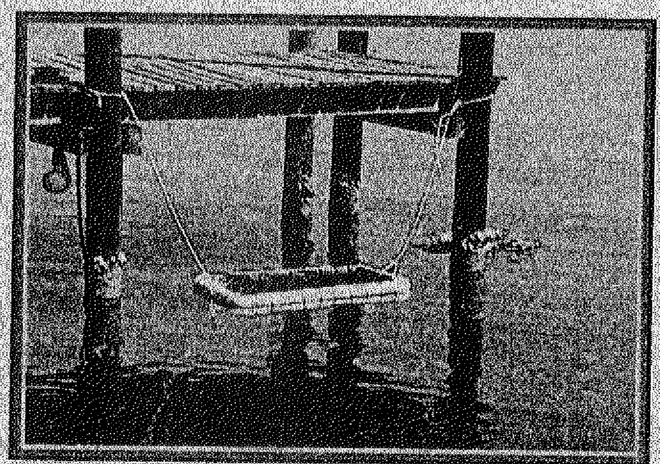
MOBILE BAY OYSTER GARDENING PROGRAM TRAINING MANUAL



Mobile Bay National Estuary Program
Mississippi-Alabama Sea Grant Consortium
Auburn University Marine Extension & Research Center

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Sea Grant Auburn University

MASGP-01-026

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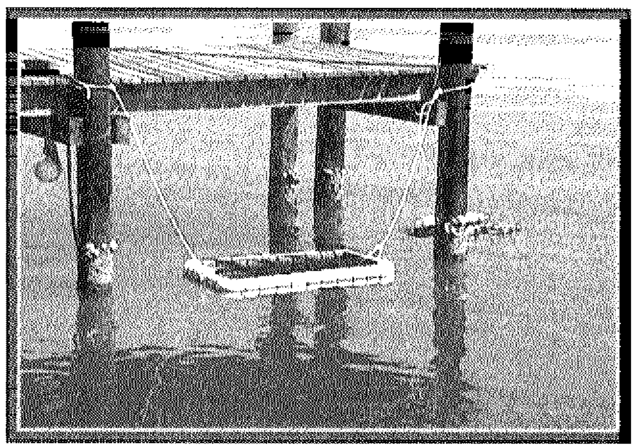

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2001

Mobile Bay Oyster Gardening Program

Mobile Bay National Estuary Program
Mississippi-Alabama Sea Grant Consortium
Auburn University Marine Extension & Research Center

WARNING

The oysters used in this project are not for human consumption. Their intended purpose is to be used for restoration efforts only.

"Oysters Rule"
Mobile Bay NEP Oyster Gardening Program

Welcome! Thank you for helping us launch our Mobile Bay Oyster Gardening Program. This project is a joint effort between 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 Resource Division.

Oyster gardening was first introduced in Chesapeake Bay during the early 1990's. Since1995 their restoration efforts show promising results for improving water quality and oyster reef populations. With that in mind, we believe a similar oyster gardening program will work in Mobile Bay to restore dwindling oyster populations and eventually improve water quality.

How can Oyster Gardening help the Bay? As filter feeders, oysters cleanse the water of excess nutrients and suspended particles. One oyster is capable of filtering five gallons of water per hour. Oyster reefs in Mobile Bay provide habitat for other marine species. Healthy water conditions provide economic benefits to our area through many varied commercial and recreational uses.

Our goal, through volunteer participation, is to increase the productivity of local oyster reefs, while improving the water quality of Mobile Bay.

Acknowledgements

We greatly appreciate the time, effort, and expertise of everyone involved in this project, especially:

LaDon Swann
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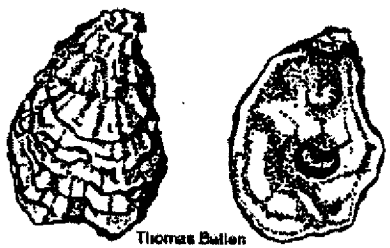
EPA Gulf of Mexico Program

Mobile County Cooperative Extension System

How to Select an Oyster Gardening Site in Mobile Bay



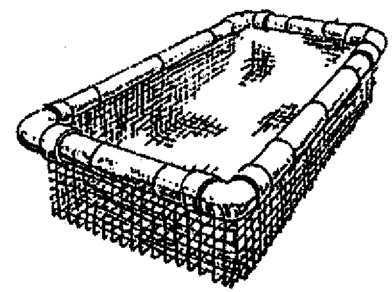
Introducation
The Eastern oyster, *Crassostrea virginica*, is an important commercial shellfish species for Alabama. Total landings for the 1997-98 season were 3.5 million pounds of meats valued at $5.3 million. Recent figures indicate that Alabama ranks first in the nation for oyster processing. Regionally, 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, setting the 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 exist in Maryland and Virginia as a means of restoring oyster population and improving water quality in the Chesapeake Bay. Volunteer oyster gardeners on the Chesapeake grow oysters in floating rigid 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.

Successful implementation of an oyster gardening program in Mobile Bay will provide benefits to the coastal community. Oyster gardening should improve the Bay's water quality and accelerate the establishment of sustainable oyster populations on existing or constructed oyster reefs. Oyster reefs, in turn, provide excellent habitat for over 300 species including a variety of fish and crabs.

An oyster gardening program can bring intangible benefits, including greater public awareness of how oysters improve the bay's water quality, a greater understanding of the cultural importance of Mobile Bay's oyster industry, and the potential of small-scale oyster aquaculture to restore oyster reefs.



Taylor Float

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 1-2 hours per week caring for your oysters until they are ready for reef restoration?

Yes No

6. Are you willing to allow a person working on this project to check the oyster's growth and water quality parameters at your pier once per week for the duration of the project?

Yes No

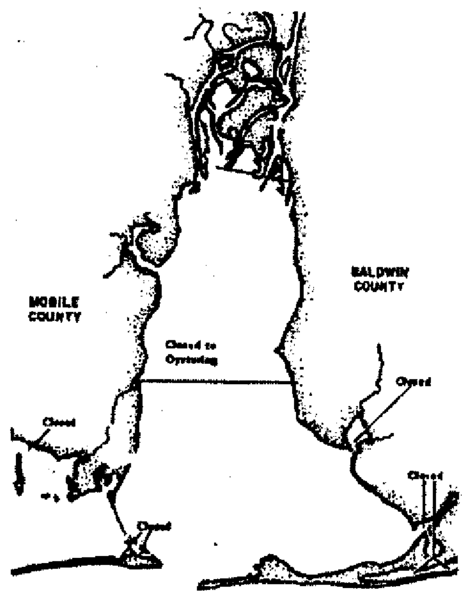
Please answer the following questions for our reference, but these questions will not affect your application as an oyster gardener:

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



For More Information

The Mobile Bay National Estuary Program (MBNEP) in cooperation with Auburn University and the Mississippi-Alabama Sea Grant Consortium is sponsoring this oyster gardening project. For more information contact the Mobile Bay National Estuary Program at (334) 431-6409 or on the Web at: http://www.mobilebaynep.com/habitats/oystergarden.htm or email: mbnep@mobilebaynep.com

Introduction

Oyster Reefs

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

Background

The American 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 & 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 & 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 & 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 & 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 & 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 & 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 their 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 & 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 & Lanier 1981). Total harvest of oysters nationwide peaked in the early 1900's and has steadily declined since that time largely because of a decline in production from Chesapeake Bay (Bahr & 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 5,000 and 6,000 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 3,500 years ago, based on pottery types throughout the coastal region (May 1971).

