Shell Bank: Oyster shell recycling, community involvement, student institute, and oyster response to environmental change

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Introduction

Coastal habitats such as oyster reef provide ecosystem benefits that convey both ecological and economic values (Beck et al. 2001; Barbier et al. 2011). However, due in large part to anthropogenic activities, oyster populations rank highest among degraded marine systems, with an estimated 91% lost globally (Jackson 2008). Common harvesting practices such as dredging decrease the availability and complexity of hard structure necessary for larval oyster attachment and survival (Lenihan & Peterson 1998; Lenihan & Peterson 2004). As a result, historic losses of oyster-related ecosystem services, including viable fisheries, habitat provision, and water filtration have occurred (Worm et al. 2006). Native oyster landings in the Gulf of Mexico present a unique opportunity for restoration because of existing habitat and larval reserves (Beck et al. 2011).

Oyster reef restoration has become a principal strategy for reversing the trend of habitat loss while enhancing biodiversity (Grabowski et al. 2012). Yet, oyster reefs remain among the most expensive habitats to restore (Bayraktarov et al. 2016), making it imperative for solutions to be developed and implemented at the local level, and for scientists and practitioners to disseminate the results of their restoration actions to the public to inform future efforts (Kennedy et al. 2011, La Peyre et al. 2014, Blomberg et al. 2018). One major obstacle is a shortage of oyster shell, the preferred material for reef restoration. The Shell Bank oyster shell recycling program, funded through the TGLO Coastal Management Program, provides a local solution, utilizing community partnerships to recycle oyster shells from restaurants, wholesalers, and festivals for use in habitat restoration.

Project partnerships and progress

The Texas General Land Office Coastal Management Program supports the Shell Bank Project, the first integrated oyster shell reclamation, recycling, and restoration program in Texas. Original project partners were specific to Corpus Christi: the Harte Research Institute for Gulf of Mexico Studies (HRI), Texas A&M University-Corpus Christi (TAMU-CC), the Port of Corpus Christi Authority, and Water Street Seafood. Over time, the project has grown and incorporated project partners across the greater south Texas region, including: St. Mary's Fiesta Oyster Bake (San Antonio), Groomer's Seafood (San Antonio) and Austin Oyster Festival (Austin). We are continually seeking new project partners through our shell recycling, educational, and outreach efforts.

We are particularly proud of the way that recycled shells reclaimed from the Shell Bank Program have been used to restore habitat across Texas, with over 20 acres restored to date. The Coastal Management Program's investment in the Shell Bank Program has provided the seed for developing additional investments in habitat restoration using recycled oyster shells, including from the Coastal Conservation Association, National Fish and Wildlife Foundation, Fish America Foundation, Gulf of Mexico Foundation, Texas Parks and Wildlife Department, NOAA Community-Based Restoration Program, and new investments from Texas Sea Grant, starting in 2018, and from the Environmental Protection Agency, starting in 2019. We continue to seek new partners and new funds for habitat restoration, including a recent submission to the NFWF Gulf Environmental Benefit Fund (GEBF).

CMP 21 Project Objective and Goals

This objective of this CMP Cycle 21 project was to build on previous efforts toward shell recycling, habitat restoration, and community engagement in support of principal goals and priority issues defined in the Coastal Bend Bays Plan: Bay Tourism and Recreation, Habitat and Living Resources, and Public Education and Outreach. We specifically proposed four project goals:

Goal 1: Expand oyster shell collection. TAMU-CC reclaims approximately 248 cubic yards of shucked shell each year from coastal bend restaurants and wholesalers for use in restoring degraded reefs. TAMU-CC will continue working with local partners and will formalize a partnership with Groomer's, Corpus Christi's largest seafood processor. Additionally, TAMU-CC will identify new areas to expand partnerships. TAMU-CC will continue their partnership with Fiesta Oyster Bake in San Antonio to increase oyster shell collection and provide educational opportunities to over 100,000 festivalgoers.

Goal 2: Community-based restoration events. In order to create local environmental stewards, TAMU-CC will host two community-based oyster restoration events. Funds will be provided for three local schools to participate in each event. During each event, students and community volunteers will fill 400-600 mesh bags with reclaimed oyster shells to create oyster reef building blocks. With funding from restaurant partners, the shell bags will be used to restore oyster reef at Goose Island State Park.

Goal 3: Student Institute. TAMU-CC will develop habitat conservation and restoration modules for Science, Technology, Engineering and Math (STEM) student use. The modules will use case studies to teach scientific concepts and encourage critical thinking. Student Institute modules will be made available to teachers trained through the CMP funded “Oysters in the Classroom”, “Teach the Teachers”, and “Teacher Institute” programs.

Goal 4: Oyster health. Dermo disease, caused by the protozoan parasite *Perkinsus marinus*, causes severe oyster mortality in Texas estuaries, particularly during periods of high salinity and warm water temperature. Population growth and prolonged drought have altered freshwater inflows to Texas Bays and created conditions favorable to intensifying Dermo infection. TAMU-CC will use ‘scope for growth’ (SFG) to detect and define the effects of Dermo stressors on oysters.

CMP 21 Project Accomplishments

1. Expand oyster shell collection

The Shell Bank Project reclaims oyster shells from seafood restaurants, wholesalers, and festivals so that they may be used to restore degraded or lost oyster reef habitat. Project partners Water Street Seafood and Water Street Oyster Bar continue to be the keystone of our shell recycling efforts in Corpus Christi. As part of CMP 21, we also sought to reclaim shells from Groomer Seafood in Corpus Christi, Fiesta Oyster Bake in San Antonio, and Austin Oyster Festival in Austin to increase our ability to support habitat restoration efforts. We continue to work with the Port of Corpus Christi to maintain our secure shell stockpile location, where shells are held for at least 6 months to eliminate potential disease or invasive species before they are ready for use in reef restoration.

Recycling oyster shells is key to restoring oyster habitat because of the life cycle of the oyster. Oysters in Texas spawn throughout the spring, summer and fall months, releasing larvae into bay waters. These larvae remain in the water for about two-three weeks, after which they metamorphose to their final larval stage, the pediveliger, and move down toward the bay bottom to seek a suitable surface upon which to permanently attach. In a healthy bay system, the primary attachment surface available to larval oysters would be existing reefs and the shells of older generations of oysters. However, as reefs have declined in their size and distribution, so there are fewer reef building blocks remaining for these larval oysters to set and spend the remainder of their life cycle. Because oyster shell is one of the most desirable materials for attachment and subsequent growth of young oysters, the Shell Bank Program reclaims shells that would be otherwise destined for the landfill and recycles them into local bays to restore and degraded oyster reefs.

