

FINAL REPORT

Shell Bank: An Oyster Shell Recycling, Reef Planning, and Education Program for the Texas Coastal Bend

CMP Cycle 16 Final Report
GLO Contract No.: 12-142

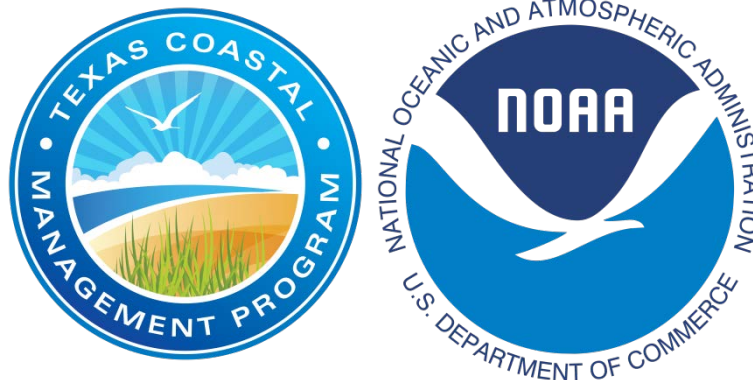
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Report Submitted to:
Texas General Land Office
Coastal Management Program

This project is funded by a grant from the Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration Award No. NA11NOS4190107.



Revision submitted: October 25, 2013

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ACKNOWLEDGEMENTS

Thanks to project partners Water Street Restaurants and the Port of Corpus Christi. The support of these partners has been, and continues to be, crucial to the successful development and growth of this oyster shell recycling program.



INTRODUCTION

Oysters are an important ecological and economic resource. They create fish habitat, filter and clean bay waters, protect shorelines from erosion, and are a valued fishery. Texas produces the second-largest oyster harvest in the U.S., generating an estimated \$17 million in 2006, yet an estimated 85% of oyster reefs have been lost globally in recent decades (Beck et al. 2011), making them one of the most threatened marine habitats on earth. Free-swimming oyster larvae depend upon the hard shells of older generations as substrate on which to settle and colonize. When the shells of harvested oysters are not returned to bay waters, oyster habitat is lost.

In the Gulf of Mexico, there are a number of historical and ongoing threats to reef sustainability, including: coastal development, nutrient pollution, altered river flows, storm damage, disease, and historical shell dredging for industry and road construction. In Galveston Bay, over 60% of oysters were lost due to impacts from Hurricane Ike (McKinley and Crawley 2009). In Louisiana, over 50% of the oyster population was lost due to freshwater diversions in response to the Deepwater Horizon Oil Spill (Upton 2011). Oyster reef restoration is one of the management strategies that has increased in scale to ameliorate habitat loss.

One of the major obstacles to restoration of degraded oyster reef habitat is the shortage of oyster shell, which forms the building blocks for larval oysters to settle and colonize (Fig. 1). In the soft sediment bays of Texas, the hard shell substrate provided by existing oyster reefs is the principal substrate available for oyster settlement. However, when these shells are removed due to harvest or lost to storms or other events, the 3-dimensional habitat is lost and oyster populations cannot maintain themselves.

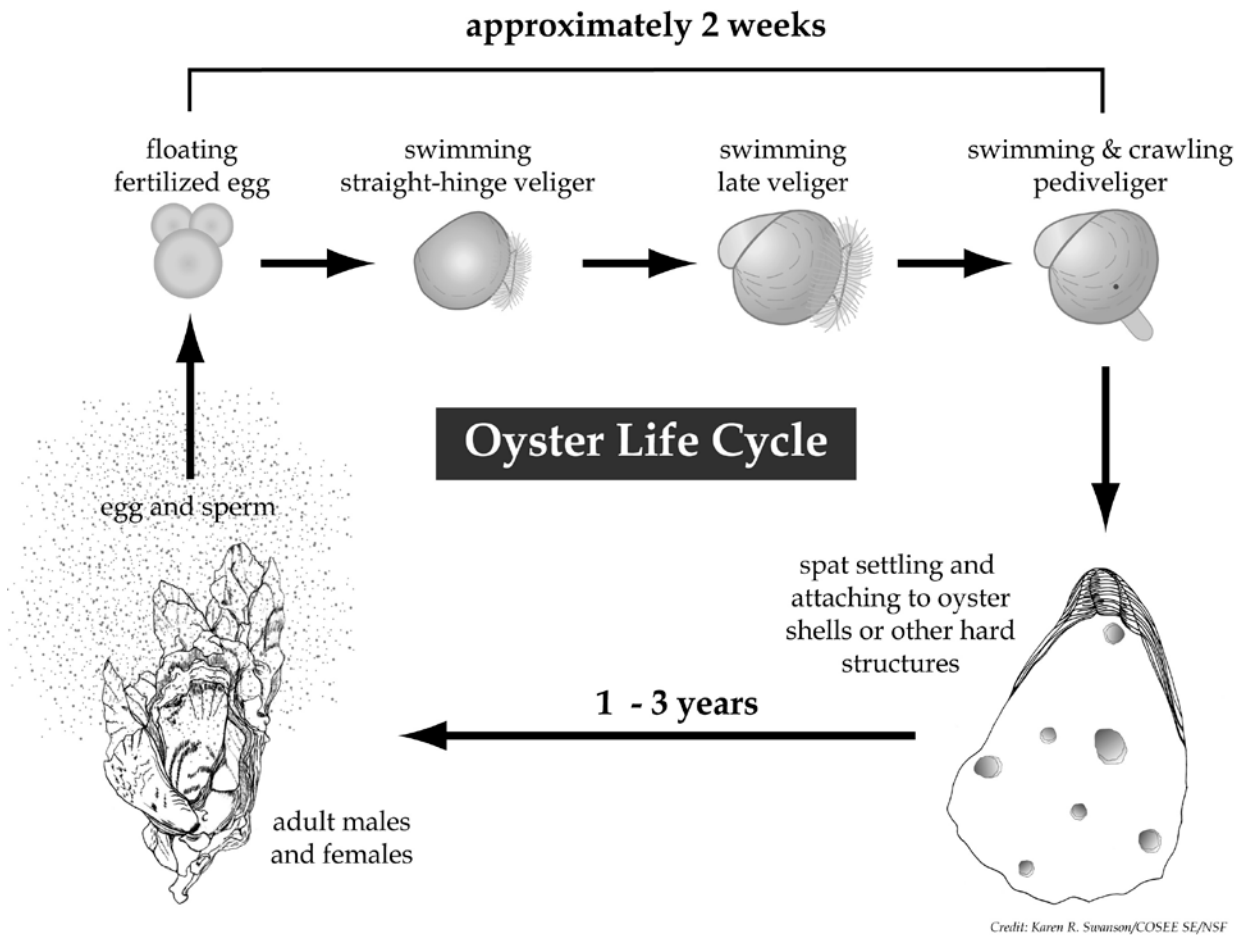


Figure 1. Oyster life cycle.

Through CMP Grant Cycle 14, the Shell Bank Project was developed. The Shell Bank is an innovative oyster shell reclamation, storage, and recycling program for the Texas Coastal Bend. Through this project shells from restaurants and seafood wholesalers were collected to reuse for oyster reef restoration. The project was expanded through Grant Cycle 15 and shell collection efforts continued. Shells reclaimed from those two projects were used to restore a 3.8 acre reef in Copano Bay, and a 2.5 acre reef in Aransas Bay with funding from the NOAA Community-Based Restoration Program. Shells reclaimed through CMP Grant Cycle 16 are already slated for inclusion in a reef restoration project for July, 2013, also in Copano Bay.

Project Goals and Partners

The Shell Bank began as a partnership between the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi, the Port of Corpus Christi Authority, and Water Street Seafood Company in Corpus Christi, TX. The goals established for the CMP Cycle 16 project, were built on previous accomplishments and included: 1) expand the oyster shell recycling program, 2) increase community involvement in oyster restoration, 3) develop lesson plans related to oyster reefs, and 4) support restaurant partners in their efforts to construct an educational oyster reef in Nueces or Aransas Bay by monitoring oyster growth and reef development.

1. EXPAND SHELL COLLECTION METHODS

The process of recycling oyster shells begins when oysters are harvested from bay waters (Fig. 2). This can be accomplished by commercial or recreational fishermen, but in Texas, the majority of oysters are harvested by commercial fishermen (using a dredge), and sold to restaurants. Inside the restaurants, oyster shuckers remove the top shell of each oyster and place it into a recycling bin. After being served to restaurant patrons, the bottom shell of each raw oyster is collected by bussers at each table, separated from restaurant trash and placed in collection bins. Periodically throughout the day, bussers take these recycling bins from inside the restaurant and dump the contents into large, customized collection bins placed outside of the restaurant. These custom bins, each holding 400 pounds of oyster shell, are picked up twice weekly using a flatbed trailer. The shells are transported to the Shell Bank Repository at the Port of Corpus Christi where they are stockpiled and quarantined for at least six months to remove any potential for disease before being used in oyster reef restoration projects. Once enough

oyster shells are reclaimed, the recycled shells are used in oyster reef restoration projects in Texas Coastal Bend bays (using external funding).

In Corpus Christi, the majority of oyster shells are produced by Water Street Oyster Bar and Water Street Seafood Restaurant. In addition, Niko's Steakhouse produced an abundance of oyster shells due to their extremely popular \$0.25 oyster happy hours. Shell collection efforts were focused at these restaurants for their high volume of shucked oyster shells.



Figure 2. The four steps of The Shell Bank oyster shell recycling process: harvest, consumption, reclamation, and recycling of shells. Image by Brittany Blomberg, Texas A&M University – Corpus Christi.

The weight of reclaimed oyster shells collected during CMP Cycle 16 generally ranged between 4,000 and 10,000 pounds per week, with an average of 6,810 pounds per week (Fig. 3). The total weight of oyster shells reclaimed from restaurant partners was 136,200 pounds, or approximately 105 cubic yards of shell.

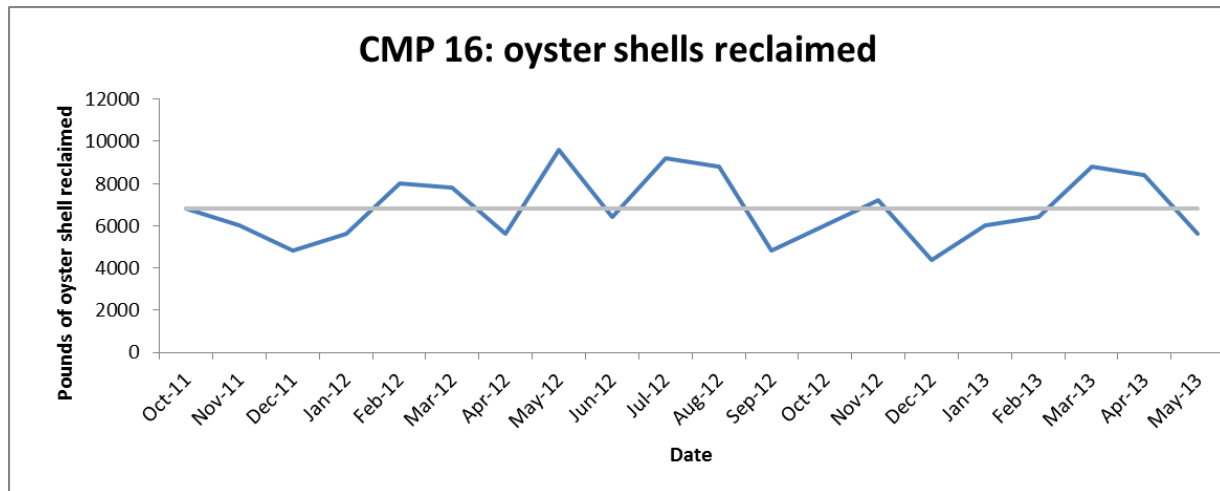


Figure 3. Pounds of oyster shell reclaimed (by month) as part of CMP Cycle 16 from October 2011-May 2013.



Figure 4. Bins for holding recycled oyster shells - located by the dumpster at Water Street Seafood Restaurant



Figure 5. Truck with trailer hauling reclaimed oyster shells from downtown Corpus Christi to the Shell Bank repository



Figure 6. Truck and trailer delivering shell for stockpile at the Shell Bank repository



Figure 7. Depositing shell at the Shell Bank repository



Figure 8. Depositing shell at the Shell Bank repository



Figure 9. Stockpiled oyster shell at the Shell Bank repository

In Texas, the public commercial and recreational oyster season runs from November 1-April 30 each year, coastwide. However, During CMP 16 Cycle, there was a persistent bloom of the red tide organism, *Karenia brevis*, throughout much of the Texas coast. Before the oyster

season opened, the Texas Parks and Wildlife Department reported mortalities due to red tide of 4.2 million fish between September and the end of October, 2011. As a result, all Texas bays were temporarily closed to the harvesting of molluscan shellfish by the Texas Department of State Health Services. The red tide produces a brevetoxin that can cause Neurotoxic Shellfish Poisoning (NSP), and is of particular concern for people consuming filter-feeding shellfish that may accumulate the toxin. Therefore, to protect public health, the opening of the 2011-2012 commercial oyster season was delayed, which likely caused the dip in number of shells reclaimed during the early part of CMP 16. In late January, certain areas of San Antonio Bay and Espiritu Santo were opened to commercial harvest; other bays followed with resumption of shellfish harvest, and by early March 2012, only Matagorda Bay remained closed.

Niko's Steakhouse discontinued their oyster happy hour specials and no longer produce any measurable amount of oyster shell, therefore it was determined that they would no longer be a viable partner. Niko's was producing 2-3 bins (800-1200 lbs) of oyster shell through mid-December, 2012. After discussions with Niko's management, and following three consecutive weeks of pickups where no oyster shells had been stockpiled, decided to discontinue this partnership (last pickup date January 2, 2012). Casterline's Fish Company (Casterline), a seafood wholesaler in Fulton, TX, was approached to participate in the program but unfortunately, they are located over 40 miles from Texas A&M University-Corpus Christi, and therefore it is cost-prohibitive to make weekly or twice weekly pick-ups. Ideally, Casterline could stockpile a large quantity of shell that could be trucked once or twice a year by a contractor. However, because Casterline is located near a number of popular restaurants and bars along Fulton Beach Road it is not possible to stockpile large quantities of (very smelly)

oyster shells. Efforts to improvise and create an innovative way to collect these unreclaimed oyster shells will continue in the future.

All of the oyster shells collected through CMP Cycle 16 before January, 2013 (to allow for six months quarantine), as mentioned previously, are planned for inclusion in oyster reef restoration projects. In July, 2013, plans are to expand an existing four-acre oyster reef in Copan Bay by an additional two acres. Construction of the reef is funded by the Coastal Conservation Association. The base of the reef will be constructed with crushed concrete, and overlaid with oyster shells to encourage larval recruitment. The oyster reef complex is designed as a series of four reef mounds (dimensions 30 yards x 20 yards x 12 inches high) where “hills and valleys” are essential elements.

2. REEF PLANNING AND COMMUNITY INVOLVEMENT

The first community shell bagging event was held on March 10, 2012 at Goose Island State Park. Over 100 volunteers filled more than 800 bags of oyster shell to create an educational oyster reef at the park. A second and third community shell bagging event was hosted at Goose Island State Park on April 28 and May 19, 2012. Approximately 150 volunteers participated in each event, including high school students, middle school students, youth groups, and Boy Scout troops. In total, across all three restoration events (March, April and May), volunteers filled 1,816 bags with reclaimed oyster shells, totaling almost 40,000 pounds of oyster shell (Figs. 10-16)! Restaurant partners funded the creation of an educational oyster reef adjacent to Goose Island State Park in St. Charles Bay, using these bags of oyster shell substrate. As part of CMP 16, the development of this reef, in particular, oyster recruitment and habitat used by fish and macroinvertebrates was monitored. See section 4: “Monitor oyster growth and reef development” for data and results.

After the final community shell bagging event, a fish fry / oyster roast celebration was held with support from restaurant partners to recognize the accomplishments of Moody High School students, who participated in all three events and helped spread the word about the shell recycling program.

The Shell Bank received three awards during the project period, one from the Texas Coastal Conservation Association and one from the Corpus Christi Independent School District for conservation efforts and involvement of students in hands-on environmental service activities. The third award, “Outstanding Closing the Loop Program” was from the South Texas Alliance for Recycling (STAR), recognizing the innovative recycling of oyster shells.



Figure 10. One of the 4 oyster shell-bagging stations (“Make it”) for making shell bags



Figure 11. Two volunteers bagging oyster shells



Figure 12. One of our youngest volunteers filling a bag with recycled oyster shells



Figure 13. Volunteers transporting shell bags down the pier to the educational oyster reef site



Figure 14. Filled oyster bags, ready to be placed into the water to restore degraded oyster reef



Figure 15. The pile of reclaimed shell is completely gone – our volunteers filled over 1,800 bags of shell!