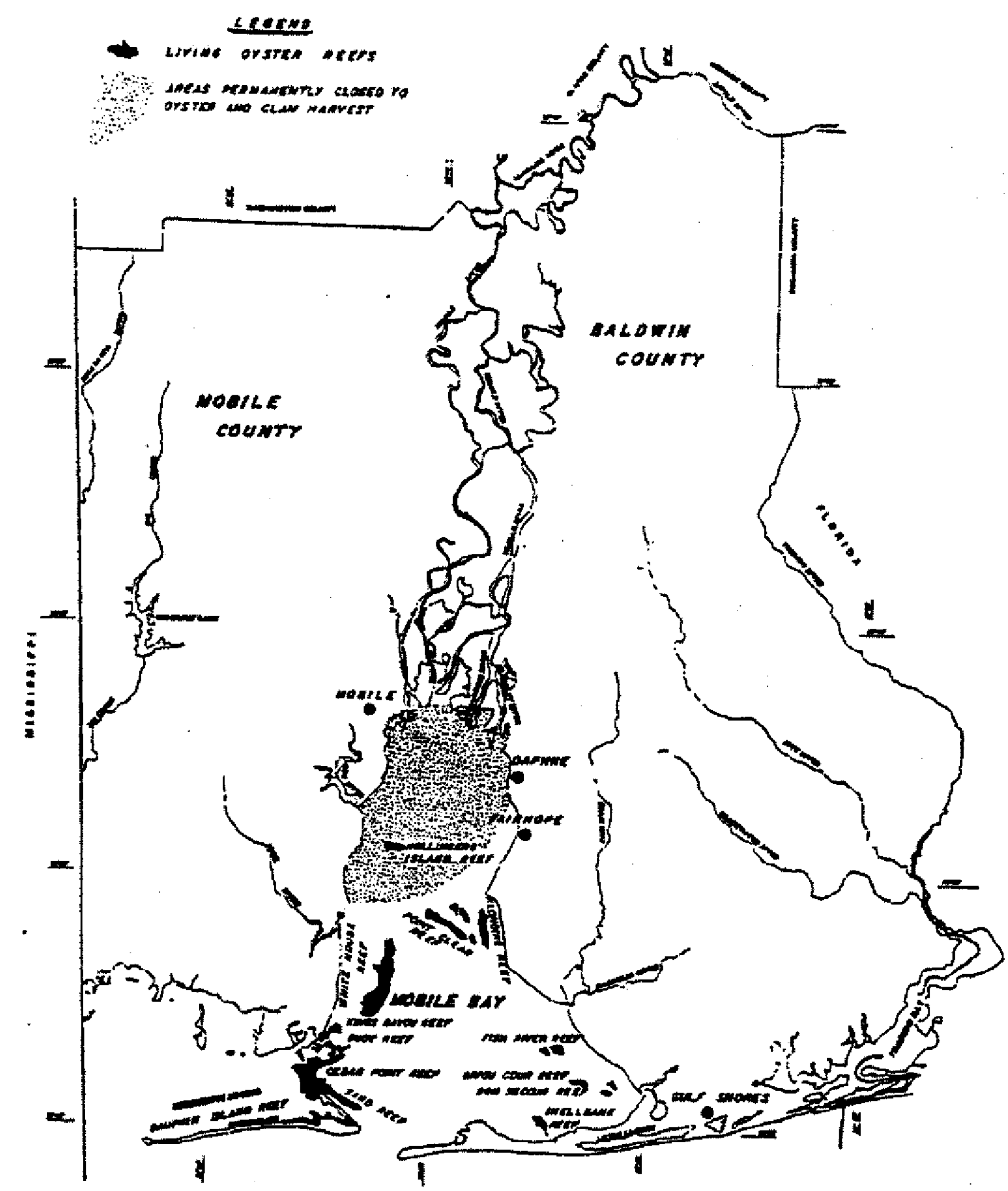
French and Spanish explorers were aware of oyster reef locations in Mobile Bay during the sixteenth century and even referred to what is now called Cedar Point as Pointe aux Huitres (Oyster Point) (May 1971). The earliest survey of oyster reefs in Bon Secour Bay was completed in the mid-1800's, but the 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 3,900 acres. In 1971, 3,064 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 oysters 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 American 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). Older literature (Ritter 1986) cited fisherman as claiming overfishing 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 1995 survey of reefs south of east Fowl River found that the reef area at Cedar Point was nearly twice that found by May in 1968 (Tatum et al. 1995). The difference seen here may be attributed to the 1995 survey including shall sub-tidal reefs not thoroughly examined in 1968. 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, both natural and anthropogenic activities 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 affect may oyster populations in Mobile Bay have increased over the years. Not only does pollution, overfishing and exposure to organochloride pesticides (i.e., DDT and 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 & 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 oyster shells on the bottom 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 has largely been concentrated in the southwest portion of Mobile Bay and the northern portion area of Mississippi Sound (Wallace et al., unpublished manuscript). In 2000 several Baldwin County reefs received shell.

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 have varied from no limit to four sacks/day and is currently set at eight sacks/day. Harvest time limitations have been used as well. Oysters can legally be taken only in daylight hours: 7 a.m. to 4 p.m. from October to May and 6 a.m. to 12 noon June through September. Time changes are to allow for a later sunrise in the winter and to decrease spat mortality due to lying on a hot deck waiting to be culled in the summer (Tatum et al. 1995). FDA requirements concerning time at hot temperatures prior to refrigeration are also considered. Along with time and sack limitations, size limitations are also used in Alabama. Size limitations were set at 75 mm in 1937, however, the commissioner 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) off bottom rack culture in Bon Secour Bay to avoid low DO near the substrate, and to minimize sediment accumulation; and 2) mitigation of man-induced hydrologic alterations. Alabama has constructed concrete protective barrier around Whitehouse and Sand reefs in Mobile County and Fish River and Shellhouse reefs in Baldwin County 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: 1) 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 & 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 & 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 June 2001

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.

Biology

Peak oyster spawning occurs in April and October when the water temperature approaches 68° 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. 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 them 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 area 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.

