Overview

The Eastern oyster, *Crassostrea virginica*, is an important commercial shellfish species for Alabama. Recent figures indicate that Alabama ranks first in the nation for oyster processing. Regionally, the Gulf of Mexico led in oyster landings with 59 percent of the national total. However, oyster production is highly variable from year to year due primarily to natural environmental and predator fluctuations.

Considerable state and regional oyster research along the Gulf Coast, including studies of oyster aquaculture, is being conducted for this valuable industry. Oyster farming consists of producing oyster larvae, protecting the juveniles (spat), and then planting in natural waters with various degrees of control. Methods of growing oysters can range from scattering the spat on the bottom to maintaining spat in an enclosed structure suspended above the bottom.

Small-scale oyster gardening programs began in Maryland and Virginia as a means of restoring oyster population and improving water quality in Chesapeake Bay. Volunteer oyster gardeners on the Chesapeake grow oysters in floating cages moored to private piers. Coordinating organizations provide spat set on shell to the volunteers, who monitor the oysters and maintain the cage. Oysters are grown inside the cages until they are approximately three inches long and then planted onto oyster reefs to augment the restoration efforts in the Chesapeake Bay.

Based on the success of this program, a similar project was initiated on the Gulf Coast in 2000. Successful implementation of an oyster gardening program in Mobile Bay will provide a number of benefits the coastal community. Oyster gardening improves the Bay’s water quality and accelerate the establishment of sustainable oyster populations on existing or constructed oyster reefs. As filter feeders, the oysters you will grow cleanse the water of excess nutrients and suspended particles—one oyster is capable of filtering up to five gallons of water per hour. Once they are added to the reefs in Mobile Bay, your oysters will also provide habitat for other important marine species who concentrate there to feed, to protect themselves, or to use oyster shell as a nursery for producing their young.

Oyster gardening programs can also bring intangible benefits, including greater public awareness of how oysters improve the Bay's water quality, the economic role of the oyster in our communities, and a greater understanding of the cultural importance of Mobile Bay's oyster industry.

The Mobile Bay Oyster Gardening Program is now in its tenth year of operation and has produced over 400,000 oysters. Through volunteer participation, our objective is to continue to provide education on the role of the oyster in the ecology of Mobile Bay while simultaneously improving the water quality and increasing the productivity of local oyster reefs. Thank you for participating in this joint effort between the Alabama Cooperative Extension System, the Mobile Bay National Estuary Program, the Mississippi-Alabama Sea Grant Consortium, the Auburn University Marine Extension and Research Center, the Alabama Department of Public Health—Seafood Branch and the Alabama Department of Conservation and Natural Resources—Marine Resources Division, Mobile Bay Keeper.

The Mobile Bay Oyster Gardening Program would like to thank its 2010 Partners:

Organized Seafood Association of Alabama: www.alabamaseafood.org
The Sybil H. Smith Charitable Trust
Wintzell's Oyster House: www.wintzellsoysterhouse.com/
Weeks Bay Foundation: www.weeksbay.org

Site Assessment

To determine if your location is acceptable please complete the following assessment.
You must be able to answer "yes" to the following criteria to qualify for the oyster gardening program.

1. Do you live on the water with a pier or landing?

☐Yes ☐ No

2. Is your property in the conditionally approved oyster growing areas according to the map provided?

☐Yes ☐No

3. Does the tide ever recede beyond the end of your pier and expose the bottom for more than 2 hours?

☐Yes ☐No

4. Do you reside at this location year round?

☐Yes ☐No

5. Are you willing to spend approximately 20 minutes per week caring for your oysters until they are ready for reef restoration?

☐Yes ☐ No

Please answer the following questions for our reference, but these questions will not affect your application as an oyster gardener:

1. Do you have freshwater plumbing at your pier?

☐Yes ☐ No

2. Do you have prior experience as a volunteer master gardener or other similar program?

☐Yes ☐ No

Oyster Growout Cages used in the Mobile Bay Oyster Gardening Program

Page Cage
Ideal for volunteers with piers
Dimensions: 1.5’ x 1.2’ x 0.7’
Carrying Capacity: ~250 oysters
No. cages per volunteer: 4

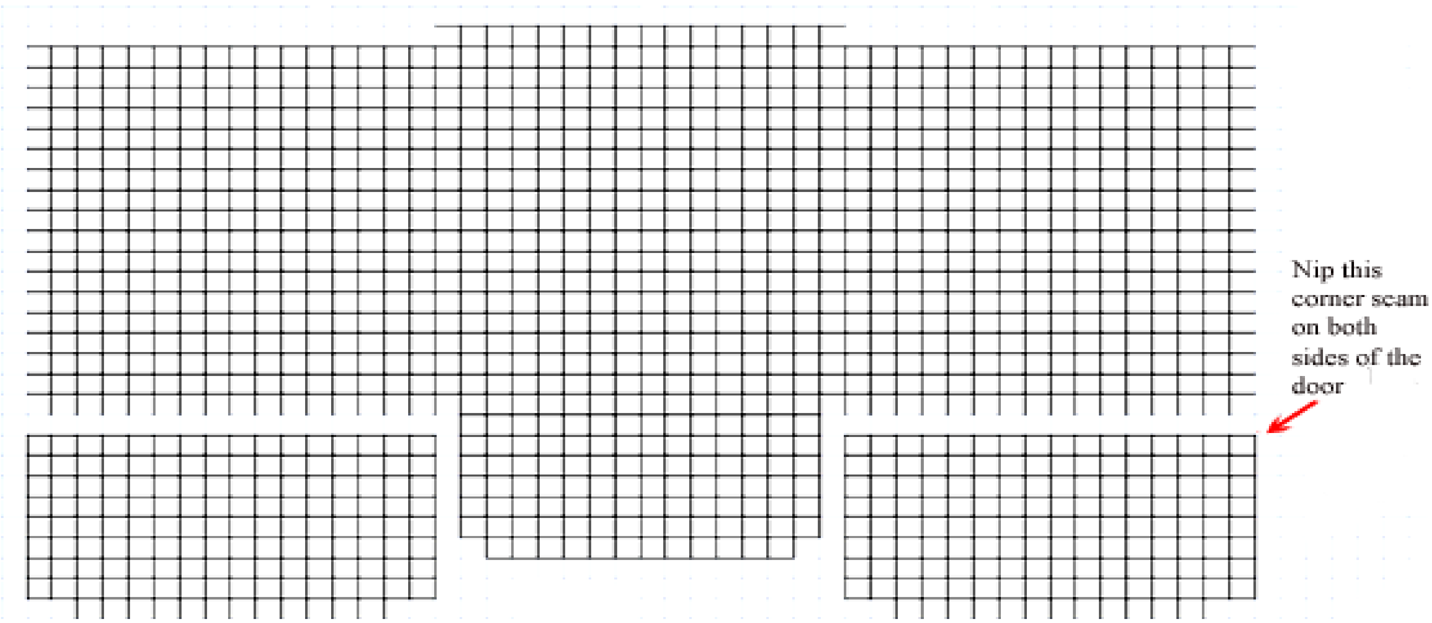
How to Build a Page Cage

Original Design: **Blan Page (AUMERC)**
Modifications: **Students of Alma Bryant High School**

Dimensions:
18” x 14” x 8”
Capacity:
~250 oysters

1.

Figure 1. Page Cage Mesh Template



2. Place a wood board across red lines and bend the wire against the board to make a 90° angle (Figure 3).

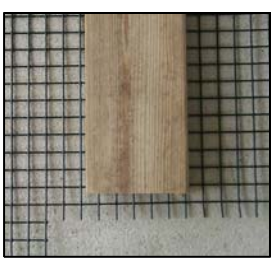
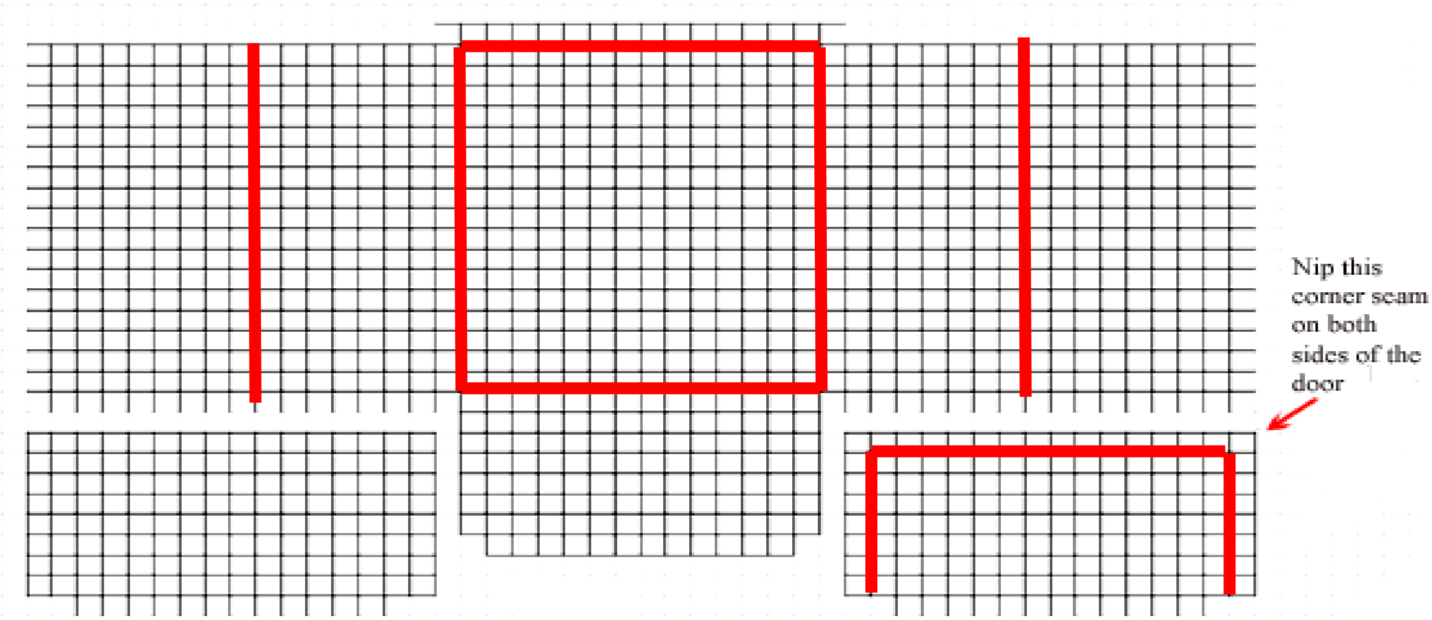


Figure 2. Place board on wire for bending.

