Shell Bank: Oyster shell recycling, community engagement, teacher institute, and oyster health

Final Report for GLO Contract # 16-065-000-9109

Prepared for

THIS PROJECT IS FUNDED BY A TEXAS COASTAL MANAGEMENT PROGRAM GRANT APPROVED BY THE TEXAS LAND COMMISSIONER PURSUANT TO NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION AWARD NO. NA15NOS4190162.

Jennifer Beseres Pollack, Ph.D.
Gail Sutton, M.S.

June 30, 2017

Table of Contents

Table of Figures

Acknowledgements

We are extremely grateful for the continued support and efforts of our community partners, including the Port of Corpus Christi, Mr. Brad Lomax, Water Street Oyster Bar, Water Street Seafood Restaurants, Mr. Richard Groomer, Groomer's Seafood, Mr. Steve Rosenauer, San Antonio Fiesta Oyster Bake, Ms. Emily Horvath, Primize Austin, and Austin Oyster Festival. We also sincerely thank the many volunteers who have dedicated their time to oyster shell recycling and habitat restoration e. We are grateful for their contributions.

Introduction

Oyster reefs are ecologically and economically important components of U.S. Atlantic and Gulf of Mexico estuaries. In 2014, commercial oyster landings from the Gulf of Mexico generated $92.8M and constituted more than 70% of all U.S. landings (NMFS 2016). Reefs also provide habitat for fishes and macroinvertebrates (Harding and Mann 2001; Nevins et al. 2014), and may increase shoreline protection (Piazza et al. 2005), de-nitrification (Beseres Pollack et al. 2013; Kellogg et al. 2013), and carbon sequestration with estimated ecosystem services values of over $5,500 per ha/year (Grabowski et al. 2012). However, oyster reefs have suffered historic losses due to overharvest, disease, and degraded water quality, with estimates of 85-91% lost globally compared to historic levels (Jackson et al. 2008; Beck et al. 2011). Given the increasing awareness of marine habitat loss throughout the Gulf of Mexico (zu Ermgassen et al. 2012) and the world (Jackson 2008), there has never been a more important time to develop effective local solutions.

Figure 1. Shell Bank oyster shell recycling program logo.

Oyster reef restoration seeks to ameliorate the effects of habitat loss, but competing uses for oyster shell (e.g. agricultural liming, gravel substitute, poultry feed amendment) have caused a shortage of this preferred substrate for oyster settlement and thus for reef restoration. As a local solution, the innovative Shell Bank oyster shell recycling program (Figure 1; http://oysterrecycling.org/), was initiated with funding through the TGLO Coastal Management Program. This program utilizes public-private partnerships to reclaim and recycle oyster shells from seafood restaurants, wholesalers, and festivals for use in habitat restoration. We transport the shucked oyster shells to the Shell Bank stockpile location at the Port of Corpus Christi and hold them for at least 6 months to eliminate potential disease or invasive species before they are ready for use in reef restoration.

Project partnerships and progress

We established the Shell Bank Project with support from The Texas General Land Office's Coastal Management Program as the first integrated oyster shell reclamation, recycling, and restoration program in Texas. This program has become a model for others across the Gulf region who seek to create local solutions to regional problems of habitat degradation and loss. Our original project partners were specific to the Coastal Bend region, including the Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi (TAMU-CC), the Port of Corpus Christi Authority, and Water Street Seafood in Corpus Christi, TX. To date, we have incorporated new partners and increased our spatial scale to the larger South Texas region, including Groomer's Seafood, St. Mary's Fiesta Oyster Bake, and Austin Oyster Festival.

A unique component of the Shell Bank Program is that recycled oyster shells have been used to restore a substantial amount of reef habitat in Texas bays, including over 14 acres throughout Copano and Aransas Bays, and 2,000 linear feet being restored in summer 2017 in St. Charles Bay to protect an eroding shoreline at Goose Island State Park. Funds from the Coastal Management Program have allowed us to generate external support for all of these habitat restoration efforts using recycled oyster shells. Funds have been provided by the Coastal Conservation Association, National Fish and Wildlife Foundation, Fish America Foundation, Gulf of Mexico Foundation, Texas Parks and Wildlife Department, and the NOAA Community-Based Restoration Program. We continue to seek new partners and new funds for habitat restoration including from Texas Sea Grant and the NOAA RESTORE Act Science Program.

CMP 20 Project Goals

For CMP Cycle 20, our objective was to build on previous efforts and support 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. Four specific goals were proposed:

Goal 1: Expand oyster shell collection.

The Shell Bank Program at TAMU-CC reclaims and recycles approximately 465 cubic yards of shucked shells each year from coastal bend restaurants and wholesalers for use in restoring degraded reefs. TAMU-CC will continue working with local partners and will identify new areas to expand partnerships. In addition, TAMU-CC will expand their partnership with Fiesta Oyster Bake in San Antonio to increase oyster shell collection and educational outreach activities for the over 100,000 people who attend the festival.

Goal 2: Community-based restoration events.

In order to train and engage the community in local environmental stewardship opportunities, TAMU-CC will host two community-based oyster reef 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 bags of recycled oyster shells will be used to restore reef in corporation with Texas Parks and Wildlife Department at Goose Island State Park.

Goal 3: Teacher Institute. To further students' critical thinking skills and teach about the management of coastal resources, TAMU-CC will create a five-day field-based program for educators using dynamic and hands-on techniques. The program will expand on the pilot "Teach the Teachers" program and will connect classroom instruction to restoration-based field experiences, yielding lesson plans that teachers take back to their classrooms. All material presented will be aligned with State curriculum and will assist teachers with concepts covered in the Statewide STAAR (State of Texas Assessments of Academic Readiness) tests.

Goal 4: Oyster health. The protozoan oyster parasite, *Perkinsus marinus*, the causative agent of Dermo disease, causes severe oyster mortalities in the Gulf of Mexico (Ray 1966), particularly during periods with high salinities and warm temperatures. Drought and resulting lack of freshwater inflow to Texas bays have created conditions favorable to intensifying Dermo infection. Warm winters also facilitate spread of the disease. TAMU-CC will monitor oyster disease on reefs throughout the Mission-Aransas Estuary to inform future water management and restoration decisions. The oyster health investigation will provide unique research and educational training opportunities to a graduate student at TAMU-CC, a Minority Serving Institution.

CMP 20 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. Recycling oyster shells for use in oyster reef restoration is a four-step process:

1) Oysters are harvested by commercial fishermen and sold to seafood wholesalers, restaurants, and festivals for consumption.

(2) Workers or volunteers separate shucked oyster shells from food waste and trash, and place them into collection containers for pickup.

(3) Reclaimed shells are stockpiled at the Shell Bank repository at the Port of Corpus Christi for at least 6 months to eliminate potential diseases or invasive organisms.

(4) Shells are used as substrate to restore or recreate lost oyster reef habitat.

During the spring, summer and fall months, oysters spawn and release free-swimming larvae into the water column. These larvae are carried by currents and after spending about two weeks in the water column, seek a suitable surface upon which to attach and begin building their calcium carbonate shells. Once settled, these oysters spend the remainder of their life cycle where they have attached. Oyster shell is one of the most desirable materials for attachment and subsequent growth of young oysters.

Our philosophy is that oyster shells that end in landfills or lost to competing uses are a key resource out of place. The Shell Bank Program encourages local partners to recycle their oyster shells so that they end up where nature intended: in local bays, supporting the sustainability of oyster reefs and their associated benefits.

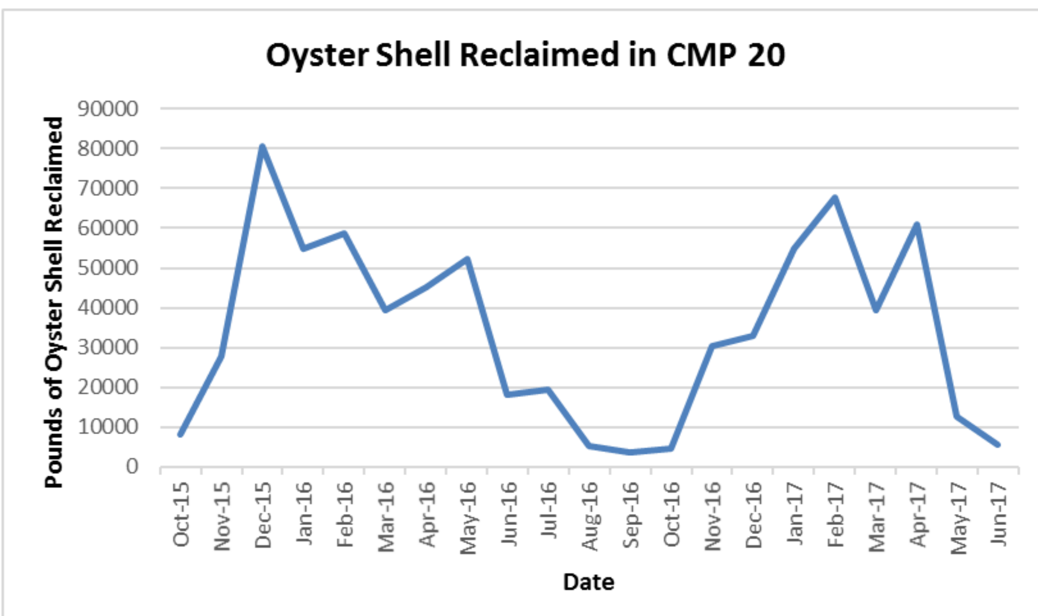


Figure 2. Pounds of oyster shell reclaimed by the Shell Bank Program during CMP 20.

The Shell Bank program reclaimed 721,700 pounds, or approximately 547 cubic yards of oyster shells from seafood restaurants, wholesalers, and festivals as part of CMP 20 (Figure 3; Figure

4). The amount of shells varied in a cyclical fashion, matching that of the commercial season in Texas (Figure 2). The greatest amount of shell was collected in December 2015 (80,700 lbs) followed by February 2017 (67,600 lbs). The least amount of shell was collected in August-October 2015 (average 4,400 lbs), just prior to the start of the commercial season.

Figure 3. Getting ready to transport collecting recycled oyster shells to the Port of Corpus Christi in our trailer.

Figure 4. Depositing recycled oyster shells at the Shell Bank stockpile location at the Port of Corpus Christi.

Also as a part of this task, we recycled oyster shells and performed community outreach at Austin Oyster Festival (February 27, 2016; Figure 5, Figure 6), and St. Mary's Fiesta Oyster Bake (April 15-16, 2016; Figure 7). For both festivals, we transported a trailer from Texas A&M University-Corpus Christi to the festival location and filled the trailer with shucked shells for the duration of the event. In addition, we walked throughout the event with buckets, picking up shells from festivalgoers and talking to them about the Shell Bank program, oyster shell recycling, and the importance of oyster reef restoration. We also teach people how to shuck oysters on occasion (Figure 8). The most frequently asked question we hear at the seafood festivals is: "What are you doing with the shells?". Festivalgoers are very interested in the program and are excited to learn about shell recycling and to hear that the oyster shells will be used for oyster reef restoration projects.

Figure 5. Recycling oyster shells at Austin Oyster Festival, February 27, 2016.

Figure 6. Speaking with a festivalgoer about the importance of oyster shell recycling and oyster reef restoration.

Figure 7. Talking about oyster shell recycling and oyster reef restoration at St. Mary's Fiesta Oyster Bake, April 15-16, 2016.

Figure 8. Teaching festivalgoers to shuck oysters at St. Mary's Fiesta Oyster Bake, April 15-16, 2016.

2. Community-based restoration events

As part of CMP 20, we hosted two community shell-bagging events at Goose Island State Park, one on Saturday, April 2, and one Saturday, May 7, 2016, both from 8:30-11:30 am. 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. There were 3 stations of restoration activities that the volunteers were engaged in: (1) they cut tubular aquaculture mesh fit roughly 2 gallons of recycled shell (Figure 9); (2) with a partner, they filled the bags with recycled oyster shell using a PVC pipe as a guide (Figure 10); and (3) they loaded the bags onto a wagon and delivered them to a staging area for reef restoration (Figure 11).

Figure 9. Aquaculture mesh is measured and cut to size at community-based restoration event.

Figure 10. Recycled oyster shell is poured into PVC pipe holding mesh bag.

Figure 11. Loading bags of recycled oyster shell into the wagon to move to the staging area.

A total of 269 volunteers participated in these community-based restoration events and bagged a total of 44,660 pounds of recycled oyster shell (Figure 12). On April 2, 113 volunteers participated and 13,500 pounds of recycled oyster shell were bagged. On May 7, 156 volunteers participated and 30,520 pounds of oyster shell were bagged—the largest amount we have ever achieved. Volunteers included students from Moody High School and King High

School from Corpus Christi, Judson High School from San Antonio, and Texas A&M University-Corpus Christi. As always, staff from Goose Island State Park were extremely supportive of these events, and even participated themselves (Figure 13).

Figure 12. Volunteers at community-based restoration event. Photo credit: Lisa Laskowski.

Figure 13. Jarrod Boudreaux, Operations Manager for Goose Island State Park, Texas Parks and Wildlife Department, helps shovel recycled oyster shells.

Additional outreach within the community was also performed throughout the project period. On June 8 and June 22, 2016, we participated in the Summer Science Field Program at the

University of Texas Marine Science Institute. As part of this program, we facilitated lab and field activities related to oyster reef restoration for 3rd and 4th graders from local schools. As part of this outreach, we taught the students about habitat restoration and the role of shell recycling and led the students in an investigation of oyster reef inhabitants.

3. Teacher Institute

Educators need field-based training and development to further students' critical thinking skills and to teach about management of coastal resources. The program we designed for this grant connected classroom instruction to field experiences. This completes the circle of learning by yielding lesson plans that teachers take back to their classrooms. Planning started in December 2015, with Gail Sutton, Jay Tarkington, Dr. Mary Ann Davis and Dr. Richard Davis working on the application process for teachers. The teachers had noted in their applications that the original plan of a 5-day institute would not work with their class schedules. The recommendation was to divide the 5-day program into two shorter periods so they could get approval to attend. The program agenda was adapted so more teachers could attend the teacher institutes.

The date for one of the institutes was set for May 6-7, 2016 at the Laguna Madre Field Station owned by Texas A&M University-Corpus Christi. The remote Field station is accessible only by boat and provided a unique backdrop for the teachers' educational experience. Eighteen (18) middle and high school teachers were selected from Coastal Bend schools. Teachers from socio-economically disadvantaged districts were preferred in the selection process. Along with discussions and activities associated with South Texas wetlands, several location specific STEM activities were developed and presented throughout the workshop (see-attached modules). The modules created for the teacher institute were designed on topics including, shoreline erosion, biologic sampling, mercury bioaccumulation, buoyancy, and critical thinking skills. One highlight of the workshop involved the teachers learning about the physics of Native American atlatls. These Native American "throwing sticks" provided the teachers not only a unique physics lesson but provided them insight in to the prehistoric people of the coast and the land mammals that once roamed the coastal plains. In addition to the specific modules created for the institute, teachers were asked to share and discuss STEM activities they are currently using in their classroom. The 2-day teacher institute provided the teachers several new location specific STEM activities based around the unique ecology found along the Texas coast.

This was an excellent forum to connect CMP 19 participant teachers with the CMP 20 participating teachers in advance of the Teacher Institute. As in prior CMP grants, Jennifer Pollack and Gail Sutton strive to link prior CMP tasks with current tasks in order to maximize impact of the grant. This institute provided local aquatic science teachers an opportunity to be mentored by the CMP 19 teachers, utilize their curriculum, and participate in field based activities based on these unique lesson plans.

The second grouping of teacher institutes, called “Day Institutes”, were designed for the teachers to apply field techniques to curriculum with their students.

These teachers with their students traveled to Goose Island State Park on St. Charles Bay to work on the Educational Reef that has been the cornerstone of the Oyster Shell Recycling Program:

- February 7-9, 2017: King High School, Amanda Rose
- February 14, 2017: Carrol High School, Robert Doemlan
- February 22-23, 2017: King High School, Amanda Rose

These teachers with their students traveled to the Laguna Madre Field and Estes Stations and the campus of Texas A&M University-Corpus Christi to apply field techniques:

- February 28, 2017: Moody High School, Vinay Dulip
- March 2, 2017: Moody High School, Vinay Dulip
- March 3, 2016: Rockport-Fulton Middle School, Kay Blaha and Bobby Jackson
- March 10, 2016: Riviera High School, Rosanna Ryan
- March 30, 2016: Little Bay Elementary, Jeff Groseclose
- April 4, 2016: Baker Middle School, All teachers invited
- April 5, 2016: Gloria Hicks Elementary, All teachers invited
- April 6, 2016: Andrews Elementary, Morgan DeLong and Jessica Tubbs

The teachers were very pleased with the outcome of the 2-day and 1-day Teacher Institutes. This allowed them the time to learn a skill set then apply it in the field. The adaptation of the timeperiod was critical to the success of the task. The lesson learned for our team was not to be overly ambitious with the schedule. The addition of the CMP 19 teachers was also a high point of the institute. Their mentoring of the CMP 20 teachers was helpful to both sets of teachers. We feel this program was a big success and plan to continue it.

Figure 14. Traveling down to the Laguna Madre Field Station.

Figure 15. One of the STEM related activities involved designing original fish traps for specific species. The traps were then tested overnight and many yielded positive results.

Figure 16. Teachers are designing tinfoil boats and testing their stability and seaworthiness with various items.

Figure 17. Teachers are conducting a buoyancy lab involving moving and underwater research station "a brick" with a limited amount of materials without physically touching the "lab". They were having to use critical thinking skills, teamwork, and demonstrate an understanding of the concept of buoyancy.

Figure 18. The teachers had the opportunity to be native hunters and explore the use of prehistoric atlatls. They were able to see how peoples from our past used simple machines (various levers) and physics to increase the power of hunting darts.

Figure 19. Teachers are experimenting with various shoreline stabilization techniques in an effort to protect their coastal city form a category IV storm. Various materials including solid bulkheads, natural vegetation, retention ponds, and living shorelines were tested and evaluated.

Figure 20. Teacher applying the lesson plan for the buoyancy lab.

Figure 21. Teacher applying the lesson plan for the buoyancy lab.

Figure 22. Teacher applying the lesson plan for the buoyancy lab.

Figure 23. Teacher applying the lesson plan for shoreline stabilization techniques.

Figure 24. Teacher applying the lesson plan for shoreline stabilization techniques.

Figure 25. Teacher applying the lesson plan for shoreline stabilization techniques.

4. Oyster health

The protozoan parasite *Perkinsus marinus* is the causative agent for Dermo oyster disease and causes severe mortality of oysters in Texas bays, particularly during periods of high temperatures and salinities. Although *P. marinus* does not affect humans, it can limit oyster harvests and dramatically affect the success of restoration projects. Due to extended droughts in Texas, the resulting uncommonly high salinities in bay waters may lead to increases in disease-related oyster deaths. We monitored oyster disease characteristics at oyster reefs along a salinity gradient in the Mission-Aransas Estuary to identify disease hotspots and determine overall oyster health.

Seven stations were sampled along a salinity gradient in the Mission-Aransas Estuary to measure oyster characteristics and water quality: Shell Bank, Lap, Causeway North, Causeway South, Grass Island, Half Moon, and Long reefs (Figure 14). At each station ≥ 20 oysters (~10 market size (≥76mm) and ~10 sub-market size (26-75mm)) were collected using an oyster dredge. Depth, temperature, conductivity, dissolved oxygen, salinity, pH, and turbidity were measured with a Hydrolab Surveyor II at the surface and approximately 10 cm above the bay bottom.

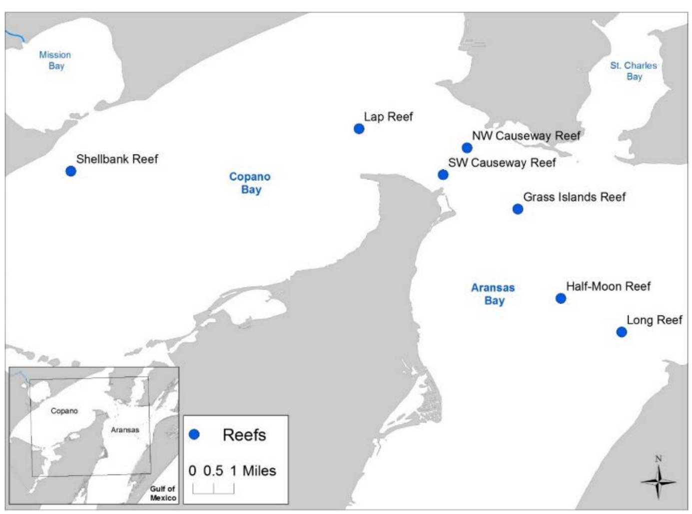


Figure 26. Oyster reefs sampled (blue points) along a salinity gradient in the Mission-Aransas Estuary.

For each oyster, *P. marinus* infection was assessed using Ray's Fluid Thioglycollate Method (Ray 1966). A 5 x 5 mm section of mantle tissue was removed and incubated in Ray's Fluid Thioglycollate Media (RFTM) for 2 weeks following the culture method of Ray (1966). Tissue cultures were then stained with 75% Lugol's solution and examined microscopically for P. marinus hypnospores (blue/black spheres). *Perkinsus marinus* intensity was scored using the 6-point Mackin scale (uninfected (0) - heavily infected (5)) adapted from Mackin (1962) by Craig et al. (1989). The proportion of oysters infected with *P. marinus* (prevalence) was calculated by dividing the number of infected oysters by the number of oysters sampled. Mean infection intensity (II) of individuals on the reef was calculated (Soniat et al. 2012), and then weighted prevalence, a measure of the relative severity of *P. marinus* infection in a population, was calculated by multiplying mean infection intensity by prevalence.

To better understand the relationship between *P. marinus* and salinity in the Mission-Aransas Estuary, field data were combined with those starting in December 2004 compiled from Oyster Sentinel (www.oystersentinel.org), a database maintained by Dr. Tom Soniat at the University of New Orleans.

Biweekly-collected salinity and temperature data obtained from Texas Parks and Wildlife Department (TPWD) Coastal Fisheries Division were used to hydrologically characterize the Mission-Aransas estuary under three inflow/salinity regimes: wet/low salinity, drought/high salinity, and normal (Palmer and Montagna 2015). Historical conditions for each estuary were determined to be in drought if mean monthly salinities were within the upper quartile of monthly salinities. Conversely, conditions were determined as being wet if the mean monthly salinities were within the lower quartile of all salinities. Normal conditions were determined if salinities were in the interquartile range of historical salinities.

Oyster infection by *P. marinus* varied by climatic conditions and across stations in the Mission-Aransas Estuary. Among climatic conditions there were highly significant positive relationships between salinity and the proportion of market-size oysters infected with P. marinus ($r = 0.735$, $P < 0.0001$, Figure 15) as well as with the severity of infection ($r = 0.827$, $P < 0.0001$). Among all reefs, *P. marinus* infections in market-size oysters significantly increased from wet (35.1%, 0.53) to normal (56.8%, 1.03), and normal to drought (68.2%, 1.41) conditions ($P < 0.0001$, Figure 16, Figure 17). In submarket-size oysters there was a lower proportion of infection with *P. marinus*, with lower relative severity of infection, in wet conditions (28.9%, 0.50); there was no difference during normal and drought conditions (43.9 - 44.7%, 0.776 - 0.804, $P < 0.05$).

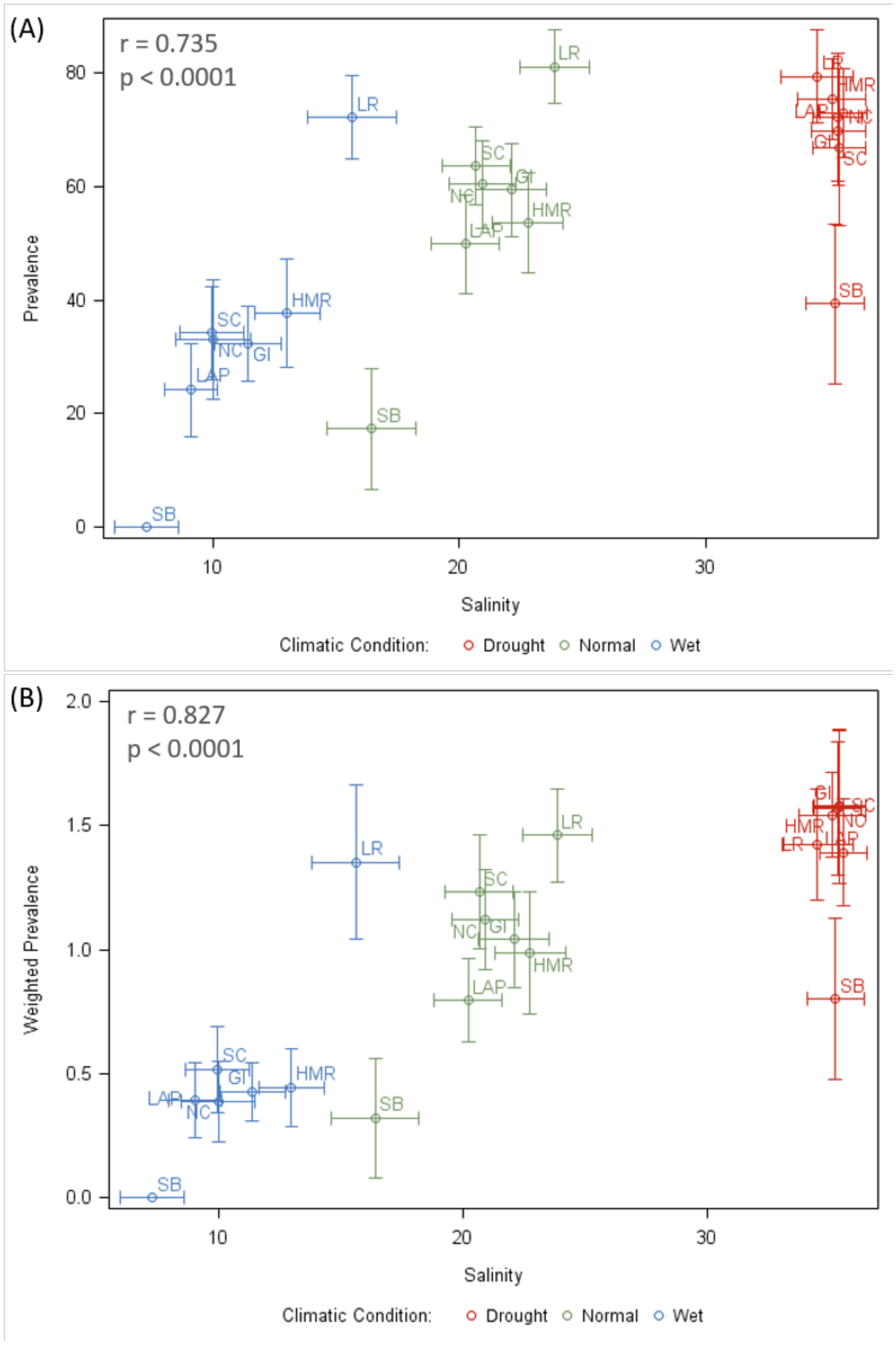


Figure 27. Correlations of proportion of oysters infected with P. marinus (prevalence) and severity of infection (weighted prevalence) with salinity among oyster reefs and climatic conditions. Bars represent standard errors about the mean. Reef abbreviations: LR = Long Reef, HMR = Half-Moon Reef, GI = Grass Islands Reef, SC = SW Causeway Reef, NC = NW Causeway Reef, LAP = Lap Reef, SB = Shell Bank Reef

In wet, normal, and drought conditions all reefs had a similar proportion of oysters infected with *P. marinus* and severity of infection, except Shell Bank Reef and Long Reef (Figure 15). The proportion of market-size oysters infected with *P. marinus* was significantly lower at Shell Bank Reef (21.1%) and significantly higher at Long Reef (78.2%), but similar among all other stations (49.1 - 57.6%, P < 0.0001, Figure 16). The relative severity of market-size oyster infection was significantly lower at Shell Bank Reef (0.42), but similar among all other stations (0.85 - 1.42, P < 0.0001, Figure 17). The proportion of submarket-size oysters infected with *P. marinus*, and the relative severity of infection was similar among all stations (P < 0.0001).

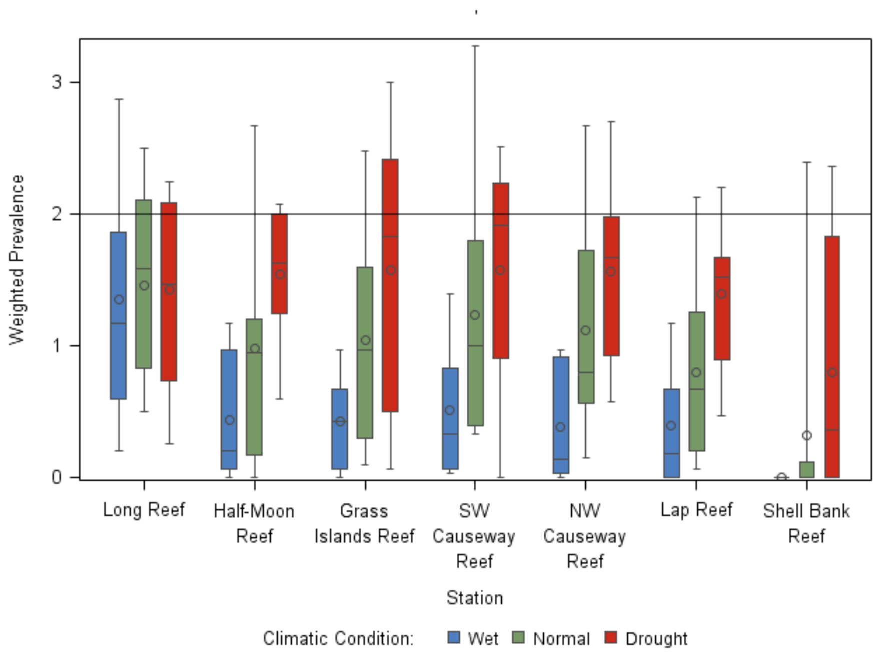


Figure 28. Relative severity of P. marinus infection (weighted prevalence) for market-sized oysters within the Mission-Aransas Estuary. Stations in order from southeast (Long Reef) to northwest (Shell Bank Reef)

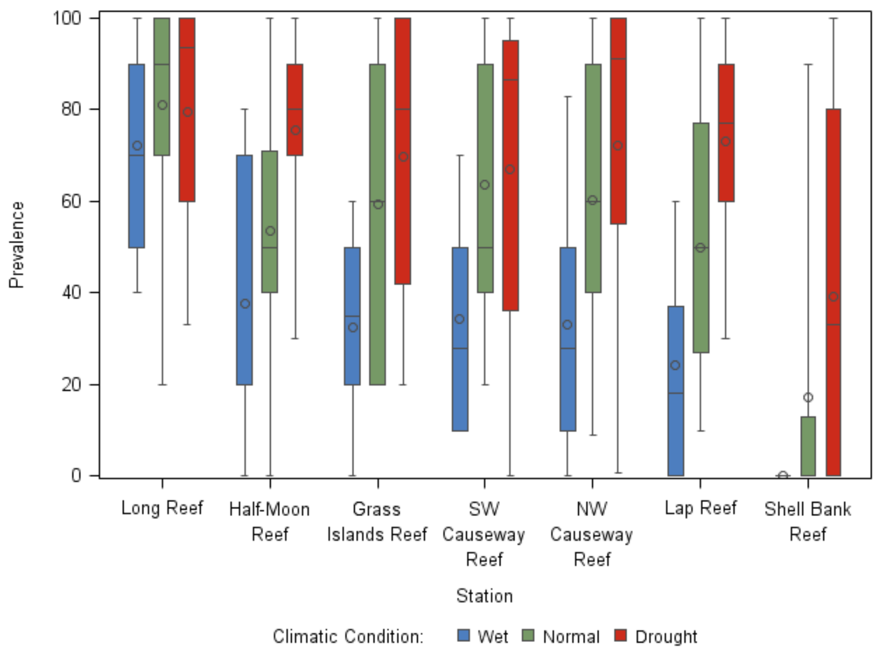


Figure 29. Proportion of oysters infected with P. marinus (prevalence) for market-sized oysters within the Mission-Aransas Estuary. Stations are in order from southeast (Long Reef) to northwest (Shell Bank Reef)

At each reef, there was a significant positive relationship between salinity and *P. marinus* characteristics in market-sized oysters ($P < 0.05$, Figure 15). In submarket-size oysters there was a significant positive relationship between the proportion of infected oysters and salinity at Shell Bank Reef and Lap Reef ($P < 0.05$) and a significant positive relationship between the relative severity of P. marinus infection and salinity at Shell Bank, Lap, NW Causeway, SW Causeway, and Grass Islands Reefs ($P < 0.05$). There were no significant relationships between temperature and proportion of oysters infected with *P. marinus* ($r = -0.027$, $P \leq 0.9117$) or severity of infection ($r = 0.019$, $P \leq 0.9356$) among climatic conditions (Fig. 8). There was a positive relationship between the relative severity of *P. marinus* infection in market-size oysters and temperature at Long Reef in summer months ($r = 0.776$, $P \leq 0.0140$). There were no significant relationships between temperature and *P. marinus* infection among reefs in winter months ($P <0.05$).

This study helped to address the effects of Texas estuarine salinity patterns on *P. marinus* dynamics. Results indicate that climatic conditions (i.e. wet, normal, drought) drive local salinity regimes in Texas estuaries, which then determine the proportion of oysters infected with *P. marinus* and the relative severity of infection. *P. marinus* infection characteristics increased with increasing salinity among wet, normal, and drought conditions. Salinity-based predictions are useful because of increasing demands for freshwater resources which have the potential to further reduce freshwater flows to the coast. Using *P. marinus* as a bioindicator of adequate salinity regimes can provide water resource managers with an effective strategy to recommend base flow regimes to support desired estuarine conditions among drought, normal, and wet climate regimes.

Conclusion

The Texas General Land Office's Coastal Management Program provides key funding to the Shell Bank oyster shell recycling program, making substantial contributions in support of coastal habitat restoration in Texas. Coastal Management Program has been extremely instrumental in expanding oyster reef habitat restoration efforts across the state. Support for our program has provided stockpiled shells to restoration projects, generated key data to support habitat sustainability through associated oyster health assessments, and educated and engaged thousands of kids and adults about coastal environmental stewardship. Project sustainability has been essential to this success, allowing for expansion of our partner base and creation of lasting connections with the community for direct involvement in habitat restoration. Moving forward, the Shell Bank program will continue educating the public, recycling oyster shells for habitat restoration, and providing scientifically grounded solutions to improve the sustainability of oyster reefs and inform adaptive management of coastal natural resources in Texas.

Literature cited

Beck MW, Brumbaugh RD, Airoldi L, Carranza A, Coen LD, Crawford C, Defeo O, Edgar GJ, Hancock B, Kay MC, Lenihan HS, Luckenbach MW, Toropova CL, Zhang GF, Guo XM. (2011) Oyster reefs at risk and recommendations for conservation, restoration, and management. Bioscience 61: 107–116

Beseres Pollack J, Yoskowitz D, Montagna P, Kim H-C. (2013) The role and value of the nitrogen regulation ecosystem service provided by oysters in the Mission-Aransas Estuary, Texas, USA. PLoS ONE 8 (6), e65314. doi:10.1371/journal.pone.0065314

Craig A, EN Powell, RR Fay, JM Brooks. (1989) Distribution of Perkinsus marinus in Gulf Coast oyster populations. Estuaries. 12:82-91.

Grabowski JH, Brumbaugh RD, Conrad RF, Keeler AG, Opaluch JJ, Peterson CH, Piehler MF, Powers SP, Smyth AR (2012) Economic valuation of ecosystem services provided by oyster reefs. Bioscience 62: 900-909

Harding JM, Mann R. (2001) Oyster reefs as fish habitat: opportunistic use of restored reefs by transient fishes. J Shellfish Res 20:951–959

Jackson, J.B.C. (2008) Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences. 105: 11458-11465

Kellogg ML, Cornwell JC, Owens MS, Paynter KT (2013) Denitrification and nutrient assimilation on a restored oyster reef. Mar Ecol Prog Ser 480: 1–19

Mackin, JG (1962) Oyster disease caused by Dermocystidium marinum and other microorganisms in Louisiana. Publ. Inst. Marine Science University Texas. 7:132-299.

Nevins JA, Beseres Pollack J, Stunz GW. (2014) Characterizing nekton use of the largest unfished oyster reef in the U.S. in comparison to marsh edge and nonvegetated estuarine habitats. J Shellfish Res 33: 1-12

NMFS (2016) National Marine Fisheries Service Commercial Fisheries Statistics. https://www.st.nmfs.noaa.gov/commercial-fisheries/.

Palmer, TA, PA Montagna (2015) Impacts of droughts and low flows on estuarine water quality and benthic fauna. Hydrobiologia. 753:111–129.

Piazza BP, Banks PD, La Peyre MK. (2005) The potential for created oyster shell reefs as a sustainable shoreline protection strategy in Louisiana. Restor Ecol 13: 499–506

Ray, S.M. (1966) A review of the culture method for detecting Dermocystidium marinum, with suggested modifications and precautions. Proceedings of the National Shellfisheries Association. 54:55–69.