Circular ANR-832 **MASGP-93-010**
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Alabama Agricultural Experiment Station
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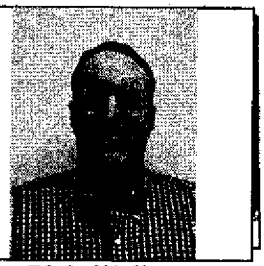
Oysters have place in region's history

Sea Grant



By Rick Wallace
Sea Grant Extension Office

If oysters could talk, what a tale they might tell us. Prehistoric Indians ate them and piled their shells in mounds along the shores of coastal waters. The Romans relished oysters and imported them from Britain for feasts in which oysters occupied the place of honor.

Early European settlers were amazed by the abundance of oysters they found when arriving on the East Coast. At times oysters helped the struggling settlers survive famine while at other times oyster reefs were considered a nuisance to navigation.

In the Mobile area, oyster shell mounds created by Indians date back to 3,500 years ago. Early Spanish and French explorers found and ate oysters in the 16th century. A map produced in 1732 referred to what is now called Cedar Point as Oyster Point. From these early times to the present, oysters have played a very important role in Alabama's seafood industry.

But if oysters could talk, they could tell us about even more ancient times when things were quite different along the Alabama shore. Oyster shells are buried under 25 feet of mud in the upper bay. The oysters at the bottom of these relic reefs are 5,700 years old, while those at the top are 5,500 years old. Further down the bay, oyster shells under two feet of mud are 2,200 to 3,100 years old.

Even those shells are relative youngsters. In a recent study headed by Will Schroeder at the Dauphin Island Sea Lab, oyster shells were collected from 11 to 45 miles offshore in depths of 54 to 130 feet of water. Radio-carbon dating indicated these shells ranged in age from 8,500 to 35,000 years. Why, might you ask, are these very old oysters found so far offshore in water far deeper than oysters normally grow? After all, modern oyster reefs usually flourish in less than 10 to 15 feet of water and are found in the bays and bayous but not on the open ocean. It turns out that the age of these off-shore shells matches (with some exceptions) the fluctuations in sea level that have occurred over the last 30,000 years.

Imagine a trip to Gulf Shores and when you finally get there, you still have another 35 miles to go before you see the water. This apparently was the situation some 30,000 years ago and again only 10,000 years ago when the sea level was considerably lower. The age of the oyster shell corresponds to times when the water was about the right depth to support oyster reefs and the old shells are still there today. Even more amazing is that the 30,000-year-old sea level was a relative high which was followed by a much lower sea level about 20,000 years ago. At that time, the Alabama shoreline would have been some 70 miles south of the current location. A subsequent sea level rise led to the younger (10,000-year-old) shells. Obviously, sea level has continued to rise over the last 10,000 years to give our present shoreline.

You may wonder about those buried oyster shells at the top of the bay. Their presence implies a higher sea level some 6,000 years ago. However, experts speculate that as the sea level rose from 10,000 years ago, saltwater penetrated far up the ancient Mobile River Valley, creating conditions conductive for oyster reefs. As the barrier islands and Mobile Bay developed, fresh water was trapped and the upper bay would no longer support oysters after about 5,000 years before the present. Oyster reefs developed southward in higher salinities as evidenced by the 3,000-year-old reefs further down the bay and today's reefs at the southern end of the bay.

Rick Wallace is an extension marine specialist with the Sea Grant Extension Program at Auburn Marine Center.

Source: Mobile Register; Date unknown

"OYSTER BARS"

The oyster reef is a popular place among marine species. Many species seek out reefs for refuge or as a place to hunt for food. Oyster reefs also provide benefits for the bay. Oysters help to cleanse the water of excess nutrients and sediments through their ability to pump water through their gills. The reefs provide structure for other sessile organisms to attach. The crevices provide shelter, as well as, spawning grounds for other species. Oyster reefs provide a stabilizing structure to keep wave action from scouring the bottom of the bay. Most of these reefs have taken hundreds or thousands of years to form and provide habitat for aquatic plants species as well.

There are literally hundreds of organisms that will be found in or around an oyster reef. Here are some of the Mobile Bay "marine crowd" you will find just below the water's surface:

Amphipod

There are over 6,000 known species of amphipods. There are many species of amphipods found around the oyster bars in Mobile Bay. The most common Suborder is *Gammaridea*. They are shrimp like in appearance with hard shell, jointed appendages, and are laterally flattened. They are opaque to translucent in color and usually less than a half-inch in length. Amphipods rely on the reefs for protection, shelter, and food.

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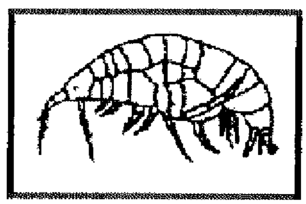
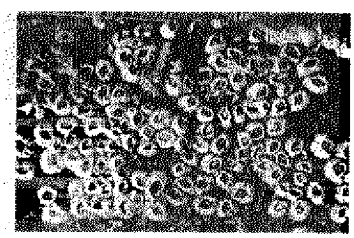


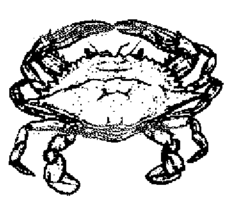
Barnacle

The predominant species of barnacle found in Mobile Bay is *Balanus subalbidus*. You will find barnacles attached to the oyster shell. They can be predators of oyster eggs and larvae. Barnacles will grow as large as one inch in diameter.

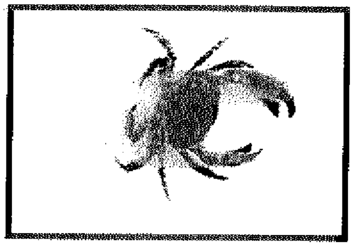


Blue Crab

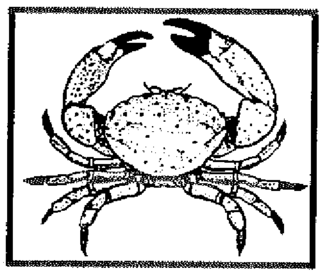
Blue crabs, *Callinectes sapidus*, use the crevices in the oyster reef to provide protection and shelter from the species that prey upon them. You can identify these crabs by their bluish-green outer shell and their bright blue claws. The female of this species have red tips on their claws. Barnacles, oysters, and mussels are the "prey of choice" for the blue crab.



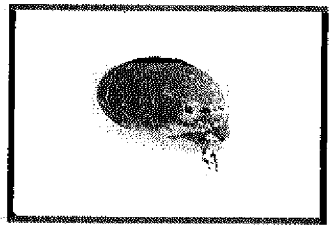
Mud Crab
The mud crab, *Panopeus herbstii*, is a small species usually less that one-inch in size. Dependent on the oyster reef for protection and shelter, this species of crab eat small oysters, barnacles, and mussels. Their shell is brown and their claws will be either black or pale white in color.



Stone Crab
Stone crabs are found in many areas along the Gulf coast. The species found in Mobile Bay is *Menippe adina*. The small, very young crabs are dark purple in color. Adult stone crabs are deep chocolate brown color. They use the oyster reef for protection and shelter as well as a place to find food.