Figure 16. Our awesome volunteers on the pier at Goose Island State Park

3. DEVELOP LESSON PLANS RELATED TO OYSTER REEFS

In order to expand the educational reach of the Shell Bank, a set of lesson plans related to oyster reefs were developed that can be easily downloaded and adopted by teachers in classrooms around the state. Lisa Calvo, Aquaculture Extension Program Coordinator for the Rutgers University Haskin Shellfish Research Laboratory, was contacted to assist with this task. Lisa previously developed an educational program for elementary through high school students called Project PORTS (Promoting Oyster Restoration Through Schools) that focuses on the Delaware Bay ecosystem. Lisa agreed to share her lesson templates, so they could be modified for the Texas Coastal Bend region.

Julie Findley, a recently retired schoolteacher from the Corpus Christi Independent School District, assisted with updating and adapting lesson plans to local area schools. The developed lesson plans enhance marine science knowledge of elementary and middle school children in preparation for the Texas Essential Knowledge and Skills (TEKS), the Texas state standardized test. The result was a comprehensive set of lessons, divided into two primers, one focused on the Copano and Aransas Bay ecosystem, and the second focused on oyster biology and ecology (Tables 1, 2; Appendix 1, 2). An informational poster and coloring book focused on oyster facts, oyster biology, and the oyster life cycle, were also produced (Appendix 4). All lessons are available on the program website, www.oysterrecycling.org, under the “Sammy’s Corner” tab.

Table 1. Oyster curriculum, Primer 1, focused on the Copano and Aransas Bay ecosystem

Primer 1. Discovering the Copano/Aransas Bay System
Activity 1.1—An Estuary Nearby: A Scavenger Hunt Mapping Exercise
Activity 1.2—Going with the Flow: Constructing a Watershed Model
Activity 1.3—Life in the Estuary
Activity 1.4—Taking it with a Grain of Salt
Activity 1.5—Seasons of Change

Table 2. Oyster curriculum, Primer 2, focused on oyster biology and ecology

Primer 2. Oyster Biology and Ecology
Activity 2.1. Beach-in-a-Box—Exploring Shell Collections
Activity 2.2. Cha, Cha, Changes—A Look at the Oyster’s Life Cycle
Activity 2.3. That’s Gross Anatomy, or What’s Under that Shell?
Activity 2.4. Crunchy on the Outside, Soft and Squishy on the Inside—Designing and Constructing the Perfect Oyster Predator
Activity 2.5. I Can See Clearly Now—A Demonstration of Filter-Feeding
Activity 2.6. Parasites on the Half Shell

During her research, Findley found some great lessons related to oysters created by the Texas State Aquarium that were no longer in active use. The aquarium granted permission to post these lessons on the program website. These lessons (Table 3; Appendix 3) were particularly attractive to this program for two main reasons: 1) they are very holistic in their focus, touching on mathematics, science, history, and literature, and 2) each lesson and activity are only one page long, and can be utilized individually or as an add on activity to a larger set of lessons.

Table 3. Texas State Aquarium's integrated oyster lessons

Texas State Aquarium's oyster lessons
Pale, poetic pearls (estimating lengths in millimeters)
Old age oysters (interpretation of line graphs)
Oysters by the pound (interpretation of bar graphs)
Salt of the sea (interpretation of pie charts)
The fantastic filter (addition, multiplication, and division)
Treasures of the deep (historical and literary references to oysters)

As a follow up to the community-based shell bagging events, Jay Tarkington from the Aquatic Education Program (AEP) at Texas A&M University-Corpus Christi Center for Coastal Studies partnered with the program to provide educational experiences to local school groups related to oysters and oyster reef restoration (Table 4). The AEP has provided outdoor environmental education for over ten years with a mission to promote the ecology, history, and lifestyle of the Coastal Bend. Oysters provide an excellent backdrop for all AEP programs and for these specific programs, estuarine ecosystems were discussed and explored by the students with specific emphasis given to the role oysters play regionally within the Coastal Bend. At Goose Island State Park, students observed oyster reefs first hand. Oyster biology and reef construction were discussed as well as their niche (habitat, food webs, economy, etc.) within our regional bay systems. All students received information on the current Shell Bank Project sponsored and how they can get involved in future restoration events. Many of the students previously attended, or indicated they were planning to attend one of the future community bagging events.

Table 4. Oyster student field experiences

Date	School group	Number of students
October 9, 2012	Taft High School (Michelle Martinez)	25 students
October 10, 2012	Miller High School (Amanda Rose CCISD)	28 students
October 13, 2012	4-H Program (Art Smith Aransas County)	18 students
October 15-19, 2012	Live Oak Elementary (Martha McCleod)	150 students
November 13, 2012	Miller High School (Amanda Rose CCISD)	32 students
November 14, 2012	4-H Program (Duval County)	110 students
December 13, 2012	Taft High School (Michelle Martinez)	27 students
December 17, 2012	Yeager Elementary (CCISD)	75 students
January 8-9, 2013	Flour Bluff Jr. High (Terri DiMosco)	200 students
January 27, 2013	Moody High School (Vinay Dulip CCISD)	36 students
January 30, 2013	Miller High School (Amanda Rose CCISD)	32 students
February 22, 2013	Home School Group (Carlile)	18 students
February 27, 2013	Moody High School (Vinay Dulip CCISD)	31 students
February 28, 2013	Miller High School (Amanda Rose CCISD)	26 students
March 25, 2013	Seashore Academy (Katie Sikes)	27 students
TOTAL		835 students

We had two main training events for teachers. For the first event, from July 22-29, 2012, 5 Coastal Bend Aquatic Science Teachers were sponsored by the Harte Research Institute to attend the Mississippi Rivers Institute, Waters to the Sea Summit hosted by Hamline University in St. Paul, MN. The purpose of the trip was to expand the local teachers' knowledge of various teaching methodologies and curricula related to watersheds and relating it to habitats. Hamline University prepared an additional day of instruction for the Coastal Bend Teachers on the "Estuaries in the Balance" materials. This included the bays and estuaries of the Coastal Bend: San Antonio Bay, Corpus Christi Bay and Copano Bay. Oysters are one of the keystone species in the curriculum so Jay Tarkington and Gail Sutton presented materials and field activities for the teachers. We are trying to link all of these resources together, with the "Estuaries in the Balance" as the common teaching tool.

Upon returning from this extensive workshop the teachers met with Jay and Gail to discuss what supplies were needed so the teachers could start implementing the oyster curriculum. The teachers decided the Backpack Labs would not be as useful as singular test kits, water monitoring equipment and camera equipment. The Harte Research Institute (HRI) purchased \$11,379 worth of YSI Probes (pH, Temperature, Dissolved Oxygen), Skyvue Outdoor Monitor, and 3 Go Pro Video cameras. The equipment was packed into individual containers that teachers can check out from HRI. The teachers have been using the equipment since August 2012 with great success. They are able to compare readings from the YSI water monitoring equipment versus the test kits and discuss any similarities or variances. The video cameras are used for filming habitats and animals then reviewing the video in the classroom. Rather than removing animals from their habitat, students are taught to review the video to gather information and not to disrupt their surroundings.

Table 5. Teachers attending Mississippi Rivers Institute Training Session

Teachers attending:
Cherye Flores, Seashore Learning Academy
Yolanda Aviles, Martin Middle School
Felicia Trevino, Rose Shaw Special Emphasis Elementary
Julie Findley, Retired Teacher and Volunteer at Olson Elementary
Martha McLeod, Fulton Learning Center
Facilitators:
Gail Sutton, Harte Research Institute
Jay Tarkington, Center for Coastal Studies
Elizabeth Smith, International Crane Foundation
Joan Garland, International Crane Foundation
Erica Cochran, International Crane Foundation
Cinde Thomas-Jimenez, Guadalupe-Blanca River Authority

The second teacher training event was June 11-14, 2013, in conjunction with the Coastal Bend Bays and Estuaries Program. The four day Learning on the Edge Workshop included

training for 40-50 Coastal Bend teachers in the Leopold Education Project, Project Wild, and specialized field experiences emphasizing the integration of coastal ecology, oysters, and whooping cranes into the classroom curriculum. In addition to an extensive boat trip into Aransas Bay, the teachers visited the educational oyster reef at Goose Island. The teachers later received training in the Waters to the Sea education module highlighting the ecologic and economic value of local oysters. Through their participation in this workshop, the teachers are better able to reach their students with a powerful, local environmental message. In addition, 89 teachers from across the state learned about oysters at the annual Consortium for the Advancement of Science Teaching (CAST) meeting held in Corpus Christi, November 8-10, 2012. These teachers either attended a half-day field trip exploring Texas Bays or attended a coastal/wetland workshop that emphasized the importance of Texas oysters.



Figure 17. Moody High School student measuring water quality at Goose Island State Park using YSI data sonde



Figure 18. King High School students using water quality test kits at Goose Island State Park



Figure 19. Teacher Amanda Rose (King High School; on left in white hat) teaching students to use water quality test kits at Goose Island State Park



Figure 20. Fulton Learning Center students learning to use YSI data sondes for measuring salinity and temperature



Figure 21. Moody High School students preparing to measure water quality at Goose Island State Park



Figure 22. Martha McLeod (in white to right of photo; Fulton Learning Center) teaching students to use water quality test kits in the classroom.



Figure 23. Martha McLeod (Fulton Learning Center) teaching students to measure dissolved oxygen in the classroom.



Figure 24. Moody High School student removing a shell bag from the water to monitor oysters and other fauna



Figure 25. Teacher Vinay Dulip (Moody High School) and students monitoring oysters and water quality at Goose Island State Park

~~4. MONITOR OYSTER GROWTH AND REEF DEVELOPMENT~~

Before the monitoring program was initiated in the fall of 2012, the first task was to develop monitoring protocols for the educational oyster reef in St. Charles Bay at Goose Island State Park. After visiting the site and evaluating different methods, the decision was made to focus on the most essential components of reef development: recruitment of oysters (evidence of success for oyster reef development and sustainability), and use of the restored reef by reef-associated organisms (evidence of success of the reef in providing habitat to estuarine organisms). During each sampling period, three bags of oyster shell substrate were removed, immediately placed on ice and brought them back to the laboratory for processing. In order to accurately represent the reef as a whole, one bag each was removed from the north, middle, and south portions of the

reef. Bags were selected from locations at least one meter from the outer edge of the reef, to avoid any potential confounding edge effects where the reef abuts bare sediments.

Starting from the first sampling period in November 2012, it was evident that oyster recruitment was successful to all regions of the restored reef (Fig. 26). There was some evidence of seasonality in the abundance of oyster spat, with higher abundances present in the late fall and late spring. The number of spat varied from month to month and between locations on the reef, but the important result was that oyster larvae are present in St. Charles Bay, and are utilizing the restored oyster reef. This suggests the area is substrate-limited rather than larvae-limited (i.e. if additional substrate is provided, there are larvae that will colonize it).

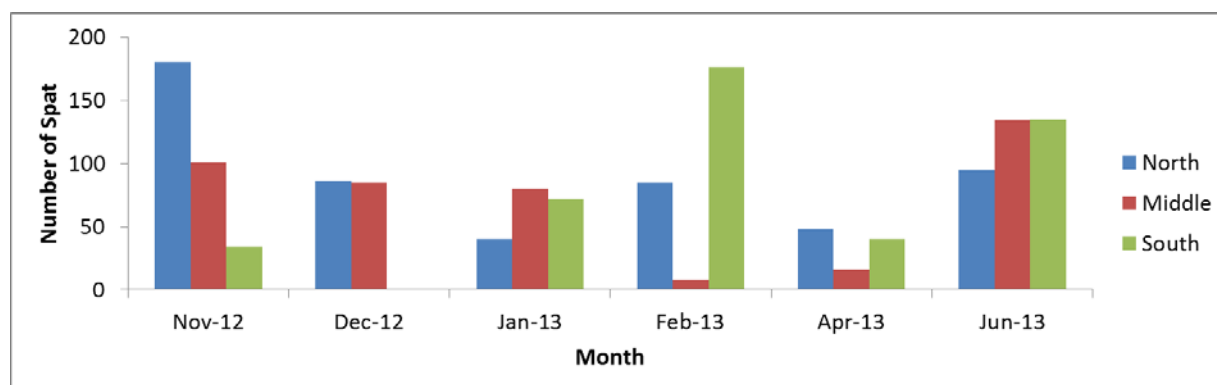


Figure 26. Number of oyster spat in shell bags from the North, Middle, and South portions of the educational restored oyster reef in St. Charles Bay, TX.

The fact that oyster recruitment has been successful and consistent through time on the restored reef is particularly important for ensuring self-sustainability. In contrast, in areas of the U.S. that are limited in the numbers of oyster larvae present in the water column (e.g. Chesapeake Bay), restoration practitioners need more extreme measures to establish oyster populations on restored reefs. Techniques such as: “spat-on-shell”, where shell substrates are taken to an oyster hatchery so oyster larvae can pre-settle in laboratory tanks, or “topping”, where live oysters are brought and added as a layer on top of shell substrates, can be extremely

labor intensive and expensive. Results indicate that the simpler method of substrate replacement can be very successful in this area.

Shell substrate bags were examined for colonization by reef-associated organisms to determine the provisioning of habitat by the restored reef. Beginning in the fall of 2012, three major groups of organisms were observed using the reef: finfish, crabs, and shrimp (Fig. 27). The crab group comprised mainly porcelain crabs (Porcellanidae) crabs and mud crabs (Xanthidae). The fish group and shrimp group were dominated by the naked goby (*Gobiosoma bosc*), and the bigclaw snapping shrimp (*Alpheus heterochaelis*) and grass shrimp (*Paleomonetes spp.*), respectively. Crabs were numerically dominant across all seasons, followed by shrimp and fish.

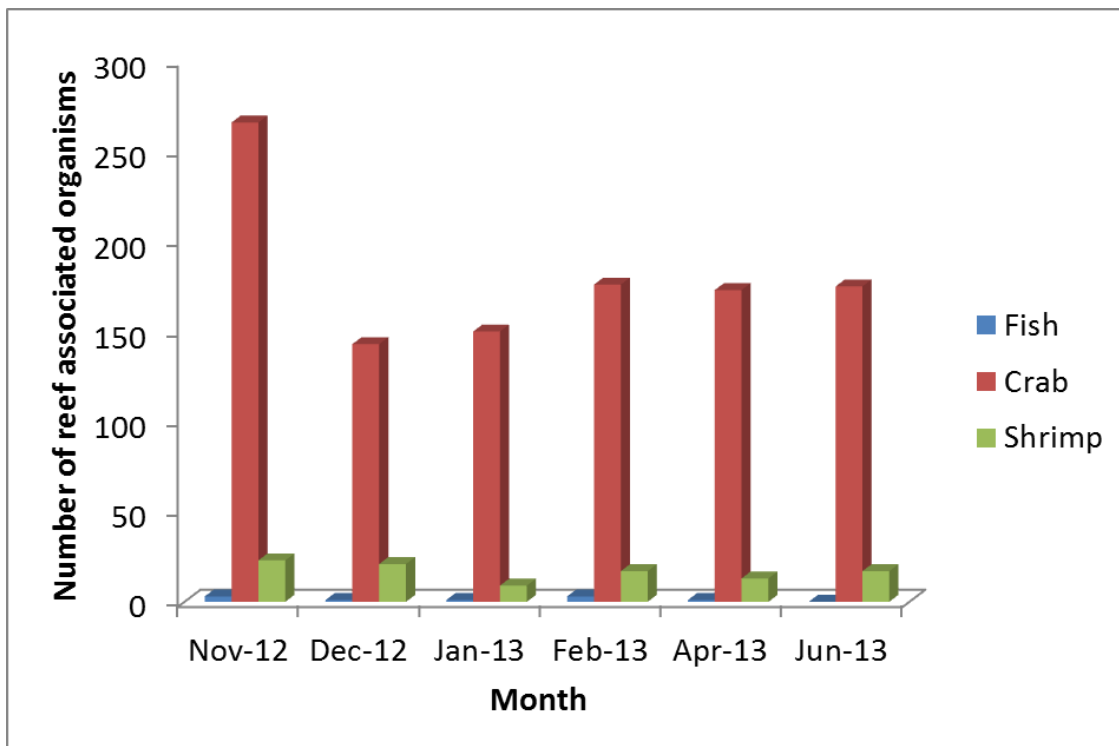


Figure 27. Number of reef-associated organisms in shell bags from the North, Middle, and South portions of the educational restored oyster reef in St. Charles Bay, TX.

These results support those shown in other regions of the U.S., whereas the three dimensional structure created by oyster aggregations can create refuge and foraging habitat for finfish and macroinvertebrates (Grabowski et al. 2005, Tolley and Volety 2005). Although few of the species that inhabit oyster reef habitat are of commercially or recreationally valuable to fishermen, they are consumed as prey by many larger fishery species and thus indirectly benefit fisheries (Peterson et al. 2003).