Figure 3. Bend wire at 90° angle against board.

Figure 4. Bend mesh (red lines) 90° against a board.



3. Use needle nose pliers to bend all the tabs straight around (180°) to lock the cage together (Figure 5). Bend tabs to hook cage together at: (1) two rows on top of the cage; (2) 3 sides of one end of the cage; and (3) 2 sides of the other end of the cage where the door will attach. Bend tabs even with the wire to prevent sharp edges.

Figure 5. Hook cage together.

Bend door cutout to attach to Page Cage (Shown in Figure 4).

4. Line up the door as shown in Figure 8 and bend the tabs of the cage in a loop around the bottom of the door in order to latch the door to the cage. Make sure the door can easily swing open and closed.

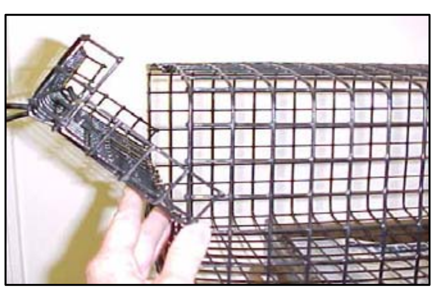


Figure 6. Attach Page Cage door.

5. To suspend the Page Cage from a pier, two bowline knots at the end of a 4' rope need to be tied around the overlapping mesh on top of the cage. Follow Figures 16 through 23 for step by step photographs of tying knots for suspension from a pier.

Tie two bowline knots to each end of the top of the cage through the overlapping mesh:

Figure 7.

Figure 8.

Figure 9.

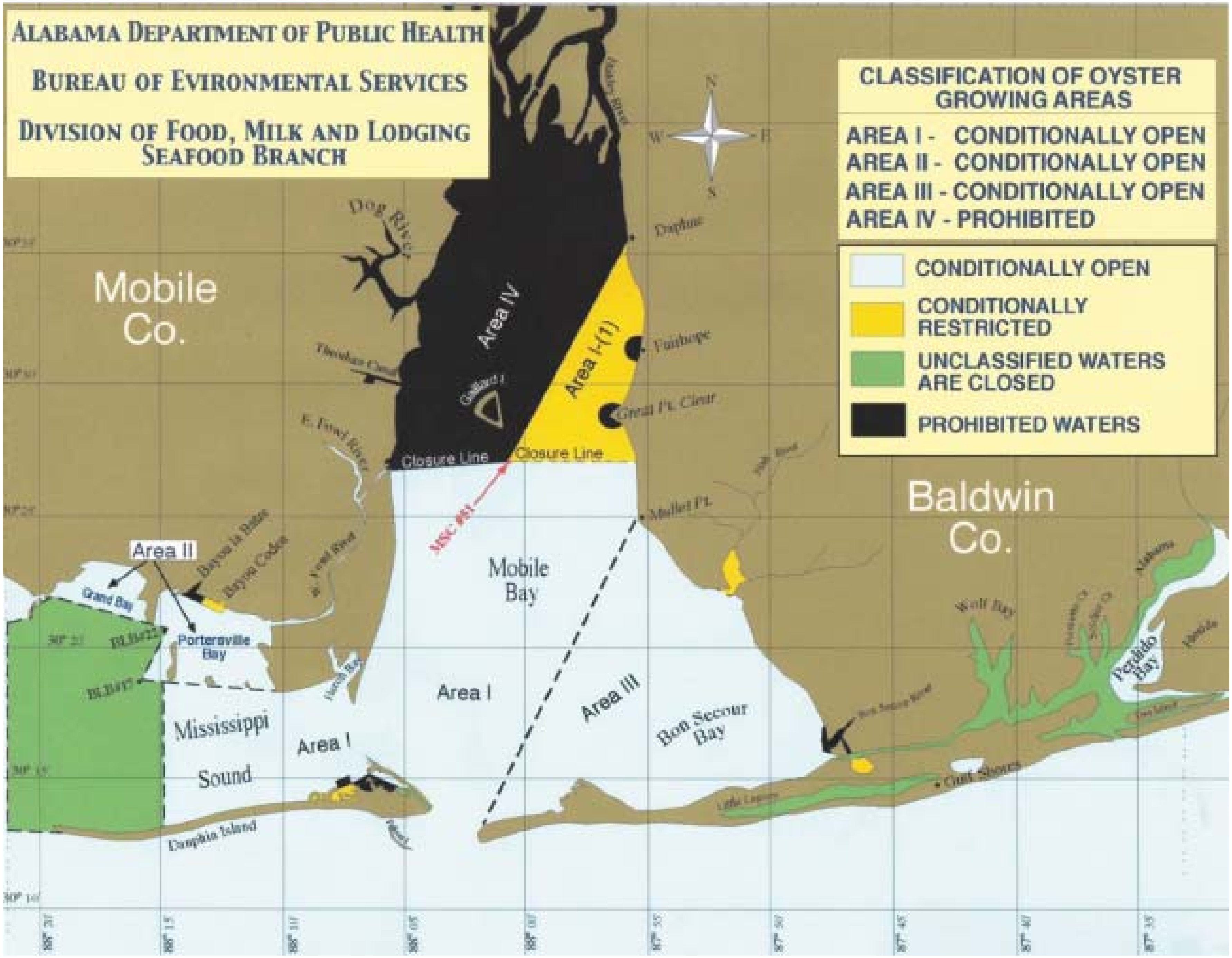
Figure 10.

Figure 11.

Figure 12.

Figure 13.

Figure 14. Page Cage suspends from a pier at least 1’ off sea floor bottom.



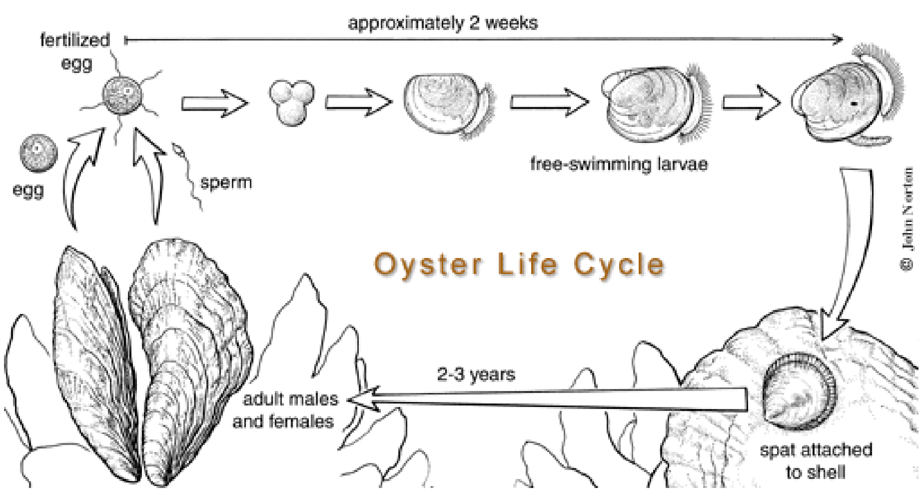
ALABAMA DEPARTMENT OF PUBLIC HEALTH
BUREAU OF EVIRONMENTAL SERVICES
DIVISION OF FOOD, MILK AND LODGING
SEAFOOD BRANCH
CLASSIFICATION OF OYSTER GROWING AREAS
AREA I - CONDITIONALLY OPEN
AREA II - CONDITIONALLY OPEN
AREA III - CONDITIONALLY OPEN
AREA IV - PROHIBITED
CONDITIONALLY OPEN
CONDITIONALLY RESTRICTED
UNCLASSIFIED WATERS ARE CLOSED
PROHIBITED WATERS
Mobile Co.
Baldwin Co.
Dog River
Area IV
Area I-(1)
Closure Line
Closure Line
Fairhope
Great Pt. Clear
Daphne
Mullet Pt.
Mobile Bay
Area I
Area I
Area II
Area III
Grand Bay
Portersville Bay
Bayou la Batre
Bayou Coden
Mississippi Sound
Dauphin Island
Bon Secour Bay
Wolf Bay
Perdido Bay
Gulf Shores
Little Lagoon
Alabama
Florida
N
S
E
W

Seed and Spat

As a volunteer with the program, you will receive young oysters, called “seed” or “spat,” that have been spawned and reared in a hatchery. After oysters are spawned they first go through a free-swimming larval phase and then reach a stage when they must attach to a hard surface, usually another oyster or shell. In hatcheries, old whole oyster shells are often used as the hard surface (called cultch) on which the larvae are “set.” Several spat may set on one oyster shell. This arrangement, where larvae set onto oyster shell, is called “cultched” seed. Cultched seed is used in the oyster gardening program because it more closely replicates oysters as they are found in nature.

In producing cultched seed in the hatchery, old oyster shell is first dried out on land in order to remove organic material that could degrade water quality in the setting tanks. Shell is placed in plastic meshed bags and stacked in tanks. The spat are generally kept in the tanks for several days, then removed to a nursery area where tides and currents provide the water exchange necessary for growth and survival. Although cultched oysters can exhibit rapid growth, sometimes reaching 25 mm in two to three months after settlement, growth is extremely variable and depends on many interacting factors, especially salinity, temperature, food availability and water quality.

You will start off with one mesh bag of spat-on-shell for your oyster garden. Cut open your mesh bag of spat. Divide the spat evenly among all four cages. Deploy cages horizontally.