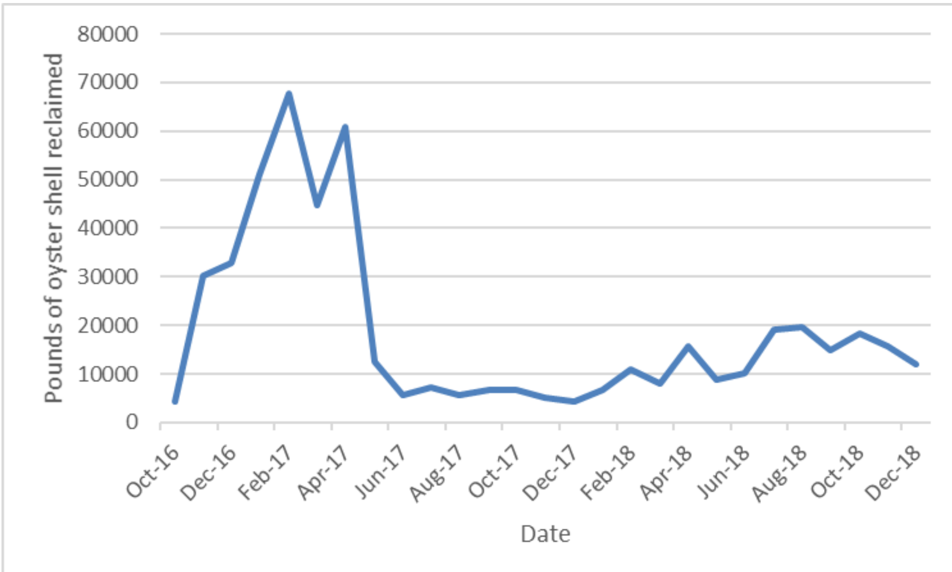

Figure 1. Pounds of shell reclaimed by the Shell Bank Program during CMP 21.

As part of CMP Cycle 21, the Shell Bank Oyster Recycling program reclaimed 505,616 pounds, or approximately 383 cubic yards of oyster shells from seafood restaurants, wholesalers, and festivals (Figure 1). The highest volume of shells was reclaimed during the first half of the grant cycle, due to the commercial harvest season in Texas, decreased sharply at the close of the season in May 2017, and then increased to a lesser extent again when the season reopened in November 2017. The greatest amount of shell was collected in February 2017 (67,600 lbs) followed by April 2017 (60,800 lbs). The main reason for the large drop in oyster volume between the first and second half of the project period was the influence of the new Harbor Bridge project in Corpus Christi (e.g. construction activities and land acquisition) on our new partner, Groomer's Seafood. The new Harbor Bridge connecting Corpus Christi and Portland will go right through the area where Groomers Seafood is currently located, forcing the business owner to identify and prepare to move to a new location. We are continuing to be in close communication with Groomer's and they plan to restart their oyster operations after the relocation.

Figure 2. Shell Bank's Oyster Shell Recycling Program Team at 2017 Austin Oyster Festival, recycling shells and performing public outreach.

Figure 3. Dumping recycled oyster shells from Fiesta Oyster Bake into the Shell Bank trailer for eventual transport back to Corpus Christi

We also recycled oyster shells from two large regional festivals: St. Mary's Fiesta Oyster Bake in San Antonio on April 21-27, 2017; Figure 3, Figure 4) and Austin Oyster Festival on February 25, 2017; Figure 2). We transported a large trailer from Texas A&M University-Corpus Christi to each festival location and filled it with shucked shells produced throughout the event. To make these shell collection efforts more efficient, we placed buckets on tables throughout the event for festival goers to easily recycle their shells (Figure 5). We also walked throughout the event with buckets, picking up shells from festivalgoers. This also provides an easy way to answer "What are you doing with the shells?" In general, festival attendees are excited to learn about shell recycling and to hear that the oyster shells they are putting into the buckets will be used for oyster reef restoration projects. It's a simple way to communicate a message about environmental stewardship and resource management to a broad audience. After the festivals are over, we transport reclaimed to our stockpile location at the Port of Corpus Christi.

Figure 5. Shell Bank program volunteers at Fiesta Oyster Bake.

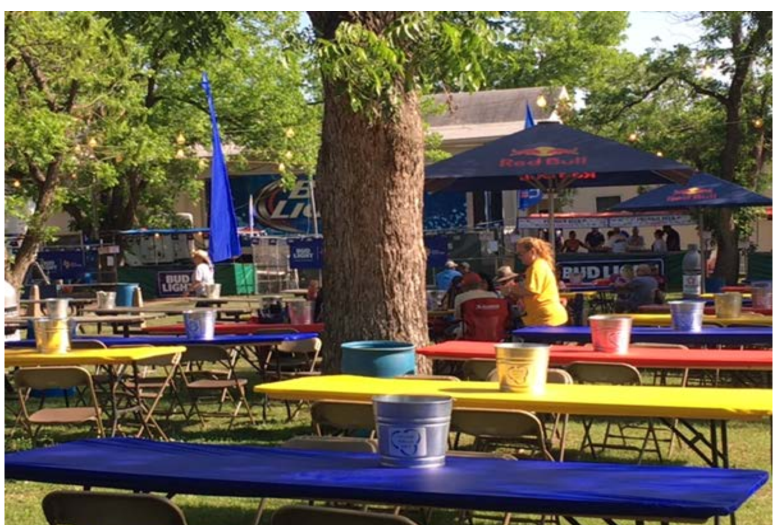

Figure 4. Shell Bank oyster shell recycling buckets on tables at Fiesta Oyster Bake.

2. Community-based restoration events

We hosted two community shell-bagging events at Goose Island State Park, one on Saturday, April 1, and one Saturday, April 29, 2017, both from 8:30-11:30 am (Figure 6-Figure 8). During each event, volunteers learned about oyster reef restoration and created the building blocks for an oyster reef by filling mesh bags with reclaimed oyster shells. Volunteers rotated through 3 stations of restoration activities: (1) cutting the mesh to an appropriate size to hold 2 gallons of recycled shell; (2) filling the newly cut mesh bags with recycled oyster shell, (3) moving the bags over to a staging area for reef restoration.

On April 1, 167 volunteers created over 785 bags of recycled oyster shells for oyster reef restoration at the park. We had student involvement from Judson High School (San Antonio), Moody High School (Corpus Christi), Boy Scout Troop 3 (Corpus Christi), and Texas A&M University-Corpus Christi. On April 29, 94 volunteers participated in the event, including students from Moody High School (Corpus Christi) and Texas A&M University-Corpus Christi. As always, staff from Goose Island State Park were extremely supportive of these events.

Figure 6. Volunteers raking recycled oyster shells and filling bags for restoring oyster reef at Goose Island State Park.