CONCLUSION

The Shell Bank continues to grow and thrive, thanks to continued funding from the Coastal Management Program. All of our stated goals as part of CMP Cycle 16 were accomplished which included: Expanding shell collection efforts; conducting three community-based shell bagging events to create the building blocks to restore a degraded oyster reef and create an educational reef near Goose Island State park; developing lesson plans and educational materials, teaching hundreds of students about the importance of oyster reefs; and monitoring the development of the educational oyster reef adjacent to Goose Island State Park. There has been overwhelming support and interest from the community in participating in community restoration events. In response, with support from funds provided through CMP Cycle 17, these important events will continue where local volunteers from students to retired folks can get involved. Using funds provided by NOAA-Community-based Restoration Partnership grants, two more acres of reef in are planned to restore in Copano Bay using shells reclaimed as part of the Shell Bank Project.

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APPENDICES

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****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.

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

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 major 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/>

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?

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

ACTIVITY**1.3****LIFE IN THE ESTUARY****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.

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

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



Invertebrates

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



Plants

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

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

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.

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

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

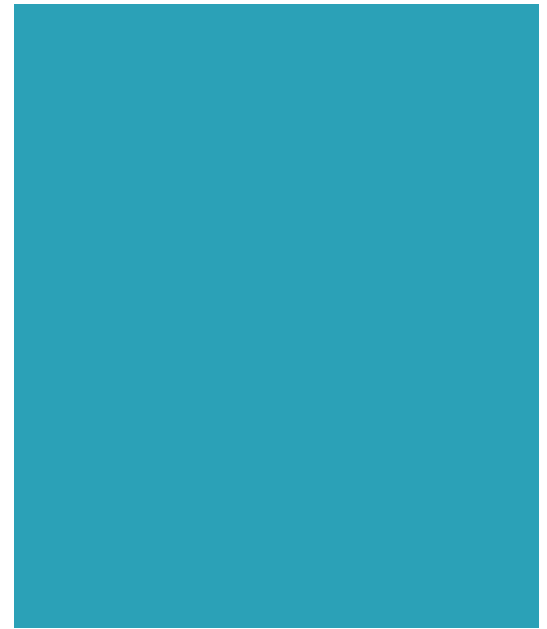
For each group of 4 to 5 students:

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.



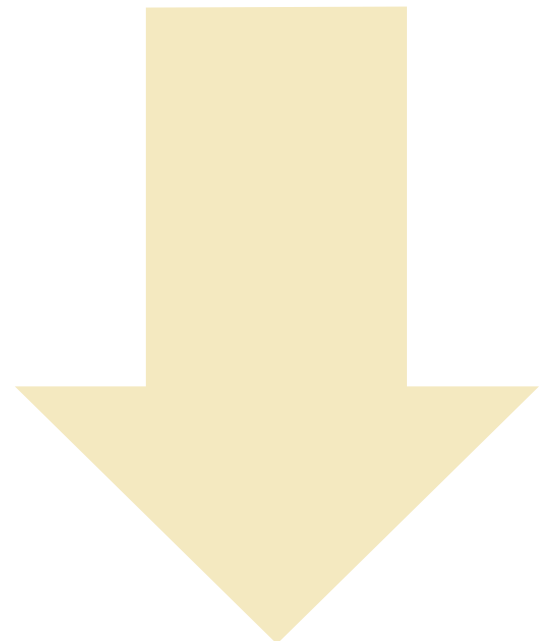
2. Introduce the term parts per thousand. Compare it to percent, which is parts per hundred. Show the class a one-liter beaker, which is usually marked "1000 mL". Review the prefix "milli," meaning one thousandth, and the fact that there are 1000 mL in a liter. Explain that if you have 35 parts per thousand (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

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 of 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.

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

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

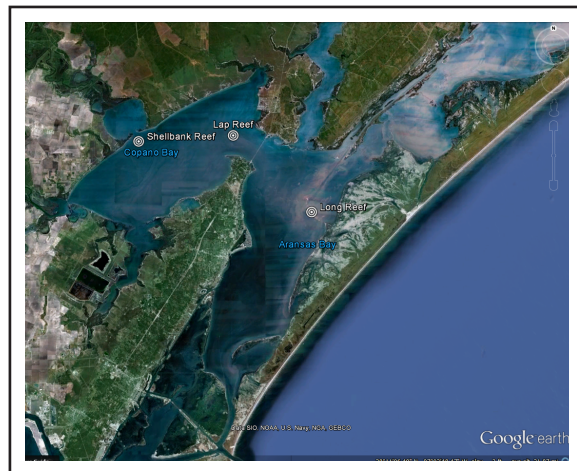
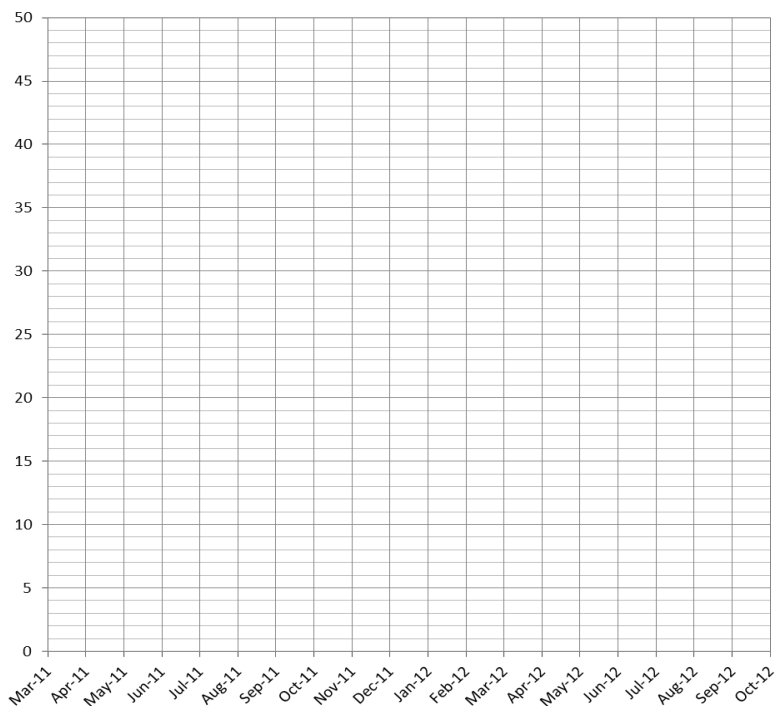


Figure 1. Map of Copano Bay and Aransas Bay, TX, showing the locations of Shellbank Reef, Lap Reef, and Long Reef.



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 (balmazar@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").

Estuaries in the Balance:

Oyster Biology and Ecology 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

2

OYSTER BIOLOGY AND ECOLOGY

Oysters are **invertebrate** animals belonging to the phylum known as **Mollusca**. Animals within this phylum are commonly called mollusks. There are about 100,000 species of **mollusks**. The phylum includes snails, clams, mussels, squids and octopuses. Among the distinguishing features of animals in this phylum are an **exoskeleton** in the form of a calcareous shell and a fold of the body wall known as a **mantle** that secretes the shell.

Oysters are commonly found in brackish and salt water. Their bodies are enclosed in an exoskeleton or shell composed of two halves or valves. Hence they are commonly called **bivalves**. Other well-known bivalves include clams, scallops, and mussels. Bivalves may be contrasted with snails, whelks, and conchs, which have only one shell or valve and are called **univalves**. The species of oyster most commonly found along the eastern coast of the United States is the eastern oyster, *Crassostrea virginica*.

Oysters begin their life as free-floating microscopic plankton known as larvae. The larvae arise from the external fertilization of sperm and eggs, which are released into the water column by mature male and female oysters. Mature oysters release gametes (spawn), after seasonal water temperatures reach about 75°F. Eggs that come into contact with sperm will become fertilized and begin cell division. The first larval stage is known as a **trochophore**. The larvae drift and swim in the water column for a period of about 2 to 3 weeks. In order to develop further, a larva must settle or attach itself to a clean hard surface. The larvae undergo a dramatic **metamorphosis**, changing from free-swimming larvae to a form that becomes permanently attached to a substrate. For the rest of the oyster's life it will remain **sessile**, not moving from its original place of settlement. The ideal settlement surface is the shell of another oyster. Once the oyster has attached to a clean hard surface, it is referred to as **spat**. Over time oysters settle on top of one another. This layering of oysters forms reefs that grow bigger and bigger over time. The oyster reefs provide shelter and food to many animals. Oyster shells provide a surface for many other plant and animal species to live upon. Often the shell of a living oyster will contain algae, barnacles, worms, and sponges. The shape, size, and thickness of oyster shells can vary greatly often in response to the environmental conditions to which the oyster is exposed. The reef structure provides an ideal **habitat** for oysters, keeping them well above the sediments of the estuary floor and placing them up in the water column where they can filter

RELATED VOCABULARY

Bivalves—mollusks that have two shells.

Crassostrea Virginica—the scientific name for the eastern oyster.

Exoskeleton—a hard structure developed on the outside of the body, such as the shell of a crab or an oyster.

Filter feeder—an animal that eats small particles (eg. Phytoplankton and zooplankton), which it filters, or collects from water.

Habitat—the place where a plant or animal lives.

Invertebrates—animals without backbones. This group includes mollusks, worms, insects, spiders, and crustaceans.

Keystone species—a species whose presence and role within an ecosystem has a large effect on other organisms within the system.

Mantle—an outgrowth of the body wall that lines the inner surface of the valves of the shell in mollusks.

Metamorphosis—a change in form from one stage to the next in the life history of an organism.

Mollusca—the phylum of animals containing animals that characteristically have a soft body protected by a hard shell. This group includes oysters, clams, mussels, scallops, snails, squid, octopus, and slugs.

Mollusk—common name for animals in the Phylum Mollusca.

Sessile—permanently attached or fixed, not free-moving.

Spat—a post-larval oyster that is attached to a surface and less than a year old.

Trochophore—a free-swimming larva common to several groups of invertebrates such as mollusks.

Univalves—mollusks that have one shell.



food from the water. Oysters feed on microscopic plants known as plankton through a process known as **filter feeding**. Oysters are known for their great capacity to filter food from the water. It has been estimated that an average sized adult oyster can filter 50 gallons a day. The removal of large quantities of plankton from the water column promotes water quality, and the ability to gain their energy needs from these tiny plants makes the oyster a dominant primary consumer in estuarine systems. They in turn become a food source for other animals, thereby serving as an important link in the food chain. Oysters are considered **keystone** species, being essential to the ecological health of the waters they inhabit.

EXTENSIONS

For more oyster-related activities, see the Texas State Aquarium's Marine Science Activities: "Treasures of the Deep," "The Fantastic Filter," "Old Age Oysters," "Oysters by the Pound," and "Pale, Poetic Pearls", and more, at: <http://oysterrecycling.org/sammys-corner/>



ACTIVITY

2.1

BEACH-IN-A-BOX: EXPLORING SHELL COLLECTIONS

CHARTING THE COURSE

Students will examine shell collections and reference sheets. They will learn that shells are made by animals and provide protection to the soft-bodied animals within. A sorting activity introduces students to how scientists classify animals.

BACKGROUND

Shells can be found in almost any habitat, but most often we associate them with the seashore. A careful treasure hunt on the beach will reveal a host of shells, some empty and some still with an animal attached. Shells are the hard outer-coverings that offer protection to soft-bodied invertebrate animals. The shells not only protect animals from hungry predators, but also protect them from changes in the environment, such as severe weather events. Many different types of animals have shells, including turtles, crabs, lobsters, snails, clams, and oysters.

Common seashells belong to the group of animals known as **mollusks**, which are classified in the phylum **Mollusca**. The phylum Mollusca is comprised of more than 80,000 species. There are seven classes of animals within this phylum. Four classes are common in the marine environment—Gastropoda (single shelled mollusks), Bivalvia (two-shelled mollusks), Cephalopoda (squid and octopi), and Polyplacophora (chitons). Most mollusks are aquatic and can be found in marine or fresh water environments, but there are also land species, which includes the slug. Scientists classify organisms into various groups using a system based on relationship (eg. similar body structure). This classification is called **taxonomy**.

The body of a mollusk is comprised of a soft visceral mass, containing the organs, and a surrounding outer tissue layer, the mantle. The mantle of shell forming mollusks contains glands that secrete the material that forms the shell. Some mollusks have a muscular foot that is used for crawling and burrowing.

A reference list of common seashells will typically include **gastropods** and **bivalves**. Gastropods, or snails, have only one shell, which usually coils in a spiral and has a wide opening at one end. Gastropods are also called **univalves**. Bivalves, which include but are not limited to clams, oysters, mussels, and scallops, have two shells, which are joined together at one side by a hinge. The living bivalve animal has strong muscles which are affixed to the shells and control the opening and closing of the valves.

OBJECTIVES

Students will be able to:

1. Identify common shells.
2. Sort shells according to like characteristics.
3. Describe the function of a seashell.
4. Become acquainted to the group of animals known as mollusks.
5. Become acquainted with the concept of classification.

MATERIALS

- Plastic boxes containing sand and a variety of seashells collected from coastal areas of Texas.
- Reference guide or books for common seashells (Peterson Field Guides *Shells of the Atlantic and Gulf Coasts and the West Indies*, by R. Tucker Abbott & Percy A. Morris is an excellent guide; alternatively, laminated folding guides can easily be obtained at book stores and tourist shops in the coastal area.)

Grade Level

3–5

Subject Areas

Science

Duration

One 30 to 40-minute class session

Setting

Classroom

Skills

Sorting, grouping, describing

Vocabulary

Invertebrate, mollusk, bivalve, gastropod, univalve, taxonomy

Correlation with TEKS (Texas Educational Knowledge and Skills)

3.2C, 3.3A, 3.4A, 3.10A, 4.2B, 4.4A, 4.10A, 5.2C, 5.4A, 5.9A, 5.10A

PROCEDURE

Warm Up

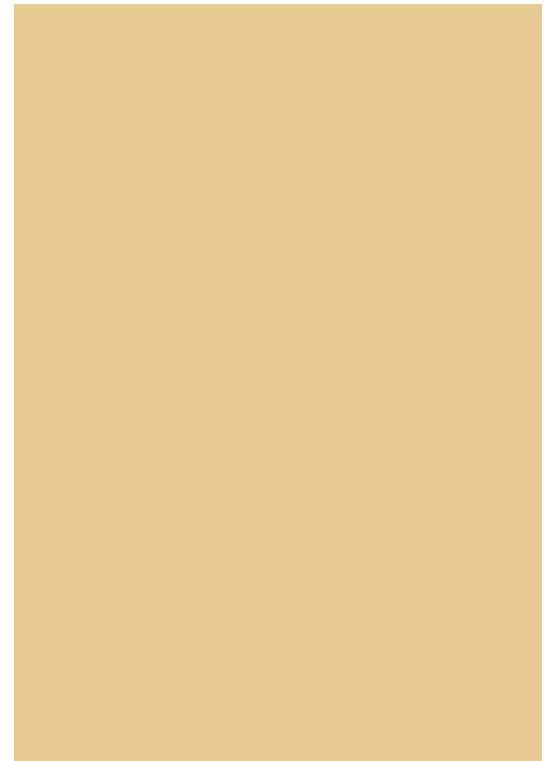
Have a class discussion about visiting the seashore. Lead into discussion of seashell collection. Ask: where do shells come from? Discuss mollusks and their key features. After describing the soft-bodied invertebrate animals that live within the shells, ask students to state the function of the shell. Explain that there are more than 100,000 species of mollusks, each differing from one another.

THE ACTIVITY

1. Divide students into teams and provide each team with a beach box and reference materials.
2. Have students sort the shells into groups having similar characteristics.
3. Have students utilize the reference guides to identify the seashells.
4. Have students prepare a survey list and illustrations of the different types of shells that they've identified.

EXTENSIONS

Take the class on a scavenger hunt to the beach to see how many different types of shells they can find. Have them construct their own shell collections. Visit the Education Program at the website of the New Jersey Marine Science Consortium (njmsc.org) for more activities such as *Seashell Homes* and *Holey Clamshells*.



ACTIVITY 2.2

CHA, CHA, CHANGES: A LOOK AT THE OYSTER'S LIFE CYCLE

CHARTING THE COURSE

Students will prepare flip-books depicting the life cycle of the oyster.