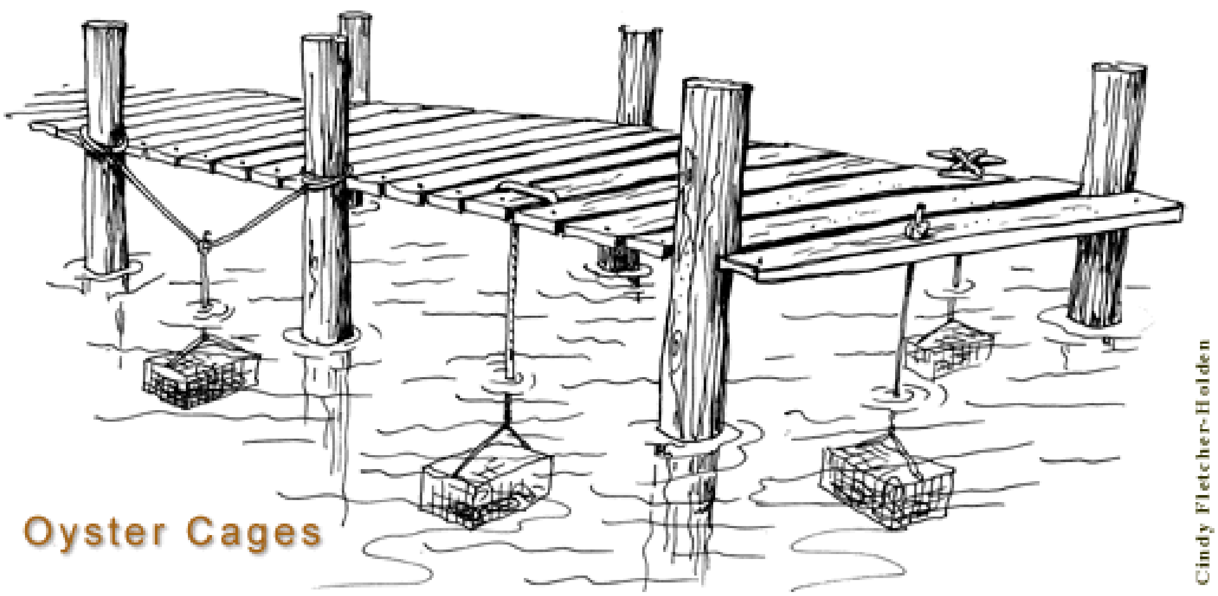


Securing Your Oyster Garden

The location of your oyster garden is important: since oysters grow best when they are located in areas with maximum water flow around them, place your garden where tidal flow is good. Securing the garden underneath your dock will shade it, and help reduce algal growth. Throughout the winter, keep an eye on your garden to make sure it is secure. Every dock site is different, because of tides, currents, salinity, water depth and dock facilities. Experience will be your best guide for determining exactly how to set up a garden at your site.

Oyster cages are usually hung horizontally to give the oysters plenty of room and to maximize their growth rates. They should be tied off so the oysters sit about one foot below the surface of the water at low tide. The top of the cage may be exposed during low tides. The objective is to keep cages as high up in the water column as possible without risking exposure to low air temperatures.

Cages can be secured to the dock in any number of ways. Each cage can be suspended between two pilings or hung by tying a line around a plank on your dock. Some gardeners drill small holes through four dock planks and thread one cage line through each hole. Knots can be tied in the top ends of the lines so they can't fall back down through the holes. Your securing system will depend on your dock site. The important point here is to make sure the cages do not bang against pilings—banging can cause oysters to close up and stop feeding.



Maintaining Your Oyster Garden

There are three things that will be the most important maintenance takes for oyster gardening: (1) keep the cages clear of fouling organisms such as barnacles, mussels, and algae; (2) remove sediment and oyster feces that will collect in the cage; and (3) remove predators that will invade your cage and feed on the young oysters. Your cage will need to be pulled from the water and allowed to dry out.

Control of Fouling Organisms

Drying out or desiccation can control most barnacles and mussels. This will be accomplished by lifting the cages out of the water and letting them sit on the dock, exposed to the fresh air. The oysters can survive extended periods exposed to the air. Letting your oysters sit in hot, direct sunlight for more than a couple of hours is not recommended. Keeping the cage shaded will help to reduce the fouling while increasing the chance of oyster survival. On cloudy or rainy days, the oysters can survive for a longer period of exposure to the air. Your cages should be left out in the air as often as every two weeks during the winter and as often as once a week during the summer. Each site will vary in the method and length of time needed to control the fouling organisms.

Filamentous algae are persistent fouling organisms. The algae do not harm the oysters but it does make it hard to observe the growth of the spat. The best way to control algae is to make sure it does not have a chance to grow. When you observe algae beginning to grow on your cage you should begin the routine of letting your cages air out in the shade. Once the algae are established it will grow very quickly. If the cages are heavily fouled with algae, remove as much as possible before the desiccation process. It is possible to control the algae growth by limiting the amount of sunlight reaching the cages.

If you cannot control the growth of barnacles, mussels, or algae using the drying out method alone, you will need to take a more direct approach. Scrubbing the cages with a hard bristle brush will help remove the algae. Scraping with a hoe can help remove barnacles. A high pressure hose can also help to remove fouling organisms.

Cleaning Cages

The cages will trap sediment that is suspended in the water. The problem you have with sediment will depend on where you are located. Some areas may have a high load of suspended sediments, while others may not. Examining the bottom sediments near your pier will be an indication of the problem you may have. Sandy sediments are seldom a major problem because the larger grains will tend to settle out of the water because of their size. Cages located in areas where high wave activity occurs may have to clean their cages after a major storm.

If your area has fine clay sediment, this will be more of a problem. The oysters in the cages will catch the sediment as it falls out of the water. Oysters will also remove some of the sediment and algae through their own filtration process. The waste product of the oyster, known as "pseudofeces" will contain some of the sediment as well as the natural oyster waste. Without routine cleaning, the oysters can quickly become covered which will inhibit their ability to feed and breathe. The oysters that are trapped below the sediment will probably die. For this reason, your cages must be cleaned on a regular basis. The time between cleaning will very depending on the location of your float and the season. All cages will need to be cleaned as often as every week. Cleaning can consist of moving the cages up and down in the water until all the sediment is rinsed off, or by using a hose if one is available. You will also need to shake your cages to prevent the oysters from growing through the mesh. When cleaning your cages, do not remove the dead oysters from the cage because they will need to be counted when collecting data on your oysters.

Dried Barnacles

Dried Algae

Controlling Oyster Predators

The structure of your oyster garden will help to exclude many predatory organisms that would normally eat your oysters. Several species of crabs, fish and other animals may feed on oysters at different stages of their life cycle. Blue crabs should be removed from your garden whenever they are noticed. While blue crabs should not cause major mortalities in your garden, a confined blue crab will eat what is available to it, and in most cases this will be your oysters. Removing any blue crabs when you see them should alleviate the potential problem. You may see many small brown mud crabs in your garden—these are not harmful to your oysters.

It is not likely that most other oyster predators will cause problems in your garden. One advantage to spat-on-shell is that they are generally more predator-resistant than cultchless oysters. The shell to which they are attached acts as protection for the spat until they reach a size where predation is more difficult.

Source: Oyster Gardening for Restoration & Education.
William Goldsborough, Donald Meritt.

Harvesting and Restoration

Community-based oyster restoration programs are one important element in widespread efforts to restore populations devastated by overfishing, habitat destruction, land runoff, pollution, and oyster disease. As an oyster gardener, you will be doing your part for Alabama's oyster restoration effort. After a year's growth, the Mobile Bay National Estuary Program and AUMERC will collect the oysters and they will be planted on reefs in Mobile Bay. Those oysters should eventually serve as a foundation for new generations of oysters. In this way, the oysters that you grow year after year will help contribute to sustainable oyster populations in the Mobile Bay ecosystem.

Harvested Oysters are Deposited on Shellbanks Reef

Contact Information

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Mobile Bay National Estuary Program
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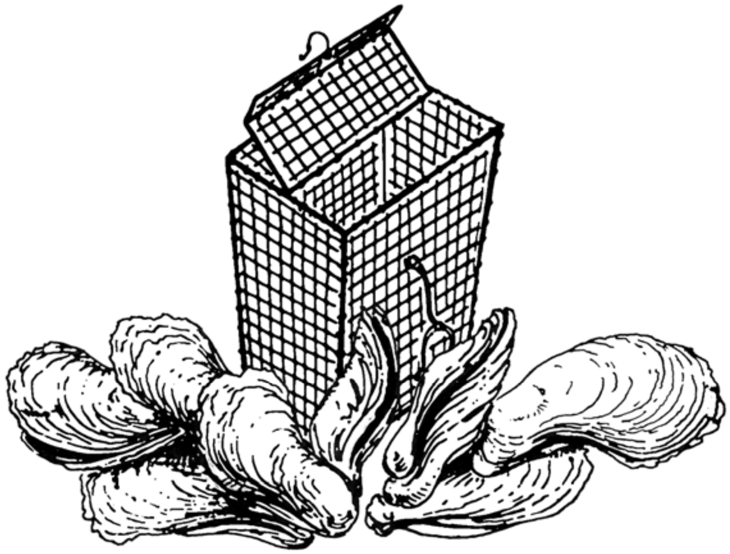
Fax: 251-431-6450



Mobile Bay Oyster Gardening Calendar

April/May: Participate in an Oyster Gardening Workshop

June/July: Auburn University Shellfish Lab will provide roughly 4 mm oyster spat spat per volunteer.

June – October:
As needed, maintain cages by removing fouling organisms. Growth of algae can add 10-50 pounds of weight to the cage. A high pressure hose most efficiently removes fouling from oysters and cages.

August/September: Check your newsletter from details on a midseason check of your oysters.

November:
The newsletter will provide details on the final pickup of your oysters. Oysters will be planted onto reefs in Mobile Bay. Cages must be removed from water and cleaned for winter storage.*

Principal Predators

Eastern Oyster (Crassostrea virginica)

Predator	***Description***
Black Drum Fish, *Pogonias cromis*	Found in the southern portion of Mobile Bay. Have large teeth used to crush the oyster shell.
Blue Crab, *Callinectes sapidus*	Primary oyster predator along the Gulf of Mexico. Identified by its blue colored claws.
Mud Crab, *Panopeus herbstii*	Small crab. Brownish color shell with pale white or black claw tips.
Oyster Flatworm, *Stylochus ellipticus*	Small, flat worms. Primarily a threat to very young oysters.
Oyster Drills, *Stramonita haemastoma*	Slow moving snail with a heavy shell. Primarily a threat to very young oysters.
Rays, *Dasyatidae*	Flat fish with an average size of 50 cm.
Stone Crab, *Menippe adina*	Large claws of unequal size. Shell can be gray, tan or deep chocolate brown.