Figure 7. Oyster shell bags filled with recycled shells for reef restoration.

Figure 8. Volunteers at the completion of the community-based oyster reef restoration event.

With funding from our restaurant partners, it was desired that the shell bags be used to restore oyster reef at Goose Island State Park along the St. Charles Bay shoreline adjacent to their Big Tree Unit. The goal was to restore the oyster reef parallel to this shoreline in order to protect and stabilize and the sediments. Unfortunately, our coastal lease from the Texas General Land Office was not executed in time to conduct a restoration event at the St. Charles Bay location. Instead, working with park staff, we continued to host our bagging events near the fishing pier. At the time of writing, we have secured the coastal lease from TGLO and will proceed to work in this new location for future projects.

On June 15 and June 29, 2017, we brought our education and outreach to Port Aransas, where we taught ~40 students in 3rd-4th grade about oyster ecology and oyster reef restoration as part of the Summer Science Field Program at the University of Texas Marine Science Institute (Figure 9-Figure 11).

Figure 9. Students at the UTMSI summer science program learn about oysters.

Figure 10. Students at the UTMSI summer science program learn about oyster biology and anatomy.

Figure 11. Students at the UTMSI summer science program learn about oyster ecology using touch tanks.

3. Student Institute

To solve real world problems, students require critical thinking skills and the freedom to utilize creative approaches to solutions. The "Student Institute" was designed to engage STEM students, through our case-study based modules, to evoke critical thinking skills that connect classroom instruction to contemporary science problems in the news, thus making science real and relevant. We developed nine habitat conservation and restoration modules for the STEM students. The case studies posed an academic question that the facilitator/instructor discussed with the students in the format of a story. These "stories" were communicated via the lens of contemporary (and/or controversial) science problems that students heard about in the media or encountered first hand, so the science was real and relevant.

We used the interrupted case method, where students were introduced to the case study and worked in small groups. Groups were told a story with some initial information then given time to discuss amongst themselves. Then the instructor provided additional information to include in their discussions and analysis. This was repeated several times as the problem got closer to completion. The students were required to prioritize difficult choices and synthesize information from multiple sources. This method mimicked the way that scientists gather and receive facts in a piecemeal fashion when researching a conservation or restoration question. We worked with existing outreach and education groups such as the Center for Coastal Studies, Harte Research Institute, Riviera ISD, UT Summer Science Program, Rockport Adventure Camp, Coastal Bend Bays and Estuaries Program's Nueces Delta Preserve, Texas State Aquarium, Camp Aranzazu, and aquatic education teachers to keep costs to a minimum and enhance existing efforts. We also engaged teachers who were previously trained in our programs to serve as teachers within the student institute.

The Student Institute was originally scheduled for late Summer and Fall 2017. Due to Hurricane Harvey all Student Institute sessions were canceled. Many students were displaced because entire schools were damaged beyond repair. A request was made to extend the grant to allow for rescheduling of the institute. Many of our student institute sessions were collapsed together due to schools intaking students from other areas and the need to make up school days. This delay did allow for our staff to restructure the content of the Student Institute materials to make it more relevant to the current issues. The addition of the new content gave the students real time field and research opportunities, so they could find solutions to these issues – the modules were expanded from between four and six, to a total of nine. The content was renamed “Hurricane Recovery Workshops for Students” and the topic areas included:

- Shoreline Stabilization
- Coastal Flooding
- Debris Removal
- Habitat Preservation and Value
- Building Codes

Modules:

- *Cloudy Water*
    - Objective – To see how disturbed bottom sediments alter food resources, habitat, and water quality within a Texas bay system.
- *Don't Just Float There – Get on the Raft*
    - Objectives – To look at marine debris from different points of view, to describe the interaction between marine debris and its surroundings, and to explore different writing styles.
- *Merging Mercury*
    - Objective – To show how mercury travels and accumulates through food chains
- *Tabletop Oil Spill*
    - Objectives - To observe the characteristics of oil in a simulated oil spill and its effects on various biological organisms and to attempt to remove the oil from the water using different techniques.
- *Water We Doing Here*
    - Objectives – To discuss how water is used every day and to brainstorm how water can be saved every day.
- *Debris Diary*
    - Objective - Discuss in a literary form, the various origins of marine debris
- *In the Gutter*
    - Objectives - Demonstrate how wetlands slow down water velocity, demonstrate how wetlands absorb water and act as storm buffers, and demonstrate how wetlands are necessary to buffer the effects of run-off.

- *Save the City*
    - Objectives - The students will evaluate different types of shoreline stabilization devices and ultimately design a structure to protect their sea-side community.
- *Vanishing Seagrass*
    - Objectives – To observe the effects on marine life when habitat is destroyed or changed.

Participation information and dates:

Groups that participated in the Student Institutes include:

- Center for Coastal Studies, Jay Tarkington
- Harte Research Institute, Gail Sutton
- Rivieria ISD, Rosanna Ryan
- Rockport Adventure Camp, Stephanie McGrew
- Texas State Aquarium, Deanna Peacock
- TAMU Summer Science STEM Camp, Dugan Um
- Coastal Bend Bays and Estuaries, Adrien Hilmy
- University of Texas "Road Scholars", Linda Fuiman
- Camp Aranzazu, Amelia Haslam

Schools that participated in the Student Institutes include:

May 18	Riviera ISD	15 Students
June 5	Texas State Aquarium	12 Students
June 6	Camp Aranzazu Staff	18 students
June 12	University of Texas Intergenerational camp	16 students

June 13	Camp Aranzazu	35 students
June 14	Rockport Adventure Camp	22 students
June 21	Rockport Adventure Camp	23 students
June 27	TAMU STEM Camp	18 students
June 28	Coastal Bend Bays and Estuaries teacher workshop	9 students
June 29	Texas State Aquarium	10 students
July 10	Texas State Aquarium	10 Students
July 11	Texas State Aquarium	10 Students
July 19	Camp Aranzazu	25 Students
July 23	Camp Aranzazu	22 Students
July 27	Texas State Aquarium	12 Students
July 31	Texas State Aquarium	9 Students

We completed our summer institute schedule with nine groups and 266 students from elementary to High School. The Student Institute modules are formatted for web publication and were placed on our website at www.oysterrecycling.org for open access. Additionally, they were distributed to teachers trained through our CMP 'Oysters in the Classroom', 'Teach the Teachers', and 'Teacher Institute' programs.

Figure 12. Students search for marine debris as part of the "Debris Diary" activity.

Figure 13. Resource manager discusses marine debris with students.

Figure 14. Students learn about Seagrasses in south Texas as part of the “Vanishing Seagrass” activity.

Figure 15. Students learn about shoreline stabilization in the "Save the City" activity.

Figure 16. Students participate in a mock oil spill cleanup activity.