Hooked Mussel
The predominant mussel species found on oyster reefs in Mobile Bay is *Ischadium recurvum,* the hooked mussel. They need the oyster reef to provide a stable structure for them to attach to and grow. Their shell color is dark black and may grow up to two inches in length.



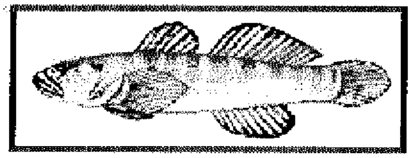
Oyster Flatworm
Oyster flatworms, *Styloachuis ellipticus*, are also known as "oyster leeches" by oystermen. Oyster flatworms are the least conspicuous predator on the reef. They have flat elliptical bodies with multiple eyes. Density of the worms varies depending on the location and the season. The flatworm needs the oyster reef to provide shelter and protection from its predators.

Polychaete Worm

There is no single species of worm that dominate the oyster reefs in Mobile Bay; many species live here. Some worms may live in the crevices of the oyster reef and some may build mud or calcium at the inside edge of the oyster shell. They can grow to be 6 inches long and are a reddish color.

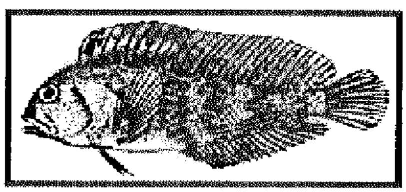
Naked Goby

The naked goby, *Gobiosoma bosc*, looks to the oyster reef to provide protection from its predators and for species it preys upon. You will find this fish swimming in and around the oyster reef. Often they will make their homes in dead oysters, called "oyster boxes". They prey on polychaete worms and small crustaceans. There are no scales on their bodies, hence their name. A naked goby can grow up to 2.5 inches long. Their greenish-gray back, pale belly, and narrow pale crossbars on their sides identify this species.



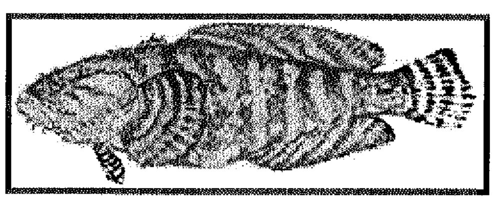
Striped Blenny

The striped blenny, *Chasmodes bosquianus*, finds an oyster reef the protective environment. They have a long dorsal fin and a laterally compressed body. Males are olive-green with blue horizontal lines that converge at the tail. Females are a darker green with pale green stripes. This species can grow up to three inches in length. Their food preferences are small crustaceans and mollusks



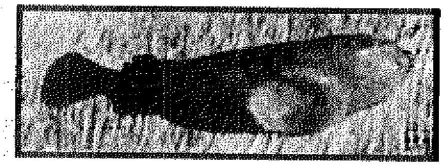
Oyster Toadfish

While this species will eat oysters, *Opsanus tau*, they prefer crabs and may actually protect the oyster reef from crab predation. Their bodies have no scales and are vertically compressed. They possess a large mouth, sharp teeth, bulging eyes, fleshy whiskers, and a broad, flat head. Growth up to 1½ feet is possible. Their skin is pale or yellowish brown with brown blotches. Toadfish use the oyster reef for protection from their predators.



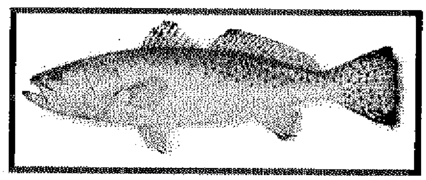
Skilletfish

This species has a scale-less body with a large sucking disk on its belly. They make their home in oyster boxes and will often lay their eggs in the empty oyster shells. Skilletfish, *Gobiesox strumosus*, are medium to light gray with brown speckles and can grow up to 3 inches. They are often found clinging to the outside of an oyster shell. Using the oyster reef as protection from predators, they also find an abundance of food from small crustaceans to polycheate worms.



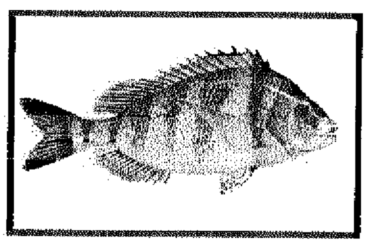
Spotted Sea Trout

Spotted sea trout, *Cynoscion nebulosus,* are frequently found among oyster reefs during the spring and summer. They generally range from one to three pounds but can be larger. The spotted sea trout is an important sport fish in coastal Alabama.



Sheepshead

The sheepshead, *Archosargus probatocephalus*, is a large fish that can exceed two feet in length and weigh as much as 21 pounds. They are a commercial and sport fish. Their feeding habits bring them around the oyster reefs. Sheepshead feed on barnacles and various species of crabs that are also found on the reefs.



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Biology

Cultivation of the Eastern Oyster *"Crassostrea virginica"*

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 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, larva develops a foot and eye spots and is referred to as a pediveliger or "eyed larva". Pediveligers settle to the bottom and can crawl short distances to find suitable sites for setting. Setting occurs when the larva cements itself to a hard substrate (usually oyster shells) and metamorphoses into a tiny oyster called a 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 it 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, 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 36 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).

Oyster Culture

Methods of oyster culture can range from very simple, with little input or control, to very intensive, with much input and control. The simplest form of oyster culture is to place (plant) oyster shells, clamshells or other appropriate materials (cultch) in an area where oyster larvae are likely to settle. Oysters are then harvested in 1 to 3 years depending on their growth rate. In some cases, small oysters are moved to areas where growth and survival are expected to be better than the location where the larvae set. After oysters are harvested, additional cultch is planted to provide substrate where more oyster larvae can set.

The most intensive culture methods involve spawning oysters in a hatchery and growing free swimming larvae in large tanks supplied with specific algae (e.g. *Isochrysis* , *Chaetoceros*, or *Tetraselmis*) that are known to be nutritious for larvae. Much of the effort and space in an oyster hatchery is devoted to producing the algae. When larvae are ready to set (14 to16 days), they are sieved from the large tanks and added to tanks containing whole oyster shells in large mesh bags.

An alternative method is to set the larvae on microscopic pieces of oyster shell (microcultch) that are held on fine screens in bucket- to barrel-size containers. Generally, only one larva sets on a piece of microcultch. This technique produces a crop of single oysters which are desirable for the oysters-on-the-half- shell market. Oyster larvae can also be shipped to locations far away from the hatchery and set. This process is called "remote setting".

Oysters Set on Shells

Oyster larvae may be set on whole oyster shells, fragments, or other types of shell (e.g. clams). Typically, well washed oyster shells that have been aged at least six months or more are loaded into large mesh (9/16 inch, 1.4 cm) bags that hold about 40 lbs (18.1 kg) of shells (approximately 215 shells). Bags of shells are placed in light colored, aerated tanks containing filtered seawater (50 micron, 0.002 inch filters) with a salinity greater than 10 ppt. Oyster larvae are added at a rate of 100 per shell with a goal of getting an initial set of 20 to 30 spat per shell. Tanks are covered with a tarp to block out light and left for 48 hours. After setting, filtered seawater water can be run through the tanks until the spat are moved to a nursery area. Hatchery-produced algae or commercially available algae paste can be used as supplemental feed.