Soniat, TM, JM Klinck, EN Powell, EE Hofmann (2012) Understanding the success and failure of oyster populations: periodicities of Perkinsus marinus and oyster recruitment, mortality, and size. Journal of Shellfish Research. 31:635-646.

zu Ermgassen, P.S.E.,M.D. Spalding, B. Blake, L.D. Coen, B. Dumbauld, S. Geiger, J.H. Grabowski, R. Grizzle, M. Luckenbach, K.A. McGraw, B. Rodney, J.L. Ruesink, S.P. Powers, and R.D. Brumbaugh. (2012) Historical ecology with real numbers: past and present extent and biomass of an imperiled estuarine ecosystem. Proceedings of the Royal Society B 279: 3393–3400

Appendix: Curriculum for Teach the Teacher STEM Workshop, May 2016

Curriculum
for
Teach the Teacher
STEM Workshop
May 2016

“Don’t Spill the Beans”

Academic Question: How do we effectively sample an area?

Objective(s):

- To introduce students to species area curve models
- To allow students to develop their own species area curve

Process (Activities):

In this activity, a pan of beans will represent a diverse wetland environment with the different beans symbolizing different species. The underling question of this activity is, “How many samples must be collected in order to obtain a true representation of the populations of a given habitat.” In real life applications, sampling is a very labor intensive and expensive activity. Species area curves are developed to give scientists information on the most efficient number of samples needed in order to complete their work, compile data, and provide solid scientific information.

1. This lab works best in groups of 2 to 4 or can be done as a demonstration.
2. Materials needed: (all materials are per group)
    - One bag of 13-15 bean soup. If necessary get several different bags of beans and mix together. Ultimately, each group should have a mixture of several different kinds of dried beans.
    - One 8.5 X4.5 (or similar) bread pan. (aluminum pans are cheap*)
    - One 16 oz. soda bottle cap (screw on type).
    - Yellow “stick it” pad (just a few are necessary)

3. Place a generous portion of beans into each pan making sure that the beans are a uniform nature.
4. Have students use soda cap to “dip” out a level sample of beans.
5. Place beans on table and organize into columns of like “species”
6. With a stick it, label this group of columns “sample one” and place label beside the group.
7. Count the number of columns.
8. Write this number on the “stick it” and label it “total number of columns (species)- sample one”
9. Have students “dip” out another sample.
10. Separate into columns like above (step 5)
11. Label columns “sample two”
12. Count only the number of new and **different** columns/species and add to total number of species from sample one.
13. Write this number on the “stick it” and label it “total number of columns (species)- sample two”
14. Continue sampling/dipping until no “new” beans (species) occur

15. Have students develop a graph with “Sample Number” being the “X” axis and “number of different species” being the “Y” axis.
16. The graph should resemble a gentle curve leveling out toward the maximum number of species.
17. The level part of the curve corresponds with the most efficient sample number.
18. Have students write down how many samples are necessary to effectively and efficiently sample their pan of beans.

Application: Have students discuss how this activity represents sampling in a local wetland area. Lead students into a discussion on different sampling techniques (nets, seines, coring devices, surveying equipment, etc.) Have students discuss how some sampling techniques are not as effective as others (using a kick net only samples epi-benthic organisms, not all organisms in a steam, etc.)

Evaluation: Have students report on their species area curve model including the graph. The report should contain the number of samples they feel is necessary to efficiently obtain a representative sample of the population. Ask students how a larger or smaller sampling device would have affected their data. Have students explain reasons why developing a species area curve is important.

Time Frame: 1-2 class periods
Grade level: 6^{th}-12^{th}

Float Your Boat

Academic Question:

How do buoyancy and weight placement relate to boat design?

Objective:

- To allow students do design and test various floating models
- To introduce students to the principles of buoyancy
- To have students experiment with center of gravity placement

Process:

Explain to the students that they are now in charge of a large barge and shipping company. Their profit is based on the total amount of weight the barges can move. Divide the group in to design teams of no more than 3 and using the material provided, have the students design and test their "boat" and determine how much weight it can carry. Once the students have designed their boat, have them begin to place pennies in to the boat until it sinks. Have the different design teams demonstrate their design for the class.

Materials:

Roll of aluminum foil cut into 12x12 inch squares.
100 or more pennies
Small tank or clear bowl filled with water to test boats.

Application/Extension:

The concepts of buoyancy, displacement, and center of gravity are all demonstrated in this project. These are the same concepts nautical architects work with in boat design.

Have students research a Plimsoll Line and comment on where they would place one on their vessel.

Have the students' research then compare and contrast current boat building materials.

Evaluation:

Have the students comment on the good and bad parts of their design and what they would change in the next design.

Timeframe:

Gradelevel:

Merging Mercury

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.

Process:

This activity will use a classroom of students representing a food chain to show the bioaccumulation of mercury through several trophic levels.

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.

Timeframe:

Typically one class period.

Gradelevel:

6-12

Save the City

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.

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. 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.

Materials:

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

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.

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.

"The Incredible Edible Tidal Flat"

Academic Question: What is the substrate content of a tidal flat?

Objective(s):

- To introduce students to the living substrate components of a tidal flat
- To allow students to model the substrate of the tidal flat
- To educate students on the invertebrates living within the tidal flat substrate

Background:

Tidal flats have a unique ecosystem that is based on large mats of blue green algae that make up the expansive substrate. The flats are irregularly flooded and alternate between wet/dry cycles leaving behind high concentrations of salt. These continually changing conditions prevent vegetation from becoming established.

The tidal flats take on different characteristics depending upon length and depth of inundation. When wet, a living algal mat forms a papery crust 1 to 20 mm. in thickness and includes blue green, unicellular green, flagellated, and diatomaceous algae as well as various strains of bacteria. The largest component of this living mat is made up of the filamentous algae, *Lyngbea confervoides* (Sorrenson and Connover, 1962).

There is a distinct zonation in the blue green algal mats. The mat community may be exposed for weeks at a time followed by flooding for weeks or months. Growth of the algal mat occurs during the flooding, while shrinkage occurs in the dry period. Alternating banded columns of black to brown to gray occur in the mats. It is made up of several different grain sizes and is related to the alternating wet and dry periods. During dry periods, sand is transported onto the flats. When inundation occurs, the blue green algal mat grows through the freshly deposited sand and establishes itself on top (Sorrenson and Conover, 1962). This top layer is black and is used as a temperature insulator, as well as a light shield for the lower layers. It becomes thicker and deeper in summer with the increased photoperiod. Below this is the blue green layer where Lyngbea is dominant. Continuing down through the algal mat is a yellow green layer with fewer numbers of Lyngbea. Along with Lyngbea, there are several flagellates, diatoms, and bacteria found here. They cause this zone to function as a decomposition layer. Below this is a pinkish layer that contains a purple, sulfur bacteria, Chromatium sp. This zone also serves as a zone of decomposition, as well as a site for anaerobic processes (Sorrenson and Conover, 1962). Below the pinkish layer is a colorless zone that varies in depth. The lower layers are highly anaerobic and contain hydrogen sulfide and reduced organic matter (Birke, 1974). When flooding occurs, large portions of the mat may float away. This may be a way of re-establishing the colony elsewhere. When wind, water, or other disturbances remove the upper crustal layer, the area left exposed quickly resumes the characteristics of the described mats.

The consumers on the wind tidal flats of the Laguna Madre begin with insect larvae, polychaets, tanaids, with the tanid Hargeric rapax being the most common (Withers, 1994). Predation takes place among some insects (predatory beetles and hemipterans), as well as by spiders (Lycosidae-wolf spiders, and Clubionidae-sac spiders) that live and feed in the cracks of the surface (Pulich et. al., 1982). Various birds and fish or other larger invertebrates such as crabs, then feed upon smaller organisms. Birds are the major consumers during dry periods and fish dominate during wet episodes (Withers, 1994). Sheepshead minnows (Cyprinidon varigatus), various shrimp (Palaemonetes sp.) and crabs (Callinectes sapidus, Uca sp.) may feed on the tidal flat depending upon length of the wet episode, and depth of the water. Various birds are found in, above, and around the wind tidal flat areas.

Process (Activities):

1. This lab works best in groups of 2 to 4 or can be done as a demonstration.
2. The students will be modeling the various layers of a tidal flat during dry conditions.
3. Materials needed: (all materials are per group)
    - Small, clear plastic cocktail cups
    - The following flavors of pudding cups: chocolate, butterscotch, vanilla
    - The following flavors of “fruit roll-up”: strawberry (pink) and grape (dark purple)
    - Oreo cookies (crushed)
    - Gummy worms and/or insects
    - Plastic spoons
    - Napkins
4. Describe the make up of the wind tidal flat substrate using the above information. Feel free to simplify. (the information provided is for teacher use) Use additional information as needed from the accompanying web site.
5. Have students draw or demonstrate for them on the overhead the layering that may be found within the substrate.
6. Associate colors with the appropriate layers.
7. Have students prepare a model of a tidal flat using the materials provided. Remember to include the various organisms they may encounter within the substrate.

Evaluation:

- Have the students measure and describe each layer of the “modeled” substrate.
- What types of organisms live “in” the substrate and what types of organisms are able to feed upon them?
- How might their model change if it were during a period of inundation?
- Why is the uppermost layer dark in color?
- Why are the lower layers dark in color?

Time Frame: 1-2 class periods
Grade Level: 6^{th}-12^{th}

Literature Cited:

Birke,L. 1974. Marine blue green algae mats. Pages 331-345 in H. T. Odum, B. J. Copeland, & E. A. McMahon (eds.) Coastal ecological systems of the United States. The Conservation Foundation, Washington, D.C. Vol. 1, Ch. A-7.

Pulich, W. Jr., S. Rabalais, and S. Wellso. 1982. Food chain components on Laguna Madre tidal flats. UTMSI Contrib. No. 573. Port Aransas, Texas. 20 pages.

Sorenson, L.O. and J.T. Conover. 1962. Algal mat communities of *Lyngbya confervoides* (C. Agardh) Gioment. Publ. Inst. Mar. Sci., Univ. Tex. 8: 61-74.

Withers, K. 1994. The relationship of macrobenthic prey availibility to shorebird use of blue-green algal flats in the upper Laguna Madre. Ph.D. Diss. Tex. A&M Univ., College Station. 117 pp.

Tote and Float

Academic Questions:

How much buoyancy is needed to float an object?

Objectives:

Design and implement a device to lift and move a submerged brick without touching it.

Process:

Explain to the students that their team has been put in charge of moving a large undersea radioactive module. This large module cannot be simply picked up of pushed to a new location. A series of marine cranes, deep sea divers, boats and barges will need to be used. (Be creative with the story). Place a brick for each team in 1-2 feet of water. (a small wading pool may work if not near a shore). Each team is given a box of supplies. Using the supplies provided, the students must devise a way to lift and move the brick.

Materials:

Brick
2 short sections of swim noodle
10 feet of string
4 Ziplock bags
5 tooth picks
4 balloons

Application:

Moving large objects underwater is a major part of the offshore oil and natural gas industry.

Evaluation/Extension:

Have the students demonstrate their design and determine what worked well and what could be improved upon then have the class determine which team had the best design overall.

Would this process work better in fresh water? (Buoyancy)

Have the students research the moving and placement of oil platforms in the Gulf of Mexico.

Time Frame:

Grade Level:

Middle school/high school

What is a benthic community?

The Benthic Community is made up of organisms that live in and on the bottom of the ocean floor. These organisms are known as benthos. Benthos include worms, clams, crabs, lobsters, sponges, and other tiny organisms that live in the bottom sediments. Benthos are divided into two groups, the filter feeders and the deposit feeders. Filter feeders such as clams and quahogs filter their food by siphoning particles out of the water. Deposit feeders, such as snails and shrimp, ingest or sift through the sediment and consume organic matter within it.

Before the age of deep-sea exploration scientists believed that there could be no life in the absence of energy from the sun. Since sunlight only penetrates the first 30m in coastal areas and 100m in the open ocean, they believed there was no life to be found on the ocean floor. What they did not realize was that there is a steady production of energy in the oceans in other forms than direct sunlight. One source of energy or food is the bodies of organisms that have died in the upper sunlit layers of the sea. They settle downward through the water column where they can be consumed. There is a constant vertical downflow of food or energy from the upper layers of the water to the benthic community.

Benthic animals are much more abundant in the shallower waters off the coast. In the shallow water the dead food material is more abundant because there is a higher population of organisms near the surface in this area. In these waters food also arrives from river sediments. Once food has reached the sea floor, currents carry this food and organisms filter it without having to use their own energy to go and get food. Another way organisms use energy is by coming out at night and rising to feed on upper-level organisms. Many large organisms are formed as they feed on microscopic food.

One of the most useful way to investigate this community is by dredging. In the benthic community many of the organisms live underneath the surface of ocean floor. Therefore water sampling, although useful, does not give an accurate picture of the benthic population. With dredging, sediment is taken up with water and filtered so that all animals in the community can be observed and accounted for.

Benthic communities can be observed by looking at the sediments at the seafloor. With new technology we are able to drill through the ocean floor and bring up sediment columns that can be observed. These columns can tell us a great deal about the intake and output of different elements. This helps us understand how this ecosystem works and stays in balance. These columns also tell us where in the sediment bed organisms are found and how they effect the community. Sediment-profile images, such as the ones below from the Narragansett Bay, help characterize the benthos and their environment.

Why are benthos important to the biological community of estuaries?

Benthos play a critical role in the functioning of estuaries. Benthic species are a diverse group that are a major link in the food chain. Filter feeders in the benthic community pump large amount of water through their bodies. As they filter this water for food, they remove sediments and organic matter, cleaning the water. Organic matter that is not used within the water-column is deposited on the bottom of the ocean floor. It is then remineralized by benthic organisms into nutrients which are given back into the water column. This remineralization of organic matter is an important source of nutrients to the ocean and is critical in maintaining the high primary production rates of estuaries.

Benthos is one of three major ecological groups into which marine organisms are divided, the other two being the nekton and the plankton. The benthos are organisms and communities found on or near the seabed. This includes those animals (zoobenthos) and plants (phytobenthos) living on (epifauna) or in (infauna) marine substrata as well as those that swim in close proximity to the bottom without ever actually leaving it. In terms of size, this is generally divided into three categories:

- Meiobenthos, the organisms that pass through a 0.5 millimeter sieve;
- Macrobenthos, those that are caught by grabs or dredges but retained on the 0.5 millimeter sieve;
- Infauna, organisms that live in the sandy or muddy bottom sediments; and
- Epifauna, organisms than live on, rather than in, the seabed.

Those in the latter category are usually larger.

Benthic life is subject to vertical zonation depending chiefly on filtered sunlight, moisture and pressure. This has led to the division of benthonic animals into two systems and seven zones. Proceeding from shallow to deep water, the first system is the phytal or littoral system, composed of the supralittoral, mediolittoral, infralittoral and circalittoral zones. The second system, the aphytal or deep system, is composed of the bathypelagic, abyssal and hadal zones.

Substrate types

The benthos has significant variation not only depending on ocean depth, but also upon the type of seabed. Some of the chief types of sea floor substrates are:

- Sandy soft substrate
- Muddy soft substrate
- Hard substrate
- Secondary hard substrate

The grain size is strongly influential on the packing density of seabed soils, so that the amount of interstitial space among sand or sediment grains affects the amount of dissolved oxygen avalable to benthic fauna, and thus is determinative as to which species can adapt to a given seabed. Another general rule is that most mud and sand bottom dwelling species are detritus feeders, the detritus being chiefly composed of plant material that has been partially decomposed by bacteria and fungi.

Depth zones

In general the organisms that live in the benthos of the epiphotic zone are those which may be primary producers, since sunlight is available, even if in small amounts. The fauna of this upper depth zone are adapted to low water pressures and generally warm temperatures, except in polar seas, where even epiphotic seas can be cold. In the deeper zones there are very few primary producers except forextremophiles such as certain bacteria who can metabolize sulfur based chemicals as an energy source.

Fauna of the mesopelagic and deeper zones must be able to withstand successively higher pressure and colder temperatures with greater depths. In addition these fauna are adapted to a dark realm, where they use smell, tactile mechanisms or sonar to locate prey and evade predation.

Ecology of sandy substrate

Nematodes represent a phylum of widespread and plentiful fauna occurring in sandy seafloors. They occupy interstitial spaces of sandy marine bottoms. Such fauna typically present as elongated and radially symmetrical with tapered ends. This threadlike, diminutive stature allows nematodes to navigate through the interstices by whiplike undulatory action.

Larger fauna found at the bottom of sandy seas include echinodermata such as the invertebrate sea cucumbers and the detritus eating sand dollars. Polychaete worms are significant annelids in sandy substrates. They have numerous setae (chitinous bristles) that allow traction along the sandy bottom; some polychaetes are found in relatively shallow seas, while others dwell in deep cold water trenches. Many sponge species are also found on sea floors composed of sand.

Ecology of muddy substrate

Mud seafloors compromise oxygen supplies, with metabolic wastes also being entrained in the mud, leading to to anoxic conditions that can produce hydrogen sulfide, severely limiting faunal survival. As in the case of sandy bottoms, microscopic organisms are found in the mud bottom. Some buried bivalves occurring beneath the anoxic zone employ siphons to extract nutrients and oxygen out of the water column above the mud.

Annelids are also found on mud bottoms; for example chaetopteridae filter feed using a mucous sac. Three piston-like parapodia push water through a tube. At the sac rear, the mucus containing embedded food is continually rolled into a pellet, and as this attains a critical mass, the fans cease beating, with the pellet being moved forward to the mouth via cilia action.

Ecology of hard substrate

Many of the fauna inhabiting hard substrates are characteristically near stationary. A common form of predation is to stretch tentacles into the water current above. There is a wide array of tenacle design and strength, manifesting the niche specialty of these predators and nature of the prey sought.

Hard substrate offers prime habitat for certain stalkless free moving crinoidea, which are suspension feeders of plankton, and therefore direct their oral aperture upward into the water column. The cirri of the aboral end suspend freely whilst in locomotion, but attach to the hard bottom when resting. The elements of their five starpoint arms serve not only as filtering organs but are also the locus from which juvenules depart from parents. The ciliated grooves along the arms convergeat the center of the oral surface to which trapped plankton are driven.

Ecology of secondary hard substrate

Secondary hard substrate is formed by consolidation of some combination of biotic and mineral debris, often consolidated into a hardened matrix by a variety of congealing mechanisms. Large amounts of micro-organic debris may have gradually accumulated on the seabed, for example *foraminifera*, or diatoms with silica wrapping, can combine with disintegration of earlier rocks and volcanic ejecta, riverine runoff or glacial scrapings; Under certain circumstances, these sediments harden to create a congealed conglomerate, simulating normal hard substrate.\

Annelid tube worms may also secrete leathery or calcareous tubes that the worms inhabit, while these species extend feather-like tentacles to strain food. The tubes themselves are an alternate form of secondary hard substrate that provide a resting place for other very tiny sedentary organisms.

Further reading

- Seas of the World on Encyclopedia of Earth
- Rhodes W. Fairbridge, editor. The Encyclopedia of Oceanography. Van Nostrand Reinhold Co., 1966.

- J.S. Link, C.A. Griswold, E.T. Methratta, J. Gunnard, Editors. 2006. Documentation for the Energy Modeling and Analysis eXercise (EMAX). United States Department of Commerce, Northeast Fisheries Science Center. Reference Document 06-15 Chapter 8.

Citation

Baum, S., & Hogan, C. (2012). Benthos. Retrieved from http://www.eoearth.org/view/article/150491

Estuaries in the Balance:

The Copano/Aransas Estuary Curriculum Guide

Development of this curriculum was made possible by funding from the Texas General Land Office Coastal Management Program. The curriculum was developed and modified from "Project PORTS", created by Lisa Calvo at Rutgers University and available at http://hsrl.rutgers.edu/~calvo/PORTS/Welcome.html.

PRIMER

1

DISCOVERING THE COPANO/ARANSAS BAY SYSTEM

The Copano/Aransas Estuary is the region where waters from the Mission and Aransas Rivers flow into the Copano Bay, and from there, to the Aransas Bay and then the Gulf of Mexico. Estuaries are dynamic systems where tidal and river currents mix fresh river water with salty ocean water. As a result the salt content, or salinity, of estuarine waters varies from fresh to brackish to salt water. Copano Bay, fed by the Mission and Aransas Rivers and Copano Creek, covers about 65 square miles. The Copano Bay watershed drains an area of 1,388,781 square miles. It connects to Aransas Bay, which has an area of 70 square miles and is in turn bordered on the east by San Jose Island, a 21-mile long barrier island.

Estuaries serve as vital habitats and critical nursery grounds for many species of plants and animals. The Copano/Aransas estuary is home to many species of finfish, shrimp, crabs, clams, and oysters. Nearby Aransas National Wildlife Refuge lists 392 bird species (resident and migratory) and 39 mammal species as having occurred on the refuge. Sixty species of fish are listed on the refuge checklist as common, and the checklist for amphibians and reptiles lists 63 species. The refuge currently lists about 850 plant species, and it is continually being adjusted and expanded. The Texas coast is well known for the large populations of migratory shorebirds and songbirds that utilize its shores as a stopover before crossing the Gulf of Mexico in the fall, and after the crossing in the spring. Thousands of people come to Texas to view migrating warblers and other birds every spring.

Estuaries are also important to humans as we rely on them for food, drinking water, industry, and recreation. Nearby Corpus Christi is the site of the fifth largest port in the nation and industrial activities including major petrochemical refineries. The estuary is also important for its commercial fishery production of oysters, crabs, shrimp, and finfish. In addition to these species, important recreational fisheries include redfish (red drum), spotted sea trout, southern flounder, black drum, and others.

RELATED VOCABULARY

Estuary—an area partially surrounded by land where fresh water and salt water meet.

Watershed—an area of land drained by a river or other body of water.

Salinity—the salt content of water. Estuarine waters vary from fresh (no salt) to marine (salty ocean water).

Density—the mass (amount of material) in a certain volume of matter.

Euryhaline—describing species which can tolerate a wide range of salinities.

Gradient—the rate at which a physical characteristic such as salinity increases or decreases over a distance.

Habitat—the place where a plant or animal grows or lives in nature.

Nursery ground—habitats of young fish and shellfish. Such areas provide food and protection for the young animals.

Fishery—the business of catching fish and shellfish, or the population of fish or shellfish that are being targeted for catching.

ACTIVITY
1.1 AN ESTUARY NEARBY: A SCAVENGER HUNT MAPPING EXERCISE

Grade Level
3–5
Subject Areas
Science, Social Studies, Mathematics
Duration
1 class period
Setting
Classroom, computer laboratory
Skills
Mapping, interpreting, computing
Vocabulary
Estuary, Salinity, Watershed, Runoff
Correlation with Texas Essential Knowledge and Skills (TEKS)
Soc. St. 3.4A,D, 3.5A-D, 3.17 A,B,D,E, 4.6A,B, 4.8C, 4.9A-C, 4.21C, 5.6A,B, 5.9A,B

CHARTING THE COURSE

In this exercise students will learn about estuaries and watersheds and become familiar with the geography of the Copano/Aransas Bay region. They will gain their sense of place within the area by locating and mapping the Fulton school in relation to the geography of the Bay region. This lesson has two parts. In Part 1 the activity takes shape as a mapping scavenger hunt. In Part 2 students employ computer skills to conduct a mapping exercise using the Internet.

OBJECTIVES

Students will be able to:

1. Describe what an estuary is.
2. Locate the Copano/Aransas Estuary on a map.
3. Recognize that many tributaries and streams flow into the estuary.
4. Locate their "space" (school) and other major geographical features in relation to the estuary.

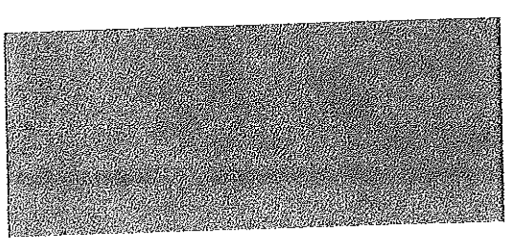
MATERIALS

- Copies of Copano/Aransas Estuary watershed map, Texas, and county road maps
- Transparency films
- Marking pens
- Computers with internet-access
- Stick on stars or other symbols

PROCEDURE

Warm Up

Open a class discussion about what estuaries and watersheds are. Ask them what the nearest bodies of water are to their school, and if they lead to a creek, estuary, or bay. Tell them they will take a Virtual Field Trip from the Fulton Learning Center in Fulton, Texas, which is near the Aransas Bay. Review the basic features of a map.



THE ACTIVITY

Part I

1. Divide class into groups of 3 to 4 students.
2. Hand out transparency films and original or copies of road maps of the Rockport/Fulton area (map should include Copano/Aransas Bays).
3. Ask students to locate the school on the map (or have a star on map designating the location of the Fulton school).
4. If not marked, have students place a stick-on star on location.
5. Now students should trace on the transparency the outline of the land/bay margin and state and mark the location of the school.
6. Using the Scavenger-Map Activity hand out, students should find, trace on the transparency and label the following items as noted in the student worksheet.

Part II

1. Have students log on to http://maps.google.com/. (For more advanced classes, have students work with Google Earth, which can be downloaded for free)
2. Search the map for their school (or use Fulton Learning Center, Fulton, TX)
3. Change the format to hybrid (this will combine satellite image with overlaid road drawings).
4. Have students point out rivers, creeks, and streams on the map.
5. Follow the most prominent waterway as far as it will go. (Students will likely see creeks, moving toward rivers, ponds, and lakes; if using maps of Rockport/Fulton, many will ultimately lead to the Copano/Aransas Estuary).
6. Based on the previous exercise, have them identify the water body.

WRAP UP

Have students discuss what they learned through this exercise. Ask: How is it possible for actions at their school to impact the estuary?

EXTENSION

If the students live outside of the Copano/Aransas Bay area, find maps for the students' home area, and complete the scavenger hunt with questions related to their area.

Name: Date:

ACTIVITY 1.1

AN ESTUARY NEARBY: A SCAVENGER HUNT MAPPING EXERCISE

1. Locate your school on the map provided.

2. Mark the location with a sticker.

3. Trace on the transparency the outline of the land/bay margin and state and mark the location of the school.

4. Trace on the transparency and label the following items:
   a. The Gulf of Mexico

   b. North, south, east and west

   c. The ajor body of water located east of your school

   d. Two rivers on the map

   e. The river closest to your school that flows into the Copano Bay

   f. A city located near the Aransas Bay.

   g. The source of salt water that enters the Aransas Bay

   h. The major source of fresh water that enters the Copano Bay (the largest river)

   i. A place where you'd like to visit and explore.

5. How far is your school from the Bay?

6. Challenge question. What path of creeks and rivers would rain falling on your school take follow to get to the Copano or Aransas Bay?

ACTIVITY

1.2 GOING WITH THE FLOW: CONSTRUCTING A WATERSHED MODEL

Adapted from "Watershed S.O.S. (Saving Our Sources)": http://learningtogive.org/lessons/unit374/

Grade Level
3-5
Subject Areas
Science, Social Studies
Duration
1-2 class periods
Setting
Classroom
Skills
Modeling, constructing, describing
Vocabulary
Watershed, Runoff
Correlation with Texas Essential Knowledge and Skills
Science 3.3C, 3.7C, 3.9A,C, 4.3C, 4.7C, 4.8B, 5.3C, 5.7B; Soc .St. 3.4A

Adapted from "Watershed S.O.S. (Saving Our Sources)": http://learningtogive.org/lessons/unit374/

CHARTING THE COURSE

In this exercise students will construct a model of a watershed, and demonstrate how water flows in the watershed.

BACKGROUND

The Copano Bay receives water draining directly from surrounding land through groundwater and surface runoff, as well as from the Mission and Aransas Rivers and Copano Creek. The entire area of land that drains into a particular water body is called a **watershed**. Watersheds are separated from one another by elevations in the area such as slopes and hills. The Copano watershed encompasses about 1,388,731 acres.

OBJECTIVES

Students will be able to:

1. Describe what a watershed is.
2. Describe the many ways that water enters the bay.
3. Construct a model watershed.

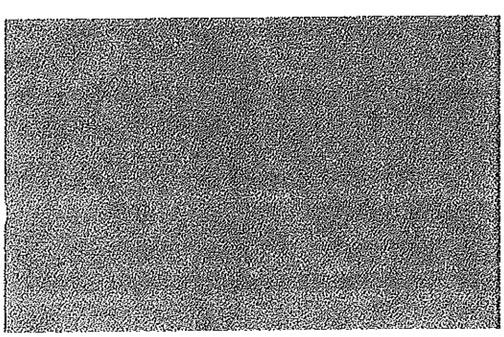
MATERIALS

- Scrap paper
- Water-based markers (blue, black, brown, red)
- Optional: materials for landscape features (i.e. coffee or sand for dirt, small pieces of felt or scrubbing pads for marshes)
- Plastic tray
- Spray water bottle

PROCEDURE

Warm Up

Open a class discussion about what estuaries and watersheds by asking how does water enter the bay? Define what a watershed is and talk about how human activities can affect the quality of the water in the bay.



THE ACTIVITY

1. Have students work individually or in teams of two to four students.
2. Distribute materials.
3. Instruct students to construct their own model of a watershed with the main criteria being that water must flow from higher lands to lower lands and flow into a bay.
4. First, crumple the paper into a loose ball. Then partially open the paper and place it on a table. The paper should still be crumpled enough to have portions that resemble hills and valleys. Be sure there is a tray under the paper.
5. Using a blue marker, have students mark streams or rivers on their papers, and also have them mark where they think the water will collect as it runs downhill (lake or bay).
6. Using a black marker, have students outline ridges that separate one stream or river from another.
7. Using the brown marker, students should draw exposed soil that could erode or wash away into the lake or bay as the water flows through the watershed.
8. Using the red marker, have students draw in some pollutants that may be found in their watershed, such as soap from washing cars, fertilizers or pesticides from lawns, or animal wastes from a farm.
9. Have students spray (or you can go around to each model and spray) a very light mist of water over each model.
10. Observe where the water runs down and collects. Record what happens to each of the colors.

WRAP UP

Have students present their models to the class and discuss the impact of the associated land use. Discuss these questions:

- What does the spray represent?
- Why does water flow down into the creases?
- What is water called when it runs down the creases? (runoff)
- What water bodies would the watershed represent in your community?
- What happened to the ink? How could this be a problem to plants and animals in the water?
- What can we do to protect the estuaries and bays?

ACTIVITY
1.3

LIFE IN THE ESTUARY

Grade Level
3–5
Subject Areas
Science
Duration
1–2 class periods plus independent work time
Setting
Classroom
Skills

Vocabulary
Habitat, Ecosystem
Correlation with Texas Essential Knowledge and Skills
Science 3.9A, 3.10A,B, 4.9A, 4.10A,C, 5.9A,5.10A

CHARTING THE COURSE

In this exercise students will become acquainted with the many plants and animals of the Estuary as they search for information about the physical appearance, adaptations, and life history of a particular species. Students will prepare reports and share information with their classmates orally and via a field guide, which the class constructs.

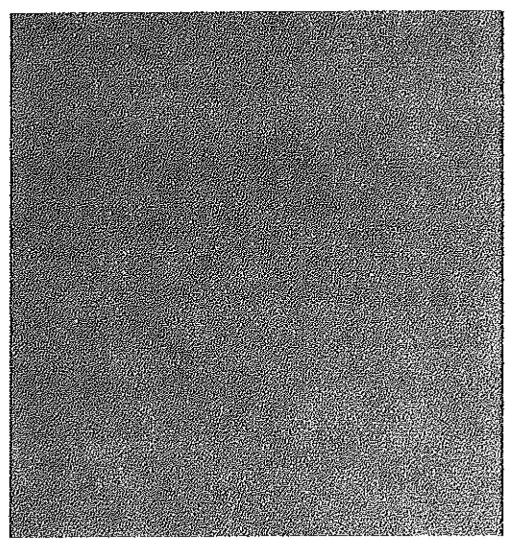
BACKGROUND

The Copano/Aransas Estuary provides important habitat to a variety of plants animals. Hundreds of species of fish, crustaceans, and other invertebrates live in the Estuary, and the sea grass beds serve as refuge and nursery grounds for many larval forms of aquatic life. The Texas Coastal Bend is noted for being a vital habitat for migratory shorebirds and songbirds, and is adjacent to the Aransas National Wildlife Refuge, winter home of the endangered Whooping Crane.

OBJECTIVES

Students will be able to:

1. Name important animals and plants of the Copano/Aransas Estuary.
2. Relate key life history characteristics of prominent estuarine species.



MATERIALS

- Copano/Aransas Estuary selected plants and animals list
- Student worksheet
- Reference materials (books, internet, others information sources)
- Binders and materials for compilation of reports/Field Guide construction

PROCEDURE

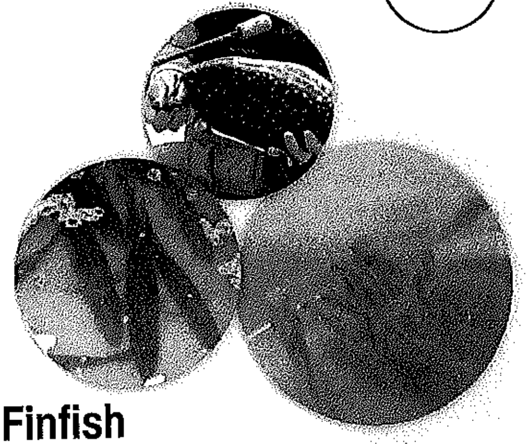
1. Have students select a plant or animal from the species list.
2. Have students conduct research/report on their species finding information indicated on the student report worksheet.
3. Have students orally present their research.
4. Construct class "Field Guide of Copano/Aransas Estuary Plants and Animals" by compiling student reports.

WRAP UP

Shared knowledge through oral presentations. Conduct a class discussion about which animals/plants students found most interesting. A class book may be made with written reports.

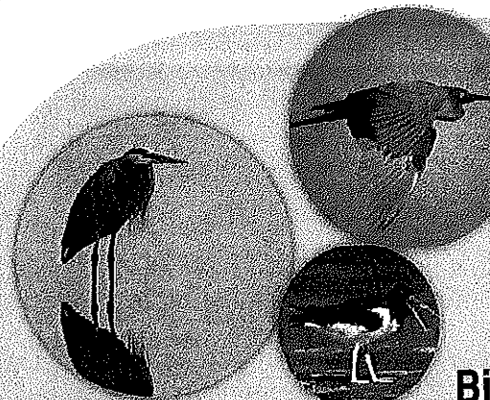
LISTS

List of animals and plants in the Copano/Aransas Bay estuary:



Finfish

Redfish • Black drum • Spotted sea trout • Southern flounder • Hard-head catfish • Gafftop catfish • Pinfish • Mullet • Pig perch



Birds

Whooping Crane • American Oystercatcher • Great Blue Heron • Great Egret • Black Skimmer • Laughing Gull • Royal Tern • Reddish Egret

Plants

Shoal grass • Manatee grass • Widgeon grass • Turtle grass • Cord grass • Black mangrove • Glasswort • Wolfberry

Invertebrates

Brown Shrimp • Grass shrimp • Blue crab • Spider crab • Eastern oyster • Lightning whelk • Marsh clam • Bay scallop

Name: Date:

ACTIVITY 1.3

LIFE IN THE ESTUARY

Common Name of **ANIMAL** or **PLANT**: ____________________

Scientific name of **ANIMAL** or **PLANT**: ____________________

Write in complete sentences.

DESCRIPTION AND ADAPTATIONS: ____________________

LIFE HISTORY

1. Habitat: ____________________

2. Life cycle: ____________________

3. Food: ____________________

Illustration: Draw and color your organism in its habitat on the back of this page, or on another sheet of plain paper.

ACTIVITY

1.4 TAKING IT WITH A GRAIN OF SALT

Grade Level
4–8
Subject Areas
Science, Social Studies, Mathematics
Duration
1–2 class periods
Setting

Skills

Vocabulary
Salinity, Density, Gradient, Estuary, Euryhaline, parts-per-thousand (ppt)
Correlation with Texas Essential Knowledge and Skills
4.1A, 4.2D, 4.4A 4.5A,C, 5.1A, 5.2C,D, 5.4A, 5.5A,D, 5.9A,6.1A, 6.4A, 6.12E, 7.1A, 7.2C, 7.4A, 7.8A,C, 7.10A, 8.1A, 8.2C, 8.4A, 8.11C,D

CHARTING THE COURSE

In this exercise students will explore the concept of salinity, and how and why it varies from rivers to estuaries to the Gulf of Mexico. Students will compare and contrast properties of fresh and salt water, learn how salinity is measured, and use a hydrometer to measure the salinity of various water samples.