4. Oyster health

The protozoan parasite, *Perkinsus marinus*, is the causative agent for the oyster disease commonly referred to as Dermo (Mackin et al. 1950). Cells are released into the water column from dead and decaying oyster tissue, as well as from the feces of live oysters (Ford and Tripp 1996). Once an oyster is infected with *P. marinus*, proliferation of the parasite occurs, resulting in decreased oyster growth and reproduction, eventually leading to death (Ford and Tripp 1996). *Perkinsus marinus* distribution is influenced by temperature and salinity patterns, with the parasite proliferating at both high temperatures and salinities (Ford and Tripp 1996). Previous studies have documented the effects of *P. marinus* on the growth of oysters using various condition indices (La Peyre et al. 2003; La Peyre et al. 2009); however, few studies have isolated the specific effects of *P. marinus* on the energetic processes involved in oyster growth. We determined the effects of rapid reductions in salinity, such as those reflective of storms, flood events, and freshets, and *P. marinus* infection on the scope for growth of *C. virginica* oysters. This study will improve our knowledge of oyster response to salinity stress and will be useful for water resource management decision-making.

We collected market-sized (≥76mm shell height) oysters from intertidal oyster reefs in the Lower Laguna Madre near Arturo Galvan Coastal Park in Port Isabel, Texas (Figure 12). Oysters were transported to the lab in coolers and scrubbed to remove remaining biofouling organisms, such as barnacles and polychaetes, and algae. Once clean, oyster shell height (mm) was measured and recorded. Oysters were drip acclimated to a salinity of 35. Oysters were starved during drip acclimation and holding prior to initiation of the experiments.

Each experiment began on the fourth day after oyster collection. Oysters were each randomly assigned into 1890 mL glass jars filled with artificial seawater at one of six salinity treatments: 10, 15, 20, 25, 30, and 35. Four experiments were conducted, each with a sample size of thirty-six oysters. Each experiment lasted 5 days, with daily water exchanges conducted at the beginning of each day. Physiological measurements for scope for growth calculations occurred on days 4 and 5 of each experiment.

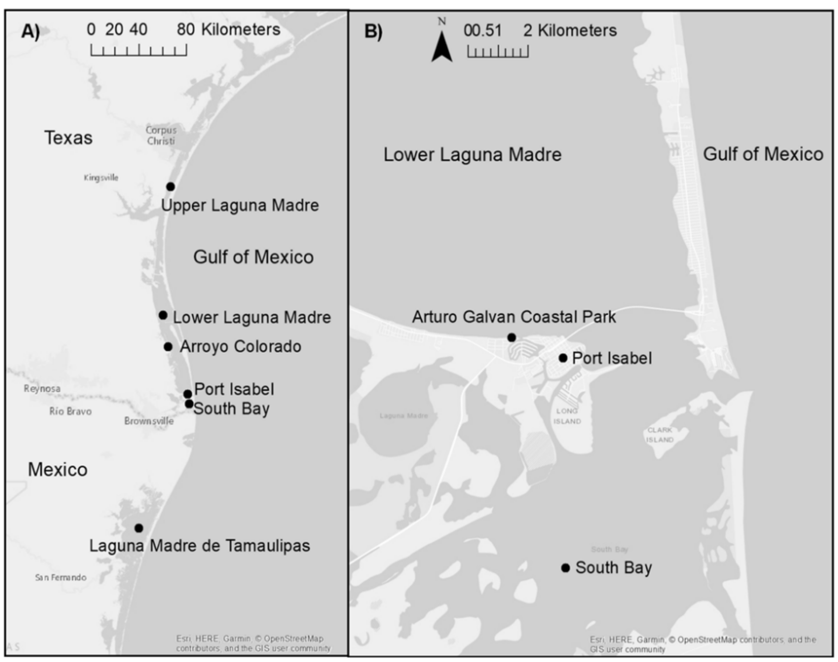

Figure 17. Map of the Laguna Madre of Texas and Tamaulipas (A), showing Arturo Galvan Coastal Park (B), the site of oyster collection.

Weight standardized clearance rate was calculated following the methods of Casas et al. (2018), using a published clearance rate value for *C. virginica* (Shumway et al. 1985). Absorption efficiency (%AE) was calculated using the equation defined by Conover (1966). Oyster feces was collected using a Pasteur pipette, placed in an aluminum boat, dried, then incinerated in a muffle furnace at 450°C for 4 hours and weighed to obtain ash free dry weight. Organic content was calculated as the difference between the dry weight and ash free dry weight. The water with remaining microalgae in each feeding trial jar was filtered, dried, and then incinerated in a muffle furnace at 450°C for 4 hours to obtain ash free dry weight. Organic content was calculated as the difference between the dry weight and ash free dry weight. Once the feeding trials were complete, Ammonia concentration (mg L^{-1}) was measured using a Thermo Orion 7 model 95-12 Ammonia probe. Change in oxygen concentration (mg L^{-1}) was measured in the static environment of a sealed 950 mL glass jar using an OXY-4 SMA oxygen meter (PreSens, Regensburg, Germany). To obtain the calorie content (g dry $weight^{-1}$) for DT's Live Marine Phytoplankton Reef Blend, algae samples were combusted in a Parr ® 6200 bomb calorimeter. The scope for growth of oysters was calculated by determining the energy budget for individual oysters using the physiological measurements: clearance rate (C), absorption efficiency (Ab), ammonia excretion (U), and oxygen consumption (R).

Following completion of the scope for growth procedures, oysters were sacrificed to determine *P. marinus* infection intensity using the culture method of Ray (1966). Briefly, a 10 mm x 10 mm section of mantle tissue was removed and incubated in fluid thioglycollate medium for 7 days. Tissue was then placed on a glass microscope slide, teased apart using stainless steel probes, stained with Lugol's solution, and observed with the aid of a compound microscope. Infection intensity was ranked and recorded from 0 (uninfected) to 5 (heavily infected) (Mackin 1962; Craig et al. 1989). Condition index was measured for each oyster using the dry flesh weight: dry shell weight ratio (Mann 1978; Lucas and Beninger 1985).

Scope for growth ranged from 37.25 J hr^{-1} g dry $weight^{-1}$ to 867.46 J hr^{-1} g dry $weight^{-1}$, and demonstrated a decreasing trend from the lowest to highest salinity treatments, indicating reduced growth potential with increasing salinity (Figure 13).