BACKGROUND

Oysters begin their life as free-floating microscopic plankton known as **larvae**. The larvae arise from the external fertilization of sperm and eggs, which are released into the water column by mature male and female oysters. Mature oysters spawn after seasonal water temperatures reach about 75°F. Eggs that come into contact with sperm will become fertilized and begin cell division. The dividing cells develop into larvae, which swim in the water column for a period of about 2 to 3 weeks. During this time the larvae increase in size and undergo metamorphosis through three main larval forms—**trochophore** to **veliger** to **pediveliger**. The trochophore stage exists during the first 24 to 48 hours and does not feed. The trochophore possesses cilia that help it spin about in the water. The veliger stage is characterized by the presence of an organ known as a velum that helps the larva swim and feed. The pediveliger is characterized by the presence of a foot that enables the larvae to crawl. The pediveliger seeks a suitable habitat and undergoes a dramatic metamorphosis, changing from the free-swimming larvae stage to a form that becomes permanently attached (**sessile**) to a hard surface. For the rest of the oyster's life it will remain sessile, not moving from its original place of settlement. Once the oyster has attached to a surface, it is referred to as **spat**. The spat develops into juvenile and adult forms, which undergo mass spawning in summer, beginning the cycle again.

Grade Level

3–5

Subject Areas

Science

Duration

One 30 to 40-minute class session

Setting

Classroom

Skills

Sequencing, describing

Vocabulary

Larvae, trochophore, veliger, pediveliger, spat, plankton

Correlation with TEKS

3.3C, 3.10A,C, 4.3C, 4.10A,C, 5.3C, 5.9A, 5.10A

OBJECTIVES

Students will be able to:

1. Demonstrate an understanding of how the oyster changes as it grows.
2. Identify various stages in the life cycle of the oyster.
3. Describe the life cycle of the oyster.

MATERIALS

- Diagram of oyster life stages
- Materials to make flip-books, construction paper, scissors, crayons, staplers, and glue sticks

PROCEDURE

Warm Up

Have a class discussion about how living things change as they grow. Describe the oyster's life cycle.

THE ACTIVITY

1. Distribute life cycle diagrams and materials to students.
2. Have students cut out, color, and sequence oyster life stages.
3. Paste sequenced images into flip-book, and label.
4. Write a descriptive sentence for each stage.
5. Have students hypothesize why each stage of the oyster is different.

EXTENSIONS

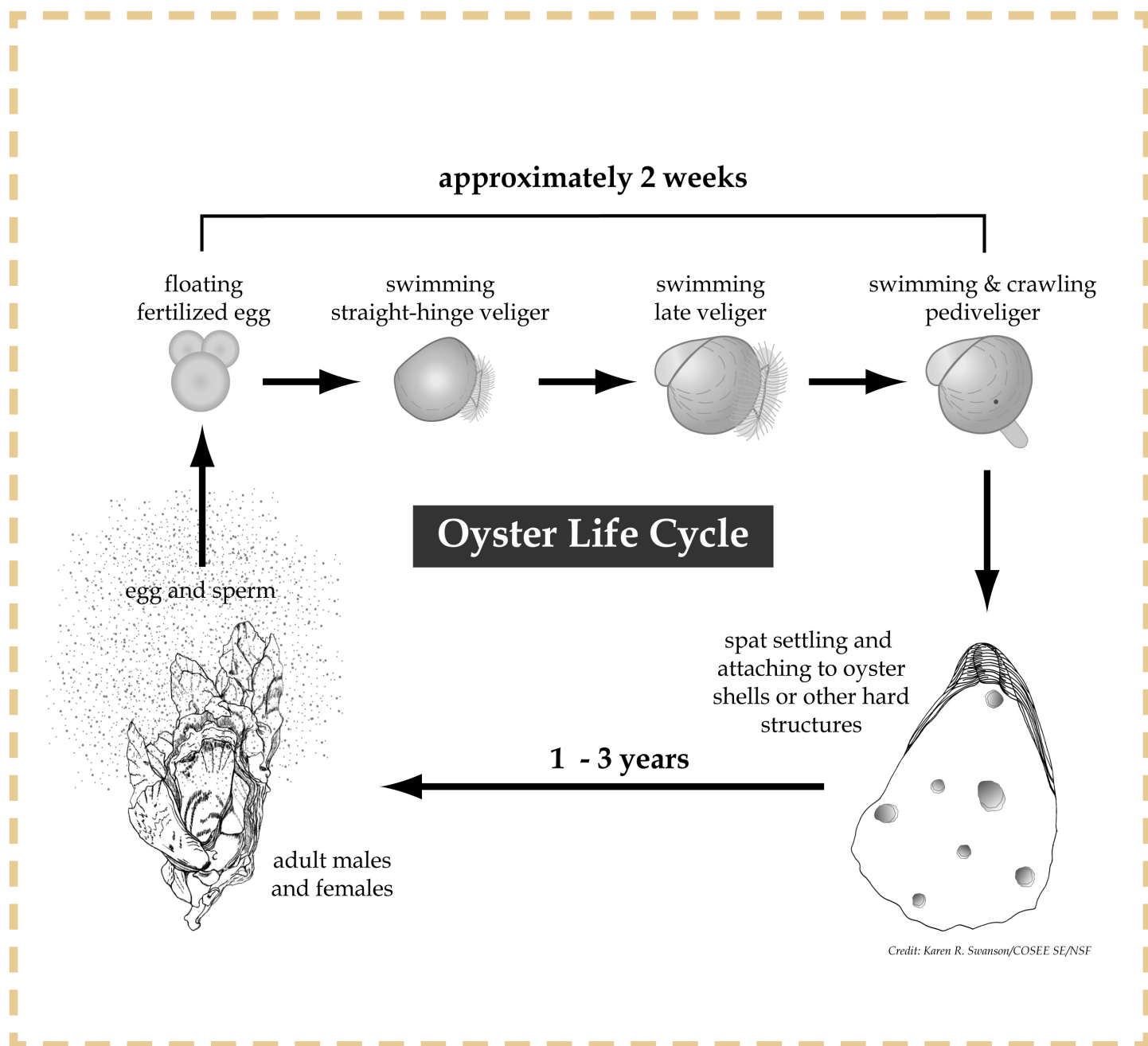
Obtain oyster or clam larvae from a hatchery (late spring, best time). Observe larvae under a microscope.

For a more elaborate design, follow larvae through time.

Compare the life cycle of the oyster to other marine animals (i.e. redfish, blue crabs, or brown shrimp).

Participate in "Sink Your Shucks" oyster restoration project. Students fill shell bags, which are deployed in Copano Bay, supplying a clean hard surface for oyster larvae to settle upon.

Oyster Life Cycle



ACTIVITY

2.3

THAT'S GROSS ANATOMY, OR WHAT'S UNDER THAT SHELL

CHARTING THE COURSE

Students will examine the morphology and anatomy of an oyster through a dissection exercise.

Grade Level

3–8

Subject Areas

Science

Duration

One or two class periods

Setting

The classroom

Skills

Measuring, identifying, describing

Vocabulary

Mollusca, bivalve, invertebrate, species, tissue, filter feeder, plankton, larvae, sessile, keystone, taxonomy

Correlation with TEKS

Science 3.1A,B, 3.2A, 3.4A,B, 3.9A, 3.10A, 4.1A,B, 4.2A, 4.4A,B, 4.10A, 5.1A,B, 5.2C, 5.4A,B, 5.9A,C, 5.10A, 6.1A,B, 6.4A,B, 6.12D,E,F, 7.1A,B, 7.4A,B, 7.10A,B, 7.11A,B, 7.12A, 7.13A, 8.1A,B, 8.4A,B, 8.11A-D



PROCEDURE

Warm Up

Discuss the significance of the oyster to the health of the bay.

Introduce the oyster in terms of important taxonomic concepts (i.e. Invertebrate (soft-bodied animal lacking an endoskeleton), mollusk, bivalve vs. univalve).

Explain that the focus of the lesson will be oyster anatomy (the structural make-up of the animal, examination of its parts).

THE ACTIVITY

1. Divide the class into groups of 2–3 students. Provide each group with a cluster of live oysters on a tray. There should be other small organisms living on or around the oysters, such as small crabs, shrimp, barnacles, and worms.

2. Have the students examine and describe the oyster community. Use forceps to extract small animals and observe them with hand lenses or dissecting microscopes. Students can list and/or draw animals.

3. Examine an oyster. Identify the two shells or valves and compare them (one is more cupped and rough, the other smooth and flat; note—in nature the deeper valve is the one that is cemented down, the flatter valve acts as a lid). Are the two shells the same size? Is one thicker than the other?

4. What is the shape of the oyster? Identify the hinge, or umbo area, the narrow point where the two shells come together. This is the oldest part of the shell. As the oyster grows, shell is laid down at the opposite end. It is also the point at which the shells are attached to one another. The other end (the ventral margin) is free to open.



OBJECTIVES

Students will:

1. Examine and describe external features of an oyster.
2. Identify and record other organisms living on or in an oyster's shells.
3. Measure and record shell height and length using a metric ruler.
4. Dissect an oyster and identify main body parts.
5. Identify key features of a bivalve mollusk.

MATERIALS

- Dissection trays (plastic plates will work)
- Oysters (can be purchased from local seafood purveyor, 1 per every 2–3 students)
- Oyster shucking knife
- Thick glove for shucking
- Forceps or other small tools for exploration
- Hand lenses or dissecting microscopes for observing organisms
- Oyster anatomy diagram
- Carmine Alum Lake dye (0.1 g of carmine dye dissolved in 5 ml of seawater)

5. Look for other organisms on the outside of the shell, or the “scars” of organisms that were once there (sponges leave many holes on the shell surface, barnacles and oyster spat, leave an oval to round mark, oyster drills leave a single hole, worms may leave networks of tubes).

6. Measure the shell height (the longest line from umbo to ventral margin) and the shell length (the longest point across in the other, perpendicular dimension).

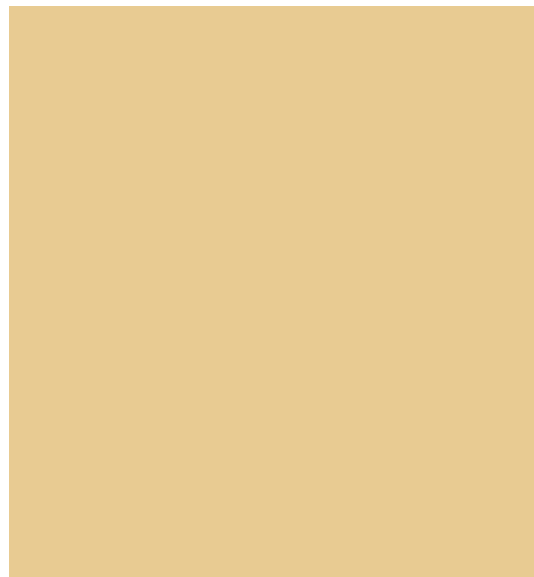
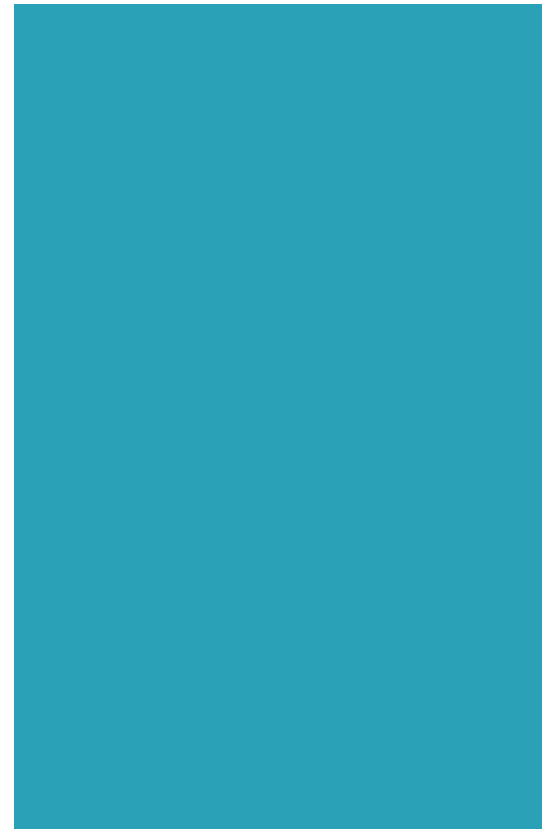
7. Record the measurements.

8. Draw the exoskeleton, or shell of the oyster and label the umbo.

9. Have students discuss the function of the shell-- what does it do for the oyster?

10. Have students try to open the oyster by pulling the shells apart. Ask them how the shells are held together so tightly.

11. The oysters should be carefully shucked open by the teacher. Instructions for shucking can be found in appendix I. **WARNING**—this is somewhat of an art and should be practiced before lesson. Teachers may want to have a separate class session for the internal anatomy, and if possible have the oysters shucked before students arrive in class. Tissues should be carefully dissected from one shell and remain attached to the second valve. Set the removed shell on top of the exposed body.



12. Have students remove the loose shell and describe the oyster’s body. Can they see or feel bones; is the tissue hard or soft, wet or dry? Is there a head? Do they see blood?

13. Have students refer to the oyster anatomy diagram. Using the diagram, have them locate the following parts:

a. Muscle—this is a notably different type of tissue, generally shaped like an oval. The muscle controls the opening and closing of the shells. The muscle leaves a scar on the shell at the point where it is attached. Have students find the muscle scar.

b. Mantle—this is the loose outer tissue that covers the entire body.

c. Gills—pull back the edge of the mantle to view the gills. There are four layers of gills; you will be able to see tiny lines crossing the gill surface. The gills are covered by tiny hairs, known as cilia, which move water across the oyster’s body and move food and remove oxygen from the water.

d. With a pipette or eyedropper, gently add two drops of carmine solution to the posterior end of the gills and observe the movement of the water by cilia under a stereomicroscope. You will see the filtering action of the gill cilia and mucus as it transports particles of dye toward the mouth.

e. Palps and mouth—follow the gills up toward the umbo area. There will be a slit followed by two thicker layers of tissue these are the palps and this is the area where the mouth can be found. Food enters the oyster through the mouth.

f. Stomach and digestive glands—locate the area where the stomach can be found. The stomach lies under the mantle layer and will often be dark brown. It connects to the intestines and the digestive glands. This is where food is broken down into usable nutrients.



g. Rectum—the rectum can be found along the edge of the muscle. It is a tube through which wastes are eliminated.

h. Heart—the heart lies just above the muscle. Sometimes you can see it beating. It is located in a clear sac and looks like a tiny sponge connected to a tube. Oysters have blood, but it is not pigmented red like human blood. The heart pumps the blood through the oyster's body. Note mollusks have an open circulatory system. There are no definite veins: blood instead drains through open sinuses within the body.

i. Tentacles on mantle edge— Oysters sense the surrounding world through tentacles that are present on the edge of the mantle. They can sense changes in light, chemicals in the water, sediments, and temperature. Oysters don't have a brain, but they do have simple nervous systems containing nerves and organs called ganglia. These will not be visible in the dissection.

j. Inner shell surface—have students describe the inner surface of the shell.

WRAP UP

Without referring to the diagram, have students point out the main features of the oyster to one another and discuss the functions of the various structures. Discuss with students how the oyster's anatomy allows them to live in the environment that they inhabit. Have students describe and draw a real or fictional predator of the oyster.

ASSESSMENT

Have students draw and label their own oyster anatomy diagrams. Have students compare and contrast oyster anatomy with that of a human. Use Activity sheet 2.3 for an alternate assessment.

EXTENSIONS

Set up an aquarium containing oysters and allow the students to observe feeding and resting living oysters. Have students compare and contrast common bivalve mollusks, including mussels and clams. Discuss how they are similar and how they are different. Take the students to the beach for a mollusk scavenger hunt and use a field guide to identify the shells that they find. Have students trace oyster shells and construct 3-D models of oyster anatomy (include valves, mantle, muscle, and internal organs).