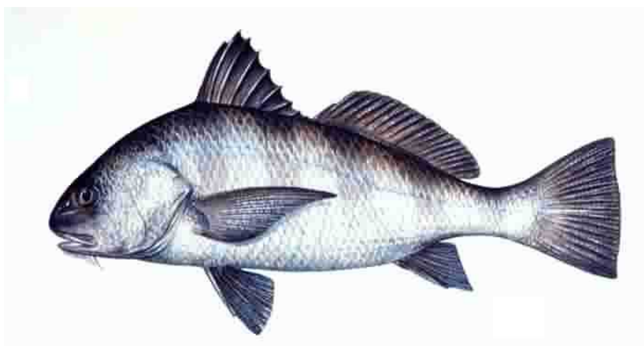
The following pages are the above listed predator fact sheets.

Black Drum Fact Sheet

Scientific Name: *Pogonias cromis*
Common Name: Black Drum

Geographic Distribution: The black drum is found along the Atlantic Coast from New York south through the Gulf States to Mexico.

Black drum is an important commercial and sport fish in the Mobile Bay area. This species tend to be found in large schools. They have very heavy teeth used to crush the oyster's shell. Black drum feed especially on the small "seed" oysters. These fish are most commonly found in the southern portion of the bay, especially near Cedar Point Reef, but are also found in the Mobile Delta. Black drum can tolerate varying salinities.



Adult

Juvenile

Blue Crab Fact Sheet

Scientific Name: *Callinectes sapidus*
Common Name: Blue Crab

Geographic Distribution: This crab is found as far south as Venezuela and as far north as Massachusetts.

Crabs are scavengers and prey on oysters and clams. Blue crabs rely on oyster reefs for protection from their predators and the reefs provide the perfect feeding ground for them. They use their strong claws to crush the shell of their prey, chipping the edge of the shell, or forcing the valve apart. The blue crab consumes any size oyster from seed size (6 to 12 mm) to market size (>75mm). The rate of predation can be very high on unprotected oyster beds. In culture situations, placing the oysters in cages with lids for protection can limit blue crab predation.

Males – View abdomen and note blue claws

Females – View abdomen and note red claws

Mud Crab Fact Sheet

Scientific Name: *Panopeus herbstii*
Common Name: Mud Crab

Geographic Distribution: This species is found from Boston Harbor south to Brazil.

Mud crabs are very small (less than one inch). They are inhabitants of oyster reefs and, like the blue crab, enjoy making a meal of oysters. They use their large, tooth-like claw to chip away at the shell of the oyster. Mud crabs select small oysters 12 to 19 mm in height. Its brownish colored shell and the claw tips, which are either pale white or black, can identify this species.

Oyster Flatworm Fact Sheet

Scientific Name: *Stylochus ellipticus*
Common Name: Oyster Flatworm

Geographic Distribution: Found in the Mid-Atlantic region and throughout the Gulf of Mexico

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Oyster flatworms are not true predators of the oysters, but they can damage or destroy the oyster. The flatworm will cause blisters to form on the muscle the oyster uses to close its shell. When this happens the shell will not completely close, allowing the worms to enter the shell and eat the oyster meat. Flatworms are thin, flat, and elliptical in shape. They are usually one inch or less in size but can grow bigger. Their color will vary.

Oyster Drill Fact Sheet

Scientific Name: *Stramonita haemastoma*
Common Name: Southern Oyster Drill

Geographic Distribution: Found along the Atlantic and Pacific coasts as well as the Gulf of Mexico.

The oyster drill, a gastropod, is the primary oyster predator in the Gulf of Mexico. It is also a significant threat in Mobile Bay. Oyster drills are small, slow moving snails with a heavy shell. They will drill a pin size hole in the oyster shell and suck the oyster out. Their preferred method of attacking an oyster is to bore between valves at the bill, their weakest point. It can take up to three weeks to eat one large oyster. These predators will attack any oyster but they are most devastating to very young oysters.
The greatest density of oyster drills will be found where the water is the most saline, usually near the mouth of the bay. The range of oyster drills is limited by salinity. Salinity greater than 15 ppt is needed for its survival. During the late 1960's, the oyster drill in Mobile Bay killed 80% of the oyster spat in a nine month period where salinities were over 15 ppt. At a salinity of 7ppt this predator will become immobile and if it remains at that level for one to two weeks the oyster drill will die. Flooding conditions that bring a great amount of freshwater will eliminate the oyster drill.

Dorsal View

Ventral View

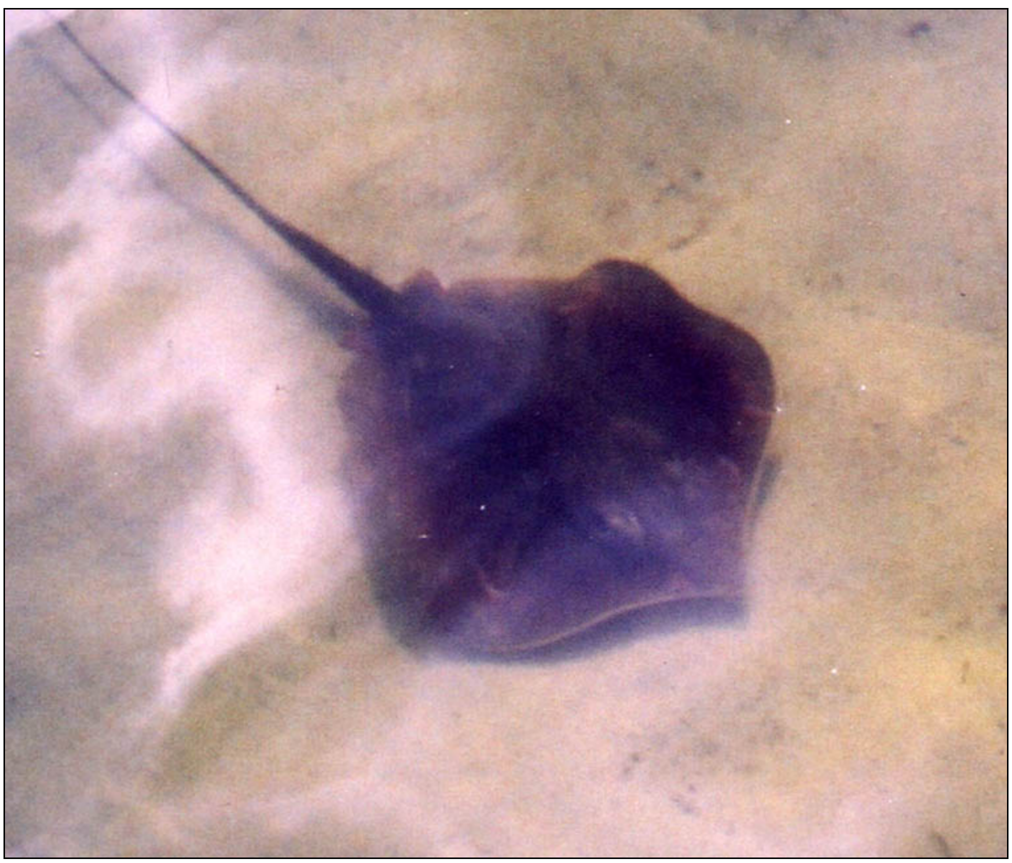
Oyster Drill Eggs

Atlantic Stingray Fact Sheet

Scientific Name: *Dasyatis sabina*
Common Name: Atlantic stingray

Geographic Distribution: Rays are found all over the world including estuaries.

Atlantic stingray, the predominate species on Alabama reefs, is a flattened fish that is closely related to the sharks. Rays vary in size but you will probably find only smaller rays in Mobile Bay. The average size of rays is around 50 cm. These fish will hunt for food on the bottom of the bay. While they eat fish, crustaceans, and worms, rays also eat oysters. The ray will use its rostral lobes to dislodge the oyster from the reef then crush it with their flat, plate-like teeth.



Stone Crab Fact Sheet

Scientific Name: *Menippe adina*
Common Name: Gulf Stone Crab

Geographic Distribution: Found along the northern and western gulf coast region.

Stone crabs use the oyster reef as habitat and source of food. The young crabs are greenish or bluish gray to gray or dark tan in color with dark spots on its shell. The adult crabs are deep chocolate brown color. Their pincher claw is used to hold an oyster while the larger claw is used to crush the shell.

Oyster Reefs

By Kenneth L. Heck, Jr. & Patricia M. Spitzer

Background

The eastern oyster (*Crassostrea virginica*) occurs over a broad geographic range. Along the east coast of North America, it is found from the Gulf of St. Lawrence, Canada to southern Florida; in its southern range, throughout the Gulf of Mexico to Yucatan, Mexico to the West Indies and Venezuela (Sellers and Stanley, 1984). The American oyster typically lives in shallow, well-mixed estuaries, lagoons, and oceanic bays that fluctuate widely from hot to cold temperatures, low to high salinities and clear to muddy waters (Sellers and Stanley, 1984).

In Mobile Bay, oyster reefs have been an integral part of the community both naturally and economically. Oysters are unique in their estuarine ecological role in that they form living reef structure, which supports a host of other associated organisms not found in the surrounding sand or mud habitats. As many as 300 species have been found to be associated with oyster reefs (Wells, 1961). Many of these species use the oysters as refuge by utilizing the increased habitat complexity provided by the reef structure, and as food. Oysters are important suspension feeders and can affect local turbidity levels by removing sediments, phytoplankton, and bacteria from the water column. Their tremendous processing capacity enables them to augment primary production by reducing shading caused by phytoplankton blooms (Bahr and Lanier, 1981). Oyster suspension feeding also plays a role in retaining nutrients in the estuary, by converting non-labile particles into labile particles for plants and returning them to the system through biodeposition (Dame et al, 1984; Dame and Libes, 1993). In fact, oysters play such an important role as filter feeders, that when abundant they may exert top-down control on the pelagic ecosystem, by preventing the negative consequences of algal blooms while at the same time amplifying the delivery of primary production to species deemed more useful to society (i.e. fish) (Newell, 1982; Ulanowicz and Tuttle, 1992). Oysters also play a role in sediment stabilization and help to prevent erosion as well as providing a stable substrate for sessile organisms (Bahr and Lanier, 1981).

In addition to the important ecological role that oysters have in Mobile Bay, they also play an important economic role. In many parts of its range, oysters have historically sustained a major commercial fishery, often supporting large fleets employing many workers (e.g. in Chesapeake and Delaware Bays), until overharvesting and diseases, among other factors, devastated the fishery. In Mobile Bay, the oyster still constitutes an important, but often-variable fishery (Sellers and Stanley, 1984).