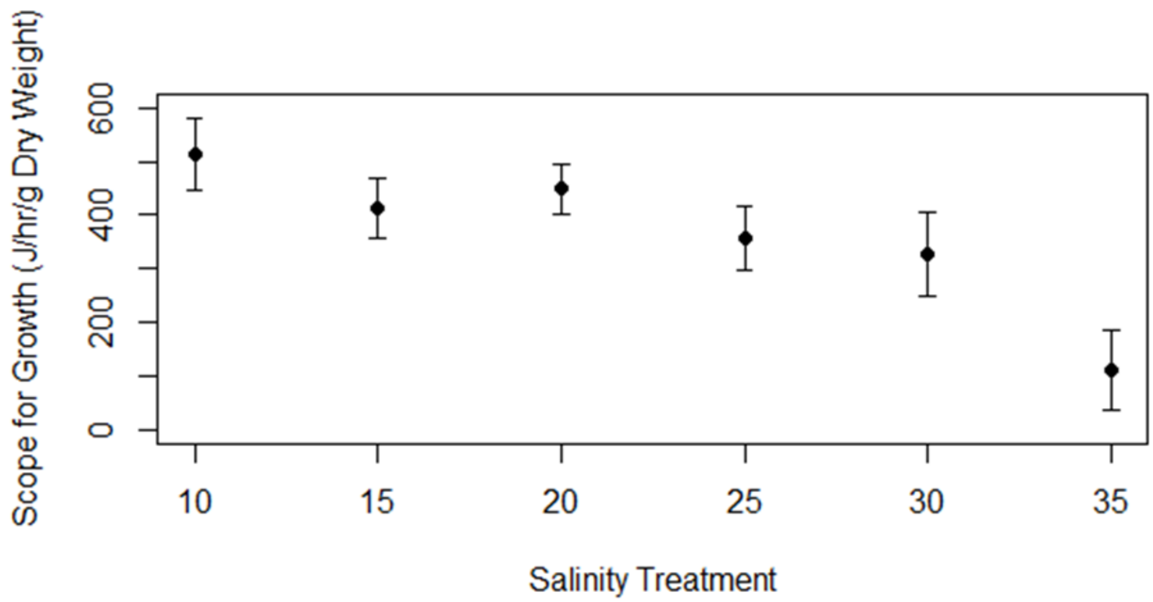

Figure 18. Scope for growth (J hr^{-1} g^{-1}) mean ± standard error values for salinity treatments

Perkinsus marinus infection intensity ranged from low (0.00) to moderately heavy (3.67), but did not have a significant effect on oyster scope for growth (Table 1).

Table 1. Dermo disease calculations (prevalence and severity) by salinity treatment.

Salinity Treatment	Dermo intensity range	Prevalence	Severity
10	0.00 – 3.67	0.83	1.49
15	0.00 – 3.67	0.79	1.35
20	0.00 – 3.33	0.92	1.56
25	0.00 – 3.33	0.92	1.43
30	0.00 – 3.33	0.92	1.50
35	0.00 – 3.33	0.88	1.36

Condition index ranged from 0.64 – 3.52 (mean 1.70 ± 0.04) and increased with salinity treatment, likely reflecting Laguna Madre oyster tolerance for high salinities (Figure 14).

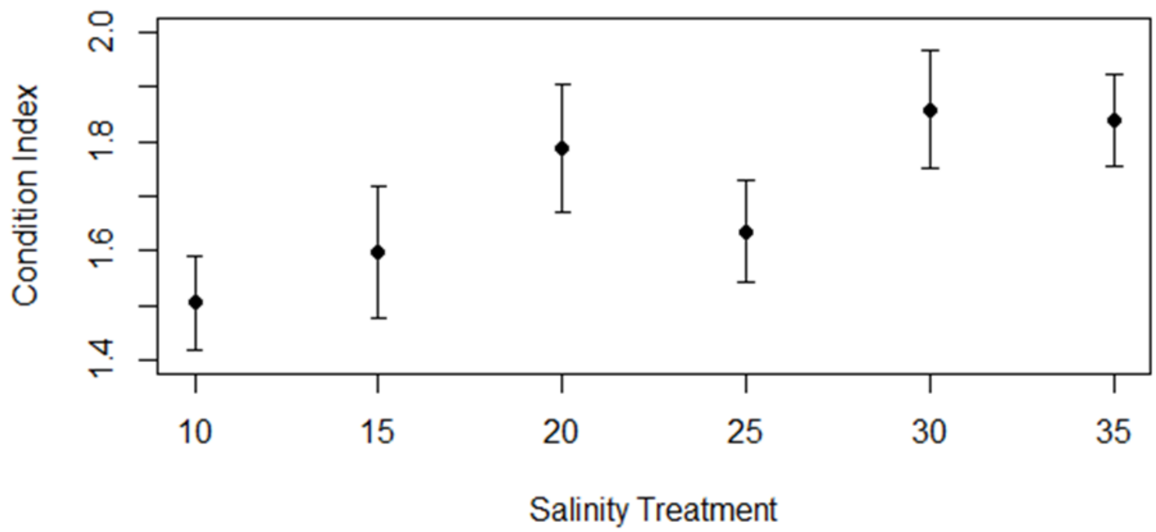

Figure 19. Condition index mean ± standard error values for salinity treatments.

Overall, oysters experiencing rapid reductions in salinity demonstrated increased physiological function compared to oysters that remained at the control salinity 35, indicating that the normally high salinities of the Laguna Madre may not present optimal conditions for oyster growth. Results improve our understanding of individual oyster response to future climate conditions, which is important for effectively managing oyster populations and to guide water management decision-making.

Conclusion

The Texas General Land Office's Coastal Management Program provides key funding to the Shell Bank oyster shell recycling program, and has provided the spark that has fueled restoration of over 20 acres of oyster reef across the Texas Coastal Bend. Support for the Shell Bank program as part of CMP 21 has resulted in over 500,000 pounds of shells being reclaimed that were destined for landfills, has improved our understanding of individual oyster response to future climate conditions in support of resource management, and has engaged hundreds of kids and adults throughout south Texas about habitat restoration and environmental stewardship. Coastal Management Program funding has provided project sustainability, which is key to partner participation and investment, both for local businesses and for community groups who are directly involved in CMP-supported habitat restoration. Moving forward, we at the Shell Bank program will continue recycling oyster shells for rebuilding habitat, directly engaging the public in habitat restoration activities, and providing scientifically grounded solutions to support conservation and sustainability of oyster reefs throughout Texas.

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Appendix: Modules for Hurricane Recovery Workshops for Students, 2017

CMP 21

Task 3

Classroom Modules

Cloudy Water

About This Lesson

Time Frame: One class period

Grade Level: 6-12

Academic Question: How does sediment disruption effect water quality?

Objective: To see how disturbed bottom sediments alter food resources, habitat, and water quality within a Texas bay system.

Application: This short experiment demonstrates how dredging can affect water quality and can also redistribute species throughout the bay.