Shell bags are moved from the hatchery to a nursery area in natural waters. The nursery area should be easily accessible for the equipment needed to deploy the bags. It should also be a site where poaching can be kept to a minimum and, most importantly, where oysters will grow rapidly.

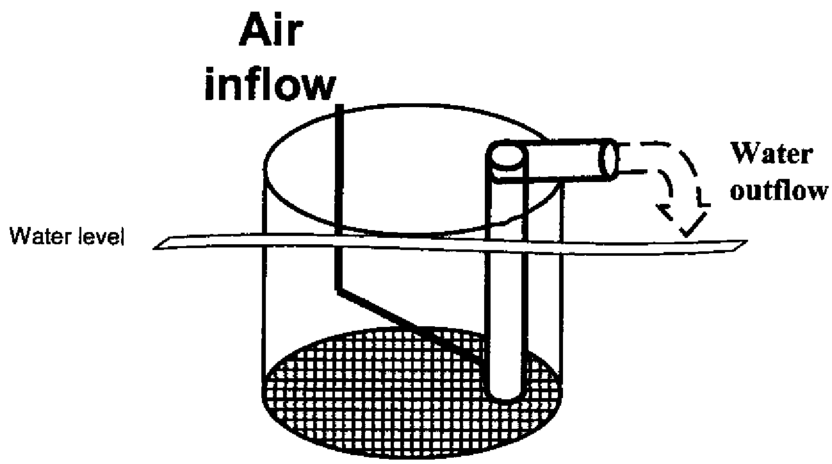
Shell bags can be strapped to a pallet and placed in natural waters for the nursery phase. Or, bags can be placed on a hard bottom or suspended from floats or racks. When oysters grow to about an inch along the longest axis, they are emptied from the shell bags onto the growing area. There can be considerable loss from predators such as crabs, oyster drills and flatworms, particularly if seed is damaged in planting. Under good conditions, three to five spat per shell should survive to reach market size. Oysters are harvested according to local gear and size regulations.

Single Oysters

Single oysters are produced by introducing ready-to-set larvae (600 per square inch, 236 / cm^2) into containers with fine mesh (150 micron, 0.006 inch) bottoms covered with finely ground and sieved oyster shells (250 micron diameter, 0.01 inch). The containers are usually suspended in a larger tank or trough of filtered seawater. An airlift pump on each container lifts water from the tank into the container; the water flows out through the mesh bottom. This arrangement is called a downweller; the downward action of the water keeps the larvae in the container until they set. As with larvae set on whole shells, the containers are covered and left for 48 hours while larvae set.

After the larvae set, the flow of the airlift is reversed to create an upweller (Fig.2) that pulls water through the bottom mesh of the container and out the top. The source water is usually filtered to keep out larger organisms and reduce fouling on the screen bottoms. As the oysters grow, they are usually moved to upwellers with larger mesh bottoms to increase flow and reduce clogging in the mesh.

Figure 2. Airlift upweller.

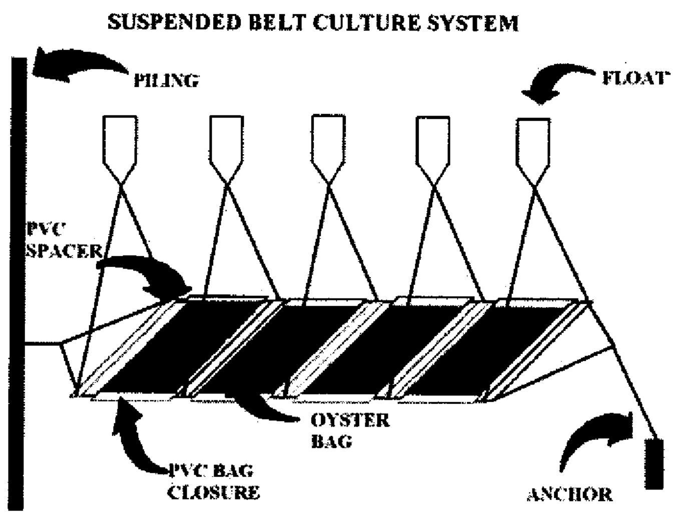


Grow-out takes place in natural waters where single oysters are placed in plastic (polyethylene) mesh bags that are typically 36 x 18 x 3 inches (91 x 46 x 7.6 cm). Single oysters are at great risk from predators if not protected in bags.

Oysters do not all grow at the same rate, so they are sieved in order to be placed in containers of the appropriate mesh-size. Representative mesh sizes and stocking densities are shown in Table 1. As oysters grow, they are moved to larger mesh containers at lower densities.

Single oysters are generally grown off-bottom so they will not be smothered by soft sediments. Oyster containers can be placed on racks attached to the bottom, on racks suspended from structures or on floating long lines. A flexible belt apparatus developed at Harbor Branch Oceanographic Institution, Inc. places a large number of bags on two parallel lines (polypropylene ropes) and uses PVC pipes to spread lines and attach bags to the lines. The flexible belts are deployed on suitable hard bottoms or suspended horizontally in the water column with floats (Fig.3). Another method is to put a float in each bag and link the bags together. As the oysters grow heavier, a considerable amount of flotation is needed for suspended oyster bags.

Figure 3. Example of a flexible belt system with floatation. (Illustrated by F. Scott Rikard)



Oyster bags often become overgrown with marine organisms such as barnacles, mussels, bryozoans, etc. Regular air drying for several hours may help, or bags may need periodic pressure washing.

Many intensively cultivated oysters come from areas where they are completely uncovered at low tide. This regularly dries the oysters, gives easier access to oyster bags, and makes it easier to maintain supporting structures and carry out the harvest.

Site Selection

While some oysters have been grown to harvestable size in ponds or in the effluent from other culture operations, most production takes place in natural waters. This means that there is little control over the many variables affecting growth and survival. Therefore, selecting a site having favorable conditions for oyster culture is essential. These factors should be considered:

1. Status or classification, by a state agency, of the water for safe shellfish harvesting
2. Substrate conditions (soft, hard, shifting, stable)
3. Salinity
4. Prevalence of diseases
5. Tidal range
6. Sedimentation rate
7. Water flow
8. Oxygen concentration
9. Algae concentration (food supply)
10. Prevalence of predators
11. Fouling organisms
12. Accessibility and security

Most potential sites within the southern U.S. are in estuarine areas where conditions are highly variable. For example, water salinity may be within an acceptable range for parts of a year or for several years at a particular site, but may be outside that range for other periods of time. Understanding such variability can help in selecting a good site. Furthermore, several factors may be closely associated, such as salinity, disease and predators. Seek help from local experts and the appropriate state agency when assessing the characteristics of a particular site.