REFERENCES

Arlington Echo Outdoor Education Center's "Out of the Ordinary Oysters" (<http://www.arlingtonecho.org/activities-and-lessons/activities-a-lessons.html>)

Texas A&M Galveston's "Guess Who's Coming to Dinner" (<http://www.tamug.edu/seacamp>)

Maryland SeaGrant's "Oyster Anatomy Laboratory" and "Particulate Matters" (<http://www.mdsg.umd.edu/issues/chesapeake/oysters/education/>)

Lessons on oyster anatomy and other activities: "Sammy's Corner:" <http://oysterrecycling.org/sammys-corner/>

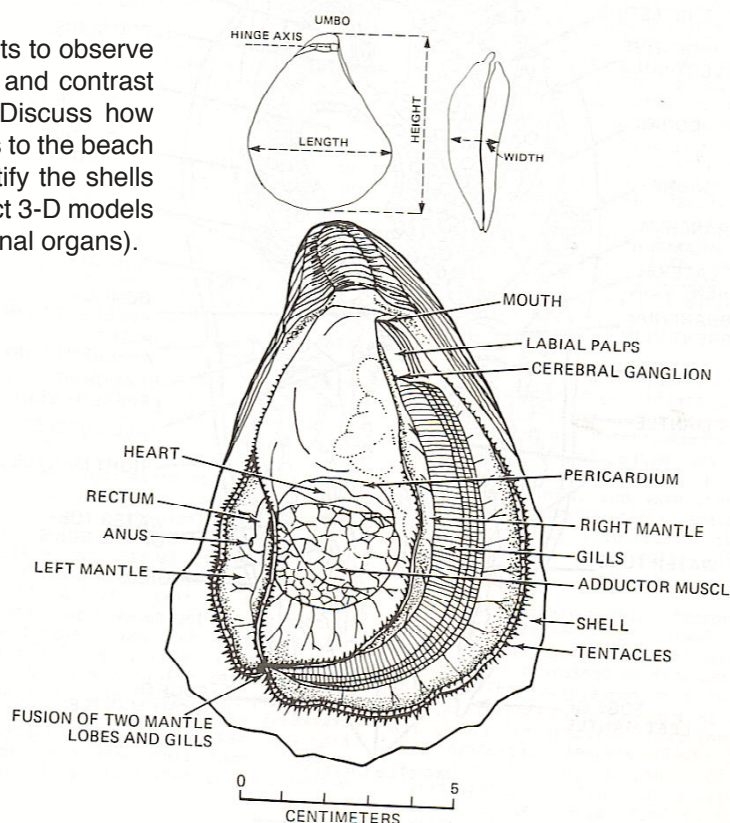


Figure 1. Anatomy of the oyster, *Crassostrea virginica* and proper methods for measuring shell height, length, and width. Figure credited to Galtsoff (1964)

Name:

Date:

ACTIVITY

2.3

THAT'S GROSS ANATOMY, OR WHAT'S UNDER THAT SHELL

1. What kind of a creature is an oyster? (Describe it.)
2. What is a baby oyster called?
3. What does an oyster eat?
4. How does an oyster eat?
5. Name two animals that live on an oyster reef:
6. Even if you don't want to eat an oyster, why are they helpful to have in an estuary?
Give 3 reasons:
7. Describe one reason why an area might temporarily be closed to oyster harvesting.
8. Describe one other interesting fact that you learned about Eastern oysters.

ACTIVITY

2.4

CRUNCHY ON THE OUTSIDE, SOFT AND SQUISHY ON THE INSIDE: DESIGNING AND CON- STRUCTING THE PERFECT OYSTER PREDATOR

CHARTING THE COURSE

Students will generate examples of an oyster predator. They will describe the structural and behavioral adaptations that allow their fictional oyster predator to survive.

BACKGROUND

Oyster predators can easily locate oyster prey and since oysters are not mobile once found there is no means for escape. However, the oyster's thick shell presents a significant deterrent to oyster predators as they must first penetrate the shell before consuming the tissue. Successful oyster predators possess specialized adaptations that help them crush, drill, or open the shell exposing the meat within. Common oyster predators include snails, crabs, starfish, flatworms, and fish. (such as cow nose rays, oyster toadfish, flounder, and black drum).

Predatory snails (gastropods) such as oyster drills and moon snails are common in marine environments and represent significant oyster predators. They move slowly but have voracious appetites. Using mechanical and chemical action they bore holes through the shell of the oyster and insert a large proboscis that extracts the flesh of the oyster. For their small size, less than 1 inch, oyster drills can cause a surprising amount of oyster mortality. Crabs such as the blue crab, mud crab, rock crab, and green crab are particularly harmful to oyster spat and juvenile oysters. Crabs have specialized claws that enable them to crush oyster shells. Flatworms of the genus *Stylochus* are commonly found on oyster beds. These small flat worms prefer to attack small oysters, which they enter through the oyster's gaping shells. Starfish are highly destructive oyster predators. They employ two different methods to open oysters. First they use force with their appendages gripping and pulling apart the oysters shells and then they secrete an anesthetic substance from their stomachs to numb the oyster and cause them to gape. When the valves gape 1 mm the starfish extends its stomach into the shell and begins to digest the oyster flesh. Fish use both visual and chemical clues to locate oyster prey. Most expose the oyster's tissue by crushing the shell. Cow nose rays, summer flounder, skates, and black drum have been noted to cause significant oyster mortalities. Of course one of the most cunning predators of oysters is man.

OBJECTIVES

Students will be able to:

1. Demonstrate an understanding of the oyster's role in the food web.
2. Describe common predators of oysters.
3. Understand that organisms have adaptations that promote their survival as predators and prey.
4. Describe the structural and behavioral adaptations that allow organisms to survive.
5. Generate a model of an oyster parasite.

MATERIALS

- Paper and drawing tools.
- Assorted materials for 3-D models.

PROCEDURE

Warm Up

Have a class discussion about food webs and the variety of ways that organisms interact in an ecosystem. Discuss the role of oysters as the first consumer of primary production and how energy is transferred through the food web. Engage students describing how an oyster protects itself from predators and how predators might be specially adapted to prey on oysters.

Grade Level

3–5

Subject Areas

Science, Language arts, visual arts

Duration

One 40-minute class sessions

Setting

Classroom

Skills

Describing, constructing, creating, interpreting

Vocabulary

Food-web, predator, prey, adaptation

Correlation with TEKS

Science 3.9A,B, 3.10A, 4.9A,B, 4.10A, 5.9A,B, 5.10A

Language Arts 3.17A-E, 3.20A, 4.15A-E, 4.18A, 4.20, 5.15A-E, 5.18A, 5.20

THE ACTIVITY

Have students construct 2-D or 3-D models of fictional oyster parasites. Students must note (label or discuss) the structural and behavioral adaptations of the organism, which promote its survival.

EXTENSIONS

Have students report on oyster predators.

ACTIVITY

2.5

I CAN SEE CLEARLY NOW: A DEMONSTRATION OF FILTER-FEEDING

CHARTING THE COURSE

Students demonstrate via an experiment how oysters can filter and clear water as they feed.

BACKGROUND

Oysters feed on microscopic plants known as phytoplankton through a process known as **filter feeding**. Oysters are known for their great capacity to filter food from the water. It has been estimated that an average sized adult oyster they can filter 50 gallons a day. As oysters filter food from the water they also remove sediments, nutrients (nitrogen and phosphorus), and even pollutants from the water. The removal of these substances from the water column helps increase water clarity and can have a positive effect on water quality. The oyster's ability to obtain energy needs from these tiny plants makes the oyster a dominant primary consumer in estuarine systems.

Grade Level

5–8

Subject Areas

Science

Duration

Two 40-minute class sessions

Setting

Classroom

Skills

Hypothesizing, designing, comparing, interpreting

Vocabulary

Filter-feeding, phytoplankton, algae, control, treatment, hypothesis

Correlation with TEKS

Science 5.1A,B, 5.2A-G, 5.4A,B, 5.9A, 5.10A, 6.1A,B, 6.2A-E, 6.4A,B, 6.12E, 7.1A,B, 7.2A-E, 7.4A,B, 7.10A, 7.12A, 7.13A, 8.1A,B, 8.2A-E, 8.4A,B, 8.11B,C,D

OBJECTIVES

Students will be able to:

1. Demonstrate an understanding of how bivalve animals obtain their food via the process of filter-feeding.
2. Demonstrate an understanding of the oyster's role in the food chain.
3. Establish a hypothesis.
4. Conduct investigations incorporating the use of a control
5. Communicate experimental findings to others

MATERIALS

- 3–5 live oysters
- 2 5-gallon aquaria
- 6 to 10 gallons of Bay water, or dechlorinated tap water mixed with sea salt* salinity 20–30 ppt
- Aquarium air pump, air tubing and air stones (use two pumps, one for each aquarium or obtain adaptor to divide air supply between two pieces of tubing)
- oyster feed (available from aquaculture sources such as Reed Mariculture at www.reed-mariculture.com; Phyto-Feed or Instant algae species *Thalassiosira weissflogii* recommended)
- microscopes
- depression microscope slides
- 1 ml pipette and pipette bulb
- small graduated cylinder
- data sheets

*artificial sea salt can be purchased from pet stores, to adjust water to approximately 20 ppt add 20 mg salt per liter of water (approximately 80 mg per gallon)

PROCEDURE

Warm Up

Have a class discussion about how bivalve mollusks feed by filtering phytoplankton from the water. Explain how this process can improve water quality. Explain that this will be tested via a laboratory experiment. Have the class establish a hypothesis for this experiment. Engage them in designing the experiment, defining the need for a control and treatment tank.

THE ACTIVITY

Class period 1

1. Open the class with pre-laboratory warm-up lesson.
2. Divide students into teams and have them design an experiment to test the hypothesis relating to filter-feeding and the improvement of water clarity.
3. Have groups present their experimental designs.
4. Explain the design that will be used for the class—(1) establish a control tank (no oysters) and a treatment tank (oysters), (2) add equal amounts of algae to each tank, (3) assess change in water clarity through time by quantifying the change of the abundance of algal cells in the water.

Set up two 5-gallon aquaria tanks, each containing 4 gallons of water. Aerate aquaria using air pump, tubing and air stones. Place 3–5 oysters in one tank (the treatment tank) and no oysters in the other tank (the control tank). Allow oysters to acclimate overnight.

Class period 2

5. At the beginning of class have students add 25 ml of oyster feed to each tank (this should color the water, if it doesn't add an additional measured amount to each tank—note both tanks must receive the same amount of algae). Record the temperature and if possible salinity of the tank water.
6. Gently stir the water to mix.
7. Immediately remove a 0.5 ml sample of water from each tank, place on 2 separate microscope slides, and cover with cover slip. Count the number of algae cells in 5 fields of view. This is the initial or time 0 sample. Each team can collect samples. They should carefully record the counts for each sample. The counts from the five fields represent replicates. Because of the error associated with sampling and counting it is important to include replication when you run an experiment. The mean value of the replicates will provide a more accurate estimate of the algae abundance than any individual count.

Repeat sampling through time as permitted. The oysters should clear the water in about 2 hours. Try to have at least three time points (such as 0, 30 minutes, 2 or 24 hours).

8. Have students, interpret and discuss results (written or orally).

EXTENSIONS

Design other methods to assess the change in water quality through time. Compare oysters to clams, or small oysters to large oysters, or oysters maintained at different temperatures. Have students write up formal scientific papers on the topic. Relate to lessons on the scientific method.



ACTIVITY

2.6

PARASITES ON THE HALF SHELL

CHARTING THE COURSE

In the following Data Activity, students become shellfish biologists and examine the *P. marinus* disease dynamics at three Copano/Aransas Bay oyster reefs. Students will correlate their disease data observations with environmental conditions at the site.

BACKGROUND

During the past eight decades, oyster populations have been plagued by a disease-causing protistan oyster parasite. Though quite harmful to oysters, the disease does not affect humans. The oyster parasite, *Perkinsus marinus* (also called Dermo disease) was first documented in the Gulf of Mexico in the 1940s and caused severe oyster mortalities. Today *P. marinus* remains a significant threat to Gulf coast oyster populations and causes severe mortalities of oysters in moderate to high salinity areas of the coast.

In order to gain a better understanding of the disease and to better manage oysters in Texas, scientists carefully monitor the levels of the disease throughout the coast. You can't tell if an oyster is infected with the disease just by looking at it, a tissue sample must be analyzed using a special diagnostic assay for an accurate diagnosis to be made. Typically 20 to 30 oysters from a particular site are examined. The percentage of infected oysters in the sample is termed the disease **prevalence**. Epizootic is the term for an outbreak of a disease in a particular animal population. Epizootiology refers to the sum of factors controlling a particular disease in an animal population. *Perkinsus marinus* prevalence varies seasonally and annually in response to varying environmental conditions. *Perkinsus marinus* prevalence increases during the summer and fall in response to warm water temperatures and then declines in the winter and spring in response to cooling temperatures. The distribution of the parasite within a particular estuary or tributary varies with salinity—*P. marinus* prevalence is generally higher down bay where higher salinities prevail than up bay where lower salinities are dominant. The disease tends to be more prevalent in drought years when river flows are reduced and salinities increase bay wide than in wet years.

Grade Level

6–8

Subject Areas

Science

Duration

One 40-minute class sessions

Setting

Classroom

Skills

Interpreting, hypothesizing, correlating, graphing

Vocabulary

Protistan, *Perkinsus marinus*, prevalence, epizootic

Correlation with TEKS

6.2D,E, 6.3A, 6.12D,E, 7.2D,E, 7.3A, 7.13A, 8.2D,E, 8.3A, 8.11A-D

OBJECTIVES

Students will be able to:

1. Identify two common oyster diseases.
2. Correlate environmental conditions with disease prevalence.
3. Compare and contrast oyster disease levels between years.

MATERIALS

- Student handouts.
- Data set.
- Computer graphing program (optional).

PROCEDURE

Warm Up

Set the stage by posing the question, “What might cause the oysters of Copano or Aransas Bay to decline?”

Introduce the concept of an epizootic.

Introduce *Perkinsus marinus* as a protistan disease of oysters, which has impacted Copano and Aransas Bay oyster populations.

If you were trying to manage the oyster resource, what might you want to know about the disease?

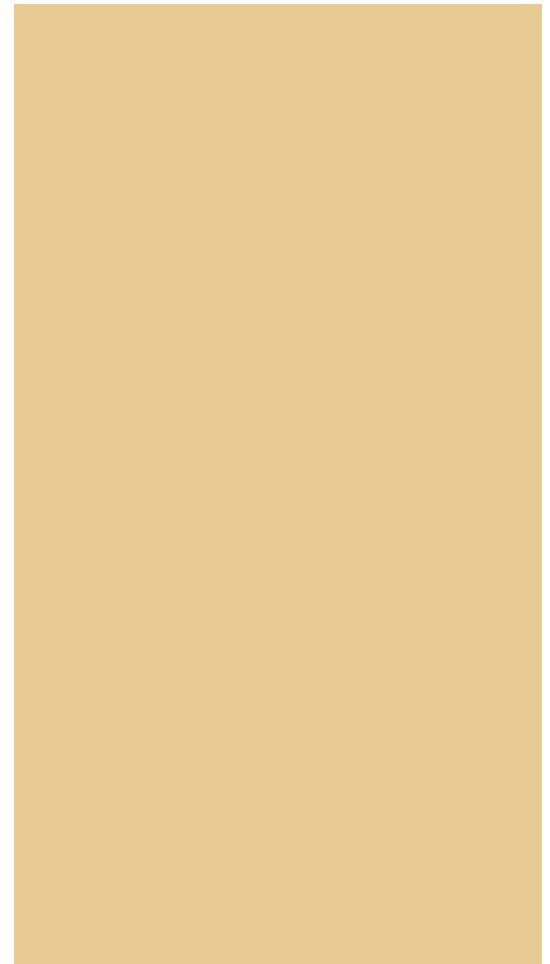
THE ACTIVITY

1. Divide the class into teams of shellfish biologists charged with studying the *P. marinus* disease in oysters.
2. Each team will receive a data set containing the results of disease, temperature, and salinity samples that were recorded for several months from 2009–2012.
3. The samples were collected at three oyster reefs: Shellbank, Lap, and Long Reefs in Copano and Aransas Bays.
4. Students should graph the data (either by hand or using Excel). Using their graphs, students should:
5. Compare temperature at the three sites.
 - Determine the maximum and minimum temperature for the year and indicate the month in which they occurred.
 - Compare salinity at the three sites: which site had the lowest salinities, and which had the highest salinities?
 - Determine the range of salinity at each site.
 - Compare *P. marinus* prevalence at the three sites, which site had the highest and which had the lowest.
 - Determine at what time of the year disease was the highest.

WRAP UP

Based on their analysis of the data, students should:

- Speculate on why they saw salinity and disease differences between the sites and why temperature varied little between sites.
- Discuss the relationship between temperature and disease levels.
- Predict which oyster bar is going to be most impacted by disease.
- As shellfish biologists what recommendations might students make to the oyster resource managers and those involved with the oyster fishery.



ACTIVITY

2.6

PARASITES ON THE HALF SHELL

-
- A. Using the chart on the following page and the data in Table 1 draw graphs to compare the monthly prevalence of *Perkinsus marinus*, temperature, and salinity at the oyster reefs known as Shellbank, Lap, and Long Reefs in 2011–2012. Be sure to put a title and labels on your graph.
 - B. After completing your graph answer the following questions:
 1. Compare temperature at the three sites.
 2. Determine the maximum and minimum temperature for the year and indicate the month in which they occurred.
 3. Compare salinity at the three sites, which site had the lowest salinities, which had the highest salinities?
 4. Determine the range of salinity at each site.
 5. Compare *P. marinus* prevalence at the three sites: which site had the highest and which had the lowest infestation?
 6. Determine at what time of the year disease was the highest.
 7. Based on your analysis of the data, speculate on why you saw salinity and disease differences between the sites, but very little temperature differences between the sites.
 8. Discuss the relationship between temperature and disease levels.
 9. Predict which oyster reef is going to be most impacted by disease.
 10. As shellfish biologists, what recommendations might you make to the oyster resource managers and those involved with the oyster fishery?

TABLE

1

Monthly *Perkinsus marinus* prevalence data at three sample locations: Shellbank, Lap, and Long Reefs. The data is for the years 2009–2012.

