The effects are detrimental in that it causes the tissue to become watery and the oyster meat to shrink. The protozoans enter the oyster thru the mantle then it travels through the gills to the palps, which then enters the organ systems. It especially attacks the gonads, which causes the oyster to respond by producing cysts (as a defense mechanism). However, the result is poor oyster health and a decrease in reproduction capabilities. The disease does not harm humans.

Materials: powerpoint

Duration: 10 minutes

Objective 3: Observe a working histology laboratory and see how slides are prepared

Students are taken to the histology laboratory at the Shellfish Research Laboratory and provided a guided tour of how we go from a fresh tissue sample to a stained slide

When an oyster is dissected to determine the presence or absence of diseases such as MSX the tissue goes through several stages of processing. First, tissue is extracted from the oyster then preserved in a container filled with 70% alcohol. Tissue samples are then placed into plastic cassettes in a tissue processor where they are dehydrated, and prepared for

embedding in paraffin. Tissue samples are removed from the processor and placed in a holding chamber with melted paraffin located inside the embedding machine. The embedding station is the machine where the tissue is embedded in a melted paraffin mold and melted wax is poured into a mold. After paraffin solidifies it is then in a solid block form. From this point, the tissue-block can be placed on a microtome and become sectioned. The paraffin acts as a material that helps support tissue while it can be sectioned. Typically, the sections are sliced at a thickness of 7um. The sections come off like ribbons which are then lifted off of the microtome with a paint brush and placed into a warm water bath. The ribbons of paraffin and tissue float in the water bath. When you have enough ribbons from that tissue block label and dip a slide into the warm water then lift it up as the ribbon of tissue/paraffin adheres to the slide. After the slide with tissue sections are dried, they are ready for the final stage, staining. Optional: Show examples of making slides by using floating sections already in the warm bath. Demonstrate how the slide is dipped into the water bath and lifted up with sections adhering to the slide.
For slide staining approximately 50 to 100 slides are placed into a holder which goes through an automated process involving chemical solutions and stains. More specifically the staining protocol takes the slides through a series of alcohol concentrations which rehydrates the tissue sections until they reach the station with the stain. The stain used is called Harris Hematoxylin which stains the nuclei of the cells dark blue or black. A counter stain (Eosin) is used to provide a good contrast color by staining tissues pink. The slides then go through another alcohol series which dehydrates the tissues. When the staining process is complete the slides are covered with permount (a permanent mounting media) then covered with a thin cover glass.

Materials: histology laboratory equipment (tissue processor, embedder, microtome, water bath, slide dryer, stainer), also have following props (container with 70% alcohol and tissue blocks, cassettes, stained and unstained slides)

Duration: 30 minutes

Objective 4: identify tissues and MSX on a prepared slide

Go back to the classroom and set the monitor and microscope system up to display slides. At this point explain some of the obvious parts of the oyster tissue such as digestive tissue (mostly stains brown with obvious phytoplankton present). Go through the presence of male and female gametes such as egg and sperm. Generally, the sperm picks up the darker stain and the eggs pick up a lighter pinkish color. Point out an epidermal layer (the first layer at edge of the tissue section). Point out the tissue types such as gonad, digestive tissue, and follicle cells, and gills. Only point out and discuss very obvious and general characteristics of the tissue. The slides may vary a little on what characteristics show up so you may or may not see the same observations in the tissue of each slide.

On the monitor show students a positive and negative slide for MSX and allow them to become familiar with the identification of the disease and various tissues

Since MSX attacks the gills first this is a good area on the slide to start looking for its presence. Working as a group, have them identify several more slides on the screen as you change out different slides. Also, include negative slides so they know what the differences are between a negative and positive slide.

Materials: microscope and monitor system, prepared oyster slides showing male and female gonads and with and without MSX present.

Duration: 15 minutes

Objective 5: determine MSX incidence and intensity

Demonstrate how to determine the intensity of MSX:

- Pick a random spot on the slide and count the number of positive cells.
- Rate each slide (at 400X) on the MSX disease scale.