Buried oyster shells also have economic value. Industry uses oyster shells for cement, road stabilization and calcium in pharmaceuticals. Oysters benefit other commercial fisheries both directly and indirectly by providing nursery grounds for commercially important species (i.e. penaeid shrimp, blue crabs, stone crabs and game fishes) and by improving the water quality. Oysters can reduce the probability of anoxic bottom waters, which can stress commercially important species (Newell, 1988) by filtering phytoplankton during spring blooms.

This can prevent water quality problems, since zooplankton biomass is low in the spring and a large portion of phytoplankton would otherwise remain ungrazed and sink below the pycnocline, resulting in anoxic waters.

History of Oysters in Mobile Bay

Oyster harvest has been important throughout its geographical range since before recorded history (at least as early as 2000 BC) (Bahr and Lanier, 1981). Total harvest of oysters nationwide peaked in the early 1900's and has steadily declined since that time (Bahr and Lanier, 1981). Carbon-14 dates indicate that oysters were established in Mobile Bay in the head of the bay in the area of the present delta between 5000 and 6000 years ago and have progressively migrated down-bay, which corresponds with the rapid rise in sea level about 6000 years ago (May, 1971). In Alabama, prehistoric Indian cultures harvested oysters from Mississippi Sound and Mobile Bay over 3500 years ago, based on pottery types throughout the coastal region (May, 1971).

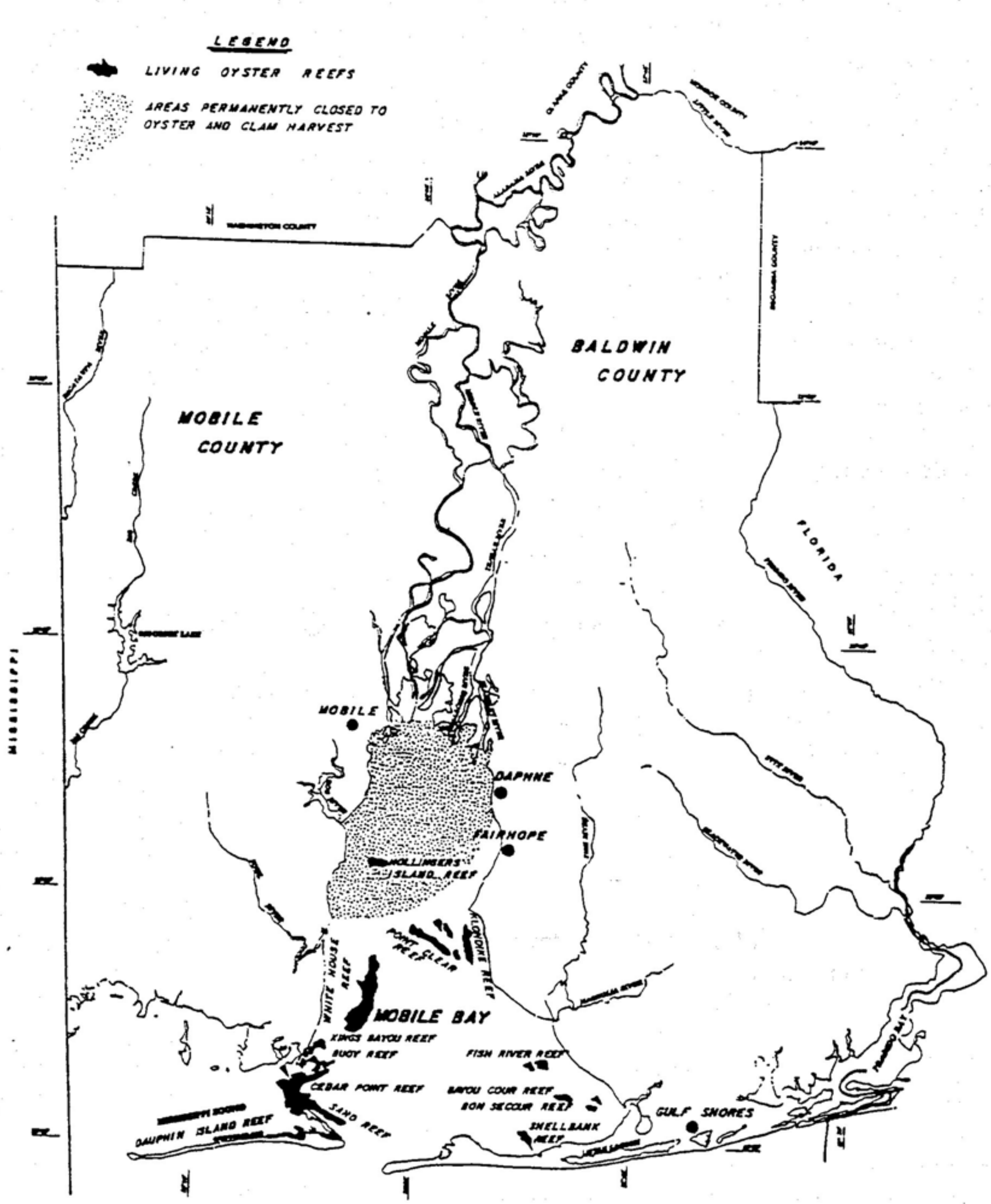
French and Spanish explorers were aware of oyster reef locations in Mobile Bay during the sixteenth century and even referred to what is now called Cedar Point as Pointe aux Huitres (Oyster Point) (May, 1971). The earliest survey of oyster reefs in Bon Secour Bay was completed in the mid-1800's, but the first attempt to map the oyster reefs accurately was not done until 1896 by Ritter (May, 1971). There have been many attempts to map oyster reef locations in Mobile Bay since the late 1800's. In 1913, Moore found a continuous reef from Buoy Reef to Pass Drury, a total of 3900 acres. In 1971, 3064 acres of natural oyster reefs were mapped in Mobile Bay (Figure O-1). Many other surveys were done but due to differing methods, rigorous comparisons are difficult. Major oyster reefs have historically been located subtidally in Mobile Bay.

In the past, many factors (both natural and anthropogenic) impacted the oyster population in Mobile Bay. The oyster drill, an important predator of eastern oysters, severely restricts oyster distribution in Alabama. Disease was suggested to be another former controlling factor of oyster population in Mobile Bay and had the potential to wipe out entire reefs (May, 1971). One of the most obvious factors affecting the oyster population was overfishing. Overfishing has occurred in Bon Secour Bay, eastern Mobile Bay and in the vicinity of Cedar Point (May, 1971). Over 73,000 acres of State waters were permanently closed to oyster harvest due to domestic and industrial pollution, although this only includes 23 acres of oyster reefs (May, 1971). Oysters may have also experienced decreased growth rates as a result of exposure to pesticides in Mobile Bay (May, 1971).

Current Status of Oyster Reefs in Mobile Bay

Oyster harvesting continues in Mobile Bay to this day. Unlike the decline recently seen in the oyster fishery on the East Coast, Mobile Bay's oyster fishery has remained stable, if not increased, over the years. Direct comparisons of oyster populations (past to present) are difficult for a number of reasons: (1) harvest numbers are based only on those numbers reported not necessarily the number of oysters harvested (2) harvest is not an accurate estimate of oyster production since size limitations restrict oyster harvest and (3) fishing changes over the years according to demand and environmental factors.

Figure O-1. Location of Living Oyster Reefs in Coastal Alabama (From: Crance 1971; May 1971, In: Friend et al. 1982).



The position of oyster reefs in Mobile Bay has progressively migrated down bay with most reefs occurring near the Gulf of Mexico at the lower end of Mobile Bay. A survey taken in 1995 found a total of 3476.6 acres of oyster reefs in the vicinity of Cedar Point, not including the acreage of Bon Secour Bay, Point Clear area, Portersville Bay and an area just south of east Fowl River. This area is nearly twice that found for Cedar Point by May in 1968 (Tatum et al, 1995). The difference seen here may be attributed to reef growth or varying measurement techniques used for the surveys. Another possible explanation is that Mobile Bay experienced several category three hurricanes during the intervening years and this may have uncovered shell that provided additional substrate for spat settlement. The 1995 estimate of this area, however, is close to that of Moore (1913), indicating that the area of oyster reef coverage may have slightly changed position but not size in the past eighty five years (Tatum et al., 1995)

As in the past, there are both natural and anthropogenic activities that impact the oyster population in Mobile Bay. The natural activities are similar to those in the past: natural predators, diseases and weather phenomena (i.e. hurricanes). The anthropogenic activities that may affect oyster populations in Mobile Bay have increased over the years. Not only does pollution, overfishing and exposure to organochloride pesticides (i.e. DDT and it's metabolites, DDE, DDD and Dieldrin) decrease the oyster population (May, 1971), many new activities are detrimental to oysters. Oyster populations could be vulnerable to: sedimentation from dredging, eutrophication, toxins (i.e. heavy metals), salinity changes due to hydrologic alterations and habitat loss due to development in wetlands (Bahr and Lanier, 1981; Tatum et al., 1995). All of these activities could potentially affect oyster populations, however, there is no current evidence that detrimental effects are occurring. Of these anthropogenic effects, overfishing and pollution (i.e. sewage treatment) are the most important. With all of these activities potentially having negative effects on oyster populations in Mobile Bay, efforts are needed to preserve this natural resource.

MANAGEMENT OF OYSTER POPULATIONS

Historically, Alabama has used shell planting on public reefs as a way to manage oyster production and harvest. Shell planting consists of placing large amounts of dead oyster shells on the benthos to provide suitable habitat for oyster spat (larvae) to settle. Shell planting works best when shells are placed on or near existing oyster reefs or where oyster reefs have lived historically. Oyster reef restoration is concentrated in the southwest portion of Mobile Bay and the northern portion area of Mississippi Sound (Wallace et al, unpublished manuscript). Currently, there is a large shell planting effort underway on Cedar Point Reef (Holan, 1998).