PERKINSUS MARINUS PREVALENCE (% commercial infected)

Year	Month	Oyster Reef		
		Shellbank	Lap	Long
2009	January	0%	30%	33%
2009	May	0%	0%	44%
2009	October	0%	0%	87.5%
2010	January	0%	0%	----
2010	August	0%	33%	100%
2010	December	0%	20%	100%
2011	April	0%	10%	90%
2011	June	0%	78%	100%
2011	September	0%	100%	100%
2011	November	0%	90%	100%
2012	May	50%	92%	100%
2012	August	75%	100%	0%
2012	November	70%	92%	92%



TEMPERATURE (C°)

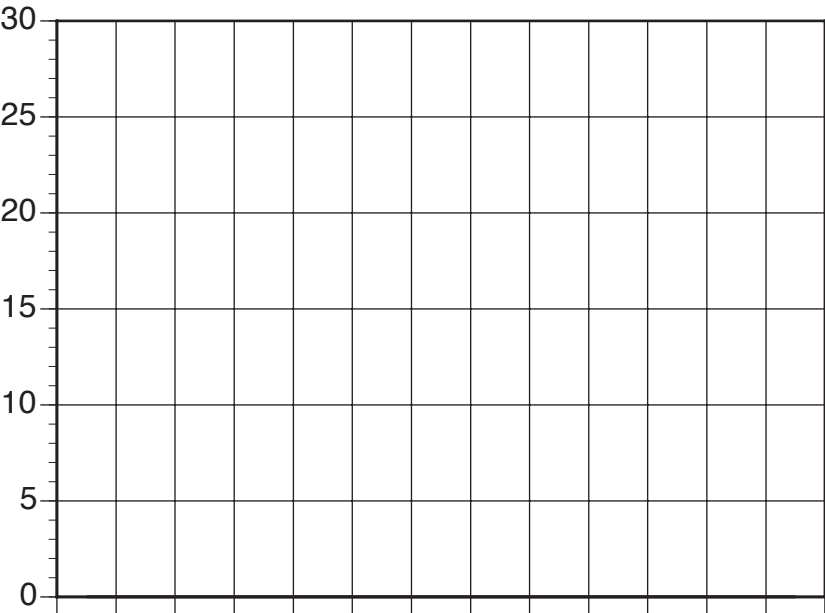
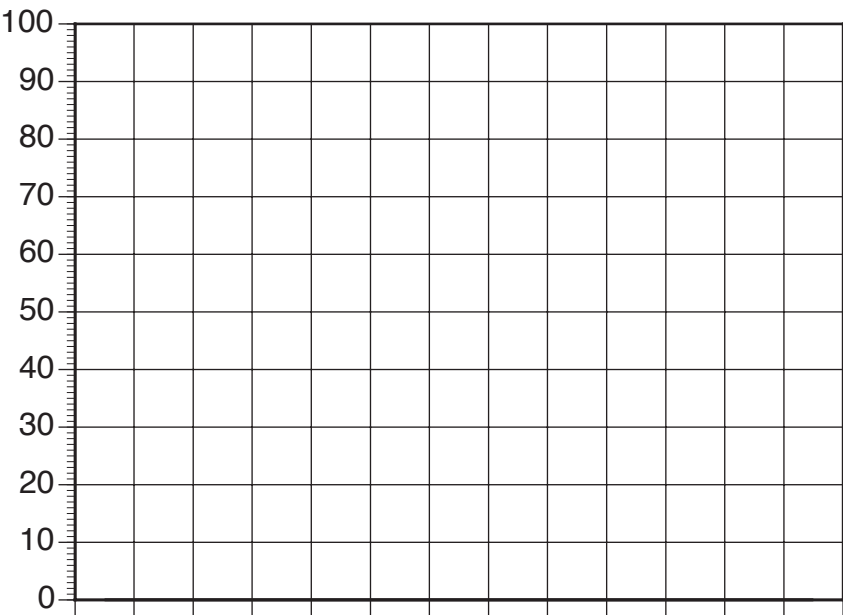
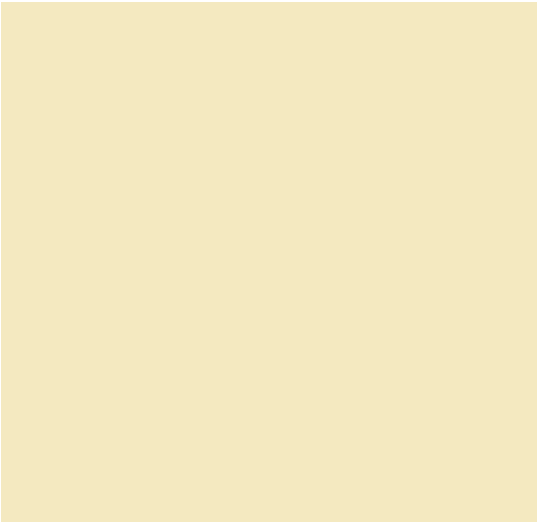
Year	Month	Oyster Reef		
		Shellbank	Lap	Long
2009	January	15	15	14
2009	May	29	28	28
2009	October	29	29	28
2010	January	13	14	----
2010	August	31	31	31
2010	December	16	17	16
2011	April	24	24	23
2011	June	30	30	30
2011	September	29	29	29
2011	November	19	19	20
2012	May	27	27	27
2012	August	30	30	31
2012	November	18	17	18

SALINITY (PPT)

Year	Month	Oyster Reef		
		Shellbank	Lap	Long
2009	January	29	30	29
2009	May	34	33	33
2009	October	43	43	42
2010	January	12	11	----
2010	August	11	13	26
2010	December	7	9	12
2011	April	16	19	26
2011	June	25	26	30
2011	September	34	37	40
2011	November	37	38	37
2012	May	25	27	28
2012	August	32	34	39
2012	November	35	34	31



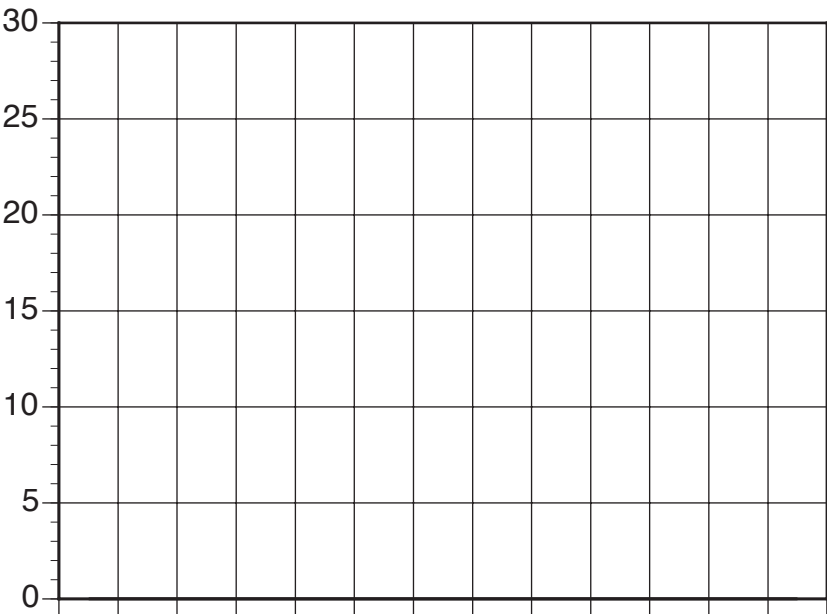
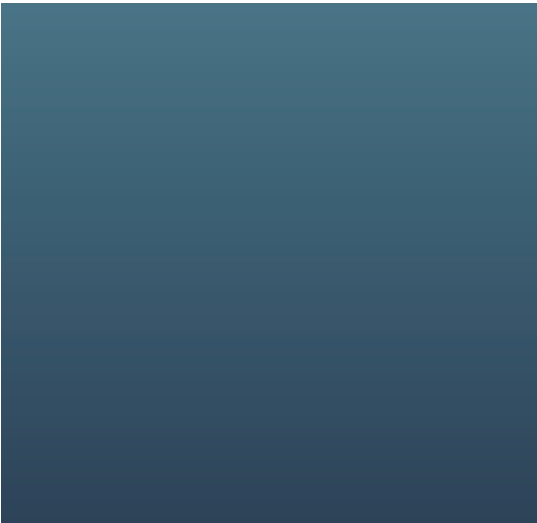
PERKINSUS MARINUS PREVALENCE

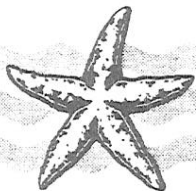


SALINITY



TEMPERATURE





PALE, POETIC PEARLS

Objective

The student will be able to estimate lengths in millimeters.

Vocabulary

cultured
gemstone

harvest
nacre

Background

The pearl was probably the earliest recognized gemstone. Greeks believed they were divine tears and the Chinese believed they stood for preciousness and purity. Ancient Syrians wore pearl necklaces, and highborn Roman women wore massive pearl earrings. Even the English crown jewels include pearls.

Pearl oysters, which are only distantly related to the commercially harvested oyster, do not occur in the United States. Most come from the South Sea and Persian Gulf. The silver-lipped oyster, LaPaz oys-

ter, and the black-lipped oyster are the most common natural pearl producers.

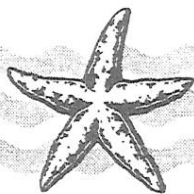
Most any mollusk is capable of making "pearls." When small particles of sand, shell, or mud work their way into the mollusk body, they are covered with nacre, creating a "pearl." But only the South Sea and Persian Gulf species produce pearls that are round and have a valuable luster.

Today, the pearl industry exists largely on cultured pearls. This process was developed in Japan and requires that a "seed" of foreign material be implanted into the oyster. The pearl forms around the seed. Most of these pearls are superior to natural pearls. The most common size pearl used in necklaces is eight millimeters in diameter. Although, they are available in other sizes. One necklace of 45 cultured pearls 16 to 19 mm in diameter recently sold for over \$2 million! Over 2000 pearl farms operate in Japan, the world's leading pearl exporter.

Exercises

Pearls are bought and sold based on their diameter which is measured in millimeters.

- Estimate the number of millimeters in one inch.
- How many 8 mm pearls would it take to be one inch in length?
- A choker necklace is 14 to 16 inches long. How many 8 mm pearls would it take for a choker?
- A princess necklace is 16 to 20 inches long. How many 8 mm pearls would it take for a princess?
- A matinee necklace is 20 to 26 inches long. How many 8 mm pearls would it take for a matinee?
- An opera necklace is 28 to 32 inches long. How many 8 mm pearls would it take for an opera?
- A rope necklace is 40 inches long. How many 8 mm pearls would it take for a rope?
- Estimate the number of 12 mm pearls in one inch.
- How many 12 mm pearls would it take for a choker? A princess?
- How many 12 mm pearls would it take for a matinee? An opera?
- Estimate the number of 16 mm pearls in one inch. How many 16 mm pearls would it take for a choker? A princess? A matinee? An opera?



OLD AGE OYSTERS

Objective

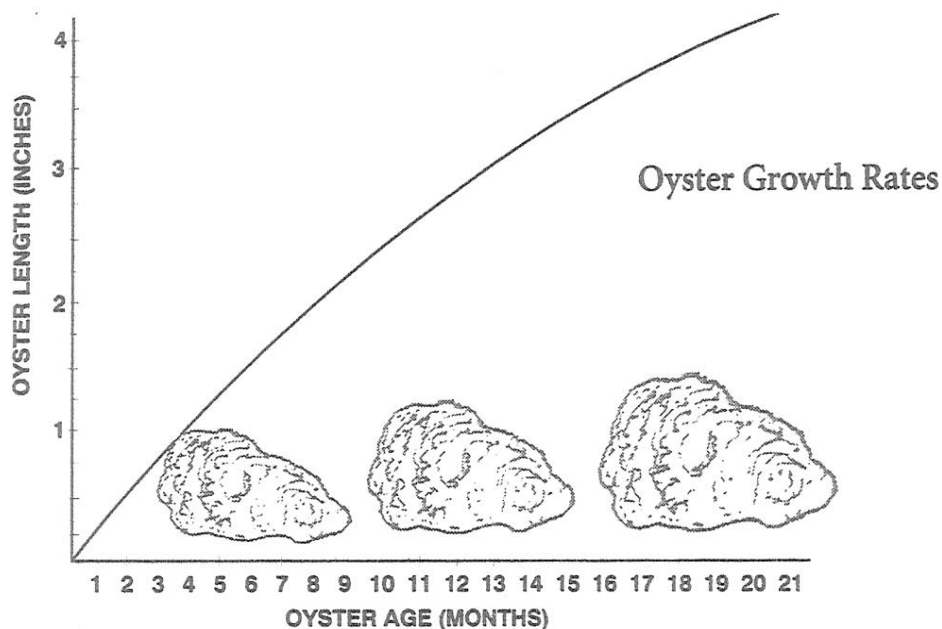
The student will be able to interpret data from a line graph.

Vocabulary

harvest
maximum
minimum

Background

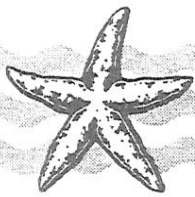
In Texas waters, oysters may be harvested from November 1 through April 30. They must be three inches or larger. Most oysters reach a harvestable size in a couple of years. In the warm waters of Texas, growth occurs all year long. Maximum growth occurs in the late winter and early spring, while minimal growth occurs during the summer spawning season. They can live to the ripe old age of 30 years old, at which time they may be 12 inches in length.



Exercises

Use the line graph above to answer the following.

- Estimate the length of an oyster that is three months old.
- Estimate the length of an oyster that is eight months old.
- Estimate the length of an oyster that is one year old.
- Estimate the length of an oyster that is 15 months old.
- Estimate the length of an oyster that is 18 months old.
- Estimate the age of an oyster that is 1.25 inches long.
- Estimate the age of an oyster that is 2.5 inches long.
- Estimate the age of an oyster that is 3 inches long.
- Estimate the age of an oyster that is 3.5 inches long.
- Extend the graph so you can estimate the age of an oyster that is 5 inches long.



OYSTERS BY THE POUND

Objective

The student will be able to interpret data from a bar graph.

Vocabulary

commercial
culled

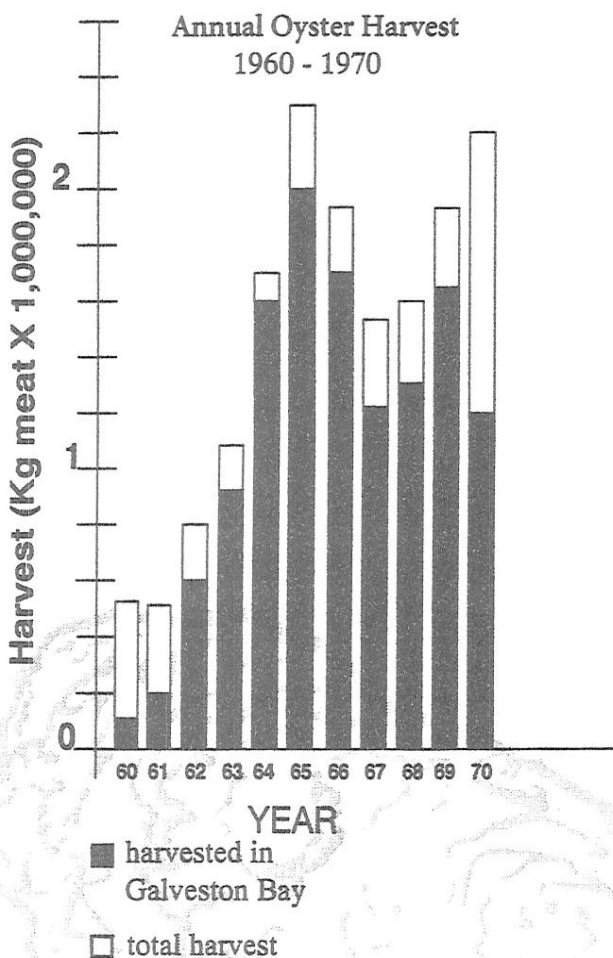
dredge
harvest

Background

The commercial oyster fishery contributes \$20 to \$30 million to the Texas economy each year. Some three to five million pounds of oyster meat are landed annually.

Oysters are found in nearly every bay in Texas, however, they are most abundant in those located north of Corpus Christi. Galveston Bay is the most productive, followed by San Antonio Bay. About 90 percent of the Texas harvest comes from these two bays.

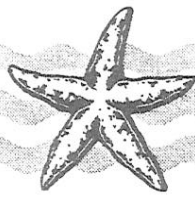
The most common method for harvesting oysters is the oyster dredge. This is a basket attached to a toothed bar that is dragged over a reef by a boat. It scrapes oysters into the basket. The catch is then brought on the boat's deck to be culled.



Exercises

Use the bar graph to answer the following.