To use a site in public waters, you must obtain permits from various agencies. This may involve a lease from the state or other formal arrangement to use water bottoms or the water column. Each state has its own requirements; at a minimum, permitting generally involves the U.S. Army Corp of Engineers, the state natural resources agency, and the state public health department.

Marketing

Oyster production in the U.S. has declined from forty years ago, while inflation-adjusted prices have remained flat or increased only slightly. This indicates consumer demand has decreased over time, possibly because of concerns about the safety of eating raw oysters and general changes in people's eating habits.

Oysters can be sold to existing markets at prevailing prices. Some producers have been able to market their oysters under brand names or regional names and obtain a premium in specific markets. A number of post-harvesting techniques that reduce human health concerns are being tried, and these may help rebuild markets. However, markets should be realistically assessed before resources are committed to oyster cultivation.

Significance

The eastern oyster is important both economically and ecologically. Oysters help filter estuarine waters, which are habitat for hundreds of species of marine organisms. Factors such as declining water quality, disease and overharvesting have greatly reduced the economic and ecological benefit of oyster reefs in some areas. Cultivation can increase oyster production and restore the ecological role of oyster reefs.

Table 1: Typical mesh size of oyster growing containers (bags) and suggested stocking densities.

BAG MESH (Inches)	*OYSTER/BAG*
0.75 (19 mm)	250
0.50 (12.7 mm)	500
0.25 (6.4 mm)	1500
0.13 (3.3 mm)	4000
0.08 (2 mm)	10,000
0.04 (1 mm)	50,000

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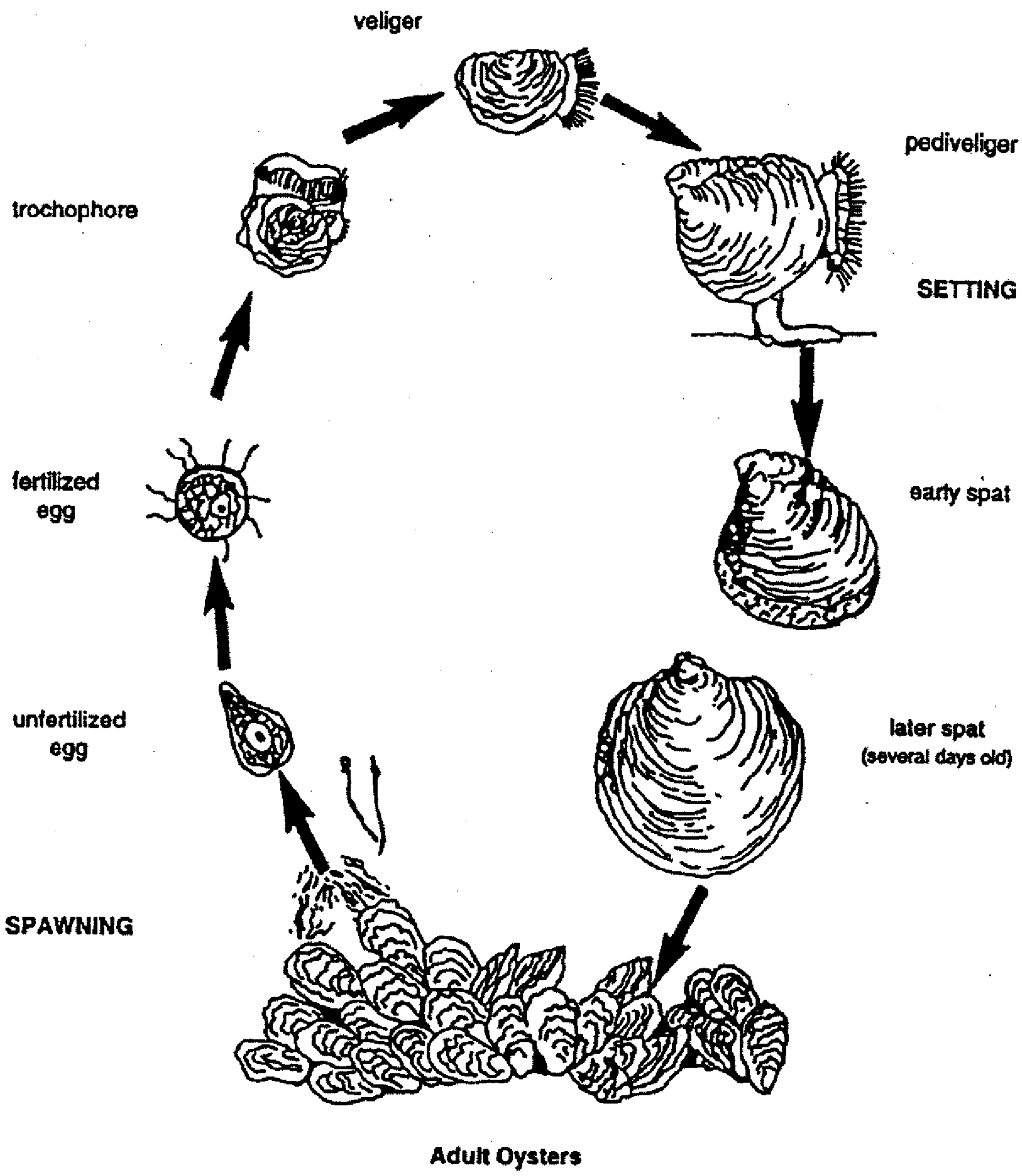


Figure 1. Life cycle of the Eastern oyster, Crassostrea virginica.