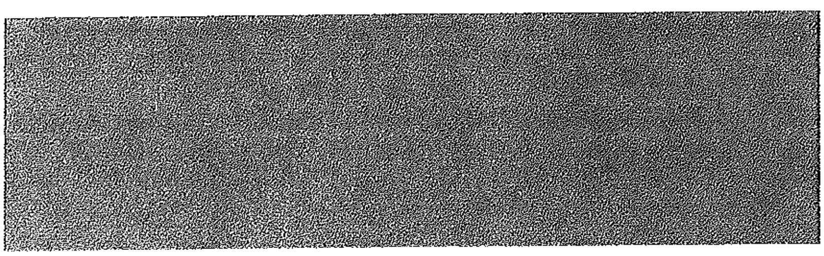
BACKGROUND

Perhaps the most distinguishing feature of an estuary is its ever-changing salinity. Salinity, the dissolved salt content in the water is the single most important factor effecting the distribution of organisms in the estuary. Unlike the ocean where salt content varies little over large areas the salt content of the estuary varies greatly, changing from nearly full strength salt water at the mouth of the bay to fresh water at its uppermost point.

The salts present in seawater include sodium chloride, magnesium chloride, potassium chloride, calcium chloride, and a number of minor constituents. One-quart of seawater contains about 1 ounce of salts. The salts in seawater originate from land and are the result of the weathering and erosion of landforms by surface waters.

Salinity is typically expressed in units of parts per thousand (ppt), the salt content in 1000 parts of water. In the Copano/Aransas Estuary salinity may approach 0 ppt near the mouth of the Aransas and Mission Rivers into Copano Bay during wet periods, but it may approach 30 ppt or higher during times of drought. Salinity gradually increases downstream to about 35 ppt at the entrance to the Gulf of Mexico. The entire salinity gradient in the bay will shift under high flow conditions and salinities will decrease bay wide. Likewise under conditions of low flow or drought, bay wide salinities will increase.

Estuaries with their widely variable salinities host both freshwater species in the upper reaches and saltwater species in the lower reaches. Only those species able to tolerate a wide range of salinities, **euryhaline** species, are able to successfully inhabit the portions of the estuary with widely fluctuating salinities.



OBJECTIVES

Students will be able to:

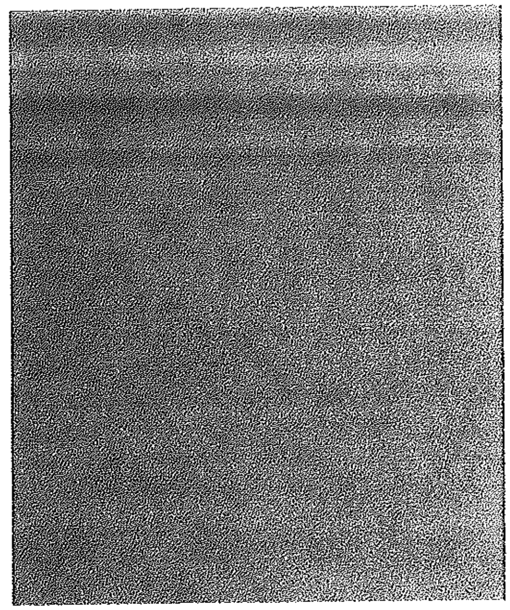
1. Define salinity.
2. Describe how salinity varies spatially and temporally in the estuary.
3. Define parts per thousand.
4. Measure salinity of seawater with a hydrometer.

MATERIALS

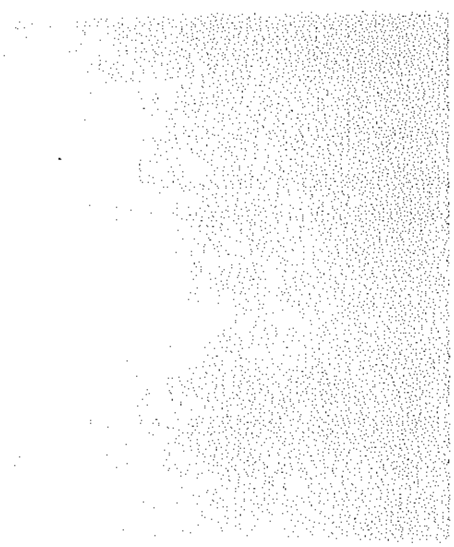
For each group of 4 to 5 students:
Water, two 250-mL beakers, plastic tray, spoon, golf ball, hydrometer, aerial map of the Texas coast (obtain from Coastal Bend Bays and Estuaries), blue, green, and yellow centimeter cubes (or other tiles), 1 set of cards with salinity values written on them.

For class: Salt (Kosher salt will dissolve best), food coloring (blue and red), two 1-liter beakers, small Petri dish, triple beam balance (or electronic balance), clear plastic box or aquarium, aluminum foil, duct tape, water

PROCEDURE: What is salinity?



1. Demonstrate one property of salinity (density) by showing students two 1-liter beakers of water, one with blue food coloring and one with red coloring. Have the red sample saturated with salt. Ask students to identify which is salt water and which is fresh without tasting the water. After taking several suggestions, pour water into smaller beakers and hand out 1 beaker of red and 1 of blue water to each group. Use a small plastic tray to contain spills. Let groups vote on which beaker they think is salt water. Lead discussion into concept of density, the amount of matter in a certain volume of liquid. Which water has higher density? (salt water) What happens to an object when it is put into water that has a higher or lower density than the object? (The object will sink if it is denser than the water; it will float if it is less dense than the water.) Let groups test if the golf ball will sink or float in each type of water. They should carefully lower the ball into the fresh water; it will sink. Using the spoon to take out the ball, they can then put it in the salt water. It should float in the salt water. (Be sure to test this ahead of time! The water must be very salty for the ball to float.) Since the salt water has more matter in it, it is denser than the golf ball, and therefore the ball floats in the salt water. However, the ball is denser than fresh water, so it sinks.



2. Introduce the term parts per thousand. Compare it to percent, which is parts per hundred. Show the class a one-liter beaker, which is usually marked "1000 mL". Review the prefix "milli," meaning one thousandth, and the fact that there are 1000 mL in a liter. Explain that if you have 35 parts per thousand (ppt) of salt, there would be 35 milliliters of salt in 1000 milliliters of water. 35 mL is about the same as 35 grams, so you are going to measure 35 grams of salt and put it in 1000 mL (actually, it should be 965 mL) of water, to make 35 ppt, the average salinity of sea water. Lead the students in measuring 35 grams of salt on the balance (remembering to measure the mass of the empty Petri dish first). Add the salt to the liter of water and stir.

3. Show the class a hydrometer and how to read it. Hand out one to each group, and have them practice with fresh water (the reading will be 0). Then give them a sample of the 35 ppt water, and test that. The readings will probably not be 35, but should be close. You may want to discuss why the reading is not 35—inaccuracies in the balance, the amount of water, or the temperature of the water (since density changes with temperature).

4. ***Optional:*** If you have access to coastal water, collect samples and have students measure the salinity of each. Have students guess (hypothesize) which water sample came from which area (river, bay, marsh, beach, etc.).

5. Collect materials and place a large map of the Texas coast on each table. Have students find their town and identify various bodies of water. Hand out yellow centimeter cubes (3 to a group) and ask students to place them in areas they think would be salty. They should choose the Gulf of Mexico, and there will be discussion about where to put the other 2 cubes. Next, give each group 3 blue cubes, and have them place them where they think the water is fresh. Most will find Lake Corpus Christi, but they may have difficulty finding other areas. Many will pick bays. They should find a river, and perhaps a pond. Finally, ask what color is made by mixing blue and yellow, and give them 3 green cubes. Ask them to place them on areas (such as an estuary) where fresh and salt water mix. Discuss each group's choices, but do not tell them if they are right or wrong at this time.

Open a class discussion about the definition of an **estuary**. Discuss the meaning of the word **gradient**, and the idea that salinity of water will increase as water from rivers mixes with salt water, and there is a gradient of salinity from a river to an estuary to bays and the Gulf of Mexico (at another time, you may introduce the concept of hypersalinity, but it might be confusing at this point). Explain that salinity in the bay can change depending on how much river flow enters. In dry years, flow is low and salinity increases, while in wet years, flow is high and salinity decreases. Within the year, salinity tends to be lowest in the spring as a result of rain. During the summer, rains decrease and evaporation increases, leading to higher salinity.

Explain the importance of the salinity gradient in the distribution of organisms living in the bay. Estuaries with their variable salinities host both freshwater species in the upper reaches and saltwater species in the lower reaches. Only those species able to tolerate a wide range of salinities, **euryhaline** species, are able to successfully inhabit all portions of the estuary.

Hand out cards with salinities printed on them. Have students order them from low to high salinity, and match the cards with potential locations on the map. If you have measured the salinity of local water samples, tell the students the locations you sampled, and challenge them to identify which water sample came from which area.

Optional: In a small aquarium or clear plastic box, make a divider of aluminum foil in the center. Be sure the foil is securely taped so that no water can leak under it. Pour salt water on one side and fresh water on the other. Using a pin or paper clip, make several holes in the foil, allowing the water to pass through. Fresh water will enter the salty side and float, while salt water will enter the fresh side and sink. You might be able to put the golf ball in the water, and see if it will float at the interface of salt and fresh water.

WRAP UP

Students should discuss how salinity changes from location to location in the bay and how the distribution of animals changes as a result. What other things might affect the distribution of animals in an area? How might changes in weather affect the salinity and animal distribution in the bay.

ACTIVITY 1.4
Salinity Cards (make one copy for each group)

35 PPT	**14 PPT**	**0 PPT**
6 PPT	**24 PPT**	**30 PPT**

Name: Date:

ACTIVITY 1.4

TAKING IT WITH A GRAIN OF SALT

1. Draw a picture of your two beakers with a golf ball in each one. Tell what happened to the golf ball, and why it floated or sank.

2. In your own words, what is **salinity**?

3. What is **density**?

4. If water has a salinity of **35 parts per thousand**, what does this mean?

5. What is an **estuary**?

6. Describe the salinity **gradient** from a river to an estuary and then to the gulf or ocean.

7. What types of environmental factors affect the water salinity in our bays and estuaries?

8. How can animals in the estuary be affected by changes in salinity?

ACTIVITY

1.5 SEASONS OF CHANGE

Grade Level
6–8
Subject Areas
Science, Social Studies, Mathematics
Duration
1–2 class periods
Setting
Classroom
Skills

Vocabulary
Salinity, Gradient, Euryhaline, parts-per-thousand (ppt)
Correlation with Texas Essential Knowledge and Skills
Science 6.2C,D,E, 6.12E; 7.2C,D,E, 7.8C, 7.10A, 7.13A; 8.2C,D,E, 8.11B,C,D

CHARTING THE COURSE

In this exercise students will construct and interpret graphs comparing monthly salinity measurements for a 1-year period for three oyster bars located along a salinity gradient, demonstrating how one environmental variable changes seasonally. This activity follows the same concepts as Activity 1.4 and can be conducted as an extension, or instead of Activity 1.4.

BACKGROUND

Activity 1.4 (Taking it with a Grain of Salt) presents relevant background information about salinity and its importance in defining the estuary and the distribution or organisms in the Bay. Salinity, the dissolved salt content in the water is the single most important factor effecting the distribution of organisms in the estuary. Unlike the ocean, where salt content varies little over large areas the salt content of the estuary varies greatly, changing from nearly full strength salt water at the mouth of the bay to fresh water at its uppermost point. This activity expands on the concept and focuses on spatial and temporal changes in salinity throughout the estuary.

The salinity at a particular place in the estuary can fluctuate greatly with in a year through the seasons as well as from year to year. Typically the spring yields high fresh water inputs as melting snow and springtime rainfall increase fresh water flow into major rivers. This results in decreases in salinity in upper estuary locations. The salinity gradually increases through the summer and fall, as rainfalls typically are lower than in spring. On an annual basis a dry or drought year will result in relatively high salinities through out the bay where as wet years will cause a reduction in bay-wide salinities. For oysters this can greatly impact survival, as disease and predation tend to be higher at higher salinities.

OBJECTIVES

Students will be able to:

1. Define salinity.
2. Describe how salinity varies through space and time in the estuary.
3. Show how salinity affects the distribution of animals in the estuary.

MATERIALS

- Map of the Copano/Aransas Estuary with sample sites marked
- Monthly salinity data set
- Graph paper, or computer software for creating graphs

PROCEDURE

Warm Up

Open a class discussion about the definition of an estuary and the importance of the salinity gradient in the distribution of organisms living in the Bay. Or follow up with the Taking it with a Grain of Salt Activity. Explain that salinity in the bay can change depending on how much river flow enters. In dry years flow is low and salinity increases; in wet years flow is high and salinity decreases. Within the year salinity tends to be lowest in the spring as a result of rain.

THE ACTIVITY

1. Distribute salinity data set and materials for constructing graphs.Instruct students to plot the salinity data presented. The x-axis should be time (month) and the y-axis should be salinity in parts-per-thousand (ppt). Students should draw three lines, one for each site.

2. Have students interpret the graph, answering the following questions.
   Does the salinity at each site remain constant or change through time?
   Does the salinity differ between sites?
   Overall which site has the higher salinity?
   What is the highest and lowest salinity for each site?
   What is the range of salinity for each site?
   When did the highest and lowest salinity occur for each site?
   How would salinity change if a drought occurred and river flow was below average for the next 12 months?

WRAP UP

Students should discuss their interpretations of the salinity graph. Be sure to emphasize that there is great variability in the environment. Factors such as salinity in the estuarine environment are constantly changing. What trends do they observe? What other factors might similarly change? Also, have students speculate on how this information would be used in real life.

Name: Date:

ACTIVITY 1.5

SEASONS OF CHANGE

A. Using the data in Table 1, draw a graph to compare the salinity at the oyster reefs known as Shellbank, Lap, and Long Reefs in Copano and Aransas Bays. Be sure to put a title and labels on your graph.

B. After completing your graph answer the following questions.

1. Does the salinity at each site remain constant, or does it change through time?

2. Does the salinity differ between sites?

3. Overall, which site has the highest salinity?

4. Overall, which site has the lowest salinity?

5. What is the highest and lowest salinity for each site? **When** did each occur?

High:	Shellbank-_______	Lap- _______	Long- _______
	Date: _______	_______	_______
Low:	Shellbank-_______	Lap- _______	Long- _______
	Date: _______	_______	_______

6. What is the **range** of salinity for each site? (Subtract lowest from highest)

Shellbank-_______ Lap- _______ Long- _______

7. How would you expect the graph to look the next year if there is above average rainfall all year long?

8. How would this information be used in real life?

TABLE

1

Monthly salinity data at three sample locations: Shellbank Reef, Lap Reef (both in Copano Bay), and Long Reef (Aransas Bay). The data is for the years 2011–2012. real life.

SALINITY PARTS PER THOUSAND (PPT)

	Shellbank Reef	Lap Reef	Long Reef
2011:			
Apr	16	18.5	26
June	25	26	30
Sept	34	37	40
Nov	37	38	37
2012:			
May	25	27	28
Aug	32	33.5	40
Nov	35	34	31

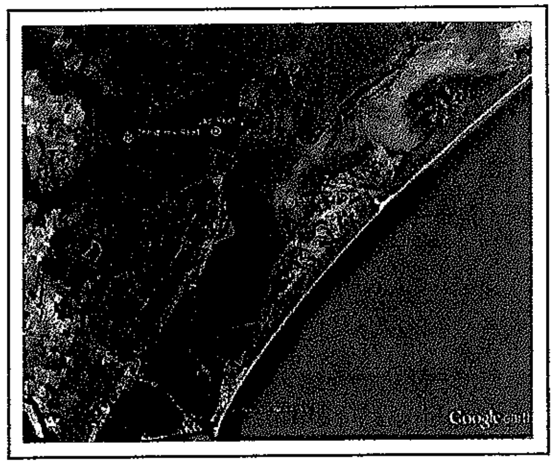
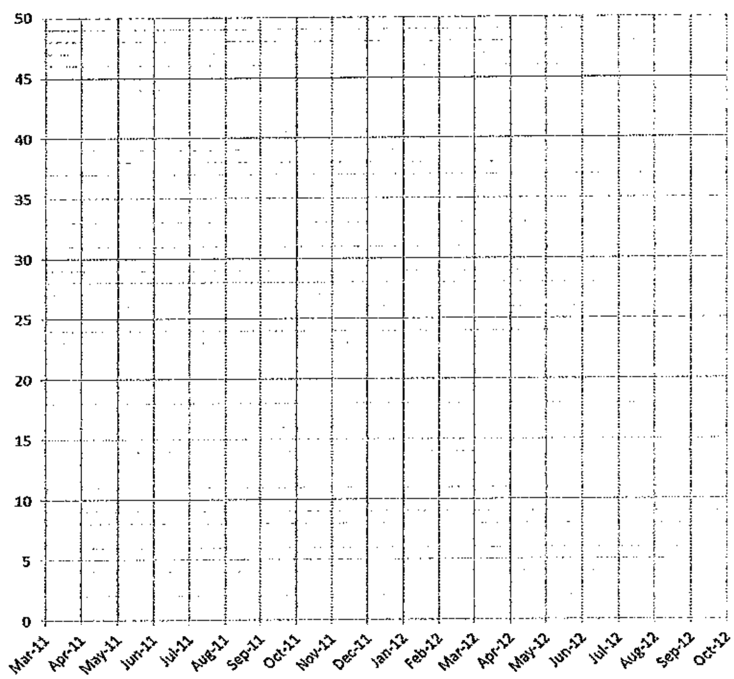


Figure 1. Map of Copano Bay and Aransas Bay, TX, showing the locations of Shellbank Reef, Lap Reef, and Long Reef.



EXTENSIONS

Introduce the concept of non-point source pollution.

Storm drain mapping activities are available through the state and other organizations (Texas Natural Resources Conservation Commission: http://files.dep.state.pa.us/water/Watershed%20Management/WatershedPortalFiles/StormwaterManagement/MS4_Information_Resource_CD_Files/storm_drain_stenciling_manual.pdf)

Invite Aquatic Resource Specialist Beth Almaraz from the Nueces River Authority to speak on watershed issues and demonstrate a watershed model (balmaraz@nueces-ra.org; http://www.nueces-ra.org/NRA/)

Visit NOAA's Estuaries 101 for more activities on estuaries and salinity (http://estuaries.noaa.gov/teachers/MiddleSchool.aspx)

Estuaries in the Balance is a web-based curriculum centered on the Texas coast; it offers short videos followed by games and lessons on estuaries and on four keystone species: blue crab, oyster, redfish, and whooping crane (http://cgee.hamline.edu/CoastalBendEstuaries/)

Give students a list of bay animals and have them research the animal's salinity requirements.

Take a Bay field trip on the R/V Wetland Explorer with Capt. Jay Tarkington (TAMUCC Center for Coastal Studies Aquatic Education Program at http://ccs.tamucc.edu/programs-2/aep/).

Analyze and interpret a pie graph containing percentages of all dissolved minerals in seawater (Texas State Aquarium lesson: "Salt of the Sea").

CORER

Materials:

1 10.15 x 76.14 cm (4.0 x 30.0 in.) schedule 30 PVC pipe (sewer pipe)
1 2.54 x 40.61 cm (1.0 x 16.0 in.) PVC pipe
1 1.27 x 10.15 cm (0.5 x 4.0 in.) PVC pipe
1 sewer pipe cap
2 2.54 cm (1.0 in.) PVC pipe caps
1 9.51 mm x 11.42 cm (3/8 x 4.5 in.) bolt with washer and nut
PVC cleaner
Epoxy PVC glue
Marine Goop, or a comparable silicone waterproof sealant (need caulking gun)
Drill
3.17 cm (1.25 in.) hole saw drill bit without guide bit
9.51 mm (3/8 in.) drill bit
7.11 mm (1/4 in.) drill bit
Wrench set
Rubber mallot
Small saw (hand or electric)

Method:

Taking the sewer pipe, use the drill and the hole saw bit and bore two holes on opposite sides of each other. These holes are 8.88 cm (3.5 in.) down from the top of the pipe. The center of the hole saw bit should be at the 8.88 cm mark. Remember that the pipe is 10.15 cm in diameter. See Diagram 1. Pushing forcefully, and using the rubber mallot, insert the 2.54 cm (1.0 in.) PVC pipe through these holes. The sewer pipe is very flexible, but be careful because it will break. This will be the handles for the corer. Now with the 3/8 in. drill bit, bore a hole through the sewer pipe, going through the handles. This hole is on the opposite sides of the handles and 3.5 in. down from the top of the sewer pipe. Insert the 3/8 in. bolt into the hole. See diagram 2. Do not put the washer and bolt on yet. This will be a dry run to ensure a proper fit. See Diagram 3. Because sewer pipe is flexible, the pipe may take on an oblong shape. Using the rubber mallot, lightly hammer near the handles until the pipe regains a round shape. Check for roundness at several intervals, especially before application of the cap.

Carefully measure the intervals where the bolt is exposed on the inside of the sewer pipe. See Diagram 4. Cut the 0.5 in. PVC pipe to these lengths to be used as spacers. These spacers will not only help keep the corer's shape, but also prevent the bolt from rusting. Be careful not to make them too long, or the sewer pipe will take on an oblong shape (a little short is better). Take out the bolt, and run it back though with the spacers in place. See Diagram 5. Now put the washer and nut onto the bolt and tighten. Take the marine goop and spread around the inside seams of the corer. Use your fingers to spread around. Be sure to line all areas around the inside seams of the handles, the bolt and the spacers. This will not only help to prevent corrosion, but help ensure a good vacuum during use.

Before fitting the caps, read all directions on the PVC cleaner and glue. Use the PVC cleaner to clean all surfaces that the caps will fit onto. Spread the glue onto the surface, and place on the caps. Use extra glue around the outside seams of the caps, the handles and the bolts. Again, this helps to keep water out of the inside areas. For the vacuum hole on the top of the corer, measure where is a comfortable place for the hole. Place both hands on the handles and raise one thumb onto the top cap in a comfortable position. This is the most likely spot for the vacuum hole. Using the 0.25 in. drill bit, bore a hole in the top cap where your thumb would be. See Diagram 6.

To ensure that an equal sample is taken each time, measure up from the bottom of the corer 10.0 cm and mark. The inner diameter of the corer is 10.0 cm. Using a sharp object, mark a shallow line at 10.0 cm around the corer. See Diagram 7. This will help you feel for the line when it reaches the top of the substrate when coring. In this manner, you will get a 10.0 x 10.0 cm core each time.

Diagram 1

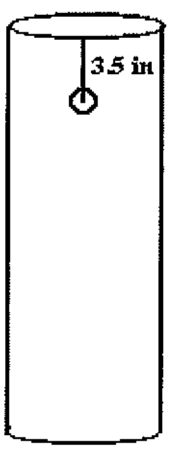


Diagram 2

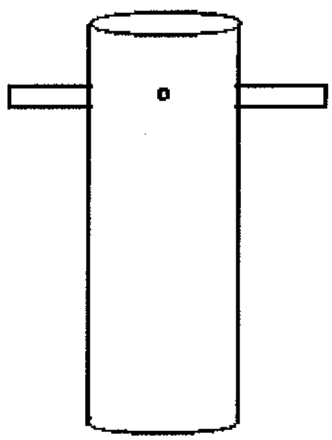


Diagram 3

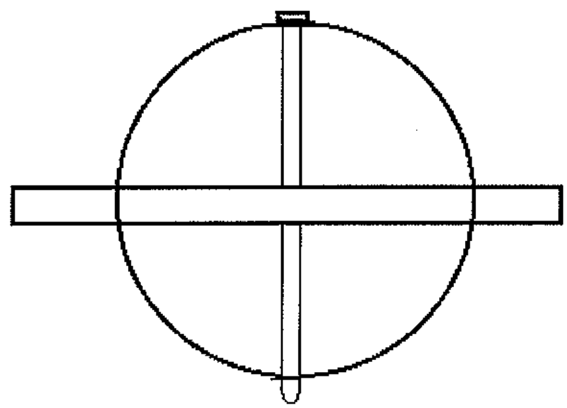


Diagram 4

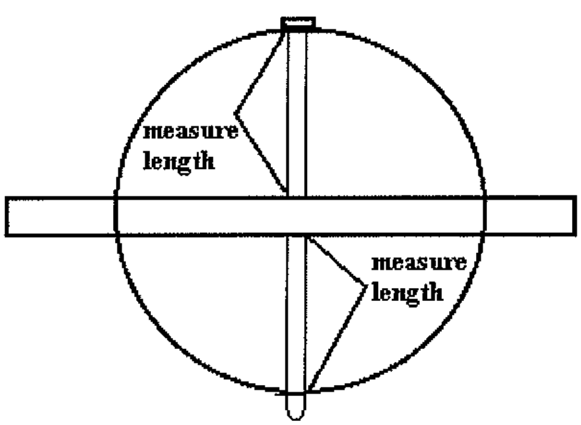


Diagram 5

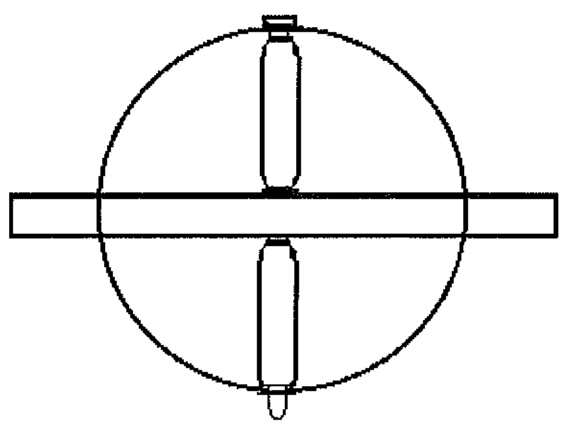


Diagram 6

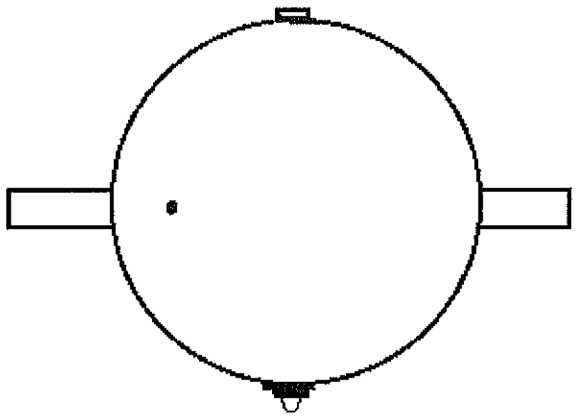
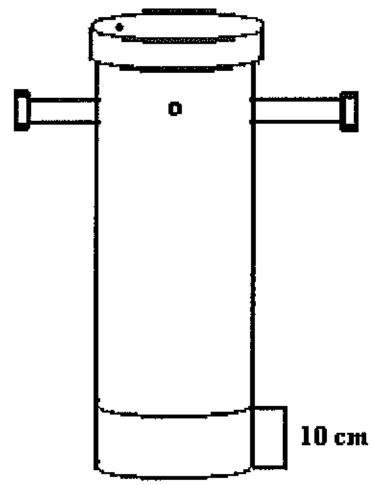


Diagram 7



EDGE PROFILE RIG

Materials:

2 5.08 x 182.87 cm (2.0 in. x 6.0 ft.) wooden dowel rod
2 5.08 x 5.08 x 15.23 cm (2.0 x 2.0 x 6.0 in.) treated board
1 9.5 mm x 11.42cm (3/8 x 4.5 in.) bolt
1 9.5 mm (3/8 in.) fender washer
Wood epoxy
Yellow mason string
Small line level
Plumb bob or large, triangular fish weight
Red permanent marker
Black permanent marker
Drill
9.5 mm (3/8 in.) drill bit
3.17 cm (1.25 in.) pan bit
6.3 mm (1/4 in.) drill bit
Ratchet set

Methods:

Find the center of each board by drawing lines to opposite corners. The "x" in the middle is the center of the board. See Diagram 1. Do this for both sides of each board. Using the pan bit with the point on the center mark, bore out an area approx. 1.26 cm (0.5 in.) deep. See Diagram 2. As before, do this for each board on both sides. Place a dowel in one bored out circle of each board. Using the regular drill bit, drill through the center of the underneath side of the circle, going through the dowel. See Diagram 3. Remove the dowel. Follwing the instructions on the epoxy tube, place a liberal amount of epoxy in the circle that is going to house the dowel. Insert the bolt and washer into the circle and hole on the underneath side. Replace the dowel, so that the bolt goes into the dowel. Using the ratchet, tighten the bolt until it no longer moves. Be careful that the dowel does not tighten down crooked. If so, one can step on the base and push the dowel until it straightens. Do not use until epoxy has set.

On one dowel, measure up from the *bottom* of the base 0.5 m and mark this with a line. Using a small drill bit, drill a hole completely though the dowel at the 0.5 m mark. This hole should be on the 6.0 inch side of the base and in the center of the dowel. See Diagram 4. Thread one end of the yellow mason string through the hole, pull around front and tie a secure knot. With the remainder of the string, measure 10.0 m in 0.10 m increments. We use black to designate each decimeter, red to indicate half meters. At ten meters, leave another 10-15 cm and cut the string. This end is tied in a loop around the other pole. The knot should be secure, but the loop should be able to move easily up and down the pole. See Diagram 5.

To create the plumb bob line, take the large fish weight, and tie one end of the mason string securely to it. From the *tip* of the weight, measure 2.0 m in 0.10 m increments in the same manner as before. See Diagram 6. The small line level should be one that will hook onto the stretched line between poles.

Diagram 1

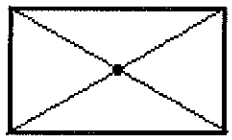


Diagram 2

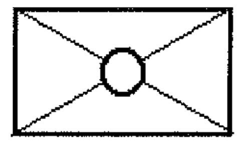


Diagram 3

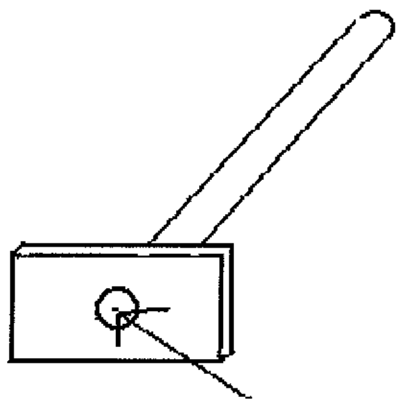


Diagram 4

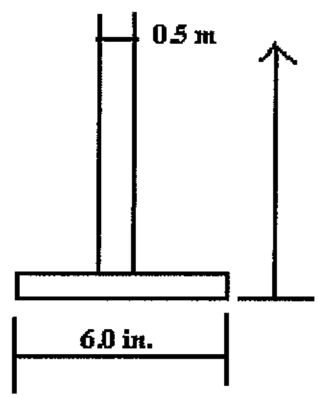
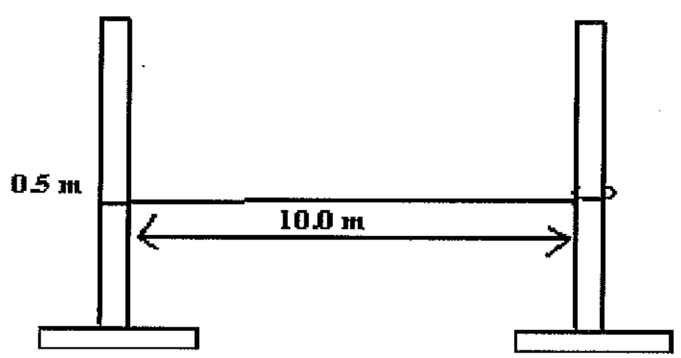


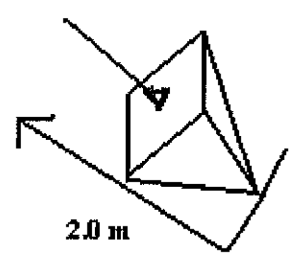
Diagram 5



Fixed end

Looped end

Diagram 6



QUADRAT

Materials:

4 1.90 x 49.1 cm (3/4 x 19.35 in.) PVC pipe
4 1.90 cm (3/4 in) PVC 45° elbows
Orange weed eater cord
Drill
3.2 mm (1/8 in.) drill bit

Methods:

Insert the PVC pipes into the elbows to form a square. See Diagram 1. Pound each pipe into the elbow securely until the *inner* length/width of the square is 50.0 cm. Find the center of each side of the quadrat by measuring 25.0 cm on the inside of the square. Drill a small hole with a 3.2 mm (1/8 in.) drill bit through each center. See Diagram 2. String the weed eater cord through the holes and tie a small knot to secure the line. Pull forcefully on the opposite end, putting pressure on the PVC pipe, and tie a small knot as close to the pipe as possible. See Diagram 3. Test to be sure the string is tight. Repeat procedure for the other end of the quadrat. The finished quadrat should be now divided into four equal sections. See Diagram 4.

Diagram 1

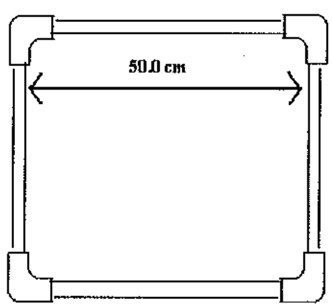


Diagram 2

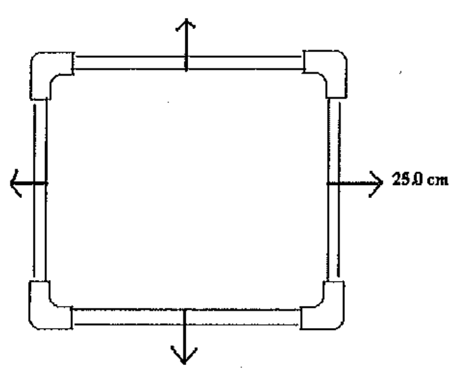


Diagram 3

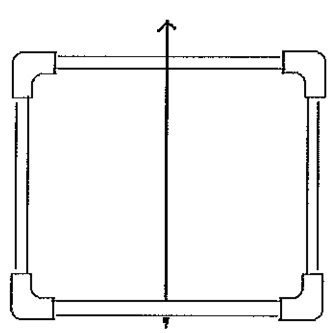
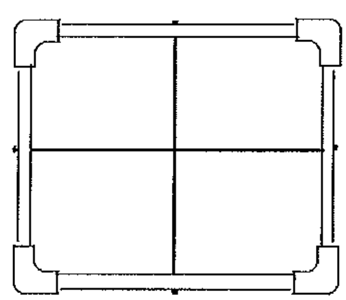


Diagram 4



SIEVE

Materials:

4 2.54 x 10.15 x 30.46 cm (1.0 x 4.0 x 12.0 in.) treated board
4 2.54 x 2.54 x 30.46 cm (1.0 x 1.0 x 12.0 in.) treated board
1 30.46 x 30.46 cm (12.0 x 12.0 in.) 1.27 cm (0.5 in.) mesh galvanized wire screen
1 30.46 x 30.46 cm (12.0 x 12.0 in.) aluminum window screen
Wire snips
Hammer
screwdriver and/or drill
1 in. wood screws

Methods:

With 2 screw at each joint, attach together the four 2.54 x 10.15 x 30.46 cm boards together to form a box. See Diagram 1. **Be sure when using screws to drill pilot holes first! This will prevent wood from splitting.** Place the window screen on an open end of the box, then the galvanized wire screen as shown in Diagram 2. You may want to cut the screen and mesh a bit large. This will ensure that the screens will be attached in place. Use a utility knife to trim excess after the sieve is completed. As before, place the four 2.54 x 2.54 x 30.46 cm boards over the screens. Attach tightly each board to the box with three screws per board. Again, drill pilot holes first. See Diagram 3.

Diagram 1

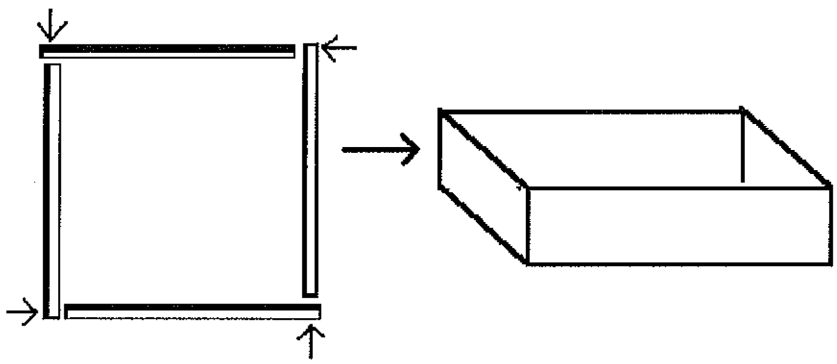
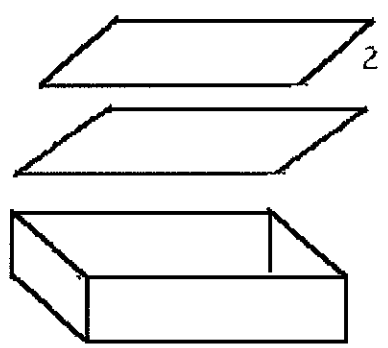
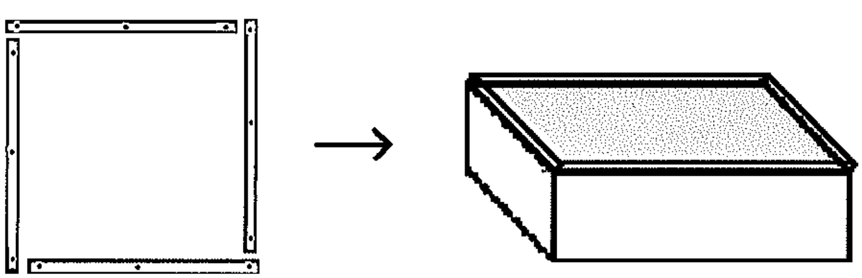


Diagram 2



1. Window screen 2. Wire Mesh

Diagram 3



Exploring South Texas Barrier Islands: lesson module

Texas A&M University-Corpus Christi

Presenters: Jennifer Smith-Engle Ph.D (jsengle@falcon.tamucc.edu)
W. Jay Tarkington M.S. (jtark@falcon.tamucc.edu)

"Does Debris Deliver?"