There have been a few efforts over the years to move oysters from closed regions of the bay to open regions, however, most of these attempts have failed due to the high cost of the transfer and the low harvest benefits (Tatum et al, 1995)

Alabama has also used take limitations to manage the oyster population. Sack limitations and harvest time limitations may vary from year to year. Currently (2003), sack limitations are set at 8 sacks/person/day (not to exceed 18 sacks/boat/day) and oysters can legally be taken only in daylight hours: 6am to 3pm from October to May and 6am to 12 noon June through September. Time changes are to allow for a later sunrise in the winter and to decrease mortality due to lying on a hot deck waiting to be culled in the summer (Tatum et al, 1995). Along with time and sack limitations, size limitations are also used in Alabama. Size limitations were set at 75 mm in 1937, however, the commisioner of conservation has the ability to reduce the size limitation to 65 mm (Tatum et al, 1995). Size limitation ensures that oysters reach reproductive stages before being removed from the system. Temporary oyster check points are established to enforce these limitations and a move has been made toward the establishment of permanent check points (Tatum et al, 1995).

Other forms of management that are being looked into are: (1) maintenance of water quality to prevent mortality due to clogged gills from heavy sedimentation or low dissolved oxygen levels; (2) off bottom rack culture in Bon Secour Bay to avoid low DO near the substrate, and to minimize sediment accumulation; and (3) mitigation of man-induced hydrologic alterations. Alabama is currently constructing a 1 mile diameter concrete, protective barrier around the Whitehouse reef near the mouth of East Fowl River to prevent further damage while the inactive reef is being restored by shell planting (Holan, 1998).

RESEARCH ON OYSTERS

Research that has been done to date can be categorized into three topics: growth and settlement studies; (2) ecosystem engineering and (3) importance of oyster filter feeding. Growth and settlement studies have mostly been done in Mobile Bay and have focused on ways to improve oyster growth. May (1969) examined the feasibility of using suspension cultures, which have been used for many centuries in Western Europe and Japan, in Mobile Bay. May (1969) found that oyster growth in suspension cultures was rapid, however, due to high production costs and low market value, he determined that suspension cultures were not beneficial to the Mobile Bay Oyster Fishery. Several recent studies have been done in Mobile Bay by Wallace et al (1996) and Heck et al (1994 -1996 unpublished). These studies have examined off- bottom cultures of cultchless oysters in bags, bottom culture of remote set oysters, hatchery techniques, natural spat settlement patterns and the variables that lead to optimum growth in nature (utilizing a model suggested for the Chesapeake Bay area).

Due to the declining oyster population along the East Coast, studies have examined the influence of oysters as ecosystem engineers. Wells (1961) examined the role of oyster reefs as habitat and found that many organisms use oyster reefs for food and protection. Newell (1988) examined the effects of the declining oyster population in Chesapeake Bay. He found that the declining population might be responsible for a shifting in the base of the food web from phytoplankton to a microbial based system. Newell (1988) suggested that the decline in oyster population reduced competition for phytoplankton among filter feeders, which resulted in an increase in zooplankton and an increase in the predators of zooplankton (i.e. ctenophores and jellyfish). Another study done in Maryland by Breitburg et al. (1995) examined the effects of the reef structure on the surrounding community. Breitburg et al. (1995) found that oyster reefs could affect the distribution and settlement of larvae from the water column by reducing current speed. The reduction of current speed not only allowed competent larvae to settle but also helped larvae remain in suitable habitats by reducing the probability of the larvae being washed away by currents.

Other studies along the East Coast have examined the importance of oyster filter feeding on water quality. Dame et al.(1984) examined the role of filter feeding on material cycling in marsh estuarine ecosystems. They found that oyster filter feeding was important in reducing the amount of particulate organic carbon (POC) and chlorophyll *a* while increasing the amount of ammonia. Another study (Dame and Libes, 1993) determined that oyster reefs function as a nutrient retention mechanism in estuaries. The increase in ammonia seen again in this study supported the hypothesis that a positive feedback loop exists between phytoplankton and oysters. Studies have also examined the role of oyster filter feeding with respect to eutrophication. In 1982, Officer et al. examined the potential of filter feeders as natural eutrophication controls in San Francisco Bay and found that filter feeders can control eutrophication under certain criteria. Officer et al (1982) determined that filter feeders were effective in shallow waters that had abundant nutrients, no critical light, temperature or turbidity limitations, poor hydrodynamic water exchange characteristics and a dense benthic filter feeding community. In 1992, a model developed by Ulanowicz and Tuttle (1992), suggested that increasing oysters in Chesapeake Bay could improve water quality and might be used to mitigate eutrophication. Increased oyster populations were hypothesized to decrease phytoplankton populations as well as POC and ultimately ctenophore populations. Gerritsen et al (1994) also used a model to determine the effectiveness of oysters in filtering out primary production in Chesapeake Bay. The model was applied to five regions of Chesapeake Bay and Gerritsen et al. (1994) found that bivalves could consume more than 50% of the annual primary production in shallow fresh and oligohaline waters, whereas, only 10% of the primary production could be consumed in deep mesohaline waters. Gerritsen et al (1994) concluded that depth and width of the estuary would restrict the use of bivalves to improve water quality unless the bivalves were artificially suspended in the water column.

EVALUATION

Alabama oyster reefs have been assessed seven times in the last century starting in 1896 and the most recent being done in 1995 (Tatum et al.1995). The surveys examined the population and the condition of the reefs for two of the seven, while the other five surveys examined the population, condition of the reefs as well as the configuration of the reef. Since the surveys used different methodologies and had variation in the interpretations, it is difficult to compare the results. Other complications resulting in different reef locations over the years may be due to the natural progression of the oyster reefs toward the southern portion of the bay.

Another difficulty with the current database on oysters is that most of the research has been done on the East Coast, particularly in Chesapeake Bay. Due to differences in physical and biological factors, the results obtained in these studies may not strictly apply to Mobile Bay.

RECOMMENDATIONS

A comprehensive survey of Mobile Bay oyster reefs should be done using state-of- the- art advanced techniques. This survey should determine the size and shape of the reefs, as well as the population density on the reefs. This survey should be repeated every five years to monitor the oyster population within Mobile Bay.

Studies should be done to investigate the ecological role that the oyster plays in Mobile Bay to determine if the roles are similar to those found on the East Coast. In particular, the role that oyster reefs may play as "nursery habitats" for economically important species should be investigated. In addition, a detailed investigation of the factors determining spat survival rate and the conditions determining growth rates should also be carried out. Finally, there should also be studies done on the filter feeding role of oysters in Mobile Bay, with respect to effects on water clarity and the indirect consequences of changing water clarity.

It is suggested that shell planting efforts continue in Mobile Bay to help stabilize the population. Fishery limitations should also be continued and adjusted as needed to prevent the oyster population decline similar to that seen on the East Coast.

Oysters in Alabama

Revised April 2003

Oysters, along with mussels and scallops, are among the invertebrates called pelecypods ("hatchet foot") that are included in the phylum Mollusca (clams, snails, squids, and octopods). More than 1000 species of oysters are found throughout the world, and Alabama waters contain several. Of these, only the Eastern oyster (*Crassostrea virginica*) is commercially important.

Oyster landings in Alabama have averaged a million pounds per year since the 1880's. However, large fluctuations occur on a year-to-year basis. For example, 1982 was a relatively good year with landings of 1.5 million pounds. The next year landings were only 336,000 pounds. The worst sustained decline occurred from 1985 to 1989 when landings went from 1.3 million pounds to 9,500 pounds. By 1992 landings had rebounded to 1.2 million pounds with a dockside value of $1.7 million and the total contribution to the economy was estimated to be about $6 million. In 2001, Alabama's oyster landings were 512,977 pounds valued at $1.1 million.

Biology

Peak oyster spawning occurs in April and October when the water temperature approaches 68°F (20°C) and salinity is above six parts per thousand (ppt). Eggs and sperm are released into the water at fertilization. Females release anywhere from 70 million to 170 million eggs into the water column. The fertilized eggs develop into a free-swimming larval stage in about 24 hours. After several weeks, the developing shell on the larvae becomes too heavy for swimming and the larvae settle to the bottom. The larval oysters require a clean hard surface for attachment and can actually move about on the bottom seeking a good substrate. If good substrate is found, the larvae secrete fluid that cements them permanently in place. Larvae settling out in soft mud or other unsuitable areas usually do not survive. Once settled, the developing oysters can become sexually mature within a month and then contribute to another generation of oysters in a very short time. Interestingly, oysters sometimes change sex after spawning. In particular, young males often become egg producing females.

Oysters eat by filtering food from the surrounding water through their gills. Under ideal conditions an oyster can pump 5 gallons of water an hour through its filtering apparatus. Alabama oysters reach harvestable size (3 inches) in about 18 to 24 months.

The Environment

Oysters are bound to one spot after they settle and are at the mercy of the water brought to them by currents and tides. When the water is too fresh (less than 10 ppt salinity) for long periods, oysters die. On the other hand, when salinity is high, oysters are likely to be devastated by oyster drills (a snail), crabs, and a tiny parasite called dermo. Oyster drills alone are capable of killing 85 percent of the young oysters on a reef. Furthermore, oysters can be smothered by sand and silt from dredging operations or extremely heavy storms.

Management

Oyster management can be divided into two areas of concern – public health and conservation. The Alabama Department of Public Health monitors the waters around oyster reefs. They close the reefs to harvesting when bacterial counts indicate that disease-causing organisms are above acceptable levels. These closures are triggered by high river flow generally in winter and early spring, which carries increased sewage into the lower Bay. Bacteria and other pollutants are a particular problem for oysters because they are filter feeders and can concentrate harmful substances in their body tissues. Generally, these pollutants do not harm the oysters but make them unfit to eat, especially raw.

The Marine Resources Division of DCNR conserves oysters by requiring licenses, enforcing size limit of 3 inches, regulating harvest by sack limits, and allowing only hand or oyster tong harvest on public reefs. The Marine Resources Division also plant cultch to provide new substrate for oyster larvae to settle on and grow. Large amounts of clam shell were planted after the oyster beds were devastated by Hurricane Frederic and after the spring floods in 1983. Approximately 10,000 more acres can be planted with shell if funds become available.

Oyster Measures

Unlike many other foods, oysters are harvested, processed, and sold on the basis of volume rather than weight. Oyster harvesters catch tubs, sacks, and barrels of oysters. Oyster shuckers are paid by the gallon for meat shucked, and consumers buy sacks of whole oysters and gallons, half-gallons, or pints of oyster meat.

The following are the approximate relationships among the different measures. A tub equals one sack; four sacks equal one barrel. An average sack yields about six pints of oyster meat, depending on the time of year. A sack should weigh about 75 pounds.