Background:

Nueces Bay is located close to Corpus Christi, Texas. It is primarily an oyster reef driven system with fresh water input provided by the nearby Nueces River. Although showing relatively high productivity, it has been affected by dredging and industrial pollution. Dredging and limited fresh water input has caused the redistribution of sediments and species throughout the bay. Due to these environmental changes and increased turbidity, many of the species have adapted to alternate food sources.

Getting Started

Materials:

- Disposable foil bread pan
- Gallon of milk
- Instant chocolate milk powder
- Bag of M&M candy
- Plastic spoons

Process:

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above.
2. Begin with a brief discussion of Texas Bays and Estuaries and lead the students into a discussion of bottom dwelling bay organisms (shrimp, crabs, oysters etc.). Also discuss fish found in the bay and what they use as a food source. Emphasize that most fish are predators and need to see their prey.
3. Present the case study to the students.
4. Pass out the materials to the assigned groups.

5. Have the students fill the bottom of their pans with the dry powder (this will simulate bay sediment).
6. Then have the students distribute the M&M’s on top of the sediment (the M&M’s represent oyster reefs)
7. Next, have the students (or teacher) slowly pour the milk slowly over a spoon to reduce splashing in to the container until the M&M’s are under the milk.
8. Have the students observe the color of the milk (it should have a slight darkening). This represents an “undisturbed” bay.
9. Now to simulate dredging, have the students zig zag a spoon slowly across the bottom of the pan down the length of the pan. Note the color change.
10. Repeat several times observing the changes occurring in the “bay water”.

Evaluation/Extension:

- Have the students describe how a fish would react to the changes in water quality after dredging.
- Have the students list potential environmental problems associated with dredging.
- Have the students research dredging along the Texas Coast.

This module was originally developed as part of the “Hurricane Recovery Workshops for Students”, held in Corpus Christi in 2017.

Don’t Just Float There- Get On the RAFT

About This Lesson

Time frame: One or two class periods.

Grade level: Elementary to high school

Academic Question: What effect does marine debris have on the beach environment?

Objective:

- To look at marine debris from different points of view
- To describe the interaction between marine debris and its surroundings
- To explore different writing styles

Background:

Texas beaches are under constant assault from various forms of marine debris. The prevailing currents and winds allow debris from all over the Gulf of Mexico and beyond to collect along the over 300 miles of gulf shoreline. The debris varies from very large to very small and is made up of everything from cigarette butts to large oil drums. Although some of the debris floats ashore from far away locales, much of the debris is deposited by the many visitors to the beach. These various forms of debris have a harmful effect on marine wildlife due to ingestion and/or entanglement. Marine turtles, and various birds seem to suffer the most. The debris also affects the areas local economy. People do not wish to vacation at beaches covered with marine debris and many times pass by various beaches in search of more pristine locations. Beach debris removal is a very costly and time-consuming process that never seems to end.

Getting Started

Materials: Writing paper and pen

Process (activities):

This is a creative writing assignment that allows the students to put themselves in the place of the debris to better understand the origins and the relationship of marine debris to the environment. This process uses a procedure known as RAFT. The RAFT stands for Role, Audience, Form, Topic. The students will form a fictitious communication using this format taking on the roles of various objects in the marine environment.

Role	Audience	Form	Topic
plastic bottle	sea turtle	e-mail	"beware of eating me."
sea shell	cigarette butt	friendly letter	"pardon me, but you are making me look bad"
glass	local surfer	memo	"sorry"
		etc.	

Using the above topics, have the students choose one selection and compose the appropriate communication type. Although a light-hearted exercise, this format is very effective in allowing the students to see the effects of various debris on the environment.

Evaluation/Extension:

- Have the students read their "letters" and allow for discussion.
- Have the students add additional roles

This module was originally developed as part of the "Hurricane Recovery Workshops for Students", held in Corpus Christi in 2017.

Merging Mercury

About This Lesson

Timeframe: Typically, one class period.

Grade level: 6-12

Academic Question: How does mercury accumulate in gamefish?

Objective: To show how mercury travels and accumulates through food chains.

Background:

Mercury, introduced or naturally occurring, can be introduced into various food chains/webs. Because mercury is stored in tissue, it is transferred between trophic levels. At lower levels, mercury concentrations do not seem to have an effect on animal function; however, as levels rise over time, animals may begin to show adverse effects of mercury poisoning (neurological/reproductive issues). Humans are a high-level consumer and therefore, potentially at risk of mercury poisoning. Mercury poisoning in humans and occurs through a process known as **bioaccumulation.**

Bioaccumulation- refers to the accumulation of substances, such as pesticides, mercury, or other chemicals in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than at which the substance is lost.

Getting Started

Process:

This activity will use a classroom of students representing a food chain to show the bioaccumulation of mercury through several trophic levels. Develop an interrupted case study scenario appropriate to your region, and present this to the students before beginning the exercise.

Materials:

- 3-5 lbs. bag of pinto beans
- 1 ½-2 lbs. bag of red beans (try to find a similar size to the pinto beans)
- Small plastic container or small shoebox to hold combined beans
- 1 ½ ounce plastic cups

Procedure:

First level

Thoroughly mix together all beans in plastic container. Have each student collect a full 1 ½ ounce cup of the combined beans. At this level, the students represent a lower organism on the food chain and the beans represent their diet. (In marine systems, this level is typically made up of polychaete worms and/or zooplankton). Have the students record the number of “red” beans in their diet for the first level and return the red beans to their sample. The red beans represent mercury that the organism has eaten or absorbed from their environment.

Second level

Have the students group together in groups of 3-4 students and combine their beans. At this level the students have moved up the food chain and now represent gastropods and bivalves that consume polychaete worms and zooplankton. Have the students record the number of “red” beans for the second level.

Third level

Have the groups of 3-4 students join with another group of 3-4 and combine their beans. At this level the students have moved to the third level of the food chain and represent small fish (pinfish/croaker) and squid. Have the students record the number of “red” beans for the third level.

Fourth level

Have the groups of 6-7 students join with another group of 6-7 and combine their beans. At this level the students have moved to the fourth level of the food chain and represent local sportfish (Redfish, Speckled Trout, Black Drum). Have the students record the number of “red’ beans for the fourth level.

Fifth level

Have the teacher “go fishing” and collect the beans representing the two or three “redfish” he/she caught that day. Have the students record the number of “red” beans consumed by the teacher and determine/discuss if they are susceptible to mercury poisoning.

Evaluation/Extension:

- This lab can be evaluated as per district procedures.
- Have students research other elements/chemicals that bioaccumulate in organisms.
- Have students research local sources of mercury within their region.

This module was originally developed as part of the “Hurricane Recovery Workshops for Students”, held in Corpus Christi in 2017.