Academic Question:

What are the percentages and types of debris found along a Texas barrier island?

Objective:

- To collect various types of debris from an assigned area
- To catalogue types and amounts of debris
- To synthesize data and produce a graph
- To identify sources 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.

Process (Activities):

This activity is best done by groups of up to five but could be modified for one large group if necessary.

Materials:

Meter stick
Heavy string or light rope cut to five meters.
Several trash bags or other suitable collection devices.

One pizza box
Markers, glue, pen/pencil, paper, calculator

Procedure:

After giving the students appropriate background, have the groups select a location along the "debris line" at the shore. This can be done by teacher assignment or by random sample. Once on location the group will tie one end of their five meter line around the meter stick. This will act as the center of your circle sample area. Place the meter stick (or have someone hold it) in the sand and trace the outline of a circle formed by the five-meter line. Dragging a stick or other suitable device while walking the circumference of the circle can mark the created sample area. Once the location is determined and marked have the students collect all debris located within the circle. Once all debris is collected, have the students catalogue the debris by grouping like debris together into one of several categories including: (categories may vary in certain location and certain times of year)

solid plastics, light plastics (bags etc.), plastic bottles, miscellaneous plastics, paper, styrofoam, fishing equipment, glass, aluminum, etc.

Have the students count the number of total debris items and then formulate a percentage of each category. After calculating the percentages have the students produce a "pie chart" graph inside their pizza box. Make sure that the graph is labeled appropriately and that a representative piece of debris is glued to the appropriate "slice". Upon completion, have the students present their findings to the other groups for comparison and discussion.

Evaluation/Extension:

How does their chart compare with others?
How might their chart change at different times of the year?
Do they think this is an accurate description of the types and amounts of debris?
Have the students describe the possible origins of the types of debris.

Time frame:

This activity can be done on location in a few hours, or the procedure and collection could be done on location and then completed in the classroom at a later time.

Grade level:

Elementary to high school (categories may need to be modified)

"Don't Spill the Beans"

Academic Question: How do we effectively sample an area?

Objective(s):

- To introduce students to species area curve models
- To allow students to develop their own species area curve

Process (Activities):

In this activity, a pan of beans will represent a diverse wetland environment with the different beans symbolizing different species. The underling question of this activity is, "How many samples must be collected in order to obtain a true representation of the populations of a given habitat." In real life applications, sampling is a very labor intensive and expensive activity. Species area curves are developed to give scientists information on the most efficient number of samples needed in order to complete their work, compile data, and provide solid scientific information.

1. This lab works best in groups of 2 to 4 or can be done as a demonstration.
2. Materials needed: (all materials are per group)
    - One bag of 13-15 bean soup. If necessary get several different bags of beans and mix together. Ultimately, each group should have a mixture of several different kinds of dried beans.
    - One 8.5 X4.5 (or similar) bread pan. (aluminum pans are cheap*)
    - One 16 oz. soda bottle cap (screw on type).
    - Yellow "stick it" pad (just a few are necessary)

3. Place a generous portion of beans into each pan making sure that the beans are a uniform nature.
4. Have students use soda cap to "dip" out a level sample of beans.
5. Place beans on table and organize into columns of like "species"
6. With a stick it, label this group of columns "sample one" and place label beside the group.
7. Count the number of columns.
8. Write this number on the "stick it" and label it "total number of columns (species)- sample one"
9. Have students "dip" out another sample.
10. Separate into columns like above (step 5)
11. Label columns "sample two"
12. Count only the number of new and **different** columns/species and add to total number of species from sample one.

13. Write this number on the "stick it" and label it "total number of columns (species)- sample two"
14. Continue sampling/dipping until no "new" beans (species) occur
15. Have students develop a graph with "Sample Number" being the "X" axis and "number of different species" being the "Y" axis.
16. The graph should resemble a gentle curve leveling out toward the maximum number of species.
17. The level part of the curve corresponds with the most efficient sample number.
18. Have students write down how many samples are necessary to effectively and efficiently sample their pan of beans.

Application: Have students discuss how this activity represents sampling in a local wetland area. Lead students into a discussion on different sampling techniques (nets, seines, coring devices, surveying equipment, etc.) Have students discuss how some sampling techniques are not as effective as others (using a kick net only samples epi-benthic organisms, not all organisms in a steam, etc.)

Evaluation: Have students report on their species area curve model including the graph. The report should contain the number of samples they feel is necessary to efficiently obtain a representative sample of the population. Ask students how a larger or smaller sampling device would have affected their data. Have students explain reasons why developing a species area curve is important.

Time Frame: 1-2 class periods
Grade level: 6^{th}-12^{th}

CRITTER CLIPPERS

Academic Question: How do we identify wetland creatures' adaptations?

Objective(s):

- To learn the characteristics and ecology of common wetland animals
- To learn to recognize basic characteristics in identification of common wetland animals

Process (Activities):

This activity is a fun, informative, "out of the seat" lesson. It will allow students to sharpen their questioning and answering skills while learning about organisms and their adaptations. The activity will work with any level and with any number of students providing there are enough cards. (Several cards are attached, more can be easily added).

1. With a paperclip or clothespin, clip one Critter Clippers play card to the back of each student, with the picture showing. (Cards in attachment)
2. Have the students walk around and ask others questions about their critter.
3. Each student may only ask one question at a time, and each question must pertain to a characteristic of an organism until the animal is guessed.
4. The answers given must be in **yes** or **no** form.
5. Once the "critter" is guessed **Do Not Allow Students To Remove Critter**.
6. Have students write down or discuss a few facts about the animal on their back (place detail on adaptations).
7. After everyone has completed this step, allow students to look at the organism and read the back of the card.
8. Have students add to their discussion/list several new facts about the organism.

This activity can be conducted at many different levels. Depending on the level of the students, determine how detailed the answers must be.

Extension(s): This activity can be used with pictures of local wetland species. Students can use other resources (library/internet) to get information on the organisms.

Product/Application: This activity can be used at the beginning, middle and wrap-up of a wetland module in the classroom. It teaches students how to look for certain characteristics in identification of animals, from general to specific. It also brings in information on the ecology and life history of wetland animals.

Assessment/Evaluation: Have students develop their own version of "critter clippers" for the class. Have the student create a wetland animal checklist of those found at the field site. Or create a dichotomous key, using the characteristics of the animals used in the activity, moving from the general to specific.

Time frame: 1-2 class periods
Grade level: 6-12

Exploring South Texas Barrier Islands: lesson module

Texas A&M University-Corpus Christi

Presenters: Jennifer Smith-Engle Ph.D (jsengle@falcon.tamucc.edu)
W. Jay Tarkington M.S. (jtark@falcon.tamucc.edu)

"Debris Diary"

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.

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:

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 ect.

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.

Timeframe:

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

Exploring South Texas Barrier Islands: lesson module

Texas A&M University-Corpus Christi

Presenters: Jennifer Smith-Engle Ph.D (jsengle@falcon.tamucc.edu)
W. Jay Tarkington M.S. (jtark@falcon.tamucc.edu)

"Don't Just Float There- Get On the RAFT"

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.

Process (activities):

Materials:

Writing paper and pen

This is a creative writing assignment that allows the students to put themselves in the place of the debris in order 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 etc.	local surfer	memo	"sorry"

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

Time frame:

One or two class periods.

Grade level:

Elementary to high school

Coastal Bend Eco-Historic Tour

The Center for Coastal Studies at Texas A&M-Corpus Christi is proud to offer our Coastal Bend Eco-Historic tours **free of charge**. Travel around the Coastal Bend learning about how the ecology and history of the area are combined. Trips are led by Capt. W. Jay Tarkington, a professional wetland biologist and coastal historian at Texas A&M. A typical trip involves stops at various locations around Portland, Rockport, Lamar, Port Aransas, and of course Corpus Christi. Many who have taken the trip claim they have lived in the Coastal Bend their entire life and have not noticed many things discussed on the trip. All aspects of ecology are discussed specializing in birds, and plant ecology. Participants will leave around 9:00 a.m. aboard a spacious 20-passenger bus, and return around 4:00 p.m. (Drop-off and pick-up can be arranged) A "brown-bag" lunch is preferred to allow a "picknick" at one of the scenic stops. Drinks and cooler will be provided. Spend an exciting day with us that will certainly bring the coast to life.....

Please contact:

Capt. W. Jay Tarkington
Aquatic Education Director
Center for Coastal Studies
Texas A&M –Corpus Christi
361-825-3221 wk
361-443-6701 cell
jtark@falcon.tamucc.edu

"In the Gutter"

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 affects of run-off

Process (activities):

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.

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

Time frame: 1-2 class periods
Grade level: 6-12

ROLLING DOWN THE RIVER: AN OBSTACLE COURSE

Academic Question: How does freshwater travel to the Gulf of Mexico?

Objectives:

- To learn how freshwater travels through our waterways to the Gulf of Mexico
- Introduce students to concepts of sedimentation and bed load

Process (Activities): There is a handout for each student to read before entering the obstacle course, briefly explaining the route water travels (attached). There are nine stations to this obstacle course. Each station represents the next progression of water flow, beginning with a groundwater spring and continuing until the water reaches the Gulf of Mexico. Each student represents water flowing through each of these stations, picking up sediment and depositing sediment at different locations along the water way. Signs at each station instruct the student to the activity of that station.

This activity is a great interactive demonstration of water flow and sedimentation. It works best in an open area. There is a site description map included in these instructions.

Materials:

- One large truck innertube
- Six eight foot landscape timbers.
- 16 two foot 2X4's
- Bag of small rocks
- Several buckets
- Bag of sea shells
- Six hulla-hoops
- Rope
- Sawhorse
- Water mister

Site set up:

Refer to map.

Instructions:

Station 1: A large truck innertube works well as a "spring" for students to pass through

Station 2: We have found that three 8 ft. landscape timbers work well. Stabilize them by nailing 2-foot sections of 2x4 to the bottom at the two ends. Place 2 or 3 end to end in a zig-zag pattern, to represent a stream. Provide a small pan or bucket of small stones off to one side at the end of the "stream". Students will run along the timbers, and pick up 3 stones before moving to the next station.

Station 3: Use a long length of rope to create a lake. At the opposite end of the lake from the stream, provide an empty bucket to place stones in. Students should come off the "stream" and into the "lake", circling inside the lake two times, each time depositing one stone into the bucket. Students should have one stone left when they leave the lake.

Station 4: Students are now going over a dam. We use a large plastic trashcan with the bottom cut out or a saw horse ...use whatever works for you. Provide an empty bucket to place the one remaining stone.

Station 5: Students are now out of the dam and in the rapids of another stream. We use 5 plastic hula-hoops placed close together in a zig-zag manner. Students jump from one hula-hoop to another. In each hoop, there is a small bucket of stones. Students pick up one stone from each hoop as they jump through.

Station 6: This is similar to Station 2. Provide 2 or 3 more landscape timbers stabilized with 2x4's. Provide a bucket with stones at the end. Students walk on the timbers and pick up one stone at the end.

Station 7: Students are now entering from a freshwater area into a salt water area. Use another long rope to create a river delta and bay system. At the river delta area, provide an empty bucket to deposit stones. At the other end of the bay, provide a bucket of seashells. To represent the influence of tides, students circle around the bay, each time they pass the seashells, they pick up one. Each time the student runs by the empty bucket at the river delta, they deposit a stone. Do this until all of the stones are deposited. They should have all seashells at this point.

Station 8: Use another long rope to create the Gulf of Mexico beach. Provide an empty bucket at the far beach side. Students cross the Gulf of Mexico and place one seashell in the bucket and return to the bay. Students will continue crossing the Gulf of Mexico and depositing seashells until all of the shells are deposited. This represents the currents in the Gulf washing seashells onto the beaches.

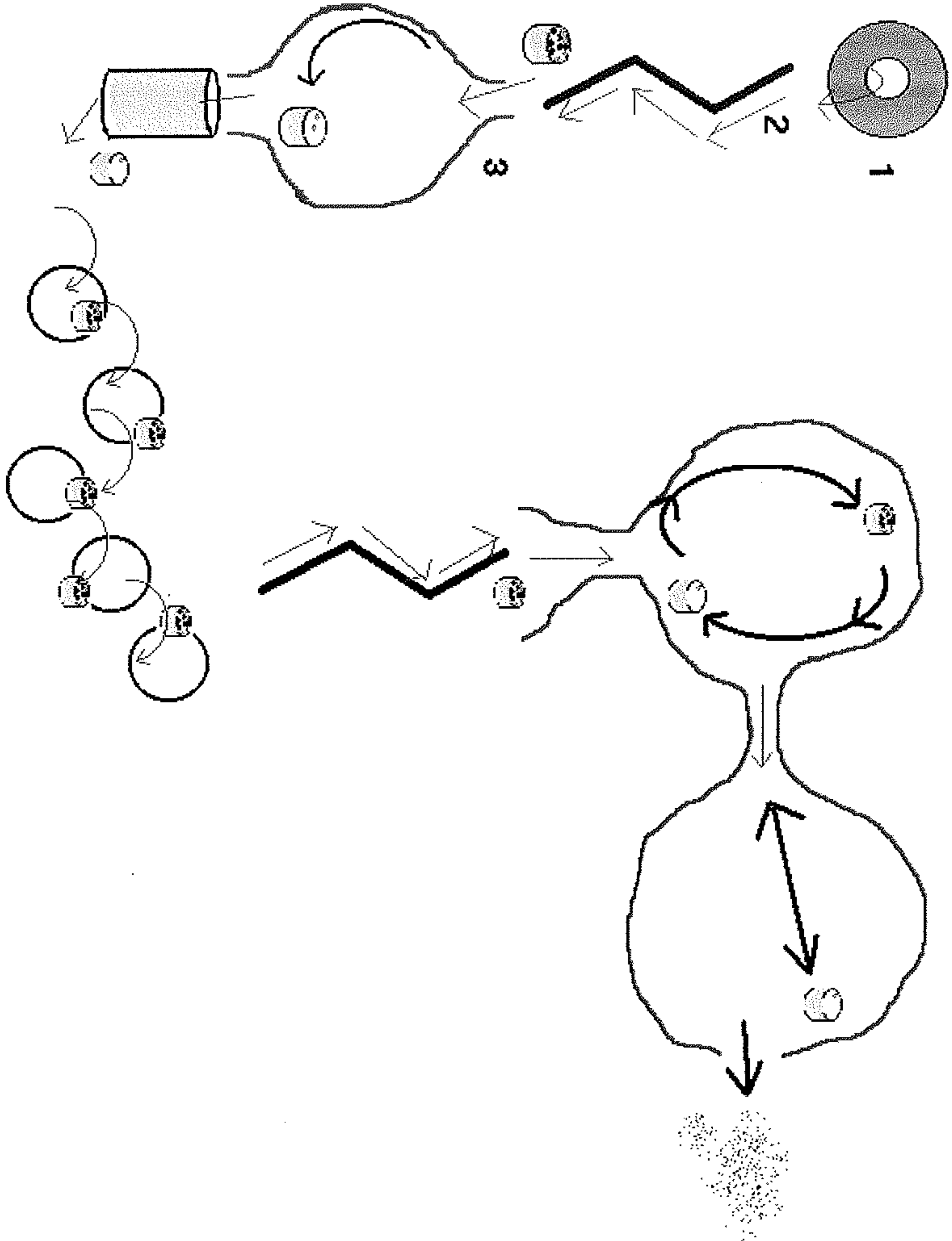
Station 9: This is the last step of the water cycle, when water turns to vapor. As students leave the Gulf, use a mister to spray them, representing the water vapor and rain, releasing them to the atmosphere.

Product/Application: Have students discuss the route water takes in their own area, where their local water comes from and where it goes. The obstacle course can be modified to fit local conditions and waterways.

Assessment/Evaluation: Use maps of area waterways to check the construction of your own obstacle course. Have the students come up with ideas on what other items could be used to represent water control structures and streams or lakes. Have students describe the effect water velocity has on bed load and sedimentation. Have students' research and discuss positive and negative effects of damming Texas rivers.

Time frame: Set up: one hour
Activity: 1 class period

Grade level: 6-12


1
2
3

Test Your Urban Watershed IQ…!

1. **A watershed is generally defined as:**
    a) a building that stores water
    b) all the land area that drains to a given point in a water body
    c) all the water area that drains to a given point in a landform
    d) a moment in time when you cross into a new area
    e) a new way of organizing environmental agencies

2. **On average, how much land is converted to urban land use in the U.S. each year?**
    a) 500,00 acres
    b) over one million areas
    c) no net loss
    d) 9.4 acres
    e) 49,000 Walmart equivalents

3. **Which of the following comprises the greatest percentage of impervious cover in suburban areas?**
    a) Rooftops
    b) Lawns
    c) Roads, parking lots and driveways
    d) Vacant lots

4. **Which of the following pollutants are frequently found in most samples of urban stormwater runoff (more than one)?**
    a) Dilithium
    b) laetrile
    c) total phosphorus
    d) vanadium
    e) copper
    f) prozac
    g) zinc
    h) fecal coliform bacteria

5. **Recent watershed research has discovered that urban stream quality begins to decline sharply once impervious cover in a watershed exceeds:**
    a) 45%
    b) 10%
    c) 75%
    d) 125%
    e) 3.1414%

6. **The residual zoning category that produces the amount of impervious cover at which stream quality begins to decline is:**
   a) ten acre lots
   b) one acre lots
   c) ½ acre lot
   d) townhouses
   e) apartment buildings

7. **What fraction of the total water supply on the planet is available for use by humans?**
   a) 0.1 percent
   b) all of it
   c) 25 percent
   d) 48 percent

8. **How many gallons fall on a one acre yard during a one-inch rainfall?**
   a) 27,200 gallons
   b) none, the rain falls only on the plains in Spain
   c) 4 gallons and one pint
   d) enough to flood my driveway
   e) 45,000 gallons

9. **How much more storm water runoff is produced by a one acre parking lot compared with a one acre meadow?**
   a) 6%
   b) 78%
   c) no difference
   d) 100%
   e) 1600%

10. **According to the US EPA, what percent of river pollution is caused by urban storm water runoff in the nation?**
    a) virtually none, industrial pollution is the major problem
    b) virtually none, trees cause pollution
    c) 21%
    d) 99%
    e) 11%

11. **A single quart of motor oil dumped down a storm sewer creates an oil slick of what size?**
    a) No slick, it sinks to the bottom
    b) 160 square feet
    c) 2 acres
    d) twice the size of the Exxon Valdez

12. What percentage of the urban population of the U.S. relies on groundwater for its drinking water?

a) 4.8%
b) 22%
c) 30%
d) 90%

13. What percentage of Americans relies on septic systems to dispose of their wastewater?

a) none
b) 16%
c) 21%
d) 25%
e) 37%

14. What percentage of Americans using a septic system does not know where they are located?

a) 0%
b) 12%
c) 2%
d) 67%

15. On average, how many pounds of nitrogen are discharged to ground water from a properly operating septic system each year?

a) 10 pounds per person using the system
b) nitrogen is fully treated by the septic system
c) 32 pounds
d) the equivalent of a herd of cows

16. Which of the following statements about urban lawns is false?

a) Some common pesticides are routinely detected in urban streams
b) Few people take soil test before applying fertilizers to their lawn
c) Atmospheric deposition supplies at least a third of the nutrients needed for a lawn
d) Lawns produce no runoff

17. How many pounds of active pesticide ingredients are applied to lawns in our country each year?

a) 18 million
b) .2 million
c) none
d) 54 million
e) 70 million

18. How many pounds of grass trimmings does the average suburban lawn generate each year?

a) 1500 pounds
b) none
c) 6 pounds, eight ounces
d) 2,100 tons

19. How many fecal coliform bacteria does an average sized dog's dropping produce?

a) 49
b) 1200
c) 3 billion
d) what a disgusting question
e) trick question, dogs produce fecal streptococci bacteria

20. According to EPA, water pollution promotes closings or swimming advisories at how many beaches around the country in 1996?

a) three in New Jersey, one in Florida
b) 1000
c) 2500
d) none
e) 216

1. b
2. b
3. c
4. c,e,g,h
5. b
6. b
7. a
8. a
9. e
10. e
11. d
12. c
13. d
14. b
15. a
16. d
17. e
18. a
19. c
20. c

"The Attempted Journey to Mexico"

Academic Question: How is a tidal flat best described?

Objective(s):

- To educate students on tidal flats
- To introduce students to the history of the Laguna Madre
- To allow students to creatively describe tidal flats

Background:

The background of the central flats area has been rather colorful, and many sidenotes in history have been made here. Early information is scarce because of isolation of the area and limited use of the waterway and shoreline. All information in the following section, unless otherwise cited, comes from an unpublished article by W. A. Price from 1949. The shallow nature of the coastal lagoons of south Texas and the bars at the tidal inlets caused settlers to depend less on waterways in Texas than settlers along the Atlantic coasts. The general treeless nature of the coast and semi-arid climate of south Texas were repellants to the colonial settlers, who had not learned the value of prairie land and were not adapted to life on it (Webb, 1931). The area was colonized only around the entrances to the Laguna Madre at Corpus Christi, Brazos Santiago, and the Rio Grande. Large herds of horses and cattle fed on the local vegetation (Fulbright et. al., 1990). Ranching headquarters were located 15 to 20 miles inland because travel was conducted on land, and the lagoon was not passable as a waterway. The first maps of the Laguna Madre and the central flats were made to accompany the early land grants of Spain and Mexico. Although Pineda had made previous maps of Texas in 1520, no exploration of the Laguna had been made. In 1788, M. A. Anglino made a map from the Rio Grande to the Mississippi. This map showed structures, trails, and Indian sites; however, it depicted the coastline as a straight line between the two rivers. The most significant map of the era was a sketch of the San Juan de Carricitos Land Grant from Spain in 1790. In this map, Redfish Bay to the north of the central flats, is shown as an enclosed body of water called "Badillas de aqua Salades" or "little fire shovels of salty water". In 1846, Lt. J.E. Blake of the Topographical Corps of the U. S. Army, in response to the war with Mexico, scouted the beaches and lagoons as practical routes down the coast to Mexico. His expedition used boats and "flats" (barges) to venture down the Laguna Madre. Although his map has not been found, he did report to the U.S. Senate that numerous shoals and bars were encountered and it was doubtful whether shallow boats could navigate it. Colonel E. A. Hitchcock, chief of intelligence for Gen. Zachery Taylor, recorded a "disgust at the lack of knowledge of information on the area south of Corpus Christi" and Gen. Philip Sheridan is reported as saying," If I possessed both Texas and Hell, I'd rent out Texas and live in Hell" (Lehmann, 1984).

In 1875, R. E. Halter of the U.S. Coast Survey hired two local fishermen to help navigate the central flats. One of the men hired was Andrew Anderson from Corpus Christi. The Anderson family of shipowners and boatmen regularly transported salt, rock, and hides from the Kenedy ranch and skinning plants from Baffin Bay through the Laguna Madre from 1870 to 1880 and fished the area to Murdock's Landing. In his report Halter describes tying up their boats and traveling across the flats in smaller boats to an enclosed body of water some 2.5 feet deep. They followed it approximately ten miles to its southern end but would go no further for fear of a northern. This is the first know attempt to cross and map the central mud flats. Later attempts were not as successful. At one time in May of 1876, Halter found 2 feet less of water under southerly winds than he did under the northerly breeze; Where there had been nine inches of water in the central part in December, in May, it was dry. Halter also did the first tidal study in the flats area around Mesquite Rincon by using grass lines to determine high and low tides. He found the height difference between high and low tide to be very little; however, with this slight increase the water would cover an area 2.5 to 5.5 miles at high tide.

In 1904, Will Anderson, brother of Andrew Anderson, made the first known actual boat trip across the central flats on a storm tide. With the discovery of oil, Humble Oil and Refining mapped the central flats in two-foot contours from 1948-1949 by using both land-based, and aerial methods. At about the same time, a canal which is part of the Intercoastal Waterway, was dug through the middle of the mud flats and is now referred to as the Land Cut.

Process (Activities):

1. This lab is an individual creative writing assignment.
2. Using the provided material, describe the brief history of the central tidal flats of South Texas.
3. Have the students write a fictional journal entry for R. E. Halter of the U.S. Coast Survey describing one of the days in 1875 where he and two local fishermen attempted to cross the tidal flats in the Laguna Madre. Have the students describe what he (Halter) sees, how they are traveling, and problems they may have encountered along this unsuccessful journey to Mexico.
4. Encourage the students to be creative.

Evaluation:

Evaluate the students writing according to district protocols.

Time frame: 1-2 class periods

Grade Level: 6^{th}-12^{th}

Literature Cited:

Fulbright, T.E., D.D. Diamond, J. Rappole, and J. Norwine. 1990. The coastal sand plain of southern Texas. Rangelands 12: 337-340.

Lehmann, V.W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, Texas.

Price, W.A. 1949. Sketch of history of mapping of Laguna Madre 1519-1949. unpublished manuscript

Webb, W.P. 1931. The Great Plains. Ginn and Co. Boston, MA. 345 pages.

The Coastal Bend Eco-Historic Tour:

Narration and script by: W. Jay Tarkington

Note: This tour contains both ecological and historical information. The roles of history are very intertwined with the ecology of the area. In learning about the coastal bend area, it is necessary to discuss both.

Leaving Texas A&M Corpus Christi:

1. TAMUCC is truly an island university. It is built on Ward Island. This island at one time had a freshwater pond and served various roles as a military post. Some of the old barracks are still in use today. Other parts of the island were utilized for training and as a munitions dump. After the military de-commissioning of the island, a long history of education began. The college on the island was first referred to as the Baptist School. Soon after the name changed to Corpus Christi A&I. Later this was changed to Corpus Christi State University, and finally in 1993, the school became part of the A&M system and is presently referred to as Texas A&M Corpus Christi.
2. As we pass over a small bridge, to the left is the "Blind Oso". This is a local example of a wind tidal flat. With different wind directions, water is either pushed into or out of the Blind Oso. "Wind tides" play an important role in the Coastal Bend. (Oso Bay will be discussed more upon returning to the university.)
3. Continuing north on Ocean Dr. we will pass many of the premiere homes of Corpus Christi. You will also undoubtedly notice many varieties of palm trees and other "tropical" vegetation. Most of the palm trees observed are not native to the area and have been imported for their "tropical" look.
4. The city of Corpus maintains several small parks along the Bay. These parks are popular recreation areas for residents and visitors in Corpus Christi. The afternoon breeze (sea breeze) caused by the heating and cooling of the shore side land makes the area a hot spot for wind surfing and the new sport of kite surfing. It is not uncommon to see twenty or more windsurfers or kite surfers off of Oleander Park racing with the wind across the bay.
5. All along this drive (Ocean Dr.) we are traveling along the top of the "natural" bluff. The steep, cliff-like bluffs are a characteristic of most Texas bays and are caused by years of wind and wave competition with the land. Several old "cuts or sloughs" through the bluff have been filled in and now support neighborhoods and apartment complexes. To compensate for the loss of these "cuts," storm water drains have been incorporated to disperse surface water. These many drain culverts are found in association with the many parks discussed earlier. After significant rainfall events, non-point source pollution floods into the bay. The city and others are presently working on solutions to this nationwide problem.
6. Immediately past Morgan street the road goes down a steep decline. We have now passed off of the natural "bluff" and are "fill" with the natural bluff continuing to the west. This area began to get filled in during the early 1900s.

Much of the dirt was trucked in from surrounding areas. Much of the locally abundant oyster shell was used for fill also.

7. The sea wall, completed in the thirties, was built to protect Corpus from "killer" storms. It, along with the surrounding breakwater, provides habitat for various "critters," animal and human alike.
8. Corpus Christi is a sailors' "Mecca". Racing occurs year round every Wednesday night starting inside the harbor.
9. Continuing north the breakwater becomes discontinuous. This allows for greater circulation and also provides critical habitat for bird rookeries.
10. We will turn left at the new Nueces County Courthouse completed in 2000. Less than two blocks away we will see the "old" county courthouse. Its once beautiful exterior is now falling apart; however, upon close observation, some of its architectural "gems" are still visible. The old courthouse's future is uncertain. There has been talk of refurbishing the once grand building to house a museum or other such venue. No matter what the outcome, the highly corrosive environment of the Coastal Bend has taken its toll on the old building.
11. Harbor bridge: I am unsure of the construction date: however, it did replace an old swing bridge. There are some great old photographs of the bridge and North Beach displayed throughout the Corpus Christi Airport. A walk over the bridge in the evening is a great (and cheap) attraction, and if you are lucky enough to time your walk with the arrival or departure of a ship, you will be in for a unique treat. Under the bridge on either side hosts a handful of attractions including the Texas State Aquarium, C.C. Museum, water garden, U.S.S. Lexington, and playhouse, as well as the convention center.
12. North Beach (sometimes called Corpus Christi Beach) is, you guessed it, north of the bridge. This area has been the resort location of Corpus Christi for decades. In its heyday in the 20s and 30s the bay provided a backdrop as giant hotels, boardwalks and ferris wheels competed for tourist dollars. Unfortunately, the natural beach is constantly eroding away and an aggressive beach nourishment program involving trucked in sand keeps tourists and merchants happy.
13. Leaving North Beach we cross over Nueces Bay. Nueces Bay is a shallow, secondary bay with several oyster beds covering the bay bottom. Many of these oyster beds were used for food, and then fill material in the past. This bay system is driven by the inputs of the Nueces River that enters into the western portion of Nueces Bay. Damming and channelization changed the natural flow of the river and its meanderings into the bay; however, efforts are being made to enhance and revitalize the original Nueces River Delta with great success.
14. You will probably notice some old wooden and concrete structures off of the east side of the causeway. These are the remnants of the original one-lane causeway that traveled to North Beach and on to Corpus. The original passageway, as well as the new causeway, are built upon an old oyster reef. Travel across the original oyster reef passage provided for a much wetter trip than today.
15. On the other side of the causeway is Indian Point. Take time to stop and look around the area. Several boardwalks and a pier allow you to observe the area closer and observe the numerous birds that inhabit the shallow tidal pools. Getting bait by seining or castnetting is not allowed in these pools. Therefore, the

bird and animal life are not as spooked by observers. Because of its close relation to Nueces Bay, oyster shell makes up most of the shoreline with beachcombers occasionally finding whelks, moon snails, and various other molluscan prizes to add to their collections.

16. Continuing north, we pass Sunset Lake to the east. This is an artificial lake created by dredging the area for filling the current roadbed we travel upon. Despite its poor circulation and limited openings to the bay, Sunset Lake hosts a large, diverse number of species. The city of Portland allows individuals to recreate among nature along a trail extending between the lake and the bay.
17. After passing through the city of Portland, North Shore Country Club appears on the right, fronting the bay. This is "supposedly" a challenging course. (I don't play golf. A **good** day golfing should be a **better** day fishing.) While trying to avoid the water during a tournament, Jack Nicholas's ball struck and settled on a jellyfish causing him to lose a stroke.
18. In the distance to the south, several large industries line the Corpus Christi Ship Channel towards the town of Ingleside. With their close proximity to water, Oxychem, Dupont, and Alcoa/Reynolds Aluminum all call this area home. The large "red" mounds in the area are the Jamaican soil "leftovers" minus bauxite extracted for aluminum production. In the past, the "red dirt" has been used for road building; however, it is currently being explored for use as a biological filter for waste from the towns of Portland and Ingleside.
19. Continuing on, we pass through an area utilized extensively for agriculture. The "black earth" is good for growing sorghum and cotton.
20. Where the area has not been cultivated, the native shrub-scrub prairie is evident. This type of vegetation is made up of mesquite, huesache, cacti, gulf bunch grass, yucca plants, and various other types of grasses.
21. As we skirt around the town of Aransas Pass, watch for several small coastal pothole wetlands. These unique areas were formed by small depressions in the soil where after years and years of decomposition thin layers of clay formed to hold water. These areas provide habitat for many diverse plant and animal species.
22. Stay alert for various species of raptors along this stretch of road.
23. Note the change in vegetation. Now the scrub-shrub prairie is dominated by coastal live oaks. The live oaks inhabit an area referred to as the Ingleside terrace. This "terrace," with its powder white sediment, extends north from Flour Bluff to Aransas County and was once the original gulf shoreline (see Brittan and Mortan). Mentally strip away the oak trees, and one can easily see the ancient sand dunes.
24. Rockport: (Alison Lakin Texas Maritime Museum)
25. After traveling through downtown Rockport detour along Water Street for excellent views of Aransas Bay and St. Jose Island.
26. Bass Ranch: St. Jose Island is privately owned by Perry Bass and is a working cattle ranch. There is a large ranch house and facilities on the island. Here, at the sight of the old Heldenfel's Ship Yard is the ranch mainland headquarters. It is quite a sight to see several head of cattle loaded onto a ferry and then traveling across Aransas Bay. Once a year the vegetation on the island is burned to

rejuvenate new growth for foraging cattle. I love telling winter Texans the smoke is because of the volcano at the southern end of the island…….

27. Heading south on Highway 35, we parallel the Gulf Intercoastal Waterway. This is an interconnected channel that runs continuously from Brownsville in deep south Texas, around Florida, and on up the east coast. In 1905, Clarence Holland, of Victoria, conceived the idea and the intercoastal waterway changed the face of the coast ecologically and economically in both positive and negative ways.
28. Across from the Bahia Bay subdivision, is the remnants of an old alligator farm. It has been out of business for decades but many of the former reptilian residents added a new consumer to the food chains of the local coastal potholes. (As a boy growing up in the Palm Harbor subdivision, I remember, after big storms, alligators in the canals behind the houses and people trying to catch them with chicken legs tied onto rope).
29. The Degussa Plant, originally owned by United Carbon began production in 1936. Utilizing the vast natural gas resources in the area for fuel, the plant produced carbon black. The black soot covered everything in the area and was visible miles away. Although the plant adheres to strict environmental regulations, remnants of the black scars caused by an earlier time still remain throughout the area today.
30. Entering the town of Aransas Pass, detour and drive past Conn Brown Harbor. This harbor once crowded with shrimp boats, is home to the mighty Gulf King shrimping fleet. With declining shrimp harvests, off shore shrimpers are forced to travel farther into the Gulf, down to the bay of Campeche and beyond in their search for the pink crustaceans. On the eastern side of the harbor a fishing pier and a memorial to lost fishermen are worth visiting.
31. One of the best examples of a Texas mangrove wetland occurs immediately to the right of the causeway bridge. This unique form of wetland supports a number of yellow crowned night herons that spend the day in its darker recesses. Mangroves can also be seen the rest of the trip along the causeway to Port Aransas. The causeway was originally a continuous railroad trestle between Aransas Pass and Port Aransas (a la Florida Keys). Cars would be loaded on to flatbed rail cars and transported to the island to drive along the beach.
32. Morris and Cummings Cut: This is the original channel that led to Corpus Christi. With ever changing winds, waves, and currents, the winding and meandering pathway still changes shape occasionally today; however, it remains relatively deep overall. The modern Corpus Christi Ship Channel has taken over as the preferred "safe" way of transport to the port.
33. Casino Boat: (no comment)
34. Port Aransas Ferry Landing: Operated by the Department of Transportation, the ferries provide one of only two ways off of the island. Dolphins provide tourists with free shows daily from the comfort of their own cars.
35. Port Aransas History: Originally known asTarpon and Ropesville, the town of Port Aransas was a cattle ranch owned and run by the Mercer family. With increasing growth throughout Texas, boat traffic through the pass increased; and with the increased traffic, the need for bar pilots became necessary. The ever shifting Aransas bar required constant attention and observation. The Harbor Island lighthouse, built in 1855, assisted ships in finding the pass until the

continuing movement of the Aransas pass drifted far to the south. The lighthouse has survived several hurricanes, the Civil War, and the harsh salt environment. It is presently owned by the H.E. Butt family and has undergone extensive historical remodeling.