- Is the portion of the harvest from Galveston Bay constant from one year to the next?
- Predict the 1971 harvest if the trend beginning in 1968 continued.
- If the 1960 and 1961 harvests were the end of a trend, predict the 1959 harvest.
- Determine the average annual oyster harvest for the 1960's.
- What was the annual oyster harvest in 1965?
- What was the annual oyster harvest in 1969?
- During which year was the oyster harvest the greatest?
- During which year was the oyster harvest the least?
- What conditions might contribute to a poor harvest?



THE FANTASTIC FILTER

Objective

The student will be able to use addition, multiplication, and division to interpret marine data.

Vocabulary

cilia
plankton

Background

Oysters feed on planktonic plants and animals. Currents are created by gill cilia. Water is brought

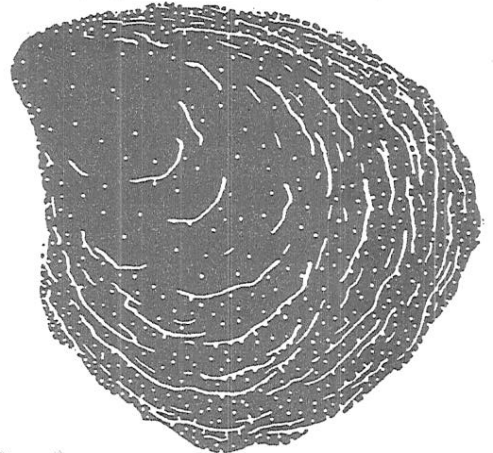
into the shell and into contact with the oyster's gills where food particles are trapped by mucous and slime. The food is then transferred to the mouth.

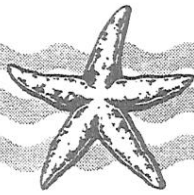
Oysters feed at any time of the day or night and may filter as much as 30 quarts of water through their shells in a single hour. For this reason, oysters are often used as sentinel organisms for the bodies of water in which they live. Because they filter such tremendous volumes of water, toxins become concentrated in their tissues. By monitoring a bay's oyster population, scientists can detect toxins in the water.

Exercises

Complete the following.

- How much water would a single oyster filter in a day?
- How much water would six oysters filter in a day?
- How much water would a single oyster filter in a week?
- How much water would ten oysters filter in a day?
- How much water would a single oyster filter in the month of June?
- How much water would seven oysters filter in the month of May?
- How much water would three oysters filter in the month of March?
- How much water would a single oyster filter in a year?
- How long would it take an oyster to filter 28,800 quarts of water?
- How long would it take two oysters to filter 14,400 quarts of water?
- How many weeks would it take five oysters to filter 50,400 quarts of water?
- How many weeks would it take for three oysters to filter 12,960 quarts of water?
- How many quarts of water would a single oyster filter during the summer (June - August)?
- How many quarts of water would a single oyster filter during the spring (March - May)?
- How many quarts of water would a single oyster filter during the winter (December - February)?
- How many quarts of water would a single oyster filter during the fall (September - November)?





TREASURES OF THE DEEP

Objective

The student will be able to identify historical and literary references to pearls.

Vocabulary

bivalve	mollusk
mantle	nacre

Materials

reference books

Background

Oysters and mussels are two bivalve mollusks that spend their lives glued to hard surfaces underwater. Sometimes bits of sand or shell enter the animals, becoming trapped in the fleshy mantle. What an irritating situation! Oysters and mussels protect themselves by secreting a milky substance that hardens around the particle, smoothing its edges. Several species of oysters and mussels secrete enough nacre to produce lustrous, beautiful pearls.

Procedure

Match the appropriate pearl from the column on the right, by placing the letter in front of the correct reference in the left column.

- _____ People implant bits of shell in oyster mantles.
- _____ A shiny nacre, or aragonite calcium carbonate that lines the shells of some oysters and mussels
- _____ These were collected by the shahs of Iran.
- _____ Julius Caesar was said to invade Britain for this reason.
- _____ These adorned dead Hopewell Indians in the United States
- _____ Famous twentieth century singer
- _____ Famous author who wrote about China
- _____ Written by John Steinbeck

A. The Pearl

B. Pearls from the Persian Gulf that back the currency of a country

C. Pearl Bailey

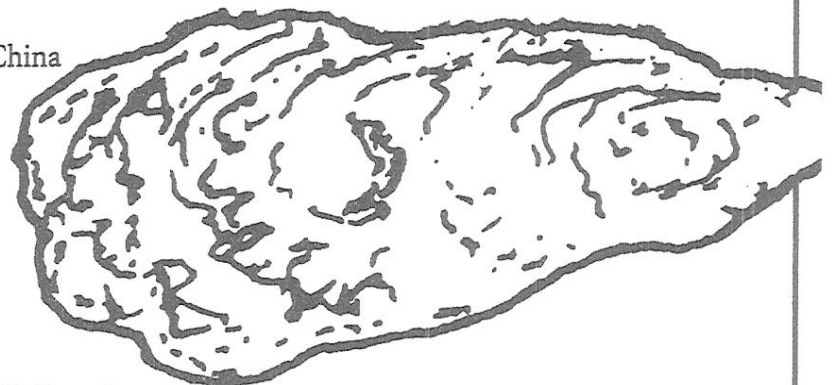
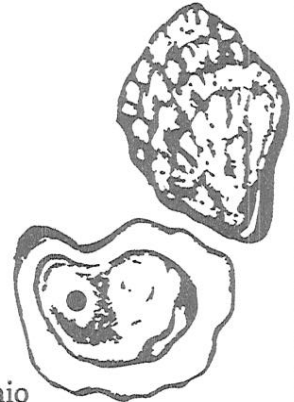
D. Cultured pearls

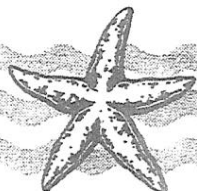
E. Hope of getting pearls

F. Mother of pearl

G. Freshwater pearls from Ohio

H. Pearl S. Buck





SALT OF THE SEA

Objective

The student will be able to interpret data from a pie graph.

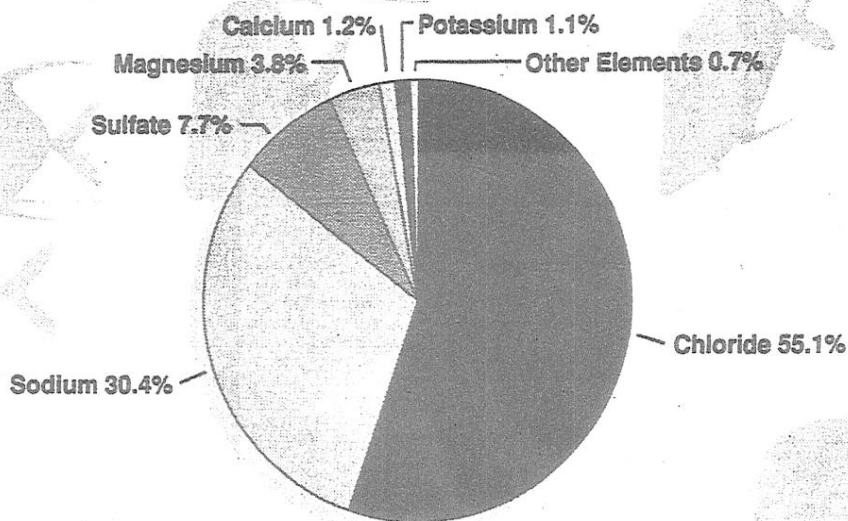
Vocabulary

parts per thousand
salinity

Background

Coral reefs are best developed in areas where the salinity of the water ranges from 35 to 38 parts per

thousand (ppt). Salinity is the measurement of dissolved salts and other dissolved materials in seawater. Most of the ocean's salinity results from sodium chloride. The majority of the salts and organic constituents of seawater were originally contained in rocks, soil, and decayed organic matter. As rain fell, it dissolved these materials and carried them into rivers and streams, and eventually, to the sea. Runoff contains not only salts, but also trace metals essential for marine plants and animals, as well as suspended food materials.



Exercises

Use the pie graph to determine the following.

- What percent of seawater is made up of sulfate?
- What percent of seawater is made up of calcium?
- What percent of seawater is made up of sodium?
- What percent of seawater is made up of chloride?

Which three constituents make up the smallest percentage of seawater?

Which two constituents make up the largest percentage of seawater?

What percent of seawater is made up of sodium, sulfate, and magnesium?

What percent of seawater is made up of chloride, potassium, and calcium?

YSTER RECYCLING



**IT'S HABITAT
FORMING**

FAST FACTS

DID YOU KNOW?

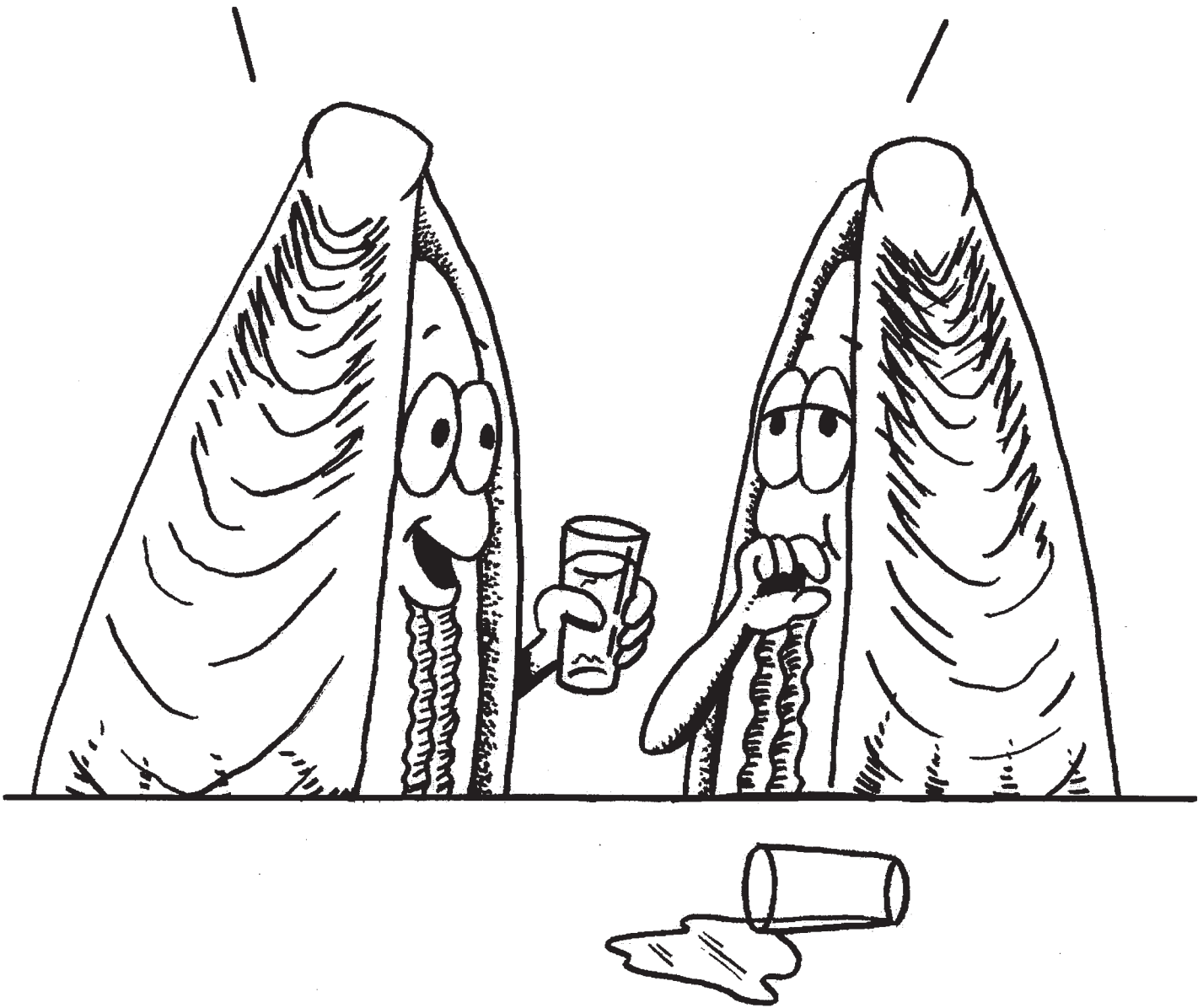
- Oysters can switch between being male and female
- A female oyster can produce over 100 million eggs per year
- Young larval oysters don't have a shell, they swim freely in the water
- After about three weeks, oysters form a shell and cement themselves to a hard substrate
- Over time, reefs are formed by the numerous oyster shells built up into the water
- Oysters in Texas can reach market size (three inches) in 18 months
- Oysters can live up to 20 years



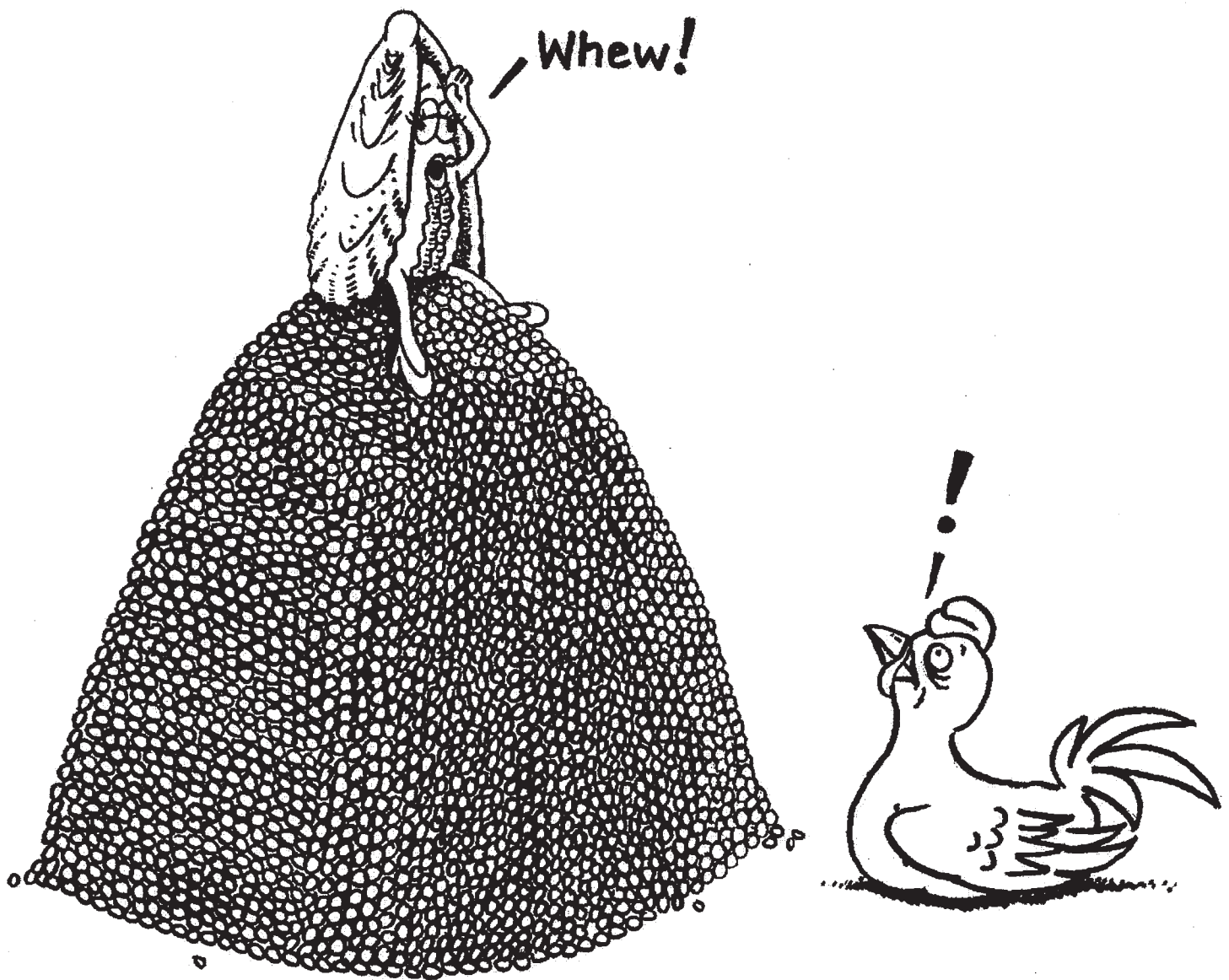
An oyster can change from male to female several times during its life!

More water?

No thanks, I'm full.