Tabletop Oil Spill

About This Lesson

Time Frame: One class period

Grade Level: 3-12

Academic Question: How does oil behave in water during an oil spill event?

Application: This short experiment demonstrates how oil can affect various species and habitats. This activity gives students an introduction to experimenting with oil removal techniques.

Objectives:

- To observe the characteristics of oil in a simulated oil spill and its effects on various biological organisms.
- To attempt to remove the oil from the water using different techniques.

Background:

Large oil spills are not common along the Texas coast; however, many smaller spills occur on a regular basis. Through training and quick response, many of these smaller spills are removed with little effect on the environment. Oil spills can cause many short and long-term problems for our environment. There are many techniques employed for the removal of oil from an aquatic system. The response to a spill in a ship channel would be different than a spill near a wetland. Most importantly, after an oil spill occurs, a plan must be quickly developed, and action must begin.

Getting Started

Materials:

- 12x15 Rubbermaid/Tupperware dishwashing pans
- Cooking oil
- ½ measuring cup
- Cold Water
- 10ft of drip irrigation tubing
- Package of ¼ inch irrigation tubing connecting barbs
- Oyster shell
- Package of bird feathers
- Small plant material (stems and leaves from the yard to simulate wetland plants- ferns and grasses work well)
- Oil-sorb diaper cut in to 6x6 inch pieces (available at auto/marine stores)
- Dishwashing soap
- Paper towels

Process:

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above.
2. Begin with a discussion of oil spills and their effect on the environment. Students should be able to recall possible recent events. Remind them that oil spills both big and small can have effects. (can be done as a demonstration or in lab groups of 3-4 students)
3. Present the interrupted case study to the students.
4. Take the plastic tubs and fill ½-3/4 full of cold water. (warmer water does not hold the oil together as well as cool or cold water)
5. Add 1/4 cup of cooking oil to the center of the tub of water.
6. The oil should form into a circle of oil toward the center.
7. Have the students lightly blow on one side of the tub and observe how the oil reacts to the simulated wind. (have them try to keep it off the sides of the tub by blowing)
8. Have the students observe what occurs when they dip a few feathers in to the water, and then the oil. Remove the feathers and place in a paper towel.
9. Have them repeat the process with the oyster shell and the small plant material.
10. Lastly, have the students develop a plan for removing the oil. The can make a simulated oil boom out of the irrigation tubing and then remove the oil using the oil-sorb diaper.
11. Remind them they now have oil-contaminated products that must be disposed of properly.
12. Once a majority of the oil has been removed, have the students clean their work area using soap.

Evaluation/Extension

- Have the students research a recent oil spill event.
- Have the students experiment with various other materials for removal or dispersal.
- Have the students look up oiled bird clean up protocols.
- Have them discuss what coastal habitat is most vulnerable to an oil spill event and why.

This module was originally developed as part of the "Hurricane Recovery Workshops for Students", held in Corpus Christi in 2017.

Water We Doing Here

About This Lesson

Academic Question: How many ways can we save water today?

Objective(s):

- To discuss how water is used every day
- To brainstorm how water can be saved every day

Product/Application: Discuss with the students on where freshwater comes from in their local area. Brainstorm ideas on what they could do to save water in the future.

Getting Started

Supplies:

- Thin kitchen sponges cut into approximately 2 x 3 in. squares, one for each student
- A medium sized plastic bowl with a lid, large enough for all of the sponges to fit into easily with water

Process (Activities):

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above. Present this to students before beginning the exercise.
2. To calibrate how much water is needed in the bowl, fill the empty bowl approximately ½ to 3/4th full, and mark the water line with a water-based pen. Carefully add sponges, squeezing them so that the water is absorbed. If there is not enough water, add more in measured amounts (by the cup), until all of the sponges are full. It is ok if there is water left over in the bowl. When finished, pour out all of the sponges. Fill the bowl to the water line plus the additional water measured earlier. Mark the water line with a permanent marker. This is the water line to be used for this activity in the future. Squeeze out the sponges and allow to dry. The sponges can now be stored in the bowl.
3. To perform this activity in the classroom, start out discussing the amount of freshwater available to us on earth. Although the surface of the earth is approximately 72% water, only 2% of that is freshwater. And of that 2%, only a fraction of that is available to us for use. Fill the bowl to the waterline, explaining that this represents all of the water we have for daily use.
4. Give each student a sponge. Walk around the room with the bowl, asking each student to place the sponge in the water and tell how he/she used water today. If you have a large classroom, you might extend use period to “this week” or “this weekend”. There should

be no two answers alike. Discuss how by each of us using water, all the available resources have been “absorbed”.

5. Now walk around and have each student take out one sponge and tell how he/she has (or could have) saved water. Each student squeezes out all the water in the sponge into the bowl with each answer. There should be no identical answers.
6. With all of the sponges out of the bowl, the water should be a little murky and lower than the original water line. Discuss how even when we are careful to conserve water and clean the water we use, the water is not completely clean and we still did not return all of the water back to its original levels.

Assessment/Evaluation: Have the students create a diagram (or the teacher can create a quiz) matching up wasteful water usage problems and their solutions.

This module was originally developed as part of the “Hurricane Recovery Workshops for Students”, held in Corpus Christi in 2017.

Debris Diary

About This Lesson

Time frame: Most creative writing assignments require more time than a single class period and may be carried over several days to allow the students to formulate unique ideas on their topic.

Grade level: Elementary to high school

Academic Question: Where does marine debris originate?

Objective: Discuss in a literary form, the various origins of marine debris.

Background:

Texas beaches are under constant assault from various forms of marine debris. The prevailing currents and winds allow debris from all over the Gulf of Mexico and beyond to collect along the over 300 miles of gulf shoreline. The debris varies from very large to very small and is made up of everything from cigarette butts to large oil drums. Although some of the debris floats ashore from far away locales, much of the debris is deposited by the many visitors to the beach. These various forms of debris have a harmful effect on marine wildlife due to ingestion and/or entanglement. Marine turtles, and various birds seem to suffer the most. The debris also affects the areas local economy. People do not wish to vacation at beaches covered with marine debris and many times pass by various beaches in search of more pristine locations. Beach debris removal is a very costly and time-consuming process that never seems to end.

Getting Started

Process (Activities):

This activity is an individual writing assignment that will allow the student to demonstrate knowledge on the topic in a creative format.

Materials:

- Various pieces of marine debris
- Paper and pen

Procedure:

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above.
2. Have the students select a piece of marine debris from a box or bag of assorted pieces. After selection have the students study their piece of debris and lead them in a discussion of its possible origin. Explain to the students that the debris was deposited along the

beach and that it may have been floating around the Gulf of Mexico for several months to years. The students will write a fictitious diary for their particular piece of debris that will contain at least five entries.