36. Jetties: The jetties around Texas seaport openings provide a manmade base for complex food webs. With the exception of oyster and worm reefs, the granite rocks of the jetties provide the only hard substrate along the coast. The goal of these long rock obstructions is to prevent the channel from moving. Prior to the building of the jetties, the channel would move up and down between San Jose and Mustang Islands. Between the years of 1862 and 1912, the channel shifted to the south about one mile. The first jetty, built in 1885, consisted of weighted brush and was only marginally successful. Following jetties consisted of rock and concrete, and incorporated a complex rail and barge system extending across Redfish Bay for its construction. Granite rock from Marble Falls was loaded onto railcars and transported to the site where it was then unloaded. Some of the old railway trestles are still visible today. Take time to explore around the jetties. Among the many organisms found here, sea turtles are not uncommon. Watch out for the many fishermen and their sharp, entangling equipment.
37. Driving south down Mustang Island you will notice several hotels and condos. Wilson's Cut is a channel that provides anglers access to the area around Shamrock Island. This island is one of the only "natural" islands in this bay system and, due to chanellization, erosion has negatively affected the island. Efforts are currently underway to replenish the island. Local legend tells of an old hermit who lived on Shamrock Island (1905-1917) who had worked on the construction of the Panama Canal. He imported tropical plants to the island and refused to leave the island even during severe hurricanes. The legend continues to explain that he was a descendent of Russian nobility, and that his family in Russia supplied him with money. Rumors abound about buried treasure on Shamrock Island. (To date nothing has been found.)
38. Fish Pass: The State decided to dredge a pass south of Port Aransas in 1971 to increase circulation and fish exchange into Corpus Christi Bay. Although constructed with granite boulders, the pass soon silted in. Presently, walking along the sandy beach between the two granite structures reminds us that Mother Nature possesses the ultimate dredge.
39. Noticing the large dunes that front the Gulf to the south, observe several more freshwater coastal pothole marshes that appear on the inland side of the dunes.
40. Packery Channel, 1852 pass, Corpus Christi pass: These three passes make up the end of Mustang Island and the beginning of Padre Island. Currently, the two islands are connected and walking between them is possible. These broad, flat areas "overflow" from time to time, usually during storm events (hence, the local name "storm passes"). During hurricane Brett eight separate passes opened up along Padre Island.
41. Packery Channel: To dredge or not to dredge, that is the question.....Currently, there is a local political push to dredge Packery Channel to allow passage to the Gulf. Biologists and real estate agents are heavily involved on both sides of the issue.

42. JFK Causeway: On the north end of Padre Island we travel back toward Corpus Christi along the JFK Causeway. The large bridge traverses the Intercoastal Waterway continuous to Brownsville. To the south is the Laguna Madre. The Laguna is a unique ecosystem that has very little freshwater input. Thus, it is a hyper-saline ecosystem. The complexities and inner workings of the Laguna Madre environment are beyond the scope of this brief narration. In short, people come from all over the world to study the unique geology and ecology of the Laguna Madre.
43. Passing through the town of Flour Bluff, the Naval Air Station (NAS) and Corpus Christi Army Depot (CCAD) are visible to the east. (Acronyms abound in C.C.)
44. We are now returning to the backside of Oso Bay, and turning on to Ennis Joslin Rd. we pass Hans Suter Park and the Oso Wastewater Plant. The wastewater from the plant is used as a source to enhance the Oso. The park is an excellent area to observe wildlife with many species of birds visible year round.

This completes our Coastal Bend Ecology Tour. We hope to have impressed upon you the great diversity found within the small fifty-mile radius surrounding Corpus Christi.

"The Incredible Edible Tidal Flat"

Academic Question: What is the substrate content of a tidal flat?

Objective(s):

- To introduce students to the living substrate components of a tidal flat
- To allow students to model the substrate of the tidal flat
- To educate students on the invertebrates living within the tidal flat substrate

Background:

Tidal flats have a unique ecosystem that is based on large mats of blue green algae that make up the expansive substrate. The flats are irregularly flooded and alternate between wet/dry cycles leaving behind high concentrations of salt. These continually changing conditions prevent vegetation from becoming established.

The tidal flats take on different characteristics depending upon length and depth of inundation. When wet, a living algal mat forms a papery crust 1 to 20 mm. in thickness and includes blue green, unicellular green, flagellated, and diatomaceous algae as well as various strains of bacteria. The largest component of this living mat is made up of the filamentous algae, *Lyngbea confervoides* (Sorrenson and Connover, 1962).

There is a distinct zonation in the blue green algal mats. The mat community may be exposed for weeks at a time followed by flooding for weeks or months. Growth of the algal mat occurs during the flooding, while shrinkage occurs in the dry period. Alternating banded columns of black to brown to gray occur in the mats. It is made up of several different grain sizes and is related to the alternating wet and dry periods. During dry periods, sand is transported onto the flats. When inundation occurs, the blue green algal mat grows through the freshly deposited sand and establishes itself on top (Sorrenson and Conover, 1962). This top layer is black and is used as a temperature insulator, as well as a light shield for the lower layers. It becomes thicker and deeper in summer with the increased photoperiod. Below this is the blue green layer where Lyngbea is dominant. Continuing down through the algal mat is a yellow green layer with fewer numbers of Lyngbea. Along with Lyngbea, there are several flagellates, diatoms, and bacteria found here. They cause this zone to function as a decomposition layer. Below this is a pinkish layer that contains a purple, sulfur bacteria, Chromatium sp. This zone also serves as a zone of decomposition, as well as a site for anaerobic processes (Sorrenson and Conover, 1962). Below the pinkish layer is a colorless zone that varies in depth. The lower layers are highly anaerobic and contain hydrogen sulfide and reduced organic matter (Birke, 1974). When flooding occurs, large portions of the mat may float away. This may be a way of re-establishing the colony elsewhere. When wind, water, or other disturbances remove the upper crustal layer, the area left exposed quickly resumes the characteristics of the described mats.

The consumers on the wind tidal flats of the Laguna Madre begin with insect larvae, polychaets, tanaids, with the tanid Hargeric rapax being the most common (Withers, 1994). Predation takes place among some insects (predatory beetles and hemipterans), as well as by spiders (Lycosidae-wolf spiders, and Clubionidae-sac spiders) that live and feed in the cracks of the surface (Pulich et. al., 1982). Various birds and fish or other larger invertebrates such as crabs, then feed upon smaller organisms. Birds are the major consumers during dry periods and fish dominate during wet episodes (Withers, 1994). Sheepshead minnows (Cyprinidon varigatus), various shrimp (Palaemonetes sp.) and crabs (Callinectes sapidus, Uca sp.) may feed on the tidal flat depending upon length of the wet episode, and depth of the water. Various birds are found in, above, and around the wind tidal flat areas.

Process (Activities):

1. This lab works best in groups of 2 to 4 or can be done as a demonstration.
2. The students will be modeling the various layers of a tidal flat during dry conditions.
3. Materials needed: (all materials are per group)
    - Small, clear plastic cocktail cups
    - The following flavors of pudding cups: chocolate, butterscotch, vanilla
    - The following flavors of "fruit roll-up": strawberry (pink) and grape (dark purple)
    - Oreo cookies (crushed)
    - Gummy worms and/or insects
    - Plastic spoons
    - Napkins
4. Describe the make up of the wind tidal flat substrate using the above information. Feel free to simplify. (the information provided is for teacher use) Use additional information as needed from the accompanying web site.
5. Have students draw or demonstrate for them on the overhead the layering that may be found within the substrate.
6. Associate colors with the appropriate layers.
7. Have students prepare a model of a tidal flat using the materials provided. Remember to include the various organisms they may encounter within the substrate.

Evaluation:

- Have the students measure and describe each layer of the "modeled" substrate.
- What types of organisms live "in" the substrate and what types of organisms are able to feed upon them?
- How might their model change if it were during a period of inundation?
- Why is the uppermost layer dark in color?
- Why are the lower layers dark in color?

Time Frame: 1-2 class periods
Grade Level: 6^{th}-12^{th}

Literature Cited:

Birke,L. 1974. Marine blue green algae mats. Pages 331-345 in H. T. Odum, B. J. Copeland, & E. A. McMahon (eds.) Coastal ecological systems of the United States. The Conservation Foundation, Washington, D.C. Vol. 1, Ch. A-7.

Pulich, W. Jr., S. Rabalais, and S. Wellso. 1982. Food chain components on Laguna Madre tidal flats. UTMSI Contrib. No. 573. Port Aransas, Texas. 20 pages.

Sorenson, L.O. and J.T. Conover. 1962. Algal mat communities of *Lyngbya confervoides* (C. Agardh) Gioment. Publ. Inst. Mar. Sci., Univ. Tex. 8: 61-74.

Withers, K. 1994. The relationship of macrobenthic prey availibility to shorebird use of blue-green algal flats in the upper Laguna Madre. Ph.D. Diss. Tex. A&M Univ., College Station. 117 pp.

"The Plastic Plate Tidal Flat"

Academic Question: What effect does wind have on tidal flats in South Texas?

Objectives:

- To introduce students to the geographic relief of a tidal flat
- To effectively model a tidal flat in relation to coastal waters
- To see the effects of human travel upon tidal flats

Background:

The wind tidal flats of the Laguna Madre are unique in their ecology, and also in their formation and geology. Approximately 125,000 years ago, during the Wisconsin glacial stage, sea level fell 90 to 160 meters. Many stream systems were formed to drain the now enlarged continental shelf. These rivers and streams cut deep channels into the surface. In the Laguna Madre, the Pleistocene (Beaumont) surface was eroded away to a depth of over 40 meters by one such stream (Fisk, 1959). Sea level began to rise and approximately 6,000 years ago, Padre Island was beginning to form (Amduer, 1978). A continuous barrier island chain was created 4,000 years ago, and the Laguna Madre was isolated at about this same time (Fisk, 1959). With Padre Island established, eolian processes took over and with the aid of hurricanes, sand was deposited, and the tidal flats were formed (Fisk, 1959). The area became sub-aerial and deposition was complete about 200 years ago (Long and Gudramovics, 1983). Eolian transport of sand from Padre Island shaped the Laguna Madre wind tidal flats. This same process continues to shape the wind tidal flats today. The blue green algal mats also effect the sedimentary processes. When wet, the sediments are held down, and with prolonged inundation they will become part of the layers in the substrate (Herber, 1981). These flats are areas with very little geographic relief and are prone to irregular flooding. These intervals of inundation are largely caused by "wind tides". A wind tide is a water surface elevation brought about by horizontal stress on a body of water (Watson, 1979). During normal conditions wind tides have an amplitude of 30 to 50 cm., and may cover areas of 50 km.2 (Miller, 1975). Inundation or exposure may occur rapidly depending upon the direction and strength of the wind. In 1968, Copeland et. al. reported a water level increase of 1.5 feet in a matter of a few hours.

Wind tidal flats occur in the Laguna Madre on the backside of Padre and Mustang Island as well as the mainland side in the area commonly known as the Land Cut. Before the dredging of the Intercoastal Waterway the two areas were connected. It was divided roughly in half at its lowest portion and continuous dredging is necessary to keep the canal at a controlled depth. The construction of the Intercoastal Waterway has had a major effect on the wind tides of the Laguna Madre. The canal serves as an escape channel for water to move freely through (Coover and Rechcenthin, 1965). The water is no longer able to "pile up" as it has in the past, nor is the water able to retreat as slowly across the flats. Depending upon the literature, the central tidal flat area is also referred to as the Kenedy mud flats, central mud flats, salt flats, salt pans, or the south Texas coastal sabkah.

Process (Activities):

1. This lab works best with groups of 2 to 4 or can be done as demonstration.
2. The students will be forming and evaluating a model of a tidal flat
3. Materials needed:
   - Small to medium disposable plastic dinner plates
   - Modeling clay
   - Toothpicks
   - Water
4. Have students press clay in to the bottom of the plate forming a flat, level surface leaving approximately 1/8 to ¼ of the plate bare and free of clay.
5. The clay should represent the tidal flat and the open area adjacent to the clay represents nearby coastal water.
6. After making sure that the tidal flat (clay) area is extremely flat, fill the open area with water.
7. Fill the open area until the water is level with the top of the clay.
8. Have the students get down to eye level with their model and lightly blow over the water area.
9. Water should pass onto the tidal flat area.
10. Have students blow the other direction over the tidal flat.
11. Most of the water should return to the pool.
12. Next, have the students make 5 to 6 tracks representing human travel (car, motorcycle, four wheeler) in the clay using the toothpicks.
13. Repeat the wind simulation.

Evaluation:

Have the students:

- Estimate the area of their tidal flat
- Describe the effect different directions of wind has on water adjacent to a tidal flat
- What effect does human travel have on water flow over the tidal flats?
- Which direction of tracks affects the water flow least?
- How could their model be better designed?

Time Frame: 1-2 class periods

Grade Level: 6^{th}-12^{th}

Literature Cited:

Amdurer, M. 1978. Geochemistry, hydrology, and mineralogy of the Laguna Madre flats, south Texas: Master's Thesis, Univ. Texas, Austin, 172 pp.

Coover, J.R. and C.A. Rechenthin. 1965. Report of a preliminary investigation of the wind erosion and salt problem on the salt flats of the Laguna Madre. USDA, Soil Conserv. Serv. Rpt. Temple, TX.

Copeland, B.J., J.H. Thompson, Jr., and W. Ogletree. 1968. Effects of wind on water levels in the Texas Laguna Madre. Tex. J. Sci. 20: 196-199.

Fisk, H.N. 1959. Padre Island and the Laguna Madre flats: coastal south Texas. Second Coast. Geogr. Conf., LSU, Baton Rouge. pp. 103-152.

Herber, J.P. 1981. Holocene sediments under Laguna Madre, Cameron County, Texas. M.A. Thesis, Univ. of Texas. Austin, Texas. 664 pages.

Long, D.T. and R. Gudramovics. 1983. Major-element geochemistry of brines from the wind tidal flat area, Laguna Madre, Texas. J. Sed. Pet. 53: 797-810.

Miller, J.A. 1975. Facies characteristics of Laguna Madre wind tidal flats. Pages 64-74 in R.S. Ginsburg (ed.) Tidal deposits. Springer-Verlag.

WATER WE DOING HERE

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

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): 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.

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.

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 of the available resources have been "absorbed".

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.

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.

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.

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

From: http://www.flmnh.ufl.edu/fish/southflorida/mangrove/Profiles.html

MANGROVES

Mangroves:

- **Include more than 50 species within 12 families**
- **Live in wet saline habitats**
- **Reproduce through viviparity**
- **Refer to an entire plant community which includes mangrove species**

What is a Mangrove?

- The term "mangrove" refers to certain species of plant life or to the entire plant community which includes individual mangrove species
- There are more than 50 species of mangroves distributed worldwide along tropical coastlines

The term "mangrove" does not refer to a specific taxonomic group of species, but to all halophytic (plants growing in saline soils) species of **tropical** trees and shrubs. This catchall, diverse group includes 12 families and more than 50 species. Although unrelated, all are adapted to life in wet soils, saline habitats, and periodic tidal submergence. Another use of the term "mangrove" includes the entire plant community including the individual mangrove species. Terms such as tidal forest, tidal swamp forest, mangrove community, mangrove forest, mangal, and mangrove swamp are synonymous with "mangrove".

Red Mangrove

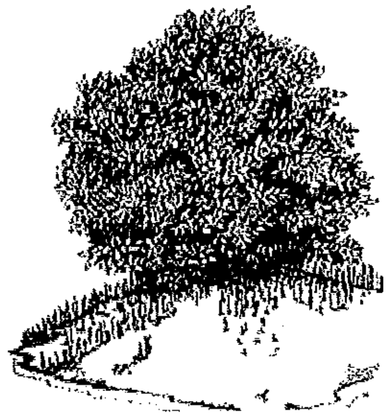
Growing along the edge of the shoreline where conditions are harshest, the red mangrove (*Rhizophora mangle*) is easily distinguished from other species by tangled, reddish prop roots. These prop roots originate from the trunk with roots growing downward from the branches. Extending three feet (1 m) or more above the surface of the soil, prop roots increase stability of the tree as well as oxygen supply to underground roots.

Under optimal conditions, this mangrove tree can grow to heights of over 80 feet (25 m), however, in Florida, red mangroves typically average 20 feet (6 m) in height. Habitat range in Florida is limited by temperature. Red mangroves occur from Cedar Key in the Gulf of Mexico and Daytona Beach in the Atlantic, southward through the Florida Keys.

The smooth-edged, elliptical leaves have shiny, dark green uppersides and pale green undersides and occur opposite from each other along the branches. Trunks and limbs are covered with gray bark, over a dark red wood from which the common name originates. Clusters of white to pale yellow flowers bloom during the spring and early summer months.

Reproductive adaptations enable seedlings to **germinate** while still attached to the parent tree. Seeds sprout into 6 inch (15 cm), pencil-shaped propagules. Seed germination while still attached to the tree gives this mangrove a higher chance of survival. When the seedling falls into the water, it may either take root alongside its parent or be carried by the tides and currents to other suitable habitat.

Black Mangrove



Avicennia germinans, the black mangrove, is characterized by long horizontal roots and root-like projections known as **pneumatophores**. It grows at elevations slightly higher than the red mangrove where tidal change exposes the roots to air. The pencil-shaped pneumatophores originate from underground horizontal roots projecting from the soil around the tree's trunk, providing oxygen to the underground and underwater root systems.

The black mangrove reaches heights of over 65 feet (20 m) in some locations, however in Florida they are smaller with heights to 50 feet (15 m). Within Florida, they range from the Keys north to Cedar Key on the west coast and St. Augustine on the east coast. Leaves occur opposite of each other along the branches, with upper sides that are shiny and undersides densely covered with hairs. The bark of this mangrove is dark and scaly. Black mangroves blossom in spring and early summer, producing white flowers.

Reproductive adaptations enable seedlings to **germinate** while still attached to the parent tree. Seeds sprout into 1 inch (2-3 cm), lima bean-shaped propagules. Seed germination occurs while still attached to the parent tree, increasing the chances of survival in this adverse environment.

White Mangrove

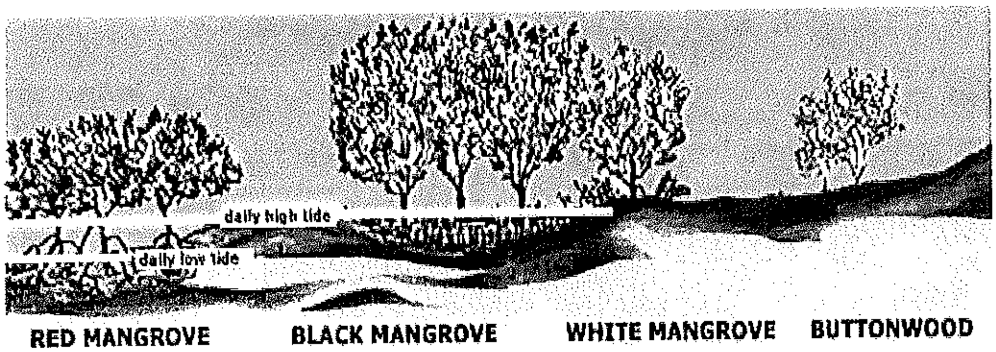
Occupying higher land than the red and black mangroves, the white mangrove (*Laguncularia racemosa*) has no visible aerial roots, unlike the black mangrove which has pneumatophores and the red mangrove with prop roots. However, when it is found in oxygen-depleted sediments or flooded for extended periods of time, it often develops peg roots.

White mangroves are the least cold-tolerant of the three mangrove species found in Florida, occurring from Levy County and Volusia County southward in Florida. This small tree or shrub grows rapidly in rich soils to heights of 50 feet (15 m). The light yellow-green leaves are broad and flat with two glands located at the base of the leaf where the stem originates. These glands are sugar glands called nectaries. White mangroves produce greenish-white flowers in spikes, blooming from spring to early summer.

Buttonwood

Often found in the upland transitional zone, the buttonwood (*Conocarpus erectus*) is often associated with mangrove communities. Sensitivity to frost restricts its range to south Florida. The name buttonwood comes from the button-like appearance of the dense flower heads that grow in branched clusters, forming cone-like fruit. This plant does not reproduce via propagules, but instead producing seed cases. While the three mangrove species have leaves that occur opposite of each other, the buttonwood leaves alternate. The leaves are leathery with pointed tips and smooth edges. There are two salt-excreting glands located at the base of each leaf. Flowers appear in cone-like heads and are greenish in color.

ZONATION



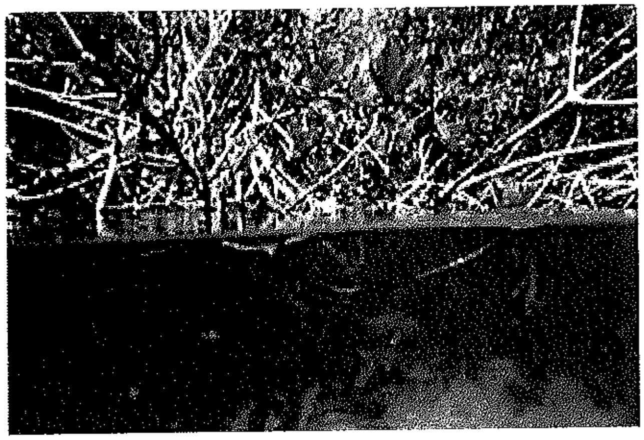
Zonation is affected by:

- Tidal Flooding
- Land Elevation
- Soil and Water Salinity

Red, black, and white mangrove trees, along with the buttonwood, may all grow along the same shoreline. When these species are found together, each is limited to different areas within the tidal zone. This **zonation** is determined by tidal changes, elevation of the land, and **salinity** of the soil and water.

Red mangroves are found along the water's edge, with full exposure to tidal variation and winds. They are well adapted to these conditions with prop roots extending from the trunk and branches. These tangles of root systems increase stability as well as capturing sediments from the surrounding water. Moving further inland, is the black mangrove, with **pneumatophores**extending upwards from the soils surrounding the trunk. These root adaptations are used to supply oxygen to the underground roots that are often in anaerobic (oxygen-free) sediments. White mangroves, often lacking special root adaptations, occur in the interior of the mangrove forest, followed by the buttonwood in the upland transitional area.

HABITAT REQUIREMENTS



Split-view of Mangrove Habitat
© Don DeMaria

Mangrove habitat requirements:

- **Tropical Climate**
- **Salinity Levels**
- **Tidal Fluctuations**

Tropical Climate

Mangroves thrive in tropical climates
courtesy National Park Service

- Mangroves are tropical species

Mangroves are **tropical** species, surviving at temperatures above 66° F (19° C), not tolerating fluctuations exceeding 18° F (10° C) or temperatures below freezing for any length of time.

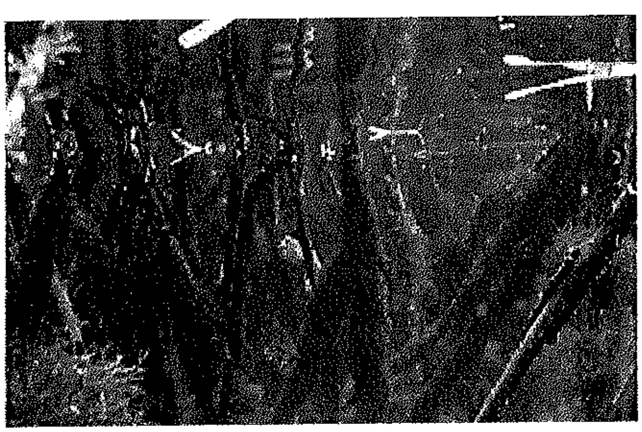
Salinity Levels

As halophytes, mangroves are able to live in freshwater and saltwater environments
courtesy U.S. Fish and Wildlife Service

- Adaptations make it possible for mangroves to live in saline environments

As **facultative** halophytes, mangroves do not require saltwater to survive. Most mangroves are capable of growing in freshwater habitats, although most do not due to competition from other plants.

Tidal Fluctuations



Nutrients are tranported into mangrove communities by tides
courtesy U.S. Geological Survey

- Tides bring in nutrients and remove wastes from mangrove communities

Tidal fluctuations play important roles in maintaining mangrove communities. The changing tides, in combination with **salinity** levels, reduces competition from other plant species. Tides transport salt water into estuaries, mixing with freshwater, thereby allowing mangroves to develop further inland than otherwise possible. Nutrients are transported into mangroves by incoming tides while waste products are removed by outgoing tides. Also of importance is the role tides play in transporting the propagules (seedlings) of mangrove trees. This increases the distribution of the mangrove trees, while limiting intraspecific (within species) competition for food and space.

ADAPTATIONS: MORPHOLOGICAL AND PHYSIOLOGICAL

Prop roots of the red mangrove
© Cathleen Bester/FLMNH

Adaptations are required for:

- **Physical Stability**
- **Salt Tolerance**
- **Anaerobic Sediments**
- **Reproduction**

Physical Stability Adaptations

- Root adaptations make it possible for mangroves to live in the soft sediments along the shoreline

Root adaptations increase stability of mangrove trees in the soft sediments along shorelines. Red mangroves have prop roots descending from the trunk and branches, providing a stable support system. Shallow widespreading roots, surrounds the trunks of black mangroves, adding to the structural stability of the tree. Other species of mangrove trees grow at higher elevations, in drier soils, do not require specialized root structures.

Mangrove root adaptations
courtesy South Florida Water Management District

Salt Tolerance Adaptations

- Adapations for salt exclusion or salt excretion allows mangroves to live where other terrestrial plants cannot

Through physiological adaptations, mangroves are able to live in harsh saline environments. Red mangroves occur where soil salinities range from 60-65 parts per thousand (ppt) while black and white mangroves are found in soils with over 90 ppt salinities. Salinities effectively limit competition from other plants, while mangroves have salt exclusion or salt excretion adaptations allowing survival in these environments.

The ability to exclude salts occurs through filtration at the surface of the root. Root membranes prevent salt from entering while allowing the water to pass through. This is effective at removing the majority of salt from seawater. The red mangrove is an example of a salt-excluding species.

On the other hand, salt excreters remove salt through glands located on each leaf. Black and white mangroves are both salt excreters. White mangroves develop thickened succulent leaves, discarding salt as the leaves eventually drop.

Black mangrove pneumatophores
© Cathleen Bester/FLMNH

Anaerobic Sediment Adaptations

- Specialized root structures allow mangroves to live in oxygen-poor sediments

Mangrove trees are adapted for survival in oxygen-poor or anaerobic sediments through specialized root structures. Plants require oxygen for respiration in all living tissues including the underground roots. In soils that are not waterlogged, air diffusion between sediment grains can supply this requirement. However, in waterlogged soils, these spaces fill with water containing lower oxygen levels than air.

In contrast to most plants, mangroves have poorly developed, shallow below-ground root systems while having well-developed aerial roots. These aerial roots allow for the transport of atmospheric gases to the underground roots. Red mangroves have prop roots extending from the trunk and adventitious roots from the branches. Although the black mangrove does not have prop roots, small air roots can be seen extending vertically from the soils surrounding the trunk. These air roots, called **pneumatophores**, extend upward from the underground roots above the soil surface. During low tides, air is taken up through open passages in the pneumatophores and transported to living root tissues.

IMPORTANCE OF MANGROVES

Mangroves Stabilize Shorelines
© Cathleen Bester

Mangroves:

- **Shoreline Protection**
- **Nursery**
- **Threatened and Endangered Species**
- **Renewable Resource**

Shoreline Protection

- Mangroves protect shorelines from erosion

Mangroves protect shorelines from damaging storm and hurricane winds, waves, and floods. Mangroves also help prevent **erosion** by stabilizing sediments with their tangled root systems. They maintain water quality and clarity, filtering pollutants and trapping sediments originating from land.

Schooling Tarpon
© Don DeMaria

Nursery

- Mangroves serve as valuable nursery areas for fish and invertebrates

Serving as valuable nursery areas for shrimp, crustaceans, mollusks, and fishes, mangroves are a critical component of Florida's commercial and recreational fishing industries. These habitats provide a rich source of food while also offering refuge from predation. **Snook** (*Centropomus undecimalis*), **gray snapper** (*Lutjanus griseus*), tarpon (*Megalops atlanticus*), **jack** (*Caranx spp.*),**sheepshead** (*Archosargus probatocephalus*), and **red drum** (*Sciaenops ocellatus*) all feed in the mangroves. Florida's fisheries would suffer a dramatic decline without access to healthy mangrove habitats.

Brown Pelican Swallowing a Fish
courtesy South Florida Water Management District

Threatened and Endangered Species

- Mangroves Support Threatened and Endangered Species

In addition to commercially important species, mangroves also support a number of **threatened**and **endangered species.**

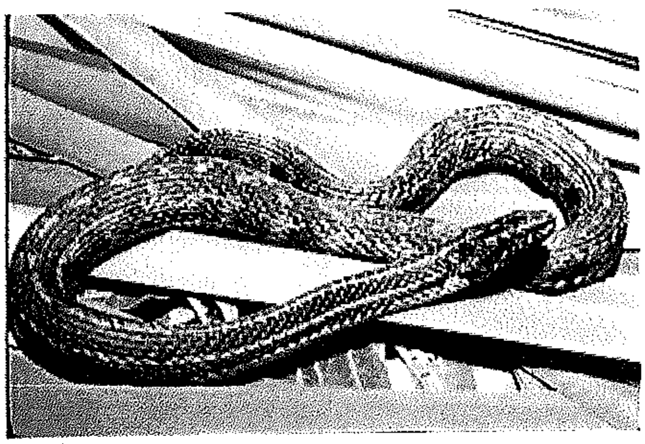
Threatened species include:

- **American alligator** (*Alligator mississippiensis*)
- **green sea turtle** (*Chelonia mydas*)
- **loggerhead sea turtle** (*Caretta caretta*)

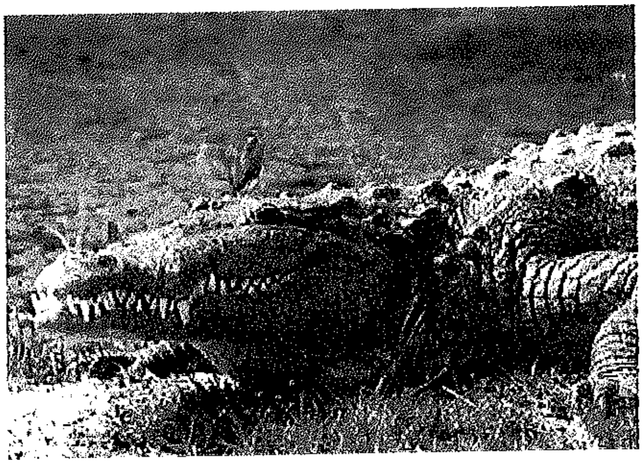
Endangered species include:

- **American crocodile** (*Crocodylus acutus*)
- **hawksbill sea turtle** (*Eretmochelys imbricata*)
- Atlantic ridley sea turtle (*Lepidochelys kempii*)
- **eastern indigo snake** (*Drymarchon corais*)
- Atlantic saltmarsh snake (*Nerodia clarkii taeniata*)
- **southern bald eagle** (*Haliaeetus leucocephalus leucocephalus*)
- **peregrine falcon** (*Falco columbarius*)
- **brown pelican** (*Pelicanus occidentalis*)
- Barbados yellow warbler (*Dendroica petechia petechia*)
- key deer (*Odocoileus virginianus clavium*)
- **West Indian manatee** (*Trichechus manatus*)

These species utilize mangrove systems during at least some portion of their life histories, while others reside their entire life spans, feeding and nesting within the mangroves.



Atlantic Saltmarsh Snake
courtesy U.S. Fish and Wildlife Service



American Crocodile
© Gerald and Buff Corsi, California Academy of Sciences

Renewable Resource

- Mangroves are utilized in many parts of the world as a renewable resource

In other parts of the world, people have utilized mangrove trees as a renewable resource. Harvested for durable, water-resistant wood, mangroves have been used in building houses, boats, pilings, and furniture. The wood of the black mangrove and buttonwood trees has also been utilized in the production of charcoal. Tannins and other dyes are extracted from mangrove bark. Leaves have been used in tea, medicine, livestock feed, and as a substitute for tobacco for smoking. In Florida, beekeepers have set up their hives close to mangroves in order to use the nectar in honey production.

Honey Bee
© Dr. Antonio J. Ferreira, California Academy of Sciences

Mangrove seedlings
© Cathleen Bester

Reproductive Adaptations

- Viviparity and dispersal are reproductive adaptations that give mangroves an increased chance for survival

All mangrove trees share two reproductive adaptations - **viviparity** and propagule dispersal. Similar to terrestrial plants, mangroves reproduce by flowering with pollination occurring via wind and insects. Once pollination occurs, the seeds remain attached to the parent tree. They**germinate** into propagules before dropping into the waters below. This ability is referred to as "viviparity". The propagules either take root in the sediments near the parent tree or are dispersed with the tides and currents to other shorelines.

The mission of Gulf Intracoastal Canal Association (GICA) is to ensure the Gulf Intracoastal Waterway (GIWW) is maintained, operated and improved to provide the safest, most efficient, economical and environmentally-sound water transportation route in our nation, serving petrochemical facilities, refineries, farms, mines, ports, commercial fisheries, recreation and more.

GICA Staff works to:

•Identify, analyze and address GIWW issues

•Educate and inform the public of GIWW's importance to the region and the nation

•Advocate for adequate capital and maintenance funding - Federal, state and locally

•Coordinate and partner with other industry groups/associations on waterways issues

•Assist USCG and USACE in identifying and rectifying hazards and improvements to the waterway – (e.g. Joint Hurricane Team)

•Partner with sister regional and national level trade associations to promote and support inland waterways transportation.

•Host an annual three-day convention, on the Gulf coast, presenting a great opportunity for learning and sharing information among the many diverse member-groups and stakeholders

OUR INLAND WATERWAYS

The inland waterways system includes 12,000 miles of commercially navigable channels and some 240 lock sites. These "inland highways" move commerce to and from 38 states, serve industrial and agricultural centers and facilitate imports and exports at gateway ports.

MOVING THE NATION'S COMMODITIES

By safely and cost-effectively moving America's cargo, barge transportation makes a vital contribution to our nation's economy, environment and quality of life. In 2012, 565 million tons of waterborne cargo transited the inland waterways, a volume equal to roughly 14% of all intercity freight and valued at nearly $214 billion.

Barges are ideal for hauling bulk commodities, including:

Coal, Petroleum, Chemicals, Grain, Iron & Steel, Aggregates, Intermodal Containers and Project Cargoes

STRENGTHENING OUR ECONOMY

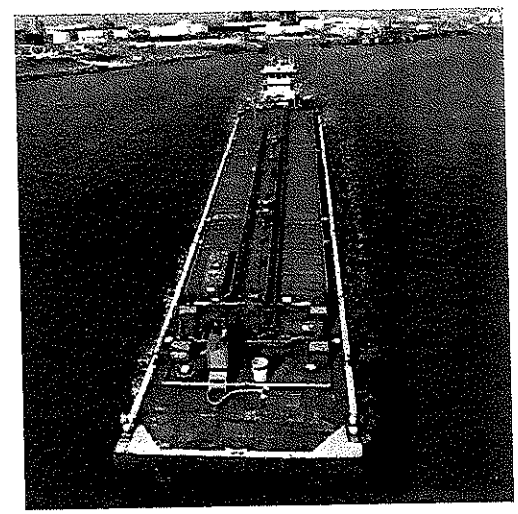
America's economy benefits from the cost efficiencies barge transport provides over transport by truck or rail. Approximately 60% of the nation's grain exports move by barge, helping our agricultural exports stay competitive in global markets. Barge transport also keeps our nation's vital energy sources flowing, fueling our industrial base and keeping our high-tech economy running. In fact, more than 22% of domestic petroleum and petroleum products and 20% of the coal used in electricity generation transit our inland waterways.

America's safe, reliable and efficient inland river transportation system is the envy of the world. With world-wide demand for waterborne commerce expected to more than double by the year 2025, our nation needs a strategic vision and must invest in the waterways infrastructure needed to maintain America's economic competitiveness.

GICA

GULF INTRACOASTAL CANAL ASSOCIATION

Serving Gulf Coast Inland Mariners Since 1905



Gulf Intracoastal Canal Association

PO Box 6846

New Orleans, LA 70174

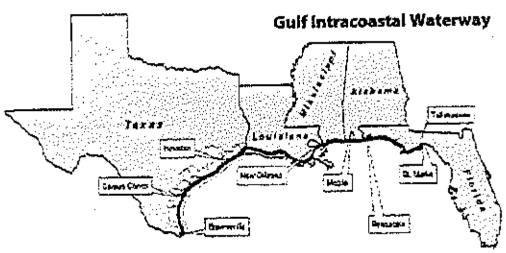
Tel: 901-490-3312

Web: www.gicaonline.com

Why The GIWW?

The Gulf Intracoastal Waterway (GIWW) is a 1300 mile inland system of channels and tributaries spanning the U.S. Gulf Coast from Brownsville, TX to St. Marks, FL. It is the third busiest inland waterway in our nation in terms of tonnage carried. Our members and others transport 116 million tons of commodities each year on the GIWW. This translates to close to $86 billion of cargoes moving on our waterway.

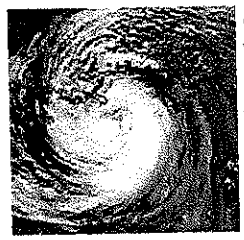
As a safe, efficient and environmentally responsible artery between ports in five Gulf states and the inland waterways to the heartland of our nation, the GIWW is critical to refiners and manufacturers who depend the waterway for reliable delivery of raw materials. Likewise, the GIWW carries much of the by-products and finished goods to Gulf distribution points. The very nature of the waterways offers distinct economic and environmental benefits to industry and contributes to the health of the nation's economy as well as our viability in the intensely competitive global market.