MSX disease scale:

Uninfected = 0 positive cells present in field of view

Localized = 1 positive cell is present in field of view

Rare = 2 or less positive cells present in field of view

Moderate = 2-5 positive cells present in field of view

Heavy = more than 5 cells present in field of view

Working as a group, students should agree on the intensity classification for three slides which will be projected onto the monitor

Materials: microscope and monitor, calculators, positive and negative MSX slides showing different intensities of infection

Duration: 15 minutes

Objective 6: determine disease prevalence and investigate why it is more prevalent at some locations

This class will require previous knowledge of charting or the educator needs to spend a few minutes introducing the latitude and longitude lines on the chart.

Students are split into 3 groups and are given a water sample, latitude and longitude reading, and 10 oyster slides. Prepare 3 water samples a high salinity, mid salinity, and a low salinity. Select 3 separate sets of MSX slides, one with no presence of MSX, one set with a middle to low prevalence of MSX, and the third set with a high prevalence of MSX. Select the latitude and longitude of 3 locations. It is preferable to use a river such as the Ogeechee, or Savannah and select three locations ranging from the mouth to several miles upstream. Use topozone.com to obtain the lat and long readings.

Students must test the salinity of the water sample, determine the location of the site on a chart and then determine the prevalence of MSX disease

To determine the prevalence of the disease at that site calculate the percentage of positive slides from the total number of slides given. You will then have the percentage, which is the prevalence.

Students must explain disease prevalence at their sites given only what evidence they have (i.e. salinity and location)

Materials: microscope, data sheet, calculators, sets of MSX slides, chart of coastal Georgia area on a bulletin board with colored pins (3 different pins), 3 samples of water with low, mid and high salinities.

Duration: 50 minutes

Quality Core Curriculum Addressed:

1. ABCI: 1.1,1.2,2.0
2. ABCII: 1.1,1.2, 2.0
3. Biology: 1.1,1.2,1.3
4. Chemistry: 1.0,1.1,1.2
5. Earth Science: 1.1,1.2,2.0
6. Geology: 1.0,1.1,1.2
7. Environmental Science: 1.0,1.1,1.2,2.0
8. Microbiology: 1.0,1.1,1.2
9. Oceanography: 1.0, 1.1,1.2, 2.0

10 Physical science: 1.0,1.1,1.2

11. Zoology: 1.0, 1.1,1.2,2.0

Appendix A

GEORGIA Biological Community Sampling (Identify and count the # of individuals of each type present and record below)		
Phylum Mollusca	**Phylum Arthropoda**	**Phylum Ecinodermata**
Class Gastropoda (Snails & Slugs)	*Class Cirrepedia (Barnacles)*	*Class Holothuroidea (Sea Cucumbers)*
Oyster Drill	Barnacle	Sea Cucumber
Mud Snail	*Class Malacostraca (Crabs, Shrimp)*	*Class Asteroidea (Sea Stars)*
Knobbed Whelk	Fiddler Crab	Sea Star
Lightning Whelk	Mud Crab	*Class Echinoidea (Sea Urchins)*
Channeled Whelk	Blue Crab	Sea Urchin
Tulip Snail	Hermit Crab	*Class Ophiuroidea (Brittle Stars)*
Dove Snail	Stone Crab	Brittle Star
Rock Snail	Porcelain Crab	
Keyhole Limpet	Spider Crab	**Phylum Annelida**
Nudibranch	Calico Crab	*Class Polychaeta (Worms)*
Other	Other	Worm
Class Bivalvia (Mussels, Clams, Oysters)	*Class Merostomata (Horseshoe crabs)*	*Class Hirudinea (Leeches)*
Ribbed Mussel	Horseshoe Crab	Leech
Hooked Mussel	*Class Pycnogonita (Sea Spiders)*	
Scorched Mussel	Sea Spider	**Phylum Chordata**
Paper Mussel		*Class Ascidiacea (Tunicates, Sea Squirts)*
Hard Clam	**Phylum Cnidaria**	Sea Squirt
Surf Clam	*Class Anthozoa (Anemones)*	Sea Grape
Oyster	Anemone	Sea Pork
Ark	Sea Whip	Other
Other	Sea Pansy	*Class Osteichthyes (Bony Fishes)*
	Other	Striped Blenny
Phylum Porifera	*Class Scyphozoa (Jellyfish)*	Oyster Toadfish
Class Demospongiae (Sponges)	Jellyfish	Skillet Fish
Redbeard Sponge	Other	Goby
Basket Sponge		Other
Finger Sponge	**Phylum Ctenophora**	
Boring Sponge	*Class Tentaculata (Comb Jellies)*	**Total Number of All Kinds:**
Other	Comb Jellies	**Total Number of All Individuals:**

Appendix B

Shannon Wiener Diversity Index Worksheet

Date: Group Name:

Calculate the Diversity Index for the reef you have sampled by completing the worksheet below (see the example on the following page).