The Future

Oysters are a valuable natural resource in Alabama. The industry provides jobs and a large economic benefit to the state. Like all marine resources, oysters depend on good water quality for continued use by man. Good water quality can be maintained by preserving wetlands, by careful planning of dredging activities, and by controlling pollution both in Mobile Bay and in the tributaries that feed the bay.

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The Eastern Oyster

Oysters have been cultivated in one form or another for over 2,000 years. Early efforts involved little more than transplanting small oysters from one area to another area where they would grow better, be better protected from predators and disease or be more readily available for harvest. This simple method of cultivation is still widely practiced today and is a major means of production for the eastern oyster, *Crassostrea virginica.*

The eastern oyster occurs naturally from the Gulf of St. Lawrence in Canada to the Gulf of Mexico, Caribbean and coasts of Brazil and Argentina. It has been introduced on the west coast of North America and other areas of the world. In recent years, the total U.S. harvest of oysters has been 30 million pounds of meats; about 75 percent of the total is the eastern oyster. About 18 million pounds of total oyster production (all species) is by cultivation.

Oyster Biology

An understanding of basic oyster biology is essential to any successful culture operation. Under natural conditions, oysters spawn as water temperatures rise in the spring. The temperature at which spawning occurs varies from north to south. Northern oysters spawn at temperatures between 60 and 68°F (15.5 - 20°C) while southern oysters spawn at temperatures above 68°F (20°C). Spawning can occur throughout the warm months.

Sperm and millions of eggs are released synchronously and fertilization occurs in the water column. A fertilized egg develops rapidly into a microscopic swimming trochophore (Figure 1). After 24 to 48 hours, the non-feeding trochophore develops into the feeding veliger stage. At this stage, the larva has a thin shell and feed primarily on tiny algae. After 12 to 20 days, larvae develop a foot and eye spot and are referred to as pediveligers or "eyed larvae". Pediveligers settle to the bottom and can crawl short distances to find suitable sites for setting. Setting occurs when the larvae cement themselves to a hard substrate (usually oyster shells) and metamorphose into tiny oysters called spat.

“Spat” usually refers to a recently metamorphosed oyster, but the term may be applied to any small oyster. Similarly, the term "seed oyster" may be given to oysters that are too small to harvest, but generally refers to juvenile oysters larger than spat.

Spat are mostly male and grow rapidly. Sexual maturity can occur within four months in southern waters. Some males change to females, being a protandric species, usually after the first or second spawning, and some females can change back to males. Growth to harvestable size (3 inches, 75mm) can take 12 to 24 months, depending on temperature, water salinity and food supply. Oysters do best in areas where the bottom is relatively firm and stable, salinities are from 10 to 30 ppt (15 to 18 ppt is considered optimal), water flow is adequate to bring food, sediment does not smother oysters, and oxygen concentrations remain greater than 3 ppm (greater than 5 ppm most of the time).

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Chapter 6

Oyster Restoration in Alabama

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Abstract

Oyster reef restoration in Alabama consists almost entirely of shell planting, although seed oyster planting was common until the late 1960s. Private seed plantings were recorded from the 1880s but were poorly documented. Significant amounts of shell were planted on public reefs historically and private shell plantings continue at a modest level on riparian bottoms. However, no public bottoms are currently leased by the state to private citizens for planting. The first public plantings took place around 1910. A succession of oyster commissions, state and federal legislation, and entities of the Alabama Department of Conservation and Natural Resources have directed public reef restoration since that time. Eight legislative acts from 1910 to 1961 required the return of various percentages of oyster shells for replanting. The 1961 Act required oyster buyers either to replant 50% of all oyster shells removed from Alabama waters or to pay the state the value of the shells plus planting costs. The act proved unenforceable until the addition, in 1987, of a $0.25 per sack oyster tag. The tag provided a method of determining the amount of shell owed by each buyer and of providing the funds for shell planting.

Alabama currently has about 1,240 ha of public oyster reef, and it is estimated that another 24,000 ha of bottom are suitable for planting. Managers have relied on the economics of oyster production to rationalize oyster restoration expenses and have not made an issue of the potential ecological benefits, nor has there been much research to help support such a position.

Recent research by state biologists indicates that fossil coral is a good substitute for oyster and clam shell, but the costs make it uneconomical at this time. University researchers have investigated off-bottom culture of cultchless oysters in bags, bottom culture of remote set oysters, hatchery techniques, natural spat settlement patterns and the natural variables that control growth. Several oyster culture methods have potential in Alabama but remain underdeveloped. The ecological benefits and costs of oyster culture in Alabama have not been addressed.

Introduction

Physical conditions on Alabama oyster reefs are dominated by the Alabama-Tombigbee River system which has the fourth largest discharge in the U. S. (mean = 1,800•m^{-3}) and reaches more than 7,000•m^{-3}•sec^{-1} during flood conditions (Schroeder 1979). During low river flow, tides and winds overcome the freshwater discharge and allow high salinity waters from the Gulf of Mexico to reach the reefs. The reefs survive in a precarious balance between periods when the water is too fresh for survival and periods of high salinity when predators such as the oyster drill (*Thais haemastoma*) can decimate the stock (Eckmayer 1979).

Alabama currently has 1,240 ha of public reefs (May 1971) and the areal extent (Fig. 1) is similar to the 1,256 ha found in 1894 (Ritter 1896). However, Bell (1952) estimated that there were 2,392 ha of public reef in Alabama. Discrepancies between these surveys are attributed to methodology and interpretation, although it is known that one reef was altered by channel construction (May 1971).

Oyster production in Alabama was reported sporadically from 1880 to 1948 and yearly thereafter (Fig. 2). Landings have averaged 419,753 kg since 1880 and, for the period 1991-1994, landings have averaged 357,226 kg with a mean annual ex-vessel value of $1.1 M.

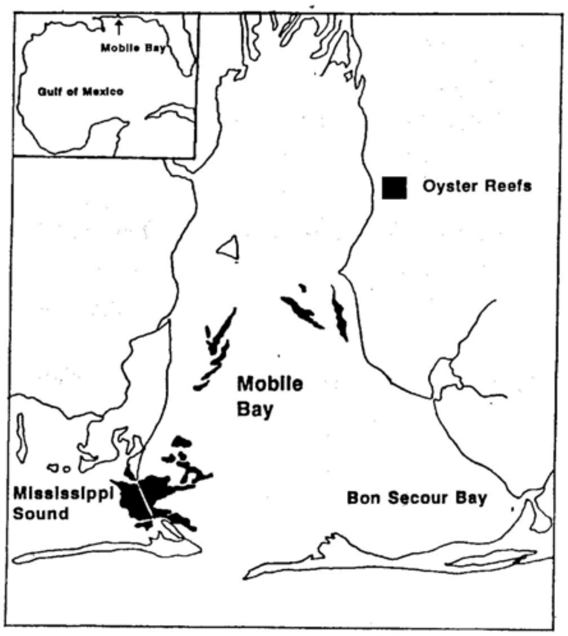

Figure 1. Location of oyster reefs in Mobile Bay, Alabama.

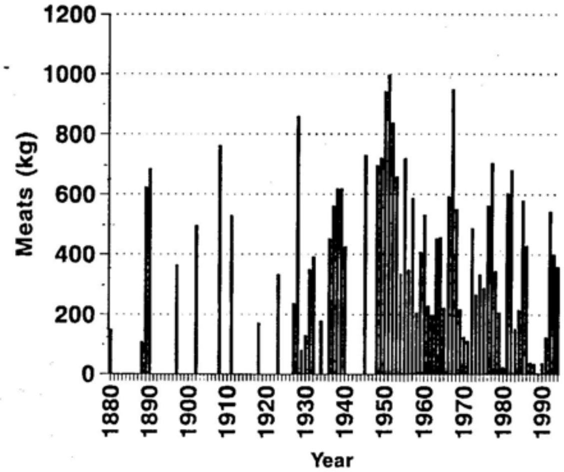

Figure 2. Alabama Oyster Landings, 1880 - 1994.

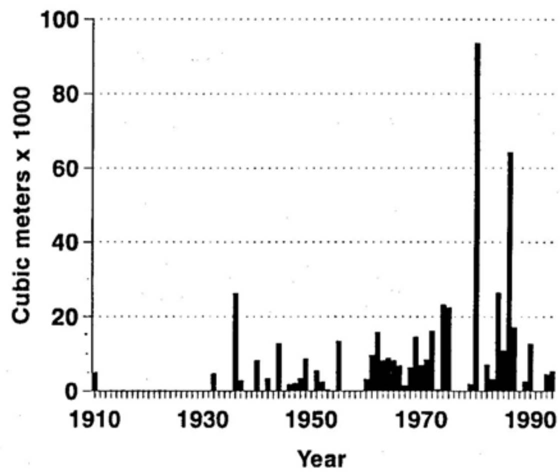

Figure 3. Public Shell Planting in Alabama, 1910 - 1994.

Alabama has three categories of oyster grounds: oyster riparian bottom, leased bottom, and public reefs. All tidally influenced subtidal bottom belongs to the state. However, in 1872 the state legislature created oyster riparian bottom which allow a waterfront property owner or his lessee the exclusive right to plant and gather oysters out to 545 m from shore. This riparian right can only be obtained when the area is surveyed, marked, and registered with the Alabama Department of Conservation and Natural Resources, Marine Resources Division (MRD). Approximately 24,000 ha are available to be claimed as riparian bottom. Natural reefs found within a riparian oyster claim remain public reef by law. The state can also lease non-riparian public bottom for oyster culture. As many as 1,600 ha have been leased in the past. The third category is comprised of existing public reefs. These areas are afforded special legal protection including prohibition of dredges (hand tong harvesting only), a 75 mm shell height limit, (often) daily catch limits and half-day harvests during the summer.

Oyster Reef Restoration

Oyster reef restoration has taken place in Alabama since at least the 1880s (Durrenberger 1992). Accounts from this early period do not always distinguish between planting seed oysters and planting shell, so it is difficult to determine how much planting activity simply involved moving oysters around compared to replacing shell or adding new shell to the bottom. Apparently most, if not all, of the planting was privately funded and took place on riparian oyster bottoms.