Recent increased petroleum traffic, due to oil shale drilling coupled with fracking operations, have combined to increase barge traffic and tonnage on the GIWW - more petroleum, sand and aggregates, in particular are moving now. This also translates into an increase in refined products. All are indicators that the critical nature of this key waterway is increasing.

Why GICA?

GICA acts as a single voice for the industries that utilize the Gulf Intracoastal Waterway. The Association advocates on behalf of our members, working closely with the US Army Corps of Engineers District Offices in Galveston, New Orleans and Mobile, to advocate for infrastructure is maintenance channel dredging to ensure a safe and reliable waterway. Additionally we partner with the Eighth Coast Guard District staff and all the Gulf Coast Sector offices to assure safe operations and aids to navigation are sustained.



GICA leads the Gulf Inland Waterways Joint Hurricane Response Team and maintains the Response Team Protocol. which outlines a coherent self-help program by which the can participate in post-storm efforts to clear the waterways and get traffic and commerce moving. GICA's work during pre-storm preparation is invaluable to mariners' and companies' storm planning efforts and greatly assists our Federal, state and local officials in making solid decisions regarding maritime safety and flood protection.

GICA stands the watch, identifying and reporting on GIWW conditions that can affect the mariner, shipper and cargo owners. GICA issues real-time Navigation Alert messaging to our members to ensure they know what's happening where. Also, through a partnership with PortVision GICA is able to provide a geographic representation of the status of the GIWW and key tributaries.

GICA provides a conduit for two-way communication between members and agencies. Through the Association, members have a forum to express their concerns and ideas to others in the industry, and collectively form a coalition of support for specific causes.

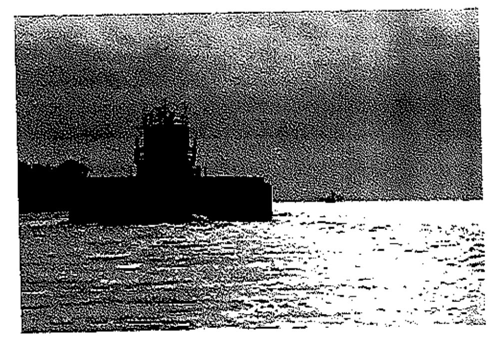
Supporting the waterway through GICA is a an investment in our future.

JOIN US!

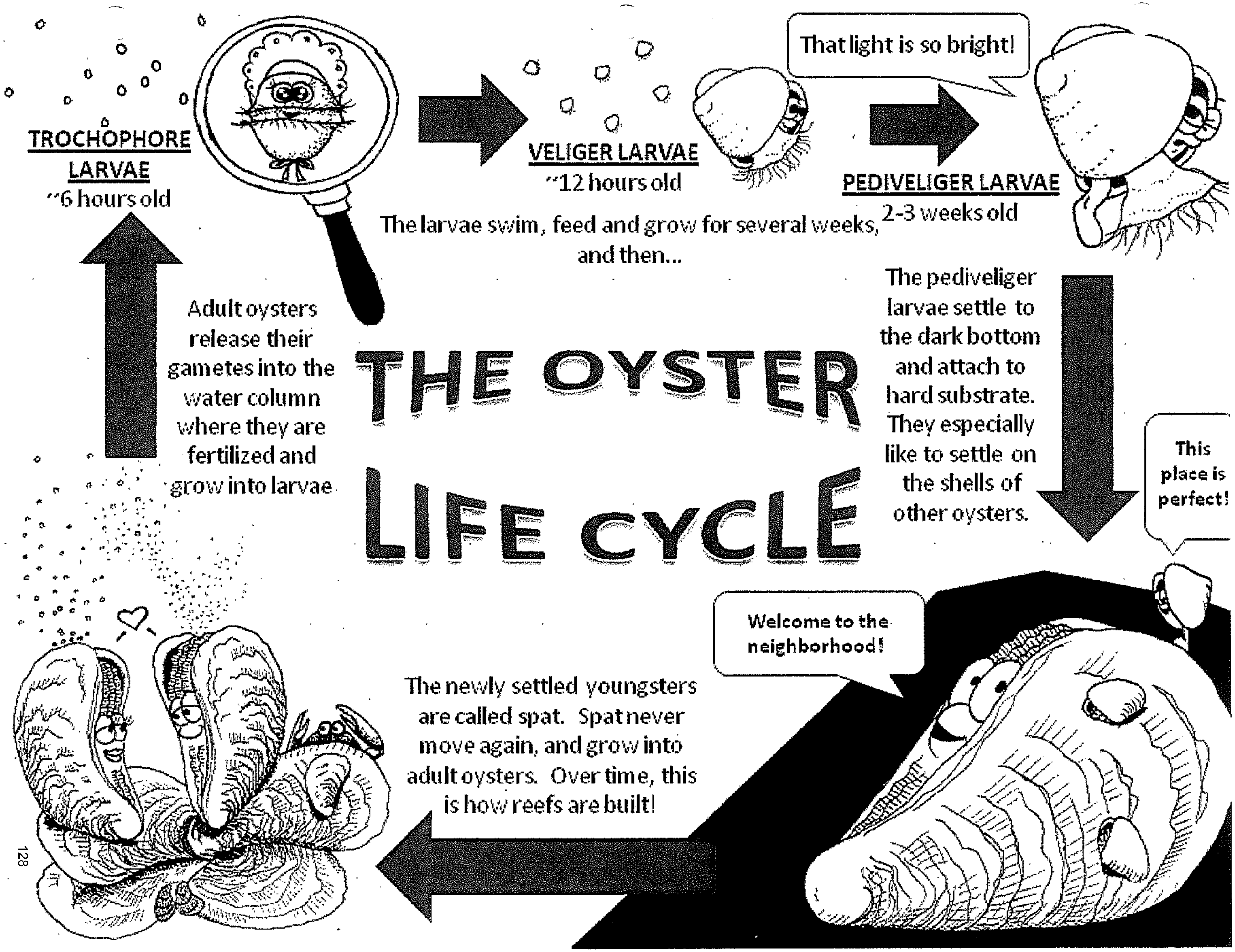
GICA membership is open to all. We presently serve members from tow and barge companies, shipyards, ports, shippers, agents, refineries, chemical plants, fuelers, government agencies, the general public and more. Dues are tailored to your business type and volume and help GICA to provide value and service to our industry.

For additional membership information or materials visit our website, or contact:

Executive Director,
Jim Stark, 901-490-3312
jstark@gicaonline.com



So, Who is GICA?


TROCHOPHORE LARVAE
~6 hours old
VELIGER LARVAE
~12 hours old
That light is so bright!
PEDIVELIGER LARVAE
2-3 weeks old
The larvae swim, feed and grow for several weeks, and then...
Adult oysters release their gametes into the water column where they are fertilized and grow into larvae
THE OYSTER LIFE CYCLE
The pediveliger larvae settle to the dark bottom and attach to hard substrate. They especially like to settle on the shells of other oysters.
This place is perfect!
Welcome to the neighborhood!
The newly settled youngsters are called spat. Spat never move again, and grow into adult oysters. Over time, this is how reefs are built!

A publication approved by the Texas Land Commissioner
pursuant to National Oceanic and Atmospheric Administration
Award No. NA12NOS4190164.

Seagrass Scarring

Background Information

Seagrasses are unique, marine, flowering plants of which there are approximately 60 species worldwide (den Hartog, 1970). With the exception of a few species that grow on rocky outcroppings, most grow in shallow, subtidal, or intertidal, unconsolidated sediment. In this type of substrate they perform many functions. Their major contribution is in holding the sediment together. Their roots and rhizomes are responsible for binding millions of acres of shallow water sediment (Fonseca, 1998). Seagrasses are unique among marine plants in their ability to bind shallow underwater sediments while simultaneously baffling wave and current with their leaf canopy (Fonseca et. al. 1983). By re-directing and slowing water flow, the canopy inhibits the re-suspension of fine particles and traps those already in the water, providing an effective and natural water column cleanser (Ward, 1984). When the water slows down, the particles drop out of the water column, and also prevent sediment from becoming re-suspended. The seagrass beds serve as a crude, but efficient mechanical filter for small particles in the water.

Not only do the seagrasses cleanse the water mechanically, cleansing also occurs by nutrient uptake and conversion. The seagrasses, as well as the associated epiphytes, take in these nutrients. Thalassia, with its long flat blades, provides an ideal location for epiphytes. One square meter of Thalassia may have a total surface area of up to 18 m2 (Taylor, 1973). The nutrients taken in by the plants are converted and used in the building of the plant biomass (Harlin, 1981).

Seagrasses occur in all coastal states in the United States, with the exception of Georgia and South Carolina. In these states, the freshwater inflow, coupled with high turbidity and tidal amplitude, combine to prevent the occurrence of seagrasses (Fonseca, 1998). A minimum of thirteen species are found in U. S. coastal waters, with five occurring in Texas (Fig. 1). In the Texas area, Halodule wrightii occurs in the shallower zones (1-2 feet), followed by Ruppia maritima. Thalassia testudinum intermixed with Syringonium fillaforme is found at depths of three to eight feet (Fig. 2). Halodule is the dominant species in the Texas coastal bend, with Thalassia dominant in the Redfish Bay area. Ruppia is found throughout the area, along with Halophila and Syringodium. In the upper Laguna Madre, Halodule is the most prevalent with no known Thalassia (Pulich et. al., 1997). Ruppia and Halodule are very tolerant of a wide range of salinities and temperatures. This explains their extensive distribution. Thalassia and Syringodium are not tolerant of salinities below 20 or above 35 parts per thousand. This makes them the least tolerant of the Texas species (Fig 2).

A definition of what constitutes a seagrass bed is difficult. They exhibit a variety of growth strategies and coverage patterns, and may range in size from many acre meadows to small patches (Fonseca, 1998). Not only is a definition difficult, but assessing a resource value for these areas also presents problems. Seagrass habitat value is best summarized as follows by Wood et. al. (1969):

1. Seagrasses have high growth and production rates;
2. The leaves support high numbers of epiphytic organisms with biomass approaching that of the seagrasses itself;

3. Although few organisms feed directly on them, seagrasses produce large quantities of detritus, which serves as a major food source for many species;
4. Seagrasses bind sediments and prevent erosion, in turn providing an acceptable environment in which many organisms can grow;
5. Seagrasses provide organic matter which encourages sulfate reduction and an active sulfur cycle;
6. Seagrasses act as nutrient sinks and sources.

It is difficult to monitor seagrass habitats. Different methods have been used; however, each has its own associated problems. One time surveys are inadequate, and data must be gathered seasonally for accurate results (Fonseca, 1998). Aerial photos are excellent ways to monitor, but cannot always be used. Lenses, film, solar angle, turbidity, wind, waves, and overall cost, cause difficulties. In aerial photography no standard altitude or field of view has been established. Ground truthing, through the use of boats, has its own set of problems, including reflectance, waves, turbidity, lack of large field of view, as well as possible damage to the area. Durako et. al., 1992, suggests going to a standard 1:24,000 (1in. = 2000 ft.) scale for aerial photography, as well as using a historical background for monitoring these areas.

Impacts to Seagrasses

Seagrasses are often impacted by human activity due to their location in the coastal zone (Fonseca, 1998). Because of their relative high light requirements, they occur in shallow, nearshore waters, making them susceptible to damage by human activity. Natural events can cause large and small-scale damage to seagrasses; however, human affairs now account for a majority of seagrass losses (Dawes, 1997). Destruction of seagrasses happens rapidly, in as little as a week or month, and recovery may take several growing seasons (Fonseca et. al., 1990). Much of the seagrass loss is related to human induced reduction of water transparency (Kenwothy and Haunert, 1991). Dredging and dredge disposal are responsible for much of this turbidity, as well as increased nutrient run off from residential and agricultural areas. The building of piers and docks causes another often-overlooked type of destruction. These structures block light from entering the water, and therefore, kill or severely limit the seagrasses. Onuf , 1996, and Dunton, 1996, have done extensive studies on the light requirements of seagrasses and have determined that quality light penetration is essential for successful seagrass habitats.

Although the loss of seagrasses due to dredging has been significant, it is likely that a majority of this loss is not a direct result of dredge and fill activities. More recently, direct impacts from mooring scars, propeller scars, jet skis, and vessel wakes are emerging as major sources of seagrass habitat loss (Fonseca, 1998). Scarring is defined as any destructive removal or disturbance of a seagrass bed, and can be caused when one or more of the following situations occur:

1. When boaters misjudge water depth and accidentally scar seagrass beds;

2. When boaters who lack navigational charts or the skill to use them stray from poorly marked channels and accidentally scar seagrass beds;
3. When boaters intentionally leave marked channels to make shortcuts through shallow seagrass beds;
4. When boaters carelessly navigate in shallow seagrass beds because they believe scars heal quickly;
5. When inexperienced boaters engage in recreational and commercial fishing over shallow seagrass beds, thinking that their boat's designed draft is not deep enough to scar seagrasses, or that the design will prevent damage to their boat;
6. When boaters overload their vessels, causing deeper drafts;
7. When boaters anchor over shallow seagrass areas and allow their boat to swing;
8. When boaters intentionally prop-dredge to form a new channel;
9. When inexperienced boaters, ignorant of what seagrasses are and the benefits they provide, accept as the norm local boating customs that disregard the environment (Sargent et. al., 1995).

As stated before, seagrass scarring is a direct result of the increased number of people venturing into theses shallow areas. In the past, boats were not designed to run in as shallow water as they are now. This, coupled with increases in prop design and technology, has been detrimental to the seagrasses. Early props were made of heavy brass or aluminum, and were easily bent or broken, thus limiting boats in the shallow areas. With the design of the stainless steel props with various blades and pitches, the shallow areas are now more accessible. The new stainless steel props are being advertised as being almost indestructible and able to go anywhere (Pers. Observ.)

When an area is scarred, it may take a long time to return, or it may never return. The seagrasses are responsible for holding the substrate together. When the area is disturbed, the substrate is many times re-suspended, and the area forms a "blowout". This blowout is an area of open sand that is adjacent to a vegetated area of seagrass. If there is moderate tidal action, the area may become enlarged, and may consume neighboring seagrass colonies (Pulich et. al., 1997).. With luck, the unvegetated area will undergo a succession of algae, followed by more rapid growing seagrasses (Fig 3). This may take many seasons, and some slow growing species such as Thalassia may never return. In the 70's a barge damaged a seagrass bed around Mud Island in Aransas Bay. In the disturbed area turtle grass never returned (Nessmith, 1980). Due to its slow growing nature, turtle grass is the most fragile seagrass found in the coastal bend. Thalassia grows from lateral rhizomes and once they are cut it takes ten months for it to generate a new apex from which it can begin to grow again (Kelly et. al., 1971). Rhizome damage and subsequent loss of reserve nutrients may reduce the ability to produce new blade tissue (Dawes and Lawrence, 1997). This type of damage does not affect shoal grass (Halodule wrightii) as severely. Shoal grass does not require a lengthy recovery period because the short shoot apical meristem can be converted to a rhizome apex (Tomlinson, 1974). Some variables that may affect recovery from scarring are: sediment composition, water quality, current velocity, wave and wind energy, drift algae, scar depth, seagrass species, water depth, and latitude (Sargent et. al., 1995).

Management

In Texas there has been little, if any, research conducted concerning prop scarring. The state of Florida is at the forefront of the seagrass scarring controversy, and has been studying the effects since the late 70's (Zieman, 1976). There have been extensive maps made showing the intensity of scarring in various areas. These areas are then classified into zones of light, moderate, or severely scarred (Fig 4). The state of Florida has also instigated a four-point approach to deal with seagrass scarring problems. This approach involves education, channel marking, enforcement of restrictions, and closure of areas (Sargent et. al., 1995).

Education

Education is necessary to inform all boaters, tourists, and residents of the sensitive nature of the seagrass community. There are many visitors as well as residents in coastal areas, and these individuals must be educated through boating classes, pamphlets, guides, and maps. Many organizations, including commercial fishermen, are behind these efforts.

Channel Marking

A more precise marking system is needed in these shallow areas. Gated or paired marks have been suggested for use in these areas; however, they do not conform to official USCG requirements, and special consideration must be made. An additional number of marks may also be used to prevent boaters from venturing into shallow areas.

Enforcement

Citations and warnings must be issued if an enforcement program is to be effective. Vessels observed operating in defined shallow areas will be fined, and can be prosecuted under law for destruction of state property.

Limited Motoring Zones

Idle speed or limited motoring zones could be used to protect sensitive resources, while allowing public access to these areas. This type of protection could be implemented in areas where damage has not occurred and is anticipated. In addition making an area “off limits” to combustion engines and allowing access only on foot or kayaks may also be effective.

Local Management Issues

There is interest in forming a management plan for seagrasses in areas of the coastal bend of Texas. With the exception of an “off limits” area in the Laguna Madre, there has been strong and vocal opposition by residents to such plans.

The major plan that recieved the most coverage was written and designed by Will Meyers and a committee created by him named the Aransas Aquatic Preserve Coalition. This proposal called for the closing of major portions of Redfish Bay and Estes Flats to combustion engine operation, and the formation of well marked “travel” lanes. The proposal was backed up with scientific information and was based on results from Florida’s plans. The proposal was presented to the public as a working model; however, many problems were encountered. The local issues of commercial fishing and tourism were not addressed in the proposal. The overall cultural differences were not researched, and were too broad to be accepted by the local citizens. Many heated debates and pointed newspaper articles resulted from this proposal.

I chose to interview three individuals in the community to comment on management strategies concerning seagrasses in the coastal bend. A local homeowner and fisherman, a game warden, and a commercial fisherman were chosen because of the different types of stakeholders they represent.

When I discussed the propscarring issue with a local homeowner, he became agitated and brought up the Aransas Aquatic Preserve proposal. He explained that older people, such as himself, would no longer be able to fish in Estes Flats because there was no way he or other older people could physically "pole" a boat across the big areas that would be closed under such a proposal. He also felt that the proposal was set up by kayakers to make the area their own private fishing area. He stated that this proposal is not the answer; however, he and others would support some "good science" in the area concerning seagrass scarring. He would like to see how severe the problem is, and form an opinion based on "local," not "Florida" science.

The next individual, a local game warden, gave an interesting view to the problem. He stated, "I feel that seagrass scarring is not only a problem for the grass but also for the people. There has been an increase of injuries on the water because people think that their boats are indestructible and run them aground throwing every one around and causing injuries. They should use common sense. You have to drive a car on the street just like you have to drive a boat in deep enough water." I explained a little about Florida's seagrass plans and asked for his comments. His concern was the enforcement of the law concerning violators. "We don't have enough people as it is, and prosecution would be very tough. I would much rather see things done to educate the public rather than give them another law that can not be enforced properly."

The last interview was quite colorful and had to be slightly edited. A local crab man who uses the area on a daily basis was chosen. He was concerned about the seagrass but felt that, as always, commercial fishermen were "getting the shaft". He stated, "My family depends on my catch. If I don't catch, we don't eat". He does not feel that there is a problem concerning the seagrass. "Hell, ducks tear up more of the stuff than a dozen outboards". He also likes the barren spots surrounded by seagrass. "They are the best spots and hold a lot of crabs". When asked what he would do if fishing were shut down in the area he replied, "I guess I would move someplace else; crabbing, shrimping, and fishing is all I know". I followed up by asking if he would support scientific studies on seagrasses in the area. "Yes, but they would probably find something wrong, and sure enough I'd get blamed for it."

In conclusion, seagrass beds are important habitats in bay systems. They are responsible for the great productivity found in the bays of the coastal bend. Increased fishing pressure in coastal areas has resulted in direct prop damage to shallow water seagrass communities, but has been poorly documented. Without restrictions on the use of power craft in shallow waters, prop damage will probably surpass dredge and fill activities as the primary threat to seagrasses (Dawes, 1997). If these seagrasses are not protected, overall production in the bays and estuaries will be severely affected. Following the precedent set by Florida, seagrass scarring is currently being researched in the coastal bend. There is a need for these studies and I feel that the public will encourage them. Education seems to be an excellent endeavor to pursue concerning seagrass scarring. Education is also not as controversial as closing fishing areas. Ultimately, getting stakeholders involved in all aspects of a management plan will be necessary in order for it to be realistic and effective. With proper planning and management, these seagrass areas will continue to thrive and contribute to the diversity of the coastal bend.

Bibliography

Dawes, C. J., J. Andorfer, C. Rose, C. Uranowski, N. Ehringer. 1997. Regrowth of the seagrass Thalassia testudinum into propeller scars. Aquatic Botany 59:139-155.

Dawes, C. J. and Lawrence, J. M. 1979. The effects of blade removal on the proximate composition of the rhizome of the seagrass Thalassia testudinum. Aquatic Botany 7: 255-266.

den Hartog, C. 1970. The seagrasses of the world. North-Holland Publishing Co., Amsterdam. 275 pp.

Dunton, K. 1996. Photosynthetic production and biomass of the subtropical seagrass Halodule wrightii Ashers. in relation to continuous measurments of underwater irradience. Marine Biology 120:479-489.

Durako, M.J., M. O. Hall, F. Sargent, and S. Peck. 1992. Propeller scars in seagrass beds: An assessment and experimental study of recolonization in Weedon Island State Preseve, Florida. Pp. 42-53 in Webb, F. (ed.), Proceedings from the 19th Annual Conference of Wetlands Restoration and Creation. Hilsborough Community College. Tampa, Florida.

Fonseca, M.S. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222 pp.

Fonseca, M.S. 1994. Seagrasses. A guide to planting seagrasses in the Gulf of Mexico. Texas A&M University. Sea Grant College Program Tech. Rept. TAMU-SG-94-601. College Station, Texas. 26 pages.

Fonseca, M.S., Meyer, D.L., Murphey, P.L., Kenworthy, W.J., Thayer, G.W., LaCroix, M.W. 1990. Performance of Lassing Park seagrass plantings. Contract Report to Florida Department of Natural Resources, St. Petersburg, FL, Nov. 30. 27 pp.

Harlin, M.M. 1980. Seagrass epiphytes. Handbook of seagrass biology—an ecosystem perspective. Garland STPM Press, New York. pp. 117-151.

Kelly, J. A. Jr., Fuss, C. M., Hall, J. R., 1971. The transplanting and survival of turtle grass Thalassia testudinum in Boca Ciega Bay. Florida. Fish. Bull. 69, 273-280.

Kenworthy, W.J., Haunert, D. 1991. The light requirements of seagrasses: proceedings of a workshop to examine the capability of water quality criteria, standards, and monitoring programs to protect seagrasses. NOAA Tech. Memo. NMFS-SEFC-287.

Nessmith, C. 1980. Natural and induced revegetation processes in an artificially disturbed seagrass meadow in Texas. M.S. Thesis, University of Texas. Austin, Texas. pp. 259-317.

Onuf, C. P. 1996. Seagrass responses to long term light reduction by brown tide in the upper Laguna Madre, Texas: distribution and biomass patterns. Marine Ecology Progress Series 138:219-231.

Pulich, W., Jr., C. Blair, and White, W.A. 1997. Current status and historical trends of seagrasses in the Corpus Christi Bay National Estuary Program study area. Final Project Report, Corpus Christi National Estuary Program, Corpus Christi, Texas.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. Scarring of Florida's Seagrasses: assessment and management options. FMRI Tech. Rep. TR-1. Florida Marine Research Institute, St. Petersburg, Florida. 37 p. plus appendices.

Taylor, J.L. 1973. Harvest and regrowth of turtle grass (Thalassia testudinum) in Tampa Bay, Florida. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 71(1): 145-148.

Tomlinson, P. B., 1974. Vegetative morphology and meristem dependence – The foundation of productivity in seagrasses. Aquaculture 4, 107-140.

Ward, L.G., W. M. Kemp, and W. R. Boynton. 1984. The influence of waves and seagrass communities on suspended particulates in an estuarine embayment. Marine Geology 59:85-103.

Wolfe, S. H., J. A. Ridenauer, and D. B. Means. 1988. An ecological characterization of the Florida panhandle. USFWS Biol. Rep. 88(12), MMS OCS Study\MMS 88 -0063. 277 pages.

Wood, E.J.F., and J.C. Zieman. 1969. The effects of temperature on estuarine plant communities. Chesapeake Sci. 10: 172-174.

Zieman, J. C. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. Aquatic Botany 2:127-139.

Zieman, J. C. 1982. The ecology of the seagrasses of south Florida: a community profile. USFWS Off. Biol. Serv. FWS/OBS-82/25. Washington, D.C. 158 pages.

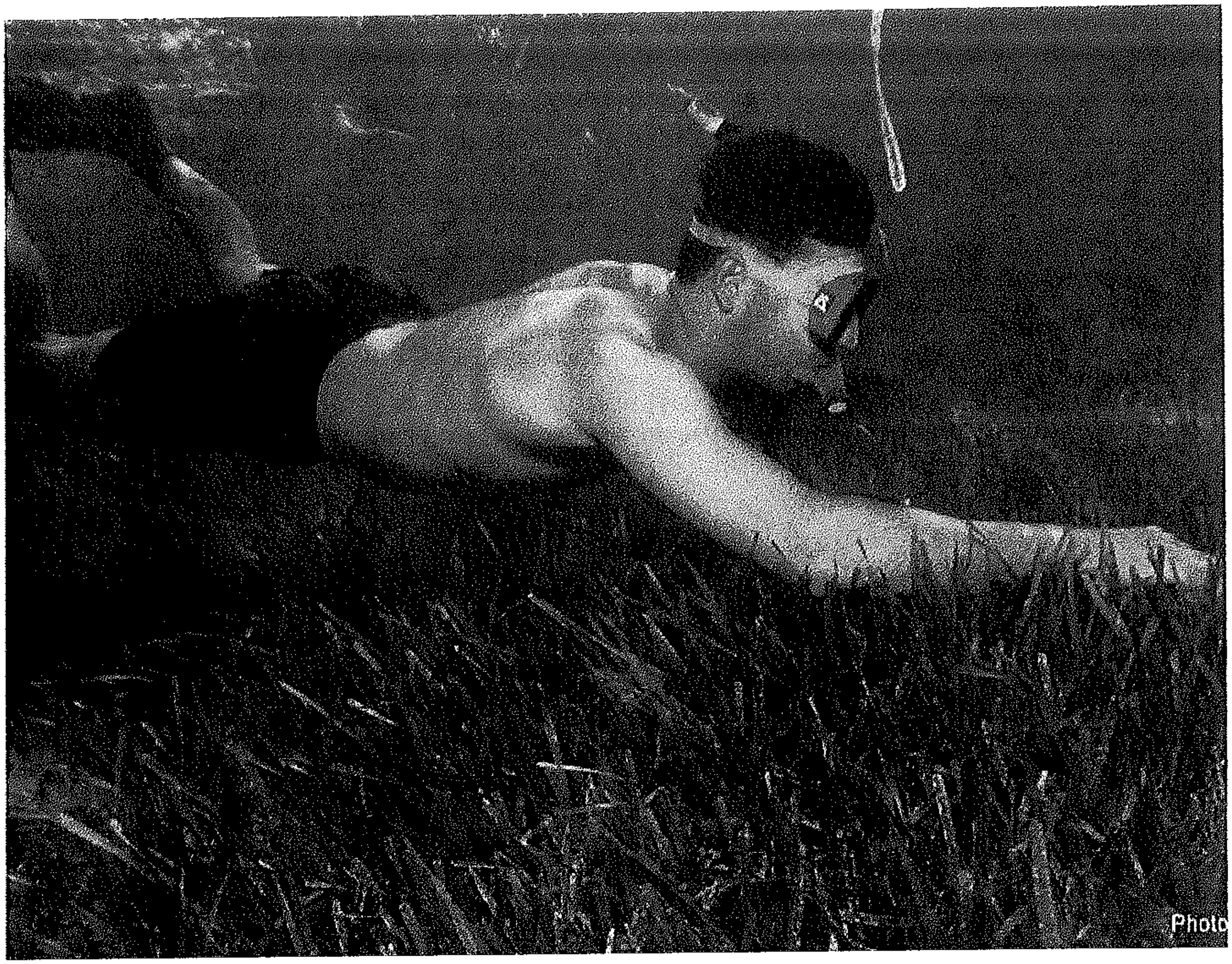
Texas Seagrass Guide

From: http://texasseagrass.org/TxSeagrasses.html

Information About Seagrasses

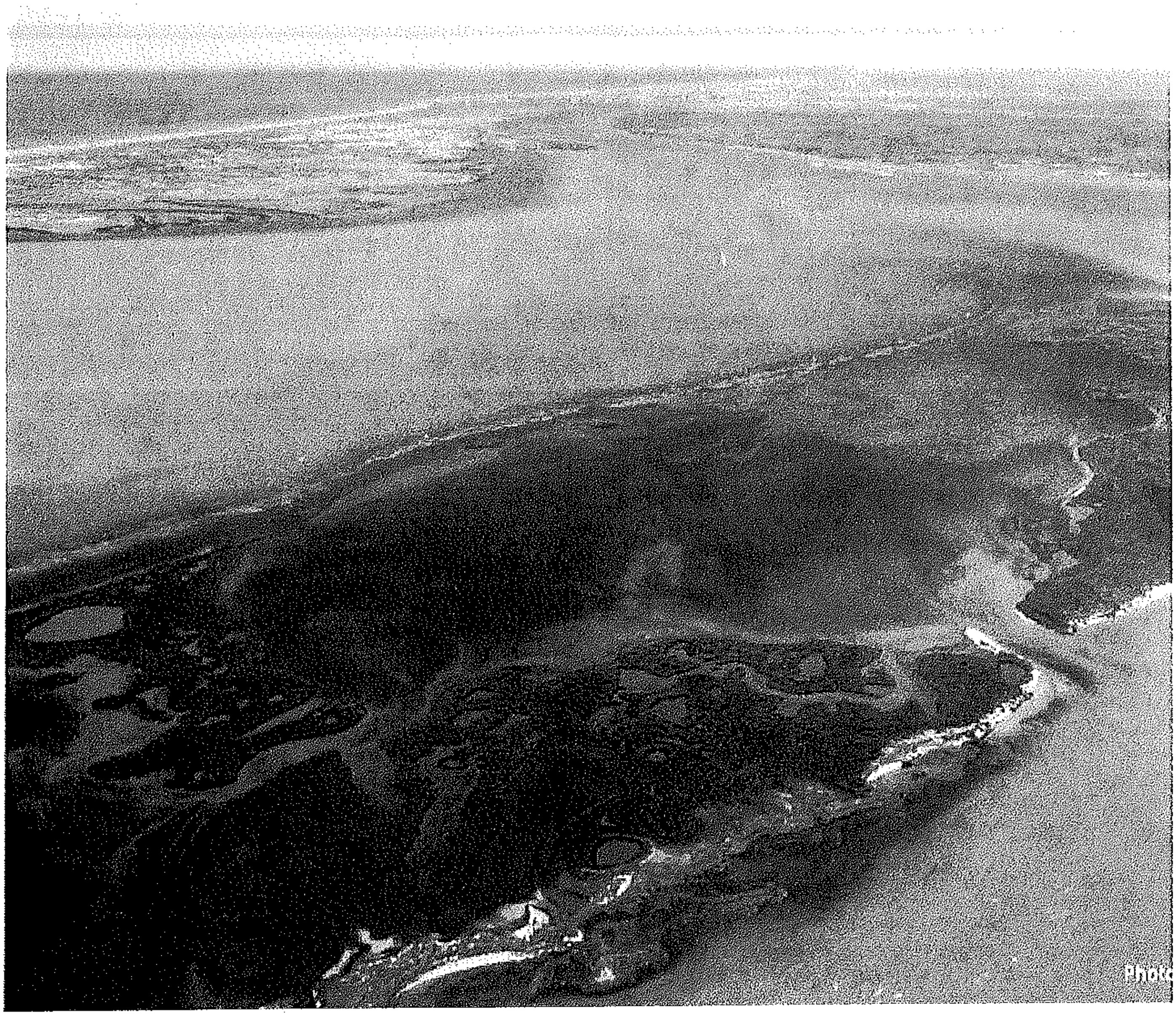
What Are Seagrasses?

Seagrasses are flowering plants that are specially adapted to live fully submerged in saline environments. They form carpets of rooted vegetation on the seabed, referred to as meadows or beds. Seagrasses, like terrestrial plants, require water, nutrients, and light in order to grow. Their high light requirements restrict the depth at which they can grow; therefore, underwater light availability is often the limiting factor restricting seagrass survival. For this reason, seagrasses are usually found in shallow waters where they are able to receive ample quantities of light and nutrients. In Texas, several studies have clearly delineated that their minimum light requirements hovers at about 18% of surface irradiance. Seagrasses are generally found within calmer waters, protected from wind and wave action. In Texas, seagrasses are found within the sheltered, shallow coastal bays, but in other parts of the world they can be found offshore in shallow shelf waters.



A snorkeler in a turtle grass (*Thalassia testudinum*) meadow in Lower Laguna Madre, Texas

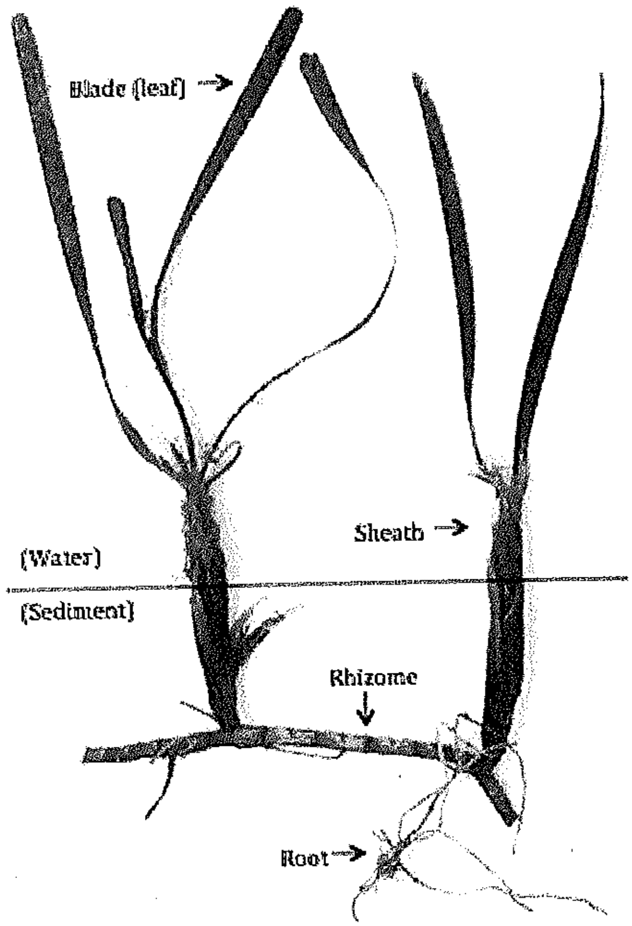
A turtle grass (*Thalassia testudinum*) meadow in Redfish Bay, Texas



Aerial photograph of seagrass meadows in East Flats, Texas

Seagrass Morphology

Seagrasses anchor themselves to the sediment using rhizomes, which are oriented horizontally several centimeters beneath the sediment surface. Smaller roots extend outwards from the rhizome. Similar to terrestrial plants, the sediments beneath seagrass meadows are densely packed with extensive rhizome networks. In fact, 60 to 80% of seagrass biomass is locked in belowground tissues, which helps stabilize the plants and allows for nutrient uptake. Seagrass leaves form within individual shoots, bundled in thin protective sheaths that grow vertically upwards from the rhizome.