	A	C	D	E
Kind	# found in sample	A ÷ B* (Total No. of all individuals)	Natural log(ln) of C	C x D

*B. Total number of individuals (Sum of A) _____
Total of (E) _____
Multiply 1.4427 to convert to log2 _____
Multiply by -1 to make positive _____

Calculated Shannon-Wiener Index Diversity Index _____

Diversity Scale

1	2	3	4	5
Not Diverse	→	Moderately Diverse	→	Diverse

Biological Diversity Index Worksheet

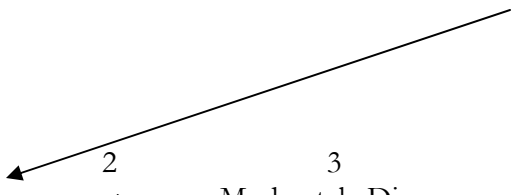
Example Date: AAW Group Name: Mud Snails

Circle type of monitoring: Box Survey, Colonizing plates, D-Net, and Seine
Calculate the Diversity Index for your sample by completing the worksheet below.

	A	C	D	E
Kind	# found in sample	A ÷ B (Total No. of all individuals)	Natural log(ln) of C	C x D
Mud crab	2	0.05	-2.99	-0.15
Polychaete worms	3	0.08	-2.53	-0.20
Periwinkles	10	0.26	-1.35	-0.35
Amphipods	23	0.59	-0.53	-0.31
Blue crab	1	0.03	-3.51	-0.11

B. Total number of individuals (Sum of A) = 39
Total of (E) = -1.12
Multiply 1.4427 to convert to log2 = -1.62
Multiply by -1 to make positive = 1.62
Calculated Shannon-Wiener Index Diversity Index = 1.62

Diversity Scale



1 Not Diverse → 2 → 3 Moderately Diverse → 4 → 5 Diverse

Appendix C

This program is sponsored by:

The University of Georgia
Marine Extension Service

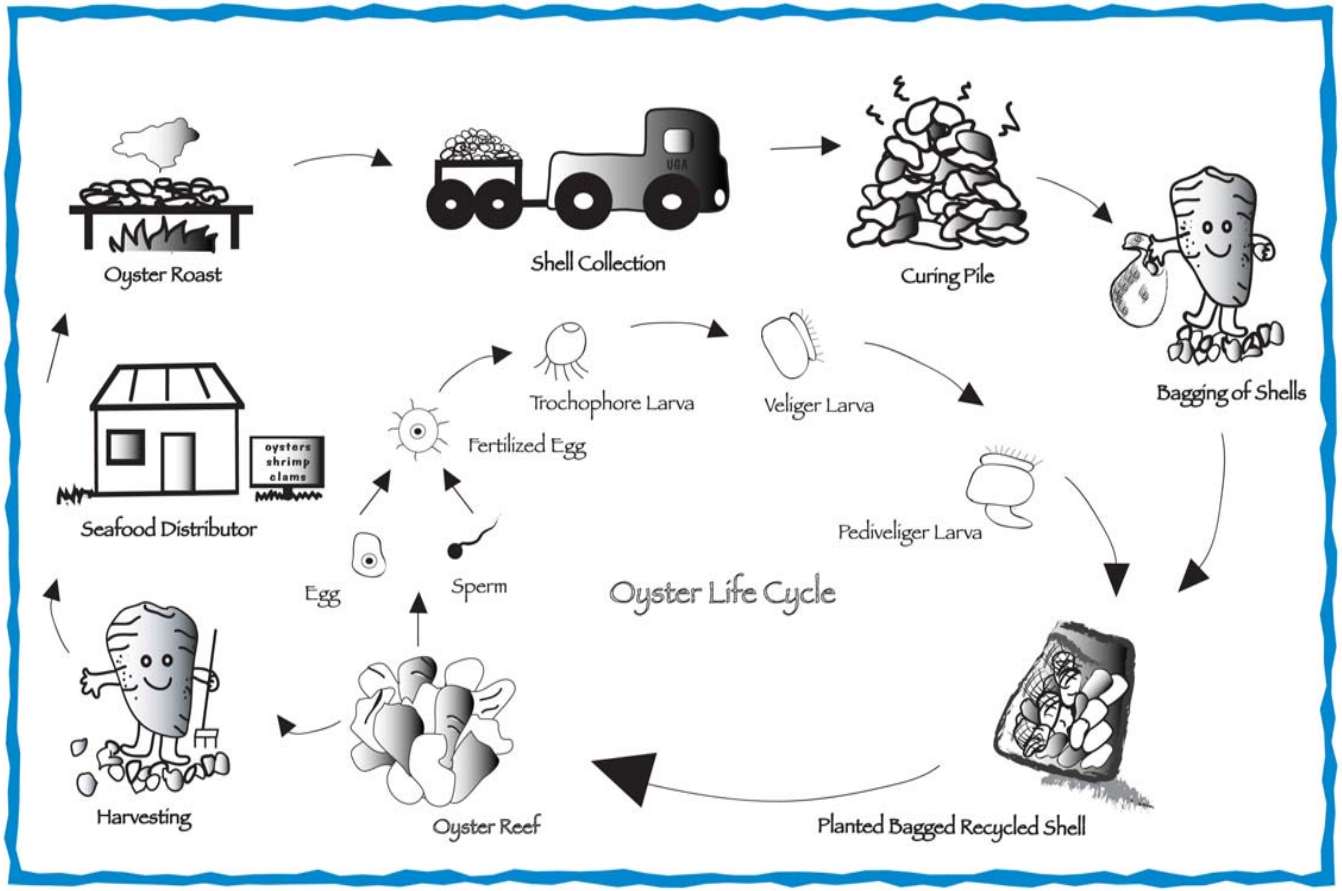
The University of Georgia
Department of Public Service
and Outreach