The first Alabama oyster commission was established by the state legislature in 1909 and abolished in 1915. The commission planted 4,830 m^3 of shell sometime between 1910 and 1915 and transported an unknown amount of seed oysters to an experimental plot (Swingle and Hughes 1976). Since 1910, oyster or clam shells have been planted in public waters 43 times in volumes ranging from 450 m^3 to over 93,000 m^3 (Fig. 3). Funding for planting efforts has come from a variety of sources including the state legislature, federal grants, various oyster taxes, and royalties from shell dredging (Swingle and Hughes 1976). Additionally, eight legislative acts from 1910 to 1961 required the return of various percentages of oyster shells from state processors for planting. It is not clear how effective these past requirements were in supplying shells for restoring oyster reefs. May (1971) noted that the 1961 Act was unenforceable and thus ineffective in providing oyster shells for planting.

From 1980 to 1987 Alabama utilized clam shell (*Rangia cuneata*) as cultch material and planting efforts were of greater magnitude. Funding was largely by federal monies and planting contracts were established by competitive bid. Planting efforts over this period are summarized in Table 1.

Environmental concerns sharply curtailed clamshell dredging in Mobile Bay during the late 1980s and eliminated this material as cheap, readily available cultch. Diminished federal funding forced Alabama not only to seek new cultch material but also new revenue sources to maintain its oyster restoration efforts. Low

Table 1. Alabama clam shell plantings from 1980-1987

Year	m^3	Funding ($) State	Federal	Total	Cost/m^3 ($)
1980	93,480	19,252	1,350,000	1,369,252	14.64
1981	____	____	____	____	____
1982	7,1311	71,996	____	171,996	24.11
1983	3,325	151,867	____	151,867	45.67[1]
1984	26,289	12,000	464,800	476,800	18.14
1985	10,988	100,000	100,000	200,000	18.20
1986	64,145	64,375	1,153,774	1,218,149	18.99
1987	17,166	1,985	246,213	248,198	14.45
Total	225,524	521,475	3,314,787	3,836,262	____

[1] Oystermen were paid to plant shell

production from public reefs from 1987-1989 prompted the state legislature to provide funds for planting in 1989 and 1990. In 1989 funds were used to transport shells donated by oyster shops, while the labor for planting was provided by a local oystermen's association. Funds in 1990 were used to purchase oyster shell and to pay oystermen for planting.

Funding of shell planting was partially shifted to the industry with the passage of a sack tagging law in 1987 that required a $0.25 tag on each sack of oysters. The industry was also tapped as a source of cultch material in 1991, when a long dormant law (the 1961 Act) was revived. The 1961 Act required oyster buyers that purchased Alabama oysters to replant 50% of the shell. An agreement was reached with the shop owners that if they donated 100% of their Alabama oyster shell, the Alabama Department of Conservation would be responsible for shell transport and planting. This agreement has proven successful with most shops donating not only their Alabama shell but also shell that is trucked in from other Gulf states. At present, Alabama has far more oyster shell available than funds to pay for transportation and planting.

Enough funds from oyster tag sales were accumulated (supplemented by money provided by the Alabama Marine Resources Division) to fund oyster reef restoration efforts in 1993 and 1994. Contracts were established by competitive bid for transporting and planting shell. Alabama shell planting efforts since 1989 are summarized in Table 2.

In addition to the public reefs, there are currently 27 recognized private beds in Alabama. These beds are on the previously described riparian oyster right bottoms and no records of shell planting are available. Of the 27 riparian beds, few exceed two ha in size and only two consistently produce commercial-size oysters. Private oyster production in Alabama exceeded the harvest from public reefs only once in the last 25 years. Alabama law also provide for the leasing of state-owned oyster growing bottoms; however, no one has leased any state oyster bottom in 15 years.

Table 2. Oyster shell acquired from oyster shops and planted on Alabama reefs, 1989 - 1994.

Year	Planted (m^3)	Cost ($)	Cost/m^3 ($)
1989	2,660	50,000	18.80
1990	12,691	397,250	31.30
1993	4,560	85,850	18.82
1994	5,320	72,527	14.20
Total	25,231	605,627	____

Research

Planting shell to restore oyster reefs has long been considered a positive management measure, but there have been few quantitative studies in Alabama to justify the practice. May (1971) noted that 340 m^3/ha shells planted on barren bottom produced 121,000 oysters/ha. More recently MRD personnel evaluated clamshell planting. Post planting dredge tows were taken from 1984-1988 to assess spat set success. The results of these tows are found in Table 3. Successful spat sets can be traced to many factors; however, location was most likely responsible for successful plantings in 1983 and 1985 since a historically productive section of the main reef was planted in those years. In other years, attempts were made to expand potential harvest areas by planting in marginal or low productive habitat but had little success.

Since oyster shell may become scarce or expensive, MRD personnel have investigated archeological coral as an alternative cultch material. It was found that a test plot of coral had a spat setting success comparable to a nearby test plot containing oyster shell (Tatum 1994). However, the price of coral ($25•m^{-3}) is not currently competitive with oyster shell.

There have been limited efforts over the years to transport oysters from areas closed to public harvest by the state health department, from areas scheduled to be renovated (dredged, filled, etc.) and from areas virtually inaccessible to tonging for reasons of depth or sea conditions to locations open and accessible to public harvest. Analysis of these efforts indicate the costs were high relative to the benefits.

Temporal and spatial distribution of oyster spat have also been studied and the information is relevant to locating appropriate sites for shell planting. Hoese et al. (1972) monitored 15 stations for oysters set in Mobile Bay and Mississippi Sound and found low spat set ($<1\text{-}2 \bullet m^2 \bullet d^{-1}$) in the southeastern and central part of Mobile Bay, higher sets ($5\text{-}10 \bullet m^{-2} \bullet d^{-1}$) in the southwestern area of the Bay and eastern Mississippi Sound. High spat sets ($100\text{-}200 \bullet m^2 \bullet d^{-1}$) were reported in the western Mississippi Sound. Unpublished studies at the Dauphin Island Sea Lab, Alabama support these findings. Researchers at MRD documented a bimodal spat setting pattern within each year over a three-year period. The earliest initial setting peaks were in June and July while the latest secondary setting peaks were in October and November. Temperature and salinity appeared to be important factors affecting the time of the set.

Oyster culture is another area of research that is related to oyster reef restoration. May (1969) concluded that string culture using oyster shell produced good growth in Mobile Bay (from 10 mm to 77 mm in 12 months); however, high costs and loss of oysters from the strings discouraged further study. Eckmayer (1983) reported that hatchery-reared oysters planted on the bottom in the southeast corner of Mobile Bay (Bon Secour Bay) all died within seven months. Mortality was probably due to freshwater flooding.

Interest in oyster culture was renewed in 1989 when production from natural reefs hit a historic low (4,300 kg) due to drought conditions. At that time, the Auburn University Marine Extension and Research Center (AUMERC) began a small oyster culture research program aimed at enhancing oyster production in Alabama. Initial research focused on growing cultchless oysters in bags on racks in a fertilized pond. Oysters grew rapidly to 34 mm in 56 days with low mortality, but were only 50 mm after one year (Wallace and Rouse 1993). Subsequently, fertilized ponds have been used only as nurseries prior to placing oysters in Mobile Bay for growout.

Table 3. Evaluation of Alabama clamshell plantings from 1983-1987.

Date Planted	Date Evaluated	# Shells Examined	% Shells with Spat
06/27–07/14/83	05/18/84	625	29.0
07/07–07/07/84	05/01/85	6510	1.6
09/09–09/13/85	04/29/86	360	19.0
07/31–08/24/86	08/10/87	2619	0.4
06/11–06/17/87	06/28/88	1929	1.5

Three basic culture techniques have been examined to date: cultchless oysters in horizontally suspended bags, cultchless oysters in bags on racks, and remote set oysters (set on whole oyster shell) in trays on the bottom. Oysters in horizontally suspended bags reached harvestable size (75 mm) in 16 months (Wallace et al. 1994). These oysters were grown in an area of Mobile Bay where there has been very little natural oyster production. A local oyster processor is continuing with this technique and has recently test-marketed "farm-raised Bon Secour oysters". Cultchless oysters grown on racks averaged 71 mm (range = 49-99 mm) while remote set oysters on the bottom averaged 82 mm (range = 57-110 mm) after 16 months (Rouse et al. 1993). Neither of these culture techniques have been adopted in Alabama.

Current mariculture studies include: production of triploid oysters using pressure and nitrous oxide, prevention and control of fouling in suspended bag culture, disease in cultured oysters, and polyculture of shrimp and oysters in ponds. The Dauphin Island Sea Lab is conducting experiments in cooperation with AUMERC to assess which areas in Mobile Bay possess the necessary conditions for good oyster growth by examining a suite of biotic and abiotic factors at different locations.

Oyster reef restoration in Alabama is driven by the desire to maintain commercial oyster production. Benefits to the Mobile Bay ecosystem derived from oyster reefs are taken for granted by fishermen, managers, and scientists, but arguments for oyster reef restoration are rarely, if ever, made on an ecological basis. It is unlikely that the general public understands the attendant benefits of maintaining oyster reefs. Public educational efforts may help justify continued expenditures for shell planting and other oyster reef enhancement projects.

The more sophisticated forms of oyster culture such as cultchless oysters grown in bags would not seem to fall within the scope of traditional oyster reef restoration and may not have the same ecological value. However, oysters in suspended bags or on racks still filter large volumes of water, provide habitat for some typical oyster reef organisms (xanthid crabs, blennies, gobies, etc.), and contribute to the natural spat set.

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Suggested Reading

There is an entire book written on the eastern oyster cited as follows:

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Suggested Web Sites

Oyster Gardening in Mobile Bay –www,oystergardening.org

Oyster Gardening for Restoration and Education is a cooperative effort of the Oyster Alliance, which includes the Chesapeake Bay Foundation, the Maryland Sea Grant Extension Program, the University of Maryland Center for Environmental Science and the Oyster Recovery Partnership.
http://www.mdsg.umd.edu/oysters/garden/

Restoring Oysters to U.S. Coastal Waters: A report on the oyster disease research program from the national sea grant college program.
http://www.mdsg.umd.edu/oysters/disease/

Aquaculture Network Information Center (AquaNIC): AquaNIC is coordinated by the Mississippi-Alabama Sea Grant Consortium, and hosted by Purdue University and the University of Illinois through the Illinois-Indiana Sea Grant College Program.
http://www.aquanic.org (homepage); http://aquanic.org/beginer/shellfish/shellfish.htm (shellfish page)