Anatomical diagram of a seagrass plant

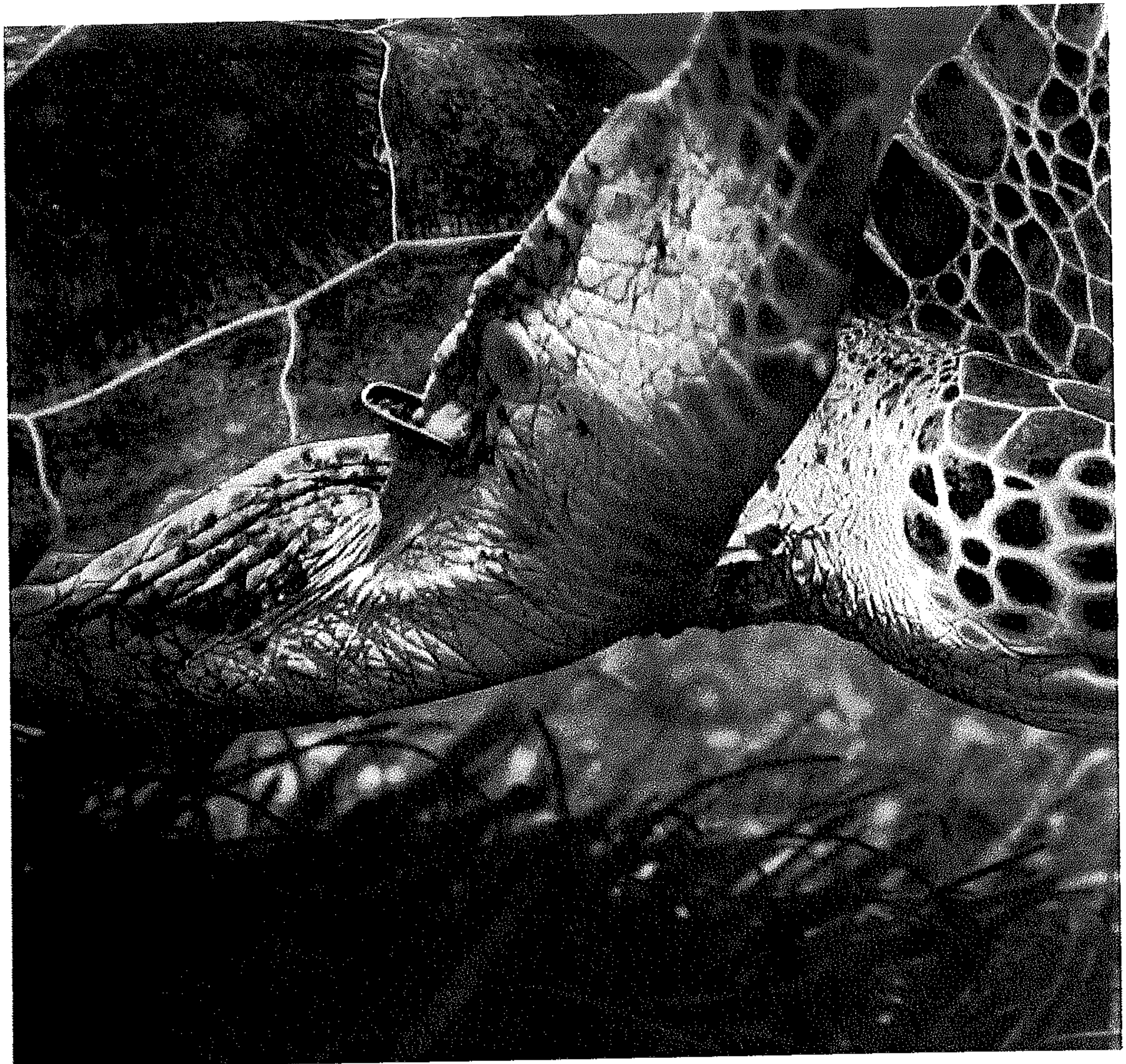
Why Are Seagrasses Important?

Seagrasses play a pivotal role within marine habitats and provide a plethora of services that benefit both the coastal ecosystem and human populations. Seagrasses are:

- Efficient primary producers that convert sunlight and carbon dioxide into usable organic forms, serving as carbon reservoirs
- Sediment stabilizers, whose rhizome networks promote sedimentation and whose canopies attenuate wave action, helping prevent coastal erosion

- Utilized as a food source for many marine organisms and constitute the base of numerous marine food webs
- Provide both substrate and shelter, serving as nusery habitats for many commercially and recreationally important estuarine species (e.g. red drum)
- Frequently used as a measure of estuarine health, since they can maintain or improve water quality by promoting sediment accretion and filtration of excess nutrients from the surrounding water column

Aside from the invaluable services that seagrass provide, they also play a vital role within the Gulf coast economy. The Texas coast is a destination for recreational fishermen and tourists, and seagrass meadows experience heavy boat traffic, particularly in the summer. Recreational fishermen contribute to local economies by means of lodging, charters, marinas, and purchasing tackle. Not only do seagrass meadows play a role in the recreational fishing industry, but they support commercial fisheries as well. Life within seagrass beds can be easily observed while snorkeling, providing a unique opportunity for tourists; enhanced water clarity allows admirers to observe marine fauna within their natural, undisturbed environments. Consequently, tourism, commercial, and recreational fishing are important sources of revenue for local coastal economies.



A green turtle (*Chelonia mydas*) munches on turtle grass (*Thalassia testudinum*) in Akumal Bay, Mexico

Threats to Seagrass Communities

Seagrass habitats provide countless functions that benefit human and marine populations alike, but what would happen if they were to disappear? The two main factors that threaten seagrasses and their overall health include: 1) environmental disturbances, and 2) anthropogenic impacts.

Natural Environmental Disturbances

Natural disturbances occur when severe wind or wave action result in increased turbidity and erosion of seagrass beds. Hurricanes, large storms, and damaging currents can uproot seagrasses completely. Other climatic factors that may result in seagrass habitat loss include modification of the local salinity regime (e.g. from too much or too little freshwater inflow). Most of these natural disturbances are short-lived or ephemeral events and seagrasses generally rebound quickly from these circumstances compared to human induced influences.

Anthropogenic (human induced) Impacts

Anthropogenic impacts may result in seagrass habitat loss both directly and indirectly. The greatest anthropogenic threats to seagrasses are: nutrient enrichment, urbanization, dredging and channeling, and commercial and recreational boating.

Nutrient enrichment (eutrophication) occurs when there is an additional input of nutrients, such as nitrogen or phosphorus, into watersheds that drain into coastal lagoons and bays. These nutrients may be introduced directly from an industrial pipe or a wastewater facility or indirectly via storm water or agricultural runoff. Excessive nutrient conditions are optimal for promoting and supporting rapid algal growth within surface waters. These dense algae blooms can outcompete benthic seagrasses for sunlight and reduce water clarity. Lower light penetration to the seagrass canopy results in a decrease in net photosynthesis, reduced seagrass biomass, and an overall decline in seagrass health.

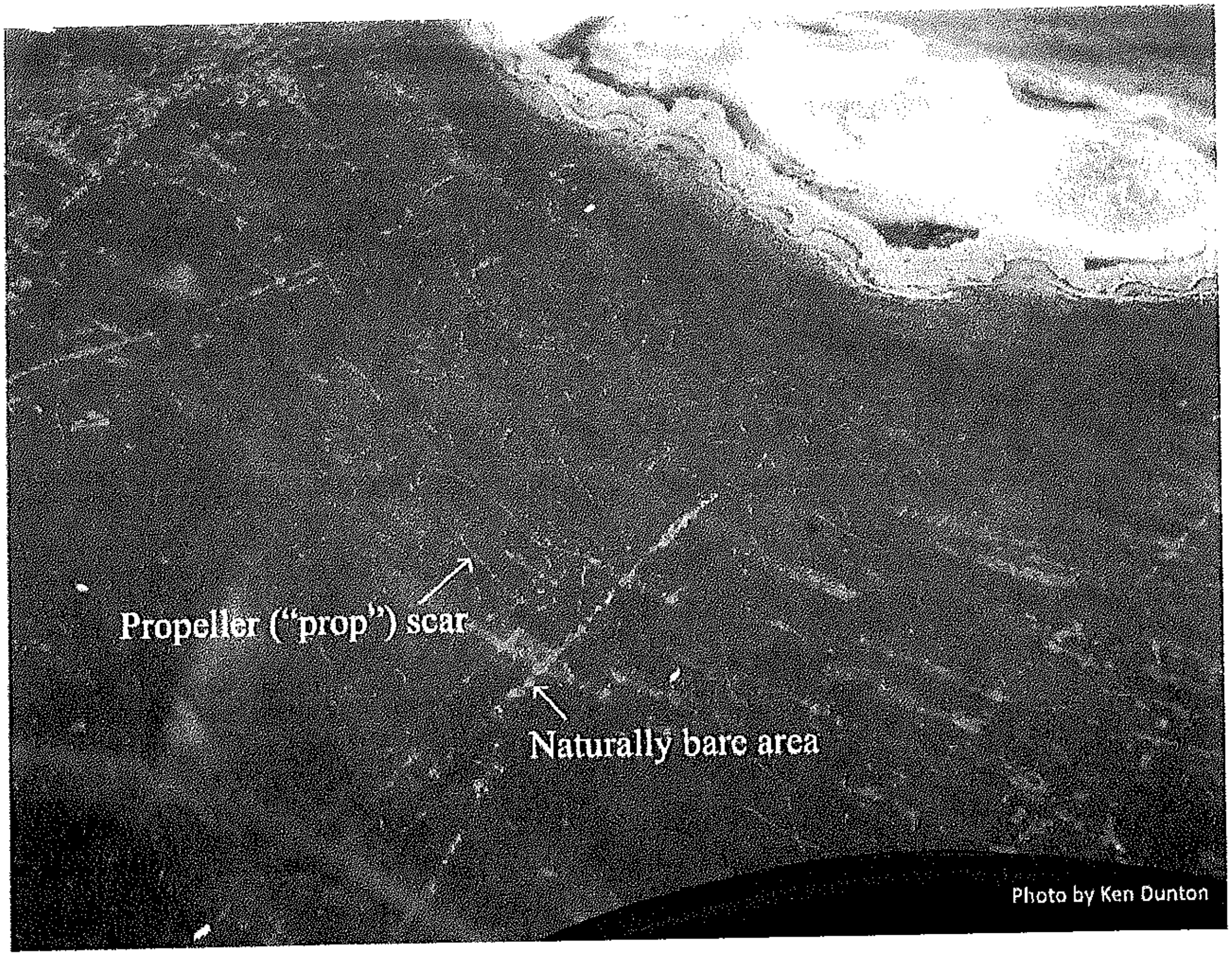
Macroalgae (*Digenia simplex*) smothers a seagrass (*Thalassia testudinum*) meadow in Lower Laguna Madre

Macroalgae (*Padina sp.*) sits on top of seagrasses (*Thalassia testudinum*) and blocks them from downwelling light

Urbanization can result in seagrass loss by physically altering coastal habitats or increasing impervious cover; these changes can lead to increased nutrient loading within coastal systems. As coastal communities continue to grow and develop, demand for more groins, jetties, and seawalls will increase. These structures alter hydrology patterns, potentially resulting in current flow or wave action redirected to seagrass habitats that are not capable of tolerating these conditions.

Dredging is a prominent activity along the Texas coast, especially along the Gulf Intracoastal Waterway and within numerous passes and inlets that must be maintained for shipping and boating activities. Dredging can either physically uproot seagrasses from the sediment, or bury seagrasses with sediment. In addition to burial, dredging results in increased sediment loading into the water column, resulting in increased turbidity and reduced water clarity. Dredged channels can also alter hydrodynamic regimes within bays and estuaries.

Finally, commercial and recreational boating activities can pose a threat to seagrass habitats. Commercial fishing vessels that utilize bottom trawls or dragging techniques damage the seabed. Seagrasses residing in these locations may be physically removed, and remaining roots and rhizomes destabilized and subject to increased erosion that slows recolonization of the disturbed area. Deep seagrass beds subject to propeller scaring can take up to 10 years to return back to their original healthy state. For information about the "Lift, Drift, Pole or Troll - Protect Texas Seagrass", please visit the TPWD website.



Propeller ("prop") scars are common physical disturbances to seagrass beds resulting from small boats

Seagrasses in Texas

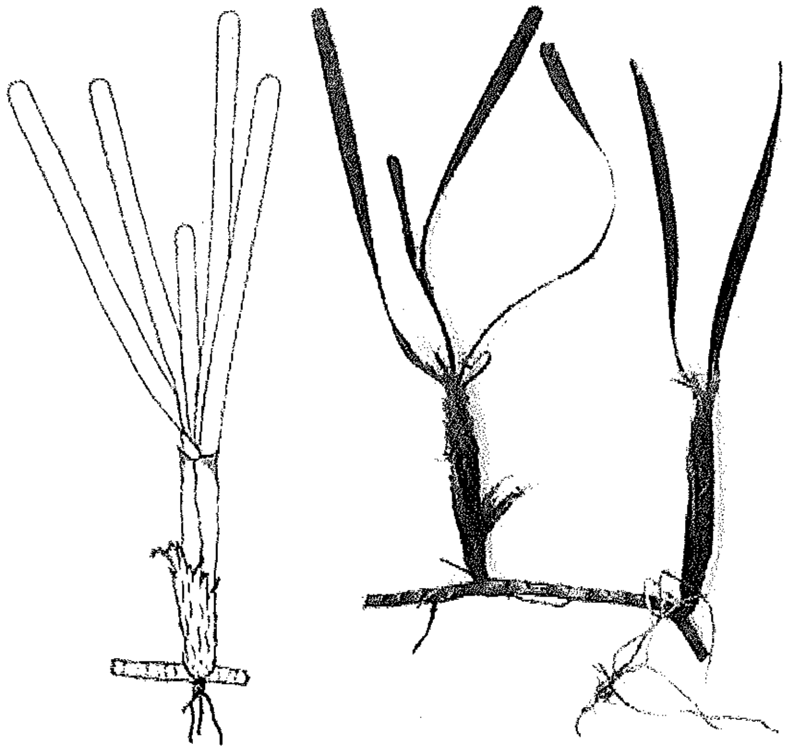
Texas seagrass beds are vital in maintaining vibrant and healthy coastal marine ecosystems. Seagrass meadows provide critical nursery habitat for many coastal fauna including flounder, redfish, speckled trout, blue crab and shrimp. These are harvested both commerically and by sports fisherman. These species, along with their primary food sources (microscopic algae, polychaete worms, small crustaceans, and other small invertebrates), are abundant in seagrass meadows. Although more than 50 seagrass species can be found around the world, six species are common within the Gulf of Mexico. Five of these six species can be found along the Texas coast, including the two most common species, shoal grass (*Halodule wrightii*) and turtle grass (*Thalassia* *testudinum*), and three others, manatee grass (*Syringodium filiforme*), widgeon grass (*Ruppia maritima*), and star grass (*Halophila engelmannii*).

Shoal grass (*Halodule wrightii*)

Left: modified from Phillips and Menez (1988); Right: photo by Ken Dunton

Shoal grass leaves are thin, flat and tinsel-like, typically 10-30 cm in length. Shoal grass occupies a wide range of salinities, and is often characterized by having large, dense beds (meadows). Shoal grass is an efficient colonizing species, engineered to colonize and proliferate on disturbed, wave dominated, or shallow water areas. Shoal grass roots and rhizomes are consumed extensively by migrating waterfowl during the winter months, including redhead ducks (*Aythya americana*). Floating wracks of senescent *Halodule* leaves are a major consequence of these grazing activities. When *Halodule* is pollinated, tiny, egg-like black seeds become buried within the sediment acting as a seed reserve. The roots and rhizomes of this pioneer species aid in sediment stabilization, ultimately prompting the succession of climax species such as turtle grass or manatee grass.

Turtle grass (*Thalassia testudinum*)



Left: modified from Phillips and Menez (1988); Right: photo by Ken Dunton

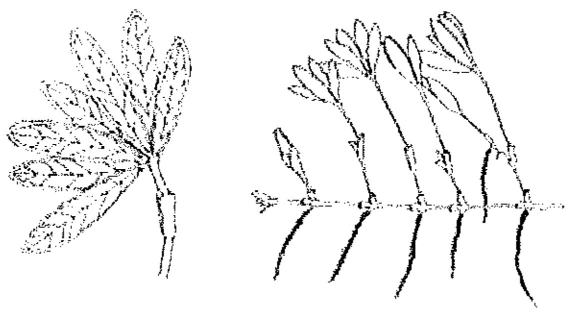
Turtle grass can be easily recognized by its distinctive blade structure. Blades are wide, flat, and ribbon-like, typically 20-50 cm in length. Leaves may be brightly colored green or appear brown, encrusted with tiny organisms called epiphytes. Turtle grass prefers high salinity water in areas buffered from intense wave action. Successful pollination results in buoyant green fruits, which are dispersed by currents. A dense network of carbon-rich roots and rhizomes provide sediment stabilization and accretion. This extensive network creates continuous, carpet-like meadows. Turtle grass received its common name from the herbivorous green sea turtles (*Chelonia mydas*) that graze prolifically on newly emerging leaves.

Manatee grass (*Syringodium filiforme*)

Left: modified from Phillips and Menez (1988); Right: photo by Ken Dunton

At first glance, manatee grass appears to resemble shoal grass. Further inspection yields blades that are tough and cylindrical in shape, culminating in a rounded and blunt tip. *Syringodium* blades can be upwards of 50 cm in length. The roots and rhizomes of this species do not penetrate deeply into the sediment and are easily uprooted. Manatee grass is usually found in mixed beds alongside turtle and/or shoal grasses, or may be found in monospecific patches. Manatee grass received its common name from the manatee, which is known to graze extensively on seagrass, particularly *Syringodium*.

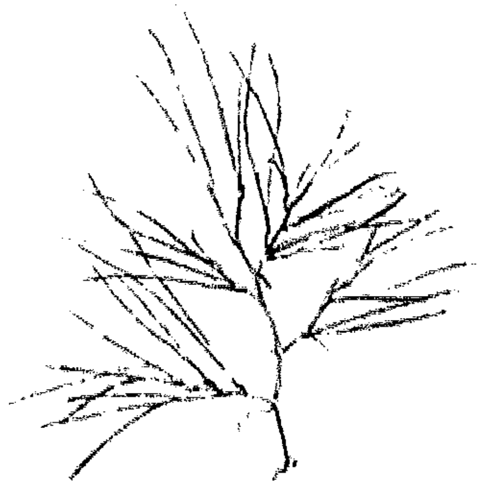
Star grass (*Halophila engelmannii*)

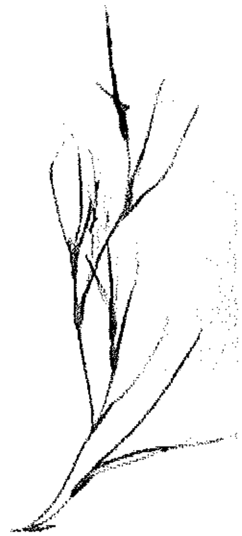


Left: modified from Phillips and Menez (1988); Right: photo by Ken Dunton

Star grass (sometimes called clover grass) is unique in the way that the blades are oriented into a star-like whorl. These whorls generally consist of 4-8 elliptical and finely serrated leaf blades. Star grass is a relatively small plant, rarely exceeding 10 cm in length. It is generally found in sandy or muddy substrates within sheltered and deeper waters. This species is more shade tolerant than most seagrasses, often occurring as an understory species within mixed seagrass beds.

Widgeon grass (*Ruppia maritima*)





Left: modified from U.S. Fish and Wildlife Service (https://www.flmnh.ufl.edu/fish/southflorida/seagrass/profiles.html); Right: photo by Ken Dunton

Widgeon grass grows in a tremendous range of salinities, including fresh, brackish and saline waters. It has been observed in Baffin Bay, Texas at salinities exceeding 100. *Ruppia* is generally found in the soft sediments of wind-protected lagoons and bays. This species closely resembles shoal grass but can be distinguished at maturity by its morphology. Widgeon grass has multiple slender, threadlike blades that protrude in an alternating fashion along the stem. These blades appear bushy and fan-like. Root and rhizome structures do not form thick, extensive mats making them easy to uproot. *Ruppia* rhizomes are also consumed by migrating waterfowl.

What is a Wetland?

Simply stated, wetlands are a part of our landscape that is defined by the presence of water. More specifically, wetlands are areas where the presence of water determines or influences most, if not all, of an area's biogeochemistry – that is, the biological, physical, and chemical characteristics of a particular site.

Wetlands typically represent transitional zones between upland and aquatic ecosystems, although not always. Some wetlands may be scattered across the landscape in depressions that collect water or zones where groundwater surfaces.

Different types of wetlands can be characterized by how much water is found and when it occurs on a site, and the chemical nature of the water, soils, and/or underlying bedrock of the wetland ecosystem. Different plant communities may be found in different types of wetlands, with each member species adapted to the local hydrology, including the spatial and temporal distribution of water and its underlying chemistry. Many animal, fungal, and microbial species are completely dependent upon wetlands for critical stages in their lifecycles, while still other species choose to make use of wetlands for many of their life's activities.

Defining Wetlands

Although we can readily describe wetland characteristics and what they do, in practice there has been a great deal of difficulty in defining specifically what constitutes a wetland. A workable definition became critical in classifying habitat for legal purposes, especially in regard to determining what lands are protected by state and federal legislation. The U.S. Fish and Wildlife Service defined wetlands as follows in Classification of wetlands and deepwater habitats of the United States (Cowardin et al., 1979):

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water... Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is saturated

with water or covered by shallow water at some time during the growing season of each year.

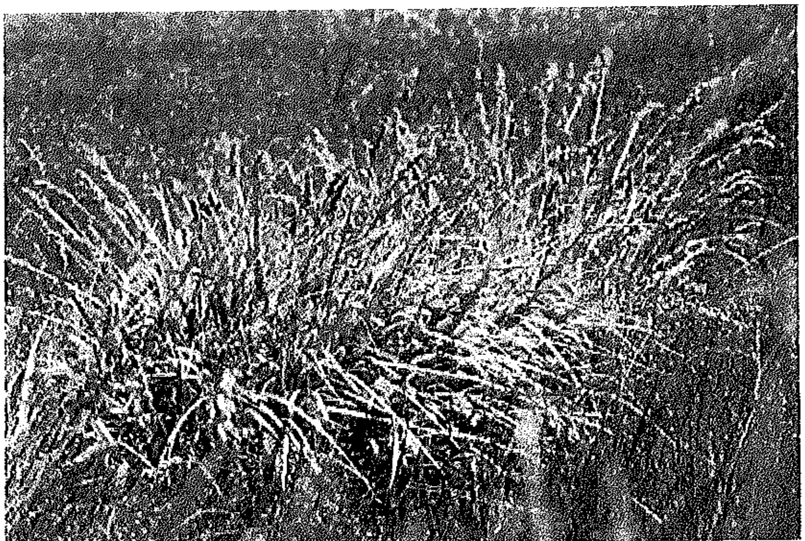
The U.S. Army Corps of Engineers, the federal agency responsible for enforcing federal laws protecting wetlands, has more recently determined that in order for an area to be considered a wetland, it must have all three of the attributes referenced above, i.e., the area must be predominantly characterized by wetland vegetation, soils, and hydrology.

Types of Wetlands

There are many different types of wetland, each determined by its hydrology, water chemistry, soils, and the predominant plant species found therein. Some wetlands are permanently flooded, while others are only seasonally flooded, but retain saturated soils throughout the unflooded periods. Still other wetlands may or may not ever be flooded, but maintain saturated soil conditions long enough for hydric soil characteristics to develop, i.e., chemical changes in the soil resulting from the low oxygen conditions associated with prolonged saturation. Wetlands may be characterized as dominated by trees, shrubs, or herbaceous vegetation. They may be fed by precipitation, runoff, or groundwater, with water chemistry ranging from very acidic to alkaline.

Marshes are wetlands that are permanently flooded or flooded during high water periods at the edges of rivers, streams, lakes, or ponds. Marshes may be dominated by submersed, floating-leaved, or emergent vegetation, including cattails, pondweeds, water lilies, and various sedges, rushes, spike rushes, grasses, and other forbs. Marshes can be subcategorized into emergent marsh and hemi marsh.

- **Emergent marsh** is the marsh found around shorelines out to relatively shallow water, and is generally characterized by up to 100% cover with emergent plant species. In the Midwest, these may consist of various graminoids such as river bulrush and rice cut grass, and characteristic forbs such as purple false foxglove, nodding bur marigold, pickerel-weed, and duck potato. These marshes are ideal habitat for a wide range of animals, including raccoons, Great Blue Herons, and a multitude of dragonflies, butterflies, and other insects. Emergent marshes also provide critical habitat for rare amphibians and reptiles, such as the plains leopard frog and Blanding's turtle. In the marsh habitat around Hennepin and Hopper lakes, one can observe breeding populations of rare bird species such as the Yellow-headed Blackbird and the Least Bittern, both of which are state-threatened.
- **Hemi marsh** is found in deeper water, and is characterized by an open mix of emergent and/or floating-leaved vegetation interspersed with a submersed plant community. The submersed community may consist of species like sago pondweed, coontail, and wild celery, while the emergent or floating-leaved group may include deeper water species like broad-leaved cattail, American lotus, mosquito fern, white water lily, and common bur reed. The combination of emergents and floating-leaved species with open water creates an ideal combination of food and cover for many aquatic-dependent birds and amphibians. American Bitterns and Great Egrets comb these areas in hunting, while Common Moorhens and Pied-billed Grebes use them as areas to nest and rear their young. The rich vegetation also provides exceptional habitat for fish and is a great production area for the zooplankton and insects that are a critical part of the site's intricate food web.



Sedge meadows (or wet meadows) are wetlands with permanently or near-permanently saturated soils. They may form a transitional zone between marshes and other wetlands with less saturated soils, or occur in wet depressions and swales, or around groundwater discharge zones. The meadows are wet grasslands often dominated by sedges and grasses with relatively few forbs. They may be low in species diversity (with as few as a single dominant species), but relatively rich in some of the rarer species adapted to saturated soil conditions. There are very many sedge species, with characteristic dominants including the lake sedge, tussock sedge, or brown fox sedge. At the Dixon Waterfowl Refuge, various rare and conservative sedges may be found, such as the brown bog sedge, fringed sedge, common yellow lake sedge, and Bebb's oval sedge, along with fringed brome and oval-stem spike rush. Birds frequenting this habitat include the King Rail, Sandhill Crane, Northern Harrier, and Sedge Wren. Reptiles such as the northern water snake and amphibians like the pickerel frog and cricket frog are also common.

Wet prairie is an ecosystem found across much of the Dixon Waterfowl Refuge at Hennepin & Hopper Lakes between sedge meadows and mesic prairies. Wet prairies are herbaceous wetlands dominated by a mixture of graminoids (grasses and sedges) and forbs, such as little bluestem, northern dropseed, prairie indian plantain, marsh phlox, and foxglove beardtongue. Wetland areas that are intermediate between wet prairie and mesic (dry) prairie can be characterized as wet-mesic prairie, the driest type of wetland in the Midwest. Animals that may be found in wet prairies include Henslow's Sparrows, Short-eared Owls, eastern hog-nosed snakes, and coyotes.

Fens and seeps are wetlands that are fed by surfacing groundwater. The type of vegetation found within these wetlands is dependent upon the water chemistry and pH.

- **Fens** are typically alkaline from groundwater emerging from calcareous or dolomitic soils or bedrock zones, and many of the species found there can only grow under those conditions. Fens are dominated by herbaceous vegetation such as grass of Parnassus, bog lobelia, or beaked spikerush, but may also include trees or shrubs, such as various shrubby cinquefoils and/or willows.
- **Seeps** are typically found along the base of slopes or glacial moraines where water emerges from saturated soils or a spring. These usually small areas consist of plant such as clearweed, jewelweed, low nutrush, and marsh marigold.

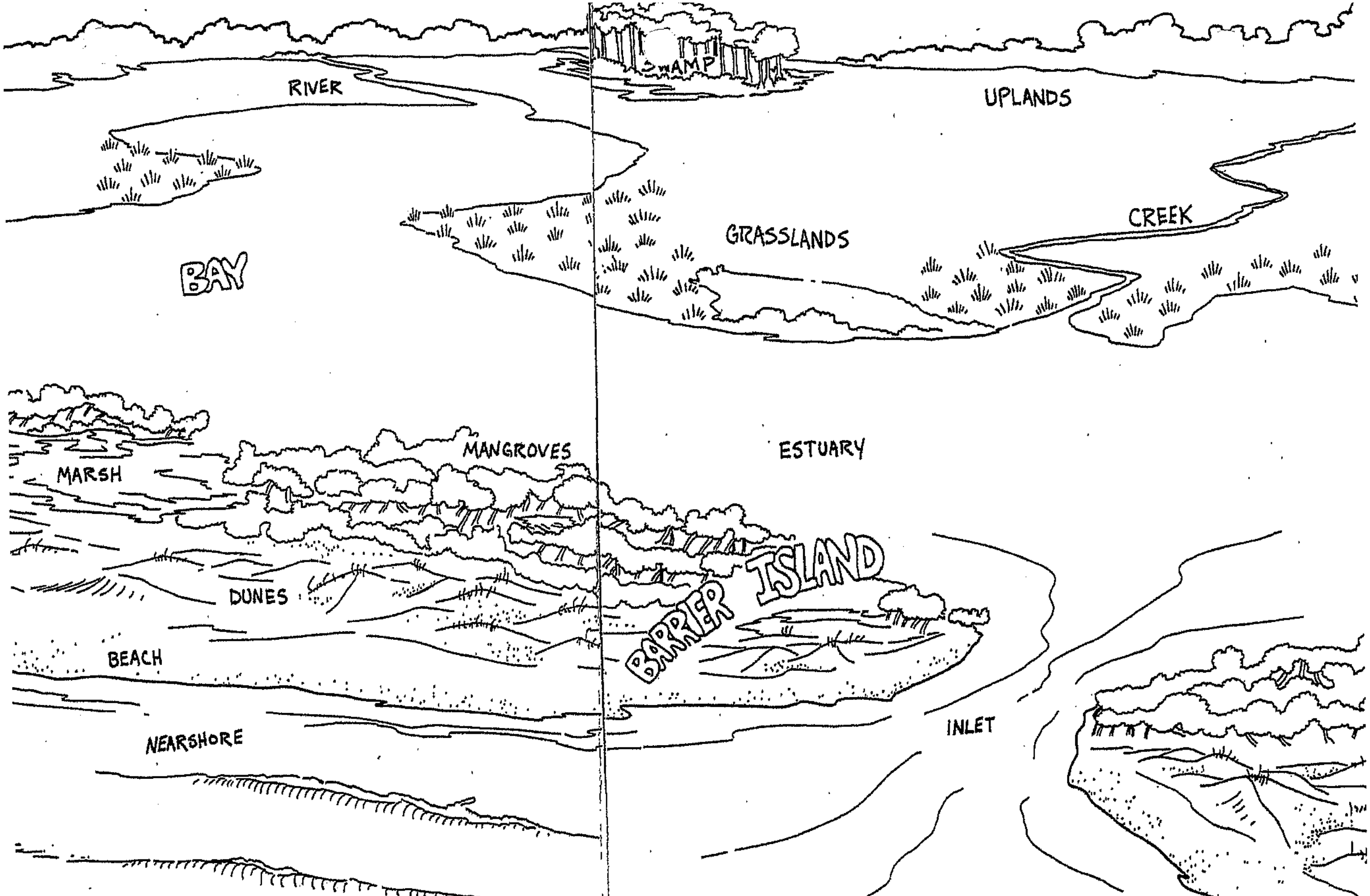
Bogs are basin wetlands for which precipitation is the only source of water, i.e., they are typically not fed by surfacing groundwater or streams. Bogs are generally dominated by sphagnum mosses, which may form a floating mat over deeper water that supports a rich assortment of other species adapted to acidic water conditions. Sphagnum mosses acidify the water down to pH levels as low as 3.0, comparable to that of acid rain. Some of the unique plants adapted to these acidic conditions include some of the carnivorous plants such as the sundews and pitcher plants, as well as such economically important species as blueberry and cranberry.

Sources:

Chicago Region Biodiversity Council. 1999. *Chicago Wilderness Biodiversity Recovery Plan*. Chicago Region Biodiversity Council, Chicago, IL.

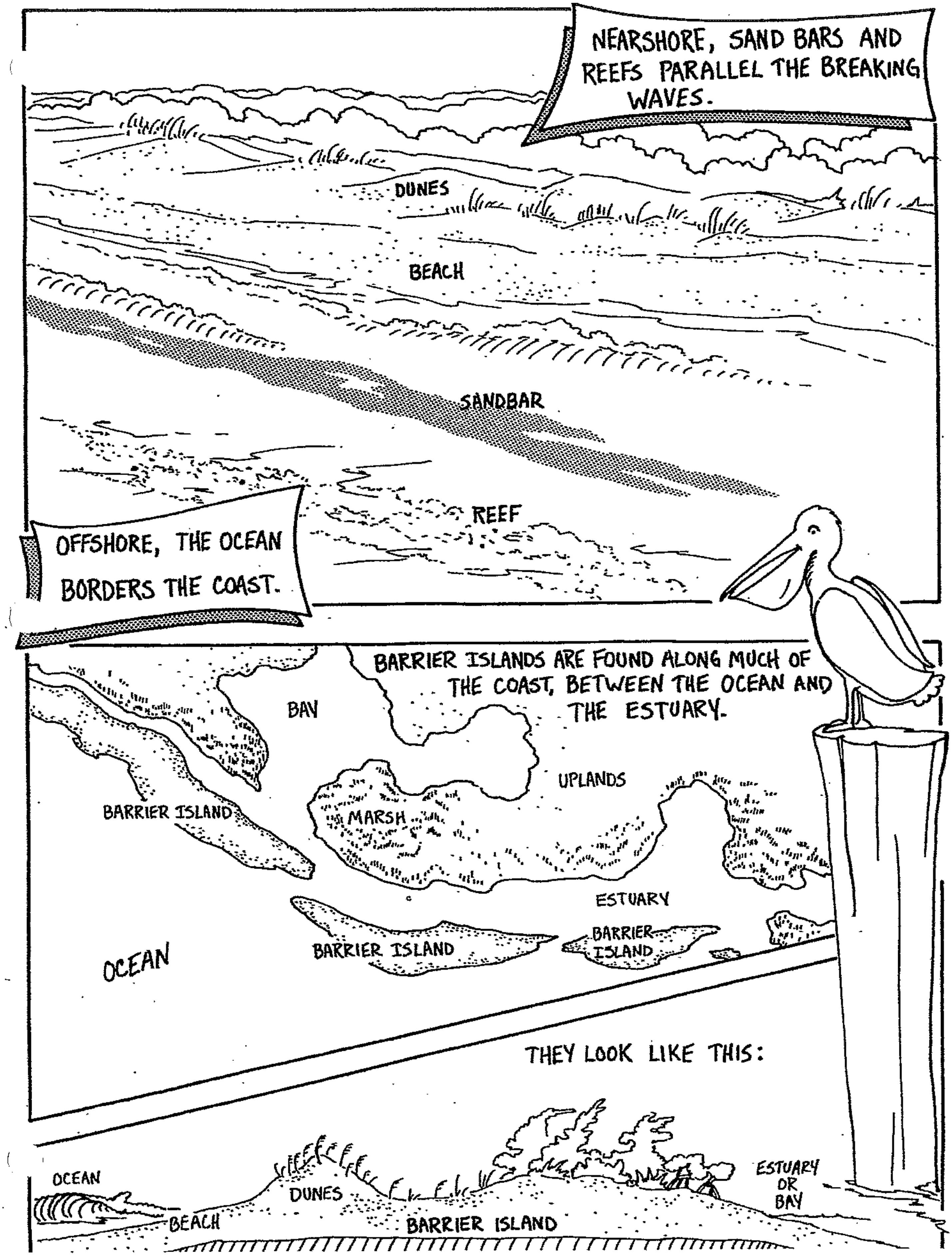
Cowardin, L.M., V. Carter, F. C. Golet, E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. U.S. Dept. of Interior, Fish and Wildlife Service, Washington D.C.

Mitsch, W. J., J.G. Gooselink. 2000. Wetlands. John Wiley and Sons, Inc.



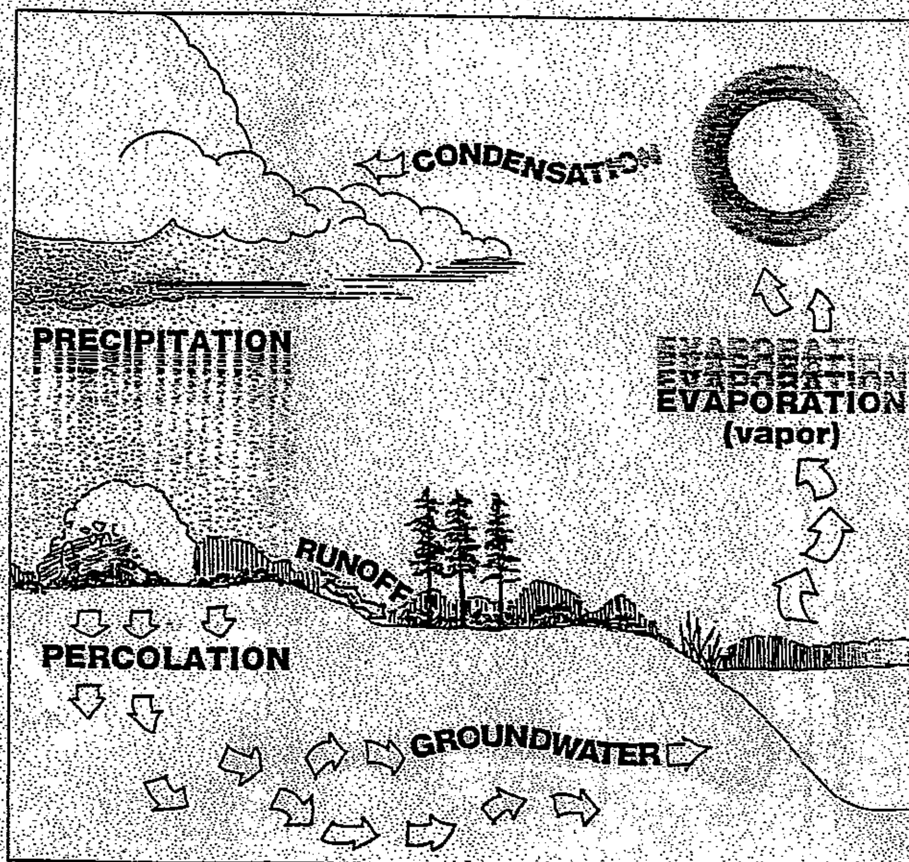
The Coast is a complex relationship
Between Wind, Water, and Land.
This Natural System is made up of many
Environments and their Habitats.