First entry: The first entry will be the day the debris (object) was created at the factory. Include where the object was produced and what its original purpose is.

Second entry: Describe how the debris (object) is deposited in to the water. Include where and what activity caused it to enter the water.

Third entry: Give a "day in the life" floating in the Gulf of Mexico. This entry may include the weather (storms), animals encountered, other pieces of debris it congregates with, etc.

Fourth entry: Describe how and where the debris washed ashore. Include the weather conditions, waves, sand etc.

Fifth entry: Describe your current location and reflect upon the journey.

Evaluation/Extension:

- This assignment can be evaluated as per district procedures.
- The students could be required to research the topic on line to better understand the origins of debris.
- Have the students research how long their piece of debris will exist before breaking down.

This module was originally developed as part of the "Hurricane Recovery Workshops for Students", held in Corpus Christi in 2017.

In the Gutter

About This Lesson

Time frame: 1-2 class periods

Grade level: 6-12

Academic question: How do wetlands affect water flow?

Objective(s):

- Demonstrate how wetlands slow down water velocity
- Demonstrate how wetlands absorb water and act as storm buffers
- Demonstrate how wetlands are necessary to buffer the effects of run-off

Background:

One of the many functions of wetlands is their ability to retain water and absorb excess amounts during storm events. By holding this water, wetlands allow chemical and biological processes to occur resulting in better water quality. Throughout the U.S., communities are dealing with extensive growth causing increased flooding due to the use of concrete. In this activity, students will design a wetland using various materials. A piece of plastic gutter will be used to hold their design. Pouring water into the gutter can then test the water absorption of the individual designs.

Getting Started

Materials:

- Two foot section of plastic gutter (available at hardware store)
- Modeling clay
- Tooth picks
- Several small sponges
- Small sections of "Astroturf" (outdoor carpet)
- Various containers for water
- 2X4 block of wood

Process (activities):

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above. Present case study to students.
2. Begin by handing out the sections of gutter
3. Have students place one end on a ~2-inch block and the other end over a sink or end of table.
4. Pour 1 liter of water into high end of gutter.
5. Water should run easily into sink (if not over sink, collect water in bucket).

6. Next, allow students to use the various materials (clay, toothpicks, etc.) to construct a “water retaining” wetland in their gutter.
7. Repeat the water pouring procedure
8. Calculate and record how much water is retained/absorbed.

Assessment/Evaluation: Have students discuss their design and describe what worked best and what did not work. Have them relate the materials used in the experiment to “real” wetland plants and soils. Begin a discussion on channelization of storm water and the effectiveness of naturalized vs. concrete ditches.

Conclusion/ extension: Have students observe local ditches and make predictions on which ditches are more efficient at retaining or moving water. Observe a large local construction project and make predictions on water flow. Trace water flow from around school grounds. For an extension to this experiment, add a small amount of “black pepper” at the beginning of the students’ wetland before adding the water. See how effective the wetland is at removing contaminants.

This module was originally developed as part of the “Hurricane Recovery Workshops for Students”, held in Corpus Christi in 2017.

Save the City

About This Lesson

Academic Question: How do engineers design structures to protect shorelines from storms and erosion?

Objective: The students will evaluate different types of shoreline stabilization devices and ultimately design a structure to protect their sea-side community.

Application:

Shoreline stabilization devices are used extensively in coastal areas. Many projects are large expansive seawalls and other may be used for small sections of individual property. Cost, material and labor are major factors in determining shoreline stabilization.

Getting Started

Materials:

- 2, 2-foot 2x4 boards
- 2 bricks
- Panty hose
- 2 Solo cups
- Ziploc bags
- Bamboo shiskabob skewers
- Cup of pea gravel or small rocks
- 2x2 piece of plywood (or appropriate device for making waves)

Process:

Begin with a discussion or unit on shoreline erosion and storms in the gulf including the destruction caused by storms and the large amount of money spent on shoreline protection. 1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above, and present this to the students. Divide the class in to design teams of 5 or less. Have the teams chose a spot on a shoreline no more than a meter way from the water for their town site. Using the materials provided, have them evaluate what device works best to prevent destruction of their town area. Waves can be produced by the plywood provided in their materials. After some experimentation, the students are charged with building the ultimate structure to protect their city. They may use any/all combinations of their materials provided. When the structure is completed, the instructor will generate waves and determine the effectiveness of each groups deign.

Evaluation/Extension:

- Have the students collect pictures in their local area of different types of shoreline structures.
- Have the students do a short research project on various storms that have affected the coast.

This module was originally developed as part of the “Hurricane Recovery Workshops for Students”, held in Corpus Christi in 2017.

Vanishing Seagrass

About This Lesson

Time Frame: One class period

Grade Level: 3-12

Academic Question: How does the absence of seagrass effect marine organisms?

Objective: To observe the effects on marine life when habitat is destroyed or changed.

Application:

This short and simple game demonstrates the importance of seagrass to aquatic species. It also highlights how easily seagrass systems can be damaged.

Background:

Many South Texas bays contain small patches to many acres of seagrass. These seagrasses provide many benefits to the aquatic environments including: bottom stabilization, water filtration, oxygen production and nursery habitat. These seagrasses require relatively clear water and sunlight. In areas where dredging and/or run-off occurs, the water may cloud up and seagrass may die. Other factors that may cause seagrass die off include prop scars from boat groundings and shading from piers. When seagrasses are damaged/removed, they will take several years to reestablish or may never return.

Getting Started

Materials:

- 36 2X2 inch squares of green construction paper
- Package of "goldfish" crackers
- Colored markers

Process:

1. Develop an interrupted case study scenario appropriate to your region, based on the background information provided above.
2. Begin with a discussion of seagrasses and their importance to South Texas Bays emphasizing their importance to both small and large fish for nursery and feeding areas. Then present the case study to the students.
3. Lay out the 36 squares in a large rectangle (approx. 12x12 inches)
4. Have a pair of students chose a goldfish and mark it with a colored marker.
5. Have the two students place the goldfish on a green square.
6. Game instructions-

7. The players are only able to move their fish one space- right or left, or up or down (not diagonally)
8. One at a time have the players move their fish and then take up any square of (seagrass).
9. As the players move their fish and remove the seagrass they must state what caused the "death" of the seagrass.
10. Continue playing until one player is "blocked" and unable to move.

Evaluation/Extension:

- Have students identify and research the five species of seagrass found in Texas.
- Using Google Earth, have the students identify seagrass and dredging scars found in Redfish Bay, and the Laguna Madre.
- Have the students go seining in a seagrass bed and an open area to see the differences in species found in each area.

This module was originally developed as part of the "Hurricane Recovery Workshops for Students", held in Corpus Christi in 2017.