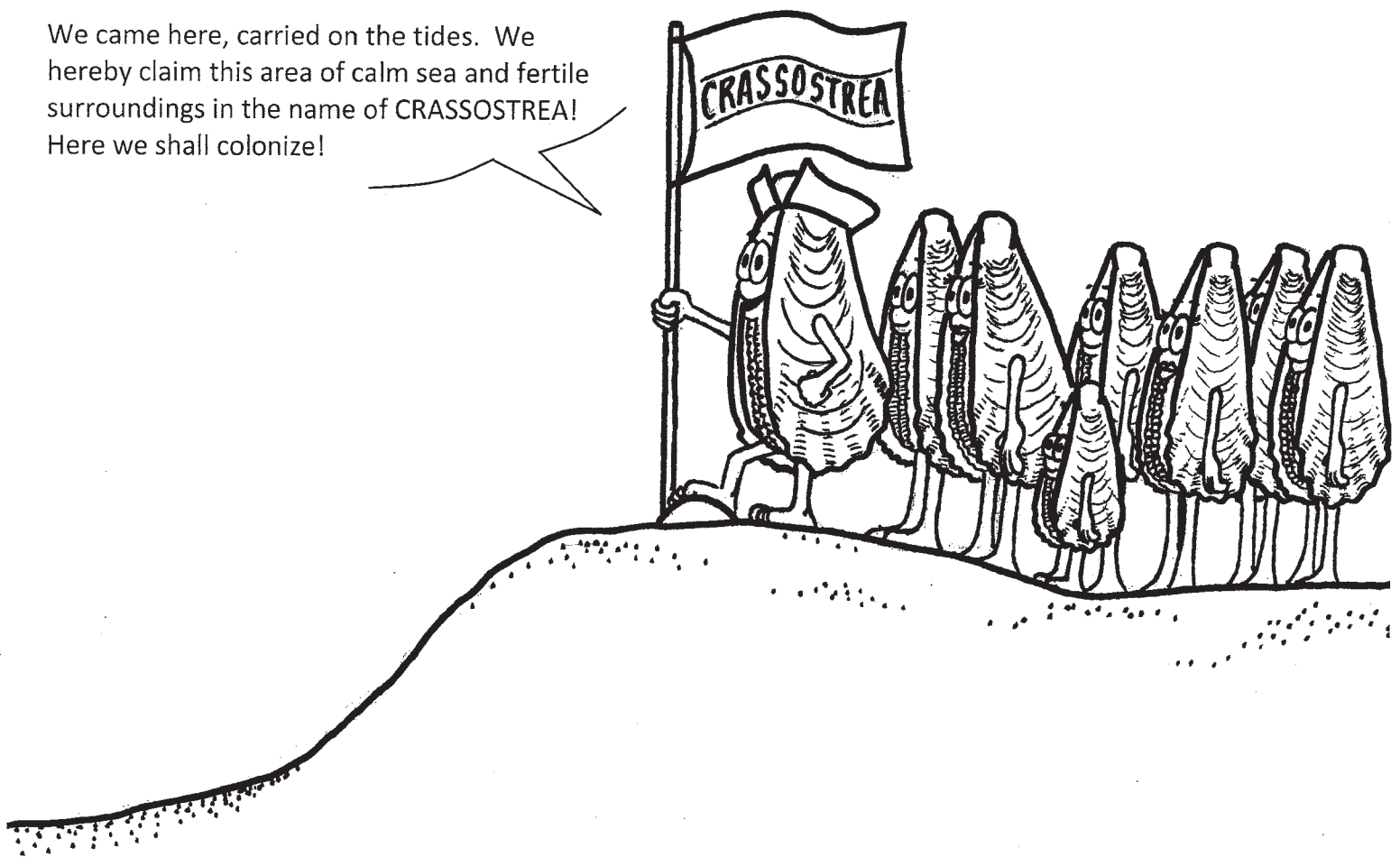


Oysters filter their food out of the water.

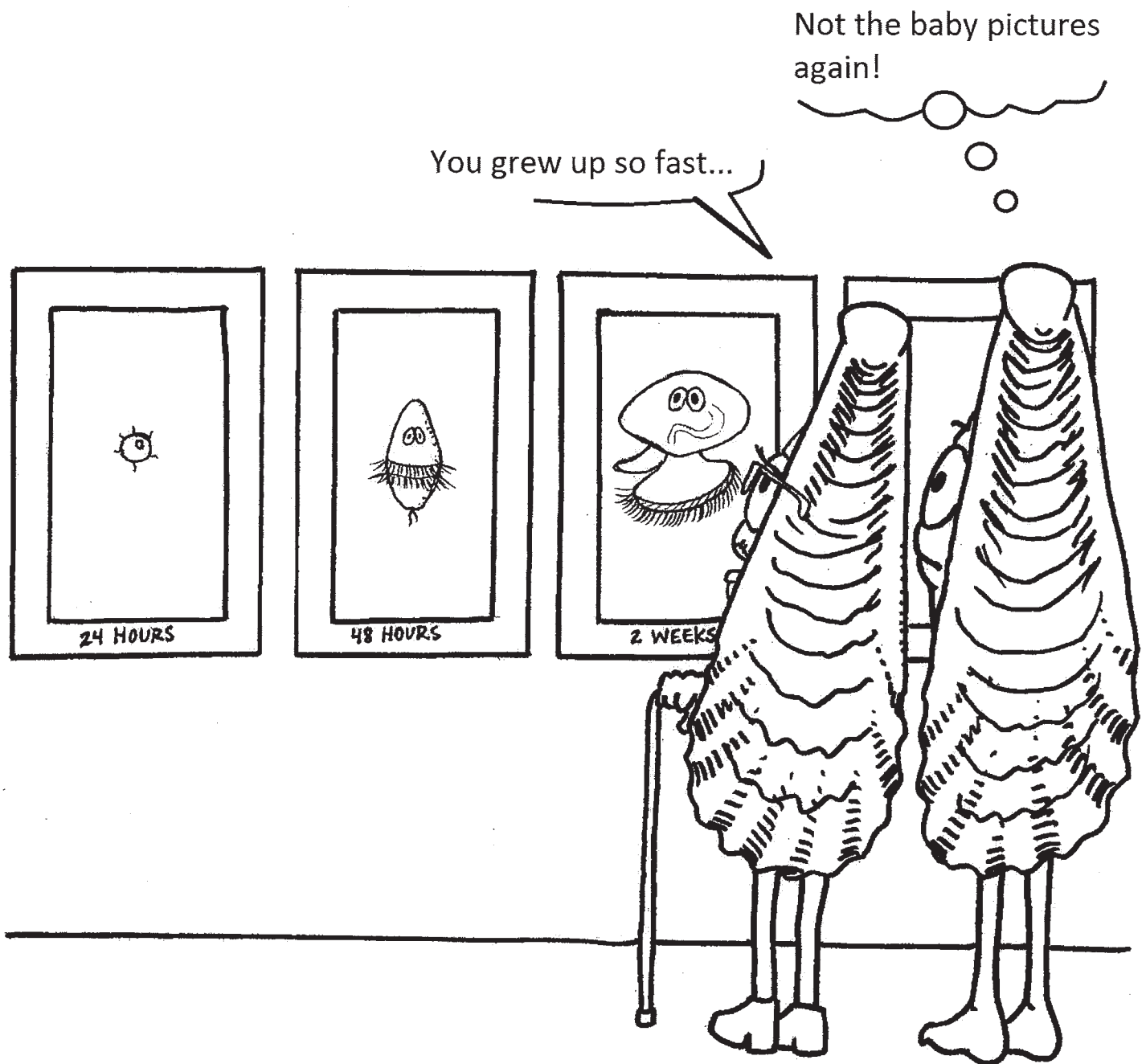


A female oyster can lay over 1,000,000 eggs in one year!

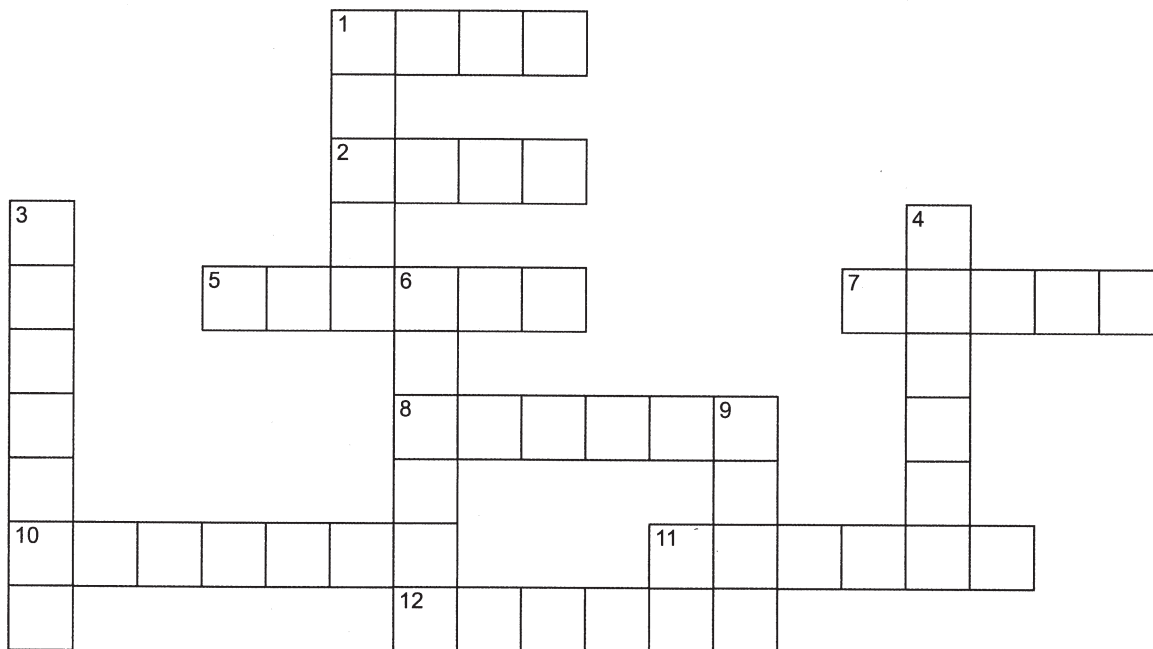
We came here, carried on the tides. We hereby claim this area of calm sea and fertile surroundings in the name of CRASSOSTREA! Here we shall colonize!



Oysters are colony builders. Groups of oysters settle together in one area.



Oyster eggs develop into free-swimming larvae. This larval stage goes on for three weeks. Eventually, the larvae settle to the bottom and never move again.



ACROSS

- 1 SPAT
- 2 EGGS
- 5 COLONY
- 7 WATER
- 8 SHUCKS
- 10 RECYCLE
- 11 FILTER
- 12 REEF

DOWN

- 1 SHELL
- 3 RESTORE
- 4 LARVAE
- 6 OYSTER
- 9 SWIM

WORD SEARCH

U X J X F N B R X F T S E T T
 F T K G O R R K E I K R A U I
 U I A L S G G E Z C E U V S Y
 E B L P J U R Z U C U J R H P
 E R O T S E R H Y F E M A E W
 H Z T T E F S C Y B Q I L L N
 K R A T P R L M S R F W Z L K
 Y E D D P E X K G S O S Q D N
 X N K Q U U Z K C K H O P C A
 G I O U Q U A E E E A D H U U
 B D K L R M F P W N B D W R K
 W M X F O Y S T E R I A I Z F
 H G V Z L C Z L A V T L H B E
 E Z G V P U A M H E A C A T W
 N R I U W O G S R P T I G T L

COLONY

HABITAT

RECYCLE

SHELL

EGGS

LARVAE

REEF

SHUCKS

FILTER

OYSTER

RESTORE

SPAT

SWIM

WATER

THE PROCESS

SINK

Oysters are commercially harvested in Texas from November through April. The majority of these oysters are sold to restaurants and seafood wholesalers.

YOUR

After an oyster is eaten at one of our partner restaurants, the shucked shells are separated from the trash and stockpiled throughout the year.

SHUCKS

When a large enough volume of shells have been stockpiled, the shells are brought back out to bay waters and used to restore degraded oyster reefs.



IMPORTANCE

ECOLOGY

Oyster reefs provide habitat for a diverse group of animals including fish, shrimp, worms and crabs. Oysters are food for larger fish, rays and crabs that are capable of crushing their shells.

ECONOMY

Oysters are big business – Texas is the 2nd largest oyster producer in the U.S. The oysters also provide “ecosystem services”: They improve water quality by filtering phytoplankton and excess nutrients, and the oyster reefs can form a protective breakwater that stabilizes the shoreline and protects against erosion.



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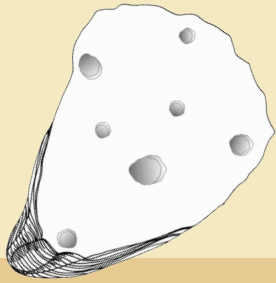
WWW.OYSTERRECYCLING.ORG

FUNDING PROVIDED BY:



INTERESTING FACTS OYSTERS...

...can live up to **20 years** 1 • 5 • 10 • 15 • 20



...in Texas can grow to market size
(3 IN.) in **18MONTHS**

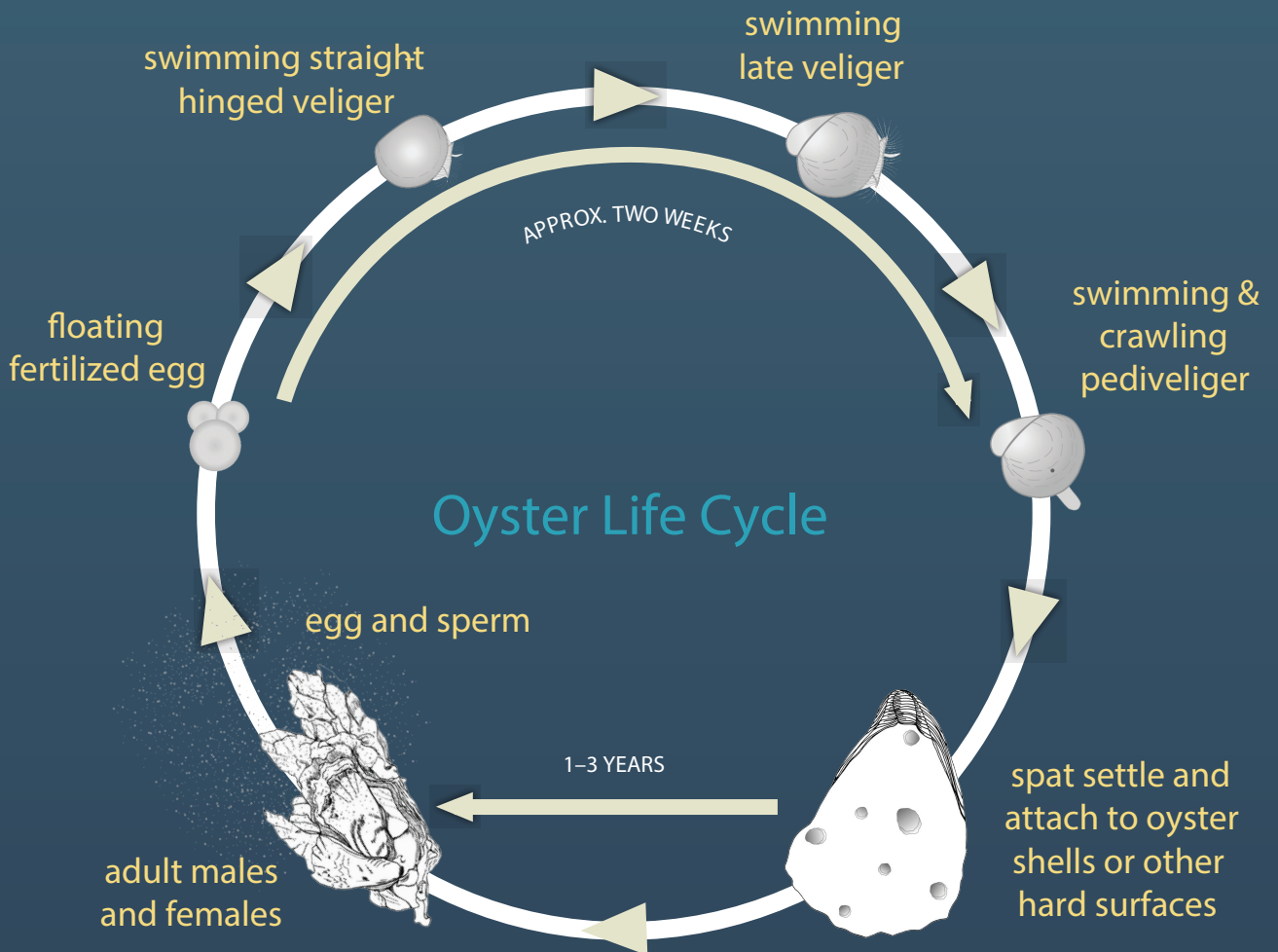
...can be eaten
year round

...feed by filtering algae and other food particles from the water

...reproduce by releasing eggs or sperm into the water when temperatures warm

...can change gender once or more during their lifetime

One oyster can filter up to **50 gallons** of water **per day**



Credit: Karen R. Swanson/COSEE SE/NSF