Water from the Land flows to the Sea.
Tides bring Seawater to the Beach.
Winds, Tides, Storms, and Sediments
Form the Coastal Systems.



NEARSHORE, SAND BARS AND REEFS PARALLEL THE BREAKING WAVES.
DUNES
BEACH
SANDBAR
REEF
OFFSHORE, THE OCEAN BORDERS THE COAST.
BARRIER ISLANDS ARE FOUND ALONG MUCH OF THE COAST, BETWEEN THE OCEAN AND THE ESTUARY.
BAY
UPLANDS
MARSH
BARRIER ISLAND
ESTUARY
BARRIER ISLAND
BARRIER ISLAND
OCEAN
THEY LOOK LIKE THIS:
OCEAN
DUNES
BEACH
BARRIER ISLAND
ESTUARY OR BAY

EXPANDING THE HYDROLOGIC CYCLE



Water Data Analysis Information

this chart as a guide as you interpret your water-quality field data. Remember that each aquatic system is erent; this chart is only a guide, not a hard and fast rule!

Water Test	What It Measures	Natural Reading	Danger Reading	Source	Remedies
Salinity	amount of dissolved SOLIDS IN THE WATER	varies—higher in summer and fall, lower in spring	—	∘ *fresh*: rain and streams ∘ *salt*: ocean water (evaporation can also increase salinity)	—
Dissolved Oxygen	amount of oxygen in the water	7-14 ppm (parts per million)	3-5 = stress 1-2 = poor 0 = anoxic	∘ wind ∘ waves ∘ running water	∘ control nutrient content, algae growth ∘ more wind and water movement
pH	acid base of the water	generally 6.5-8.5 (Bogs are naturally acidic, pH can be as low as 4.2)	below 6.5; above 8.5	∘ acid rain ∘ industrial pollution ∘ chemical spills	∘ pollution controls
Phosphates and Nitrates	amount of these nutrients in the water	0.0-0.65 ppm 0.0-0.08 ppm	any reading higher than normal	∘ sewage, industry ∘ detergents ∘ fertilizer, animal wastes	∘ removal by water treatment ∘ restrictive or banned use
Temperature	average amount of heat in the water	varies	generally above 27°C (81°F) (>24°C for trout streams)	∘ waste heat ∘ solar heat	∘ cooling towers, etc. (decreased T also increases DO)
Turbidity	clearness of the water	80-120 cm (0-8 JTU, Jackson Turbidity Units)	increased turbidity	∘ sediment ∘ excessive algae growth ∘ boat traffic, storms, etc.	∘ sediment controls ∘ reduced nutrients to reduce algae ∘ boat speed limits

ou will be monitoring water conditions for more than three days, use copies of this sheet and change the day numbers.
mpare water data to chart on p. 186.

Water Data

		Day 1: Date________	Day 2: Date ________	Day 3: Date________
W	pH			
	Temperature (T) (in degrees C or F)			
A	Salinity (S) (in ppt; or fresh, salty, or brackish)			
	Is the water tidal or nontidal?			
T	Is it high or low tide?			
	Dissolved Oxygen (DO)			
E	Turbidity			
R	Rate of Flow (give units)			
	Nitrogen (N)			
	Phosphorus (P)			

Water Chemistry: The Place Where Marine Life Occurs

Marine Plants and Animals need food, shelter and oxygen to survive and reproduce.

Properties of Water

Why does ice float? Structure of Water → Function of Water

Hydrogen Bonding in Water is partially responsible for: Water's high heat capacity
Water's high surface tension

Water Density = Mass/Volume

Direct relationship
Density of water solution increases as salinity increases.

Inverse relationship
Density of water decreases as temperature increases.

Hydrometers, calibrated floats, measure the relative densities of different liquids.
Freshwater is usually the standard for comparisons.
Substances of higher density will sink in substances of lower density.
Substances of lower density will float in a substance of higher density.

Salinity

Salinity (the concentration of dissolved salts in the water) is an important factor in a habitat. Aquatic animals are adapted to living in certain salinity ranges.

Salinity is measured as a ratio of salts to water, and is expressed in part per thousand (ppt or $^{o}/_{oo}$).

How would you make the following categories of salinity?

Fresh Water	0-0.5 ppt
Brackish Water	0.5-30 ppt
Salt Water (Seawater)	>30 ppt

Salinity, like temperature, affects the amount of dissolved oxygen in water. At high salinities, molecules of salts take up more room between water molecules so there is less space for oxygen molecules.

1 milliliter (1 mL) of water weighs 1 gram (1 g) so 1000 mL = 1 L = 1000 g

1 g salt + 1000 g (1 L) water = 1 ppt or 1 $^{o}/_{oo}$

5 g salt + 1000 g (1 L) water = 5 ppt or 5 $^{o}/_{oo}$

Try this: Take 3 samples of salt water. Leave one at room temperature. Heat one sample. Chill one sample. Measure and graph the salinities. What are the conclusions?

Dissolved Oxygen (DO) –an indicator of water quality

Facts:
Aquatic plants and animals need oxygen to survive and metabolize.
A low amount of oxygen in water is a sign that the habitat is stressed.

Oxygen from air is mixed into water with the help of rain, wind, waves, and currents.
Fast moving water has more DO than
still water because it has more contact with the air.

DO is affected by weather, temperature, and salinity.
Cold salty water holds more oxygen than warm salty water.

Water must contain at least 5 ppm to sustain life. <2 ppm = anoxic water
Dissolved Oxygen is measured chemically using Hach or LaMotte Test Kits.

pH

Factors affecting the natural pH level of water:
Vegetation types and density.
Underlying strata of rocks, sand, soil, and organic matter in the sediment.
Run-off affecting the quality of the water flowing through the area.

The pH range for natural systems under normal circumstances is typically between 6.0 and 8.0.
Use a pH scale and color change to measure the pH of a solution.

Temperature (°C)

Most creatures that live in water are cold-blooded, so their body temperatures, metabolism, and growth rates are determined (and limited) by the surrounding water temperature. Most can tolerate only a small range of temperatures.
Measure temperatures with a Celsius thermometer.

Turbidity

Cloudy water is said to be turbid. It is caused when suspended sediments and other minerals are stirred up in the water.

Rain, wind, waves, tides, animals, and various human activities can stir up suspended solids and increase turbidity.

Turbidity blocks the sunlight that is essential for photosynthesis in plants. Turbidity affects fish, oysters, and gilled animals clogging gills with sediment and may cause suffocation. Suspended particles absorb heat from sunlight. This warms the water and decreases DO.

Measure turbidity with a Secchi Disc.

Water Budget

A budget is a record of income and outgo. In a water budget, precipitation such as rain or snow is the income. Evaporation is the outgo.

For this activity, you will need graph paper and two different colored pencils. On the graph paper, draw two axes. The vertical axis represents the precipitation. The horizontal axis represents the months.

Using the information in the chart and a colored pencil, plot a line graph of the monthly precipitation for city A. Using a different colored pencil, plot a line showing the evaporation on the same axes.

Now shade in the area where the precipitation is greater than the evaporation with one of the colored pencils. Label this area "Excess." Shade in the area where the evaporation is greater than the precipitation with the colored pencil. Label this area "Shortage."

Using the chart, find the excess or shortage for each month. To do this, subtract the evaporation from the precipitation. Record these results in the row labeled "Precipitation − Evaporation." A positive value indicates an excess, while a negative value is a shortage. Add the numbers across the "Preciptation" and "Evaporation" rows and enter the yearly totals. To find the yearly excess or shortage, subtract the total evaporation from the total precipitation.

	Monthly Precipitation and Evaporation (in mm) for City A												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Precipitation	15	20	30	60	80	110	95	80	70	55	40	20	
Evaporation	0	0	15	40	95	130	155	120	75	45	5	0	
Precipitation − Evaporation													

1. Which month shows the greatest amount of precipitation? ______________

2. Which month shows the greatest amount of evaporation? ______________

3. a. Which months show an excess? ______________

   b. A shortage? ______________

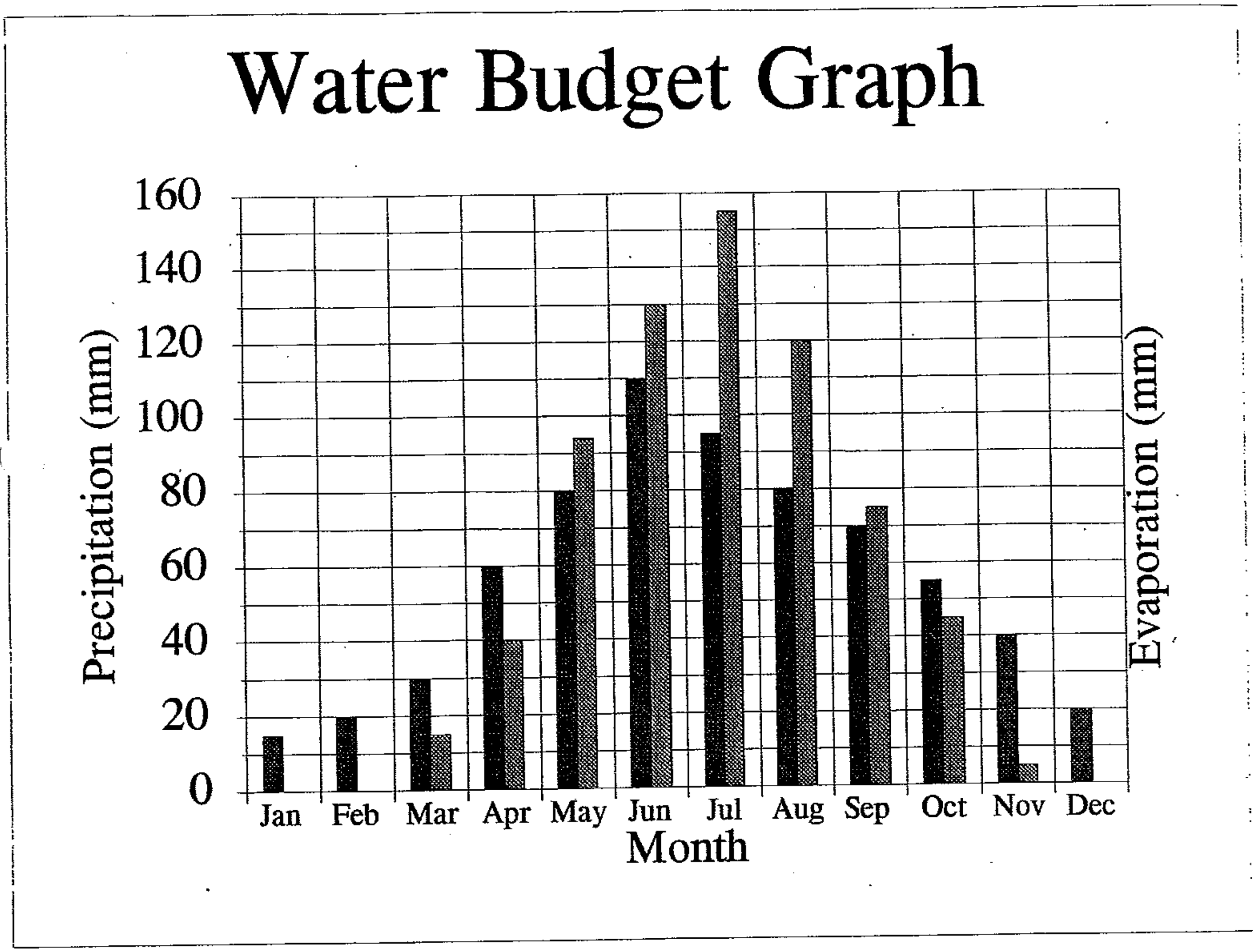
4. a. How does an excess occur? ______________

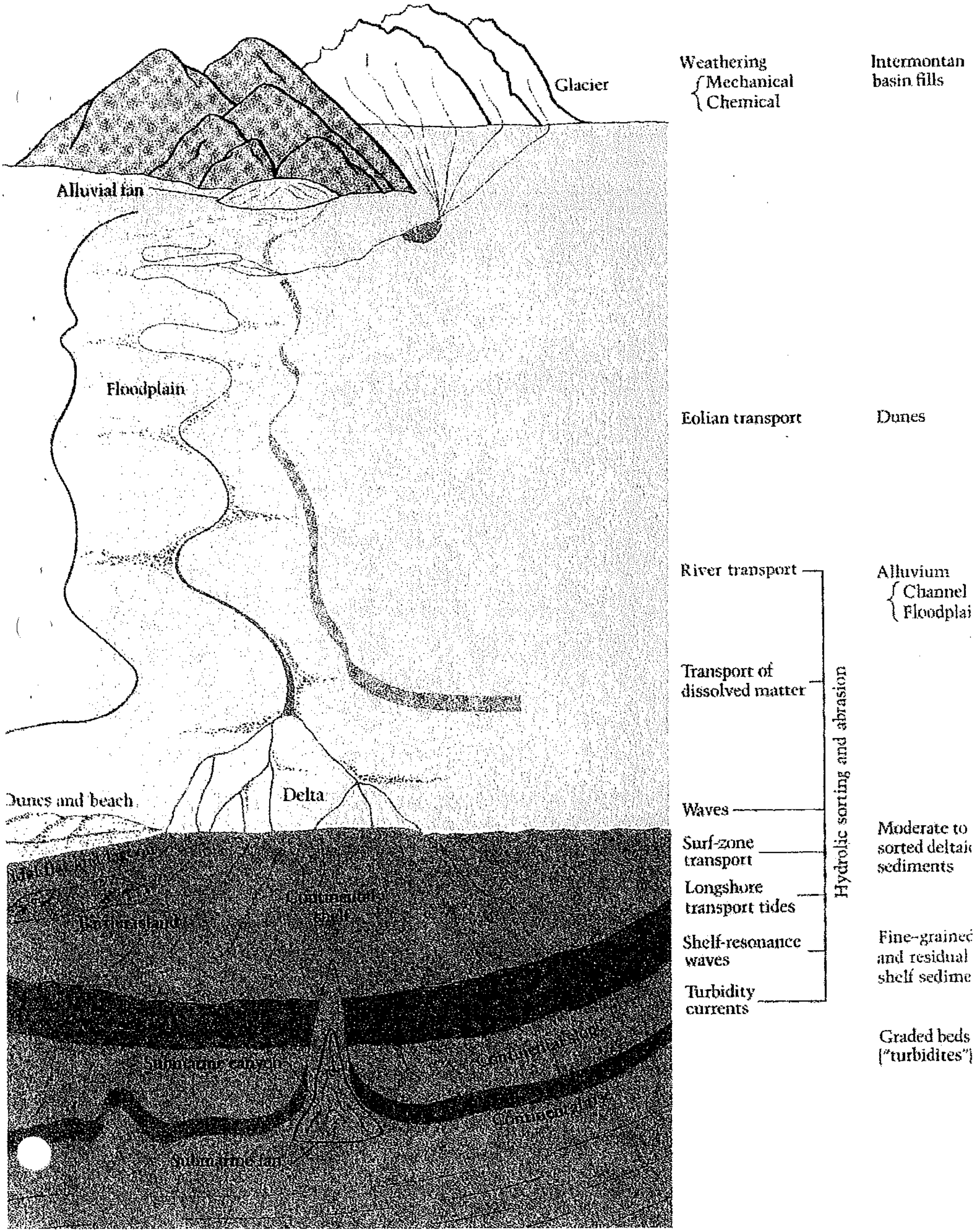
   b. A shortage? ______________

5. How can you tell if there was an excess or a shortage at the end of the year?

____

____


Water Budget Graph
160
140
120
100
80
60
40
20
0
Precipitation (mm)
Evaporation (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Glacier
Alluvial fan
Floodplain
Delta
Dunes and beach
Weathering
Mechanical
Chemical
Intermontan
basin fills
Eolian transport
Dunes
River transport
Alluvium
Channel
Floodplai
Transport of
dissolved matter
Hydrolic sorting and abrasion
Waves
Surf-zone
transport
Longshore
transport tides
Shelf-resonance
waves
Turbidity
currents
Moderate to
sorted deltai
sediments
Fine-grainec
and residual
shelf sedime
Graded beds
("turbidites")

Profile of a Coastline

51

The map used here shows the Gulf Coast in the vicinity of Galveston, Texas. It illustrates a low lying coastline and shows the type of features to be expected on such a coast. The most recent changes in sea lèvel in this area are associated with glaciation. The region has been gradually tilting downward toward the Gulf of Mexico for the last 70 million years. The numbers indicate the depth, in meters, of the Gulf of Mexico.

Strategy

You will draw a profile from the shore of Galveston to the deepest water shown.
You will compare underwater features.

Setting Up

graph paper
pencils (colored)
ruler

Getting Started

1. Lay the top edge of the graph paper along line AA' on the map on page 124.
2. Place a dot across the top edge of the graph wherever line AA' intersects one of the depth numbers on the map.
3. Drop a perpendicular line from each dot to the correct depth on the vertical scale. See the example drawn for you in Figure 51-1.
4. Connect the points with a red line to diagram the profile of the shore zone.
5. With a blue line, connect all the 10-meter depths on the map. Estimate where the 10-meter depth would fall if no depth is given.
6. Connect all 20-meter depths in the same way using a different colored pencil.

Keeping Track

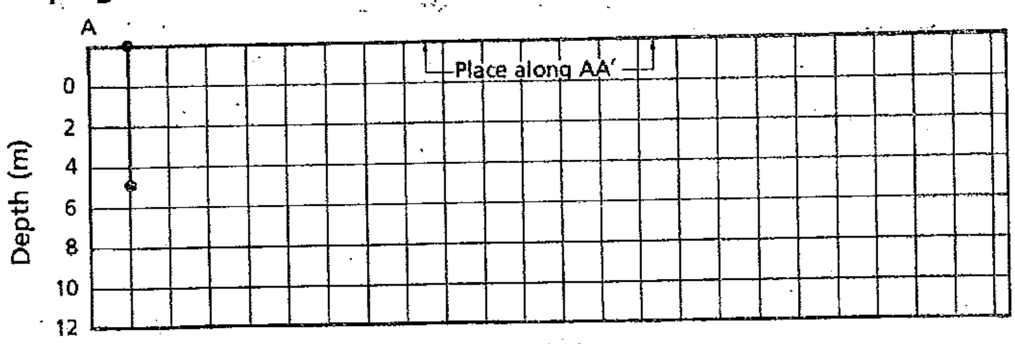


FIGURE 51-1

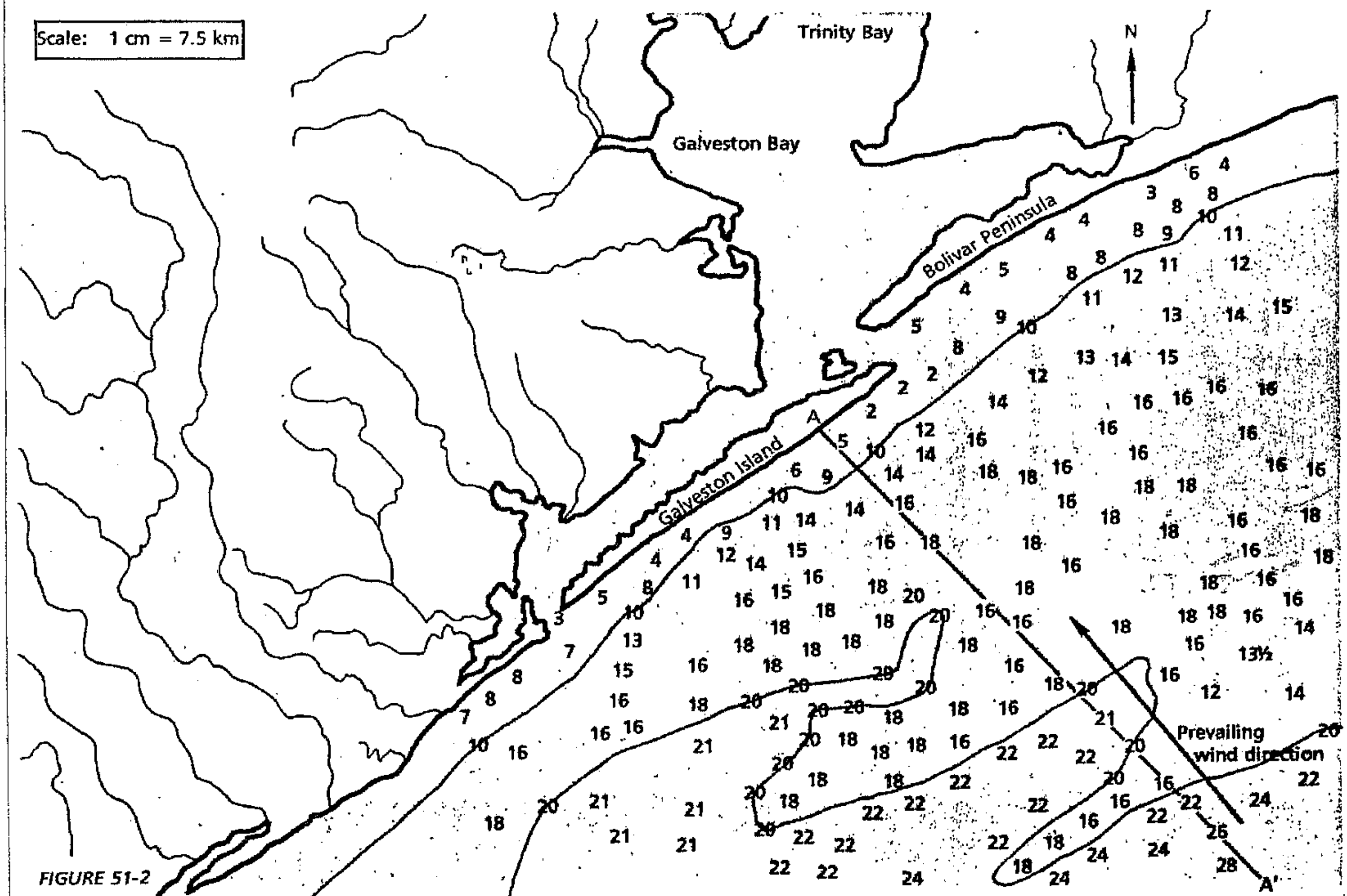

Scale: 1 cm = 7.5 km
Trinity Bay
Galveston Bay
N
Bolivar Peninsula
Galveston Island
A
A'
Prevailing wind direction

FIGURE 51-2

Summing Up

1. What does the profile of the shore zone look like?

___

___

2. From the 10-meter line, do you see any underwater ridges?

___

Explain. ___

3. Why are the seaward sides of Bolivar Peninsula and Galveston Island smooth while the leeward sides are ragged?

___

4. What features do you find with the 20-meter line?

___

What is the origin of these features?

___

___

5. What does your profile tell you about the shore zone?

___

___

Summing Up

1. **What does the profile of the shore zone look like?** The shore zone drops sharply close to shore. A wide ridge stretches from 22.5 km to 37.5 km offshore, and then the water depth increases. A steeper ridge forms about 80 km offshore.

2. **From the 10-meter line, do you see any underwater ridges?** no

   Explain. Waves strike the shore in such a way that the near shore zone is kept smooth.

3. **Why are the seaward sides of Bolivar Peninsula and Galveston Island smooth while the leeward sides are ragged?** Waves carry sand from the seaward side and drop it over the top of the ridge onto the leeward side.

4. **What features do you find with the 20-meter line?** underwater ridges

   What is the origin of these features? These ridges represent sand stirred up by waves along the breaker zone. There are two types of ridges representing different wave sizes.

5. **What does your profile tell you about the shore zone?** The profile shows where waves break most often, and that this shore zone is dominated by wave action.

F. ,TORS AFFECTING MARINE ECOSYSTEMS

Physical Factors

1 Light
- 1.1 intensity *(varies with latitude, tidal exposure, cloud cover, shore shading, biological overshadowing)*
- 1.2 quality *(varies with water depth, transparency, tidal amplitude)*
- 1.3 periodicity *(daily; seasonal)*

2 Substrate
- 2.1 solidarity *(bedrock, cobble, gravel, sand, mud)*
- 2.2 texture *(penetrability or suitability for attachment)*
- 2.3 porosity *(water-holding capacity)*
- 2.4 position regarding:
  - * water availability *(tidal flooding, wave wash, splash, spray, seepage, tidepool retention)*
  - * wave shock or disturbance
  - * ice action or cobble scour
- 2.5 solubility and erosibility
- 2.6 color *(re: intertidal heat absorption, radiation and reflection)*
- 2.7 chemical composition

3 Temperature
- 3.1 seawater/lake water temperature
  - * annual variation
  - * duration of maximum and minimum
  - * diurnal variation
  - * stratification *(thermocline position with respect to tides, mixing of nutrients)*
- 3.2 air temperature *(during intertidal exposure)*
  - * annual variation
  - * duration of maximum and minimum
- 3.3 direct heat of insolation *(complete exposure; tidepool exposure)*

4 Relative Humidity *(with respect to algae subject to exposure)*
- 4.1 seasonal variation *(in conjunction with exposure)*
- 4.2 duration *of minimum coincident with maximum exposure temperature*

5 Rain
- 5.1 seasonal extent *(coincident with tidal exposure)*
- 5.2 maximum duration

6 Pressure *(re: effect of tidal amplitude on attached seaweeds with air vesicles)*

Chemical Factors

1 Salinity
- 1.1 annual variation *from runoff*
- 1.2 tidal fluctuation *of the halocline*
- 1.3 maximum concentration *from evaporation during exposure*

2 Availability of Dissolved Oxygen *during Dark-hour Respiration*

3 Availability of Nitrogen, Phosphorus *and Other Essential Metabolic Substances*

4 Availability of Free Carbon Dioxide *for Photosynthesis*

5 pH *(mainly significant in confined pools subject to marked increases during active photosynthesis)*

6 Pollution *(from: marine organisms and waste products of human activity)*

Dynamic Factors

1 Water Movement
- 1.1 surf
- 1.2 ocean currents
- 1.3 tidal fluctuation and currents
- 1.4 maximum severity of annual storms or hurricanes
- 1.5 upwelling
- 1.6 extent of surface chop versus calm

2 Tidal Exposure *(period and amplitude)*

3 Tidal Rhythm *(coincident with release of reproductive bodies)*

4 Wind *(coincident with exposure)*

Biological Factors

1 Grazing Pressure

2 Fungal and Microbial Activity

3 Competition for Substrate

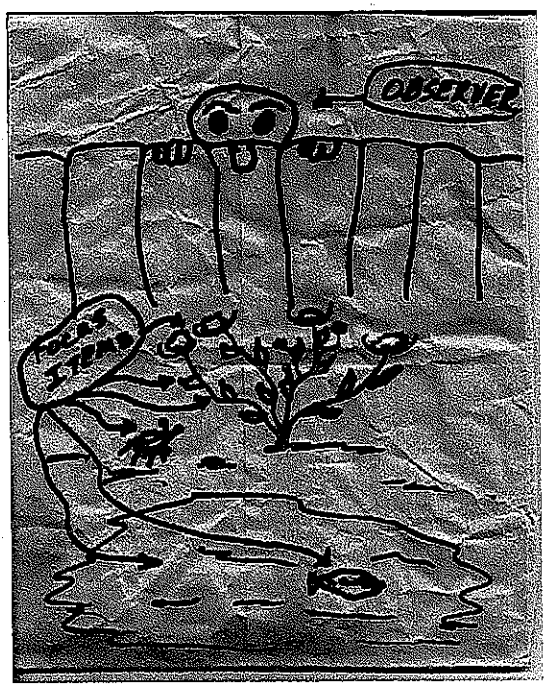
4 Protective Cover *(against desiccation during exposure)*

5 Light Restriction by Overgrowth *(by macroscopic or microscopic forms)*

6 Availability of Host Plants or Animals *(for Obligately Epiphytic, Endophytic, Epizootic, Endozootic, and Parasitic Algae)*

Field Trip: Activities and Focus Items for Small Groups

Give evidence (drawing/photo/location/explanation/data table/graph) to illustrate at least 5 examples of the activity for your focus items



Water and soil conditions—location, description temperature, movement, salinity

Animals—location, description, how they hide/protect themselves

Plants—location, description and how they survive local conditions

Weather conditions: wind, temperature, humidity, cloud cover, sun/shade

Climate conditions and the effects climate may have on plants/animals

Interfaces and edges in nature—characteristics, animals/plants found here, why?

Birds—where found—types, identifying characteristics, feeding location(s)

Colors, shadows, sounds, smells in nature—location. Description, importance

Decaying plants or animals—location, condition, role played in nature, importance

The BSCS 5E Instructional Model

The BSCS 5E Instructional Model provides a format for lessons that builds on what students already know. The model's sequence for the learning experience enables learners to construct their understanding of a concept across time. Each phase of the learning sequence can be described using five words that begin with *E*: engage, explore, explain, elaborate, and evaluate.

Learning Phase	Students' Roles	Teachers' Roles
Engage	Students are introduced to the concept. Students make connections to prior knowledge and to what is to be studied. Student thinking is clarified. Students become mentally engaged in the new learning experience.	Teachers ask questions of students and engage them in guided inquiry lessons. They use strategies such as KWL that make connections between the past and present learning experience. Teachers set a level of anticipation.
Explore	Students explore or experiment at this point. They engage in observations, use science tools and materials (manipulatives), collect data, and record data.	Teachers set up the investigation and guide students in inquiry and ask probing questions to clarify understanding.
Explain	Students verbalize their understandings from the Explore phase, look for patterns in their data, and describe what they observed. This can be done in small and/or whole groups.	Teachers ask probing questions that encourage students to look for patterns or irregularities in data.
Elaborate	Students expand their learning, practice skills, and behavior, and make connections or applications to related concepts and the world around them.	Teachers provide learning opportunities for students to apply their knowledge and to gain a deeper understanding. Activities can include reading articles and books, writing, designing other experiments, and exploring related topics on the Internet.
Evaluate	Students answer questions, pose questions, and illustrate their knowledge (understandings) and skills (abilities).	Teachers diagnose student understanding through an ongoing process. Assessment can be both formative (ongoing and dynamic) and summative (end-of-lesson final test or product).

Source: BSCS developed the BSCS 5E Instructional Model in the 1980s. Since that time, BSCS has used this model in its curriculum development programs as well as its professional development programs. The BSCS 5E Instructional Model has been widely disseminated and widely used as an effective instructional model that allows the students to construct their understanding across time. Adapted by SEDL with permission from BSCS. http://www.bscs.org.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins, effectiveness and applications.* Retrieved from http://www.bscs.org/bscs-5e-instructional-model

Build a Better Fish Trap:

Academic Question: How can scientist best collect fish species?

Objectives:

- To allow students to design and test various fish trap models
- To introduce students to sampling techniques

Process:

Assign students to do a short internet search on several small local fish species (bait fish); mullet, killifish, sheepshead minnow, menhaden, etc. After a short time have them report on their species to the class paying particular attention to their physiology and diet requirements if possible.

Divide the group in to design teams and show them their specified materials.

Allow each group to design a unique fish trap that will target a specific species. Remind students that fish need to be able to get in but not out….

Materials:

Various rolls of different diameter wire mesh
Zip ties
Wire cutters
Rope
Bait for trap (dead bait from bait shop fish/shrimp)

Application:

Have the students present their design highlighting their engineering considerations. Allow the students to bait their traps and place in the water for a designated time (overnight). Have them record the results of their catch including numbers and species caught. Allow the students to compare results with other teams.

Evaluation/extension:

- Have the students discuss/write what worked well in their design and potential changes to make their design more effective.
- Have students' research currently available commercial traps.
- Have students' research current State and federal laws concerning fish traps.

Time frame:

1-2 class periods as well as overnight soak

Grade level: Middle school-high school

"The Plastic Plate Tidal Flat"

Academic Question: What effect does wind have on tidal flats in South Texas?

Objectives:

- To introduce students to the geographic relief of a tidal flat
- To effectively model a tidal flat in relation to coastal waters
- To see the effects of human travel upon tidal flats

Background:

The wind tidal flats of the Laguna Madre are unique in their ecology, and also in their formation and geology. Approximately 125,000 years ago, during the Wisconsin glacial stage, sea level fell 90 to 160 meters. Many stream systems were formed to drain the now enlarged continental shelf. These rivers and streams cut deep channels into the surface. In the Laguna Madre, the Pleistocene (Beaumont) surface was eroded away to a depth of over 40 meters by one such stream (Fisk, 1959). Sea level began to rise and approximately 6,000 years ago, Padre Island was beginning to form (Amduer, 1978). A continuous barrier island chain was created 4,000 years ago, and the Laguna Madre was isolated at about this same time (Fisk, 1959). With Padre Island established, eolian processes took over and with the aid of hurricanes, sand was deposited, and the tidal flats were formed (Fisk, 1959). The area became sub-aerial and deposition was complete about 200 years ago (Long and Gudramovics, 1983). Eolian transport of sand from Padre Island shaped the Laguna Madre wind tidal flats. This same process continues to shape the wind tidal flats today. The blue green algal mats also effect the sedimentary processes. When wet, the sediments are held down, and with prolonged inundation they will become part of the layers in the substrate (Herber, 1981). These flats are areas with very little geographic relief and are prone to irregular flooding. These intervals of inundation are largely caused by "wind tides". A wind tide is a water surface elevation brought about by horizontal stress on a body of water (Watson, 1979). During normal conditions wind tides have an amplitude of 30 to 50 cm., and may cover areas of 50 km.2 (Miller, 1975). Inundation or exposure may occur rapidly depending upon the direction and strength of the wind. In 1968, Copeland et. al. reported a water level increase of 1.5 feet in a matter of a few hours.

Wind tidal flats occur in the Laguna Madre on the backside of Padre and Mustang Island as well as the mainland side in the area commonly known as the Land Cut. Before the dredging of the Intercoastal Waterway the two areas were connected. It was divided roughly in half at its lowest portion and continuous dredging is necessary to keep the canal at a controlled depth. The construction of the Intercoastal Waterway has had a major effect on the wind tides of the Laguna Madre. The canal serves as an escape channel for water to move freely through (Coover and Rechcenthin, 1965). The water is no longer able to "pile up" as it has in the past, nor is the water able to retreat as slowly across the flats. Depending upon the literature, the central tidal flat area is also referred to as the Kenedy mud flats, central mud flats, salt flats, salt pans, or the south Texas coastal sabkah.

Process (Activities):

1. This lab works best with groups of 2 to 4 or can be done as demonstration.
2. The students will be forming and evaluating a model of a tidal flat
3. Materials needed:
    - Small to medium disposable plastic dinner plates
    - Modeling clay
    - Toothpicks
    - Water
4. Have students press clay in to the bottom of the plate forming a flat, level surface leaving approximately 1/8 to ¼ of the plate bare and free of clay.
5. The clay should represent the tidal flat and the open area adjacent to the clay represents nearby coastal water.
6. After making sure that the tidal flat (clay) area is extremely flat, fill the open area with water.
7. Fill the open area until the water is level with the top of the clay.
8. Have the students get down to eye level with their model and lightly blow over the water area.
9. Water should pass onto the tidal flat area.
10. Have students blow the other direction over the tidal flat.
11. Most of the water should return to the pool.
12. Next, have the students make 5 to 6 tracks representing human travel (car, motorcycle, four wheeler) in the clay using the toothpicks.
13. Repeat the wind simulation.

Evaluation:

Have the students:

- Estimate the area of their tidal flat
- Describe the effect different directions of wind has on water adjacent to a tidal flat
- What effect does human travel have on water flow over the tidal flats?
- Which direction of tracks affects the water flow least?
- How could their model be better designed?

Time Frame: 1-2 class periods

Grade Level: 6^{th}-12^{th}

Literature Cited:

Amdurer, M. 1978. Geochemistry, hydrology, and mineralogy of the Laguna Madre flats, south Texas: Master's Thesis, Univ. Texas, Austin, 172 pp.

Coover, J.R. and C.A. Rechenthin. 1965. Report of a preliminary investigation of the wind erosion and salt problem on the salt flats of the Laguna Madre. USDA, Soil Conserv. Serv. Rpt. Temple, TX.

Copeland, B.J., J.H. Thompson, Jr., and W. Ogletree. 1968. Effects of wind on water levels in the Texas Laguna Madre. Tex. J. Sci. 20: 196-199.

Fisk, H.N. 1959. Padre Island and the Laguna Madre flats: coastal south Texas. Second Coast. Geogr. Conf., LSU, Baton Rouge. pp. 103-152.

Herber, J.P. 1981. Holocene sediments under Laguna Madre, Cameron County, Texas. M.A. Thesis, Univ. of Texas. Austin, Texas. 664 pages.

Long, D.T. and R. Gudramovics. 1983. Major-element geochemistry of brines from the wind tidal flat area, Laguna Madre, Texas. J. Sed. Pet. 53: 797-810.

Miller, J.A. 1975. Facies characteristics of Laguna Madre wind tidal flats. Pages 64-74 in R.S. Ginsburg (ed.) Tidal deposits. Springer-Verlag.