N.O.A.A. Community Based
Habitat Restoration Program

The Ocean Trust

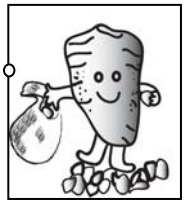
The National Fisheries
Institute, Inc.

G.E.O.R.G.I.A.



Generating Enhanced Oyster Reefs in Georgia's Inshore Areas

Appendix D



Generating Enhanced Oyster Reefs in Georgia's Inshore Areas

CHEMICAL MONITORING FORM

Investigators _____

Restored Site Name _____ Date _____ Time _____

Photo Documentation (monthly) ☐ Yes ☐ No

Biological Community Sampling (quarterly, see separate datasheet) ☐ Yes ☐ No

Boat Traffic in Last 15 Minutes? ☐ Yes ☐ No # Boats _____

Rain in Last 24 Hours? Yes/No _____ Amount _____ Inches in Last _____ Hours/Days

If Yes, Rain Was ☐ Heavy ☐ Steady ☐ Intermittent

Present Conditions: ☐ Heavy Rain ☐ Steady Rain ☐ Intermittent Rain

☐ Partly Cloudy ☐ Overcast ☐ Clear/Sunny

Tide Was: ☐ High ☐ Outgoing ☐ Low ☐ Incoming

Water Surface Conditions: ☐ Calm ☐ Ripples ☐ Waves ☐ White caps

Impaired Habitat Indicators: ☐ Foam ☐ Bubbles ☐ Oil ☐ Scum

☐ Dead Organisms_____ ☐ Erosion_____

☐ Trash Present_____ ☐ Vegetative Debris_____

☐ Dumping_____ ☐ Excessive Algae_____

Water Quality Tests

(Take two samples for tests A-D, if results are not similar take third sample)

Basic Tests:	**Sample# 1**	**# 2**	**#3**	**Average**
A. Air Temperature	_____	_____	_____	_____ (°C/°F)
B. Water Temperature	_____	_____	_____	_____ (°C/°F)
C. Dissolved Oxygen	_____	_____	_____	_____ (mg/l)
D. Water Salinity	_____	_____	_____	_____ (ppt)
E. Sediment traps **(3)**	_____	_____	_____	_____ (mm)

Additional Tests, Observations and Comments:

_____

_____

_____

_____

Sketch map of reef below. Shade in areas that have been covered by sediment and note any other unusual occurrences on the reef. Make sure to indicate the orientation of the shore/water.