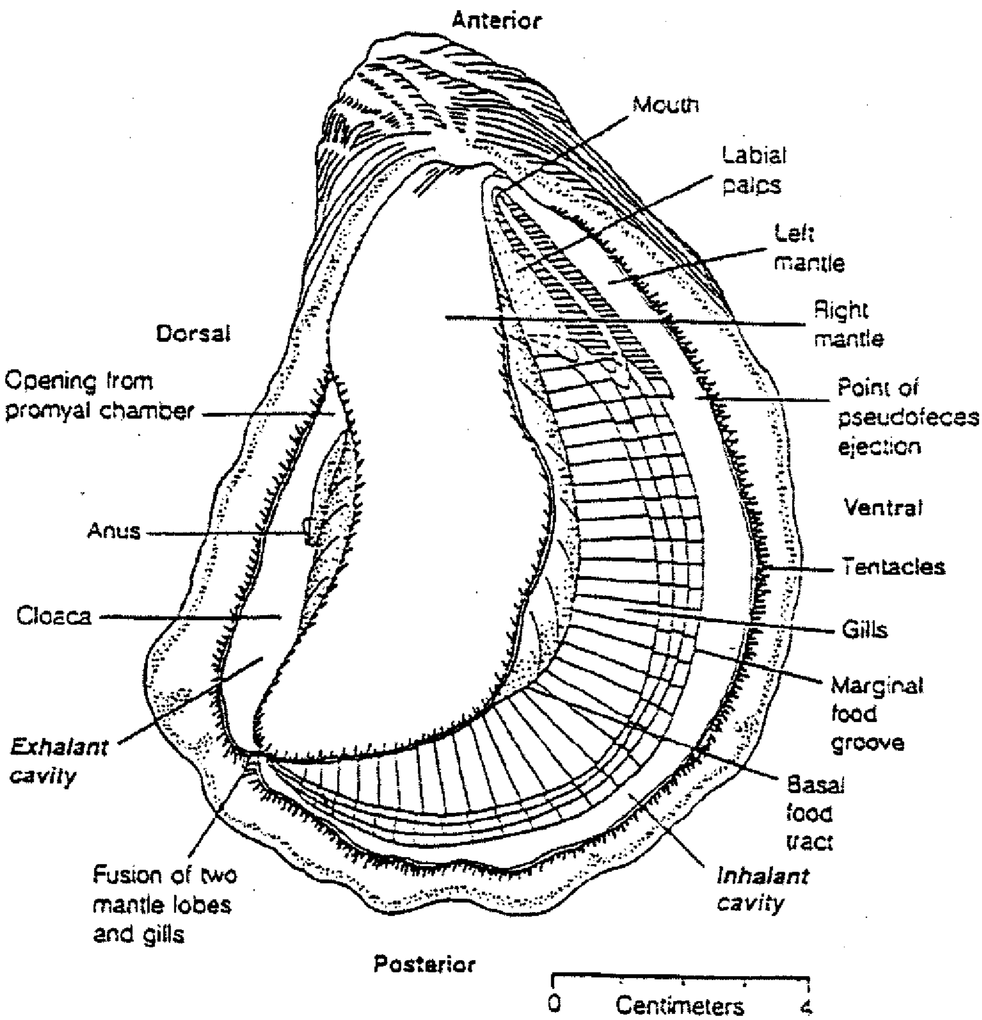


Figure 3. External anatomy of the soft tissues of *C. virginica* after removal of the right valve. Redrawn from Galtsoff (1964).

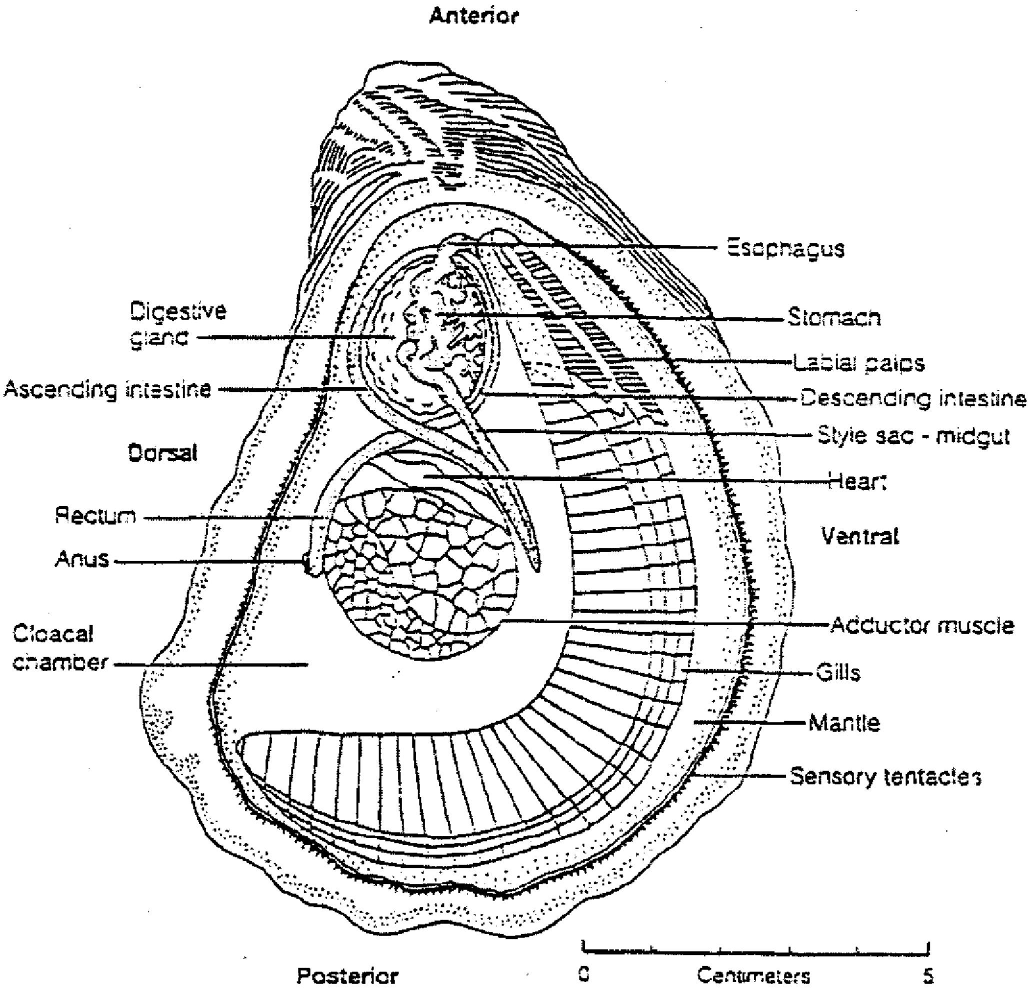


Figure 1. Oyster in left valve showing cardinal axes and digestive system including labial palps and gills. Redrawn from Galtsoff (1964).

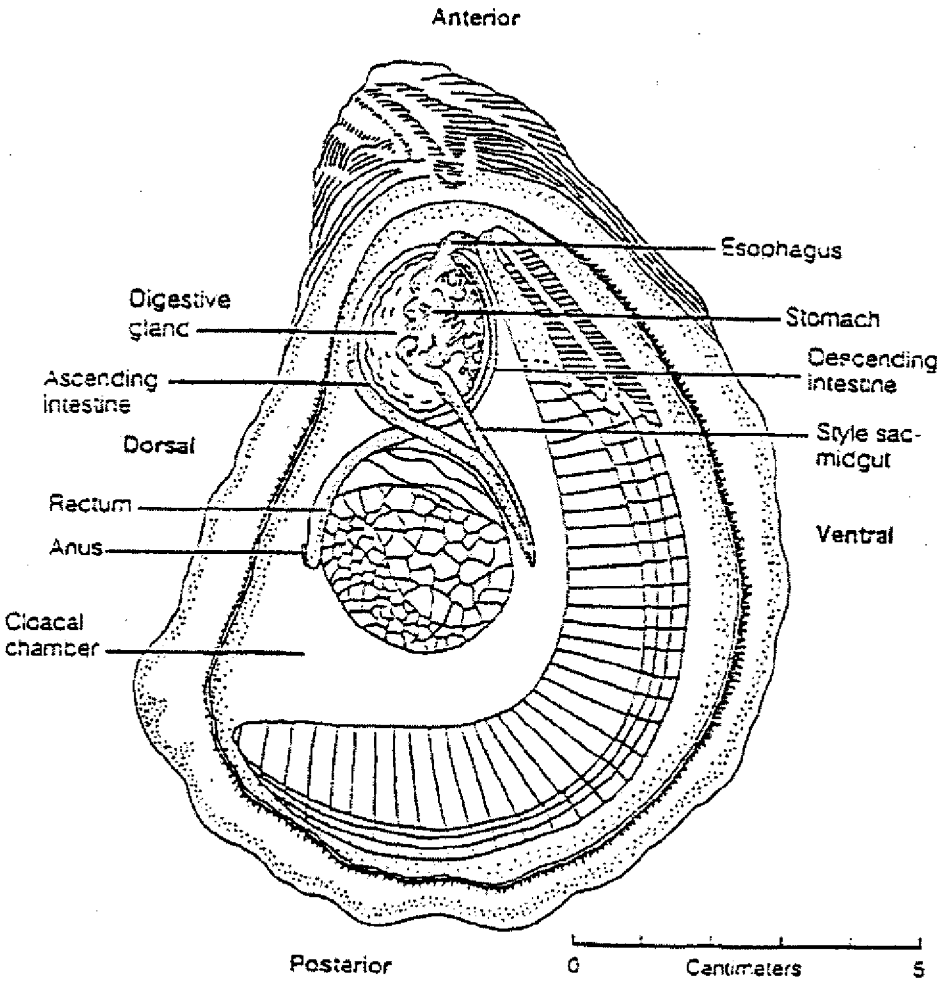


Figure 1. Digestive system of *Crassostrea virginica*. Parenchymal tissues have been removed to expose the stomach and intestine. Redrawn from Galtsoff (1964).

Diseases and Predators

Introduction to Oyster Diseases

A disease as defined by the American Heritage College Dictionary is:

A pathological condition in an organism resulting from infection or genetic defect, for example, and characterized by identifiable symptoms.

Disease is a broad term designating damage to cells sufficient to cause dysfunction of the organism. **Infection** refers to the presence of an infectious or foreign organism in tissues of the host, in this case the oyster.

Stress is a state produced by any environmental or other factor which pushes the adaptive responses of an animal beyond the normal range or which disturbs the normal functioning to such an extent that chances of survival are significantly reduced.

When describing diseases in human medicine the term **"symptom"** is used. This refers to characteristics of a particular disease condition. In animal medicine, we refer to **"clinical signs"** of disease, since these must be detected by examination rather than a verbal description from the patient.

Diseases may be caused by:

Non-infectious agents – not transmissible

- Genetic defects resulting in abnormal cellular structure and function
- Nutritional imbalances that deprive cells of essential nutrients
- External physical or chemical agents that injure cells

Infectious agents – transmissible agents that damage cells by their actions or presence

- Parasites – e.g. *Dermocystidium marinum* (Dermo) and MSX
- Bacteria – e.g. *Vibrio* and *Pseudomonas* species
- Fungi – e.g. *Ostracoblabe implexa* (shell disease – wart-like at adductor muscle)
- Viruses – e.g. Herpes-like virus around blood sinuses

Method of disease control:

- Remove dead oysters
- Keep floats clean
- Water quality (e.g., dissolved oxygen >5ppm)

Principal Diseases & Predators

Eastern (American) Oyster

Crassostrea virginica

Disease	**Description**
Dermo *Perkinsus marinus* (protozoan)	Prevalent in the Gulf of Mexico and on the East Coast of the US from Florida to Massachusetts. Causes high mortality at temperatures above 20^0C and salinities greater than 12- 15 ppt. Transmitted directly from oyster to oyster.
MSX *Haplosporidium nelsoni* (protozoan)	This disease is not yet found in Gulf waters or in Mobile Bay. Prevalent along the Atlantic coast of the US. Active at temperatures above 10^0C and cannot survive in salinities below 10 ppt. Causes oyster mortality in summer and fall. Transmission methods unknown.
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 Drills *Stromonita 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.

Dermo Disease Fact Sheet

Scientific Name: *Perkinsus marinus*
Common Name: Dermo, Perkinsus

Geographic Distribution: East coast of the US from Maine to Florida and along the Gulf of Mexico Coast to Venezuela. Dermo is also documented in Puerto Rico, Cuba, and Brazil.

Dermo was discovered in 1950 and was first documented in Mobile Bay during the summer of 1955. It is a protozoan parasite but was originally thought to be a fungus. Recent DNA studies suggest that dermo is related to the dinoflagellates.

Transmission of this disease is directly from oyster to oyster. It is important to avoid moving infected oysters to an area where there are uninfected oysters. Waterborne infective stages of the parasite are present throughout the warm months, May through October. Within the oyster, the early infections are seen in the digestive gland tissue. Usually, dermo is not found in oysters less than one year old. Occurrences of this disease during the second year increase significantly thus increasing the mortality rate.

Temperature and salinity are the two most important environmental factors influencing dermo. The parasite thrives in warm water with temperatures above 20^{0}C and oyster mortality increase in water warmer than 25^{0}C. Abnormally warm winters often result in higher occurrences of the disease during the following summer. Drought conditions bring destructive outbreaks of dermo due to higher salinity levels. Salinity levels of 0-9 ppt allow the parasite to survive but cause light infection rates. Levels of 9-15 ppt allow the parasite to develop slowly and cause low mortality rate in infected oysters. In salinity levels of 15 ppt or higher the parasite multiplies rapidly and mortality rate is highest.

MSX Disease Fact Sheet

Scientific Name: *Haplosporidium nelsoni*
Common Name: MSX (multinucleated sphere unknown)

Geographic Distribution: In the United States, MSX disease ranges from Damariscotta River, Maine to Biscayne, Florida. It is not present in the Gulf of Mexico (and it is not present in Mobile Bay). Outbreaks affecting a large number of oysters have been limited to the Chesapeake and Delaware Bays and recently Long Island Sound. The parasite has also been found in oysters in Korea and Japan.

This disease was first documented in Delaware Bay in 1957 causing massive oyster die-offs. In 1959, MSX was found in lower Chesapeake Bay. By the 1960's, the disease was found in numerous coastal bays along the east coast affecting North Carolina, Virginia, Maryland, Delaware, New Jersey, Connecticut, and New York, although die-offs were not occurring south of Virginia or north of New Jersey. During the 1980's, MSX was documented all along the east coast from Maine to Florida.

Haplosporidium nelsoni is a spore-forming protozoan. Transmission paths of this disease are unknown but it is believed to occur through the release of spores. This disease affects oysters of all ages and the infections are acquired through gill and mantle tissue. Mortality of oysters occurs from early spring through autumn. The most susceptible period of oyster mortality will occur from July through October.

Temperature and salinity are the two most important environmental factor influencing MSX. The water temperature must be above 20^0C for an oyster to acquire this disease. There are three critical temperatures for MSX. At temperatures less than 5^0C the MSX parasite and oysters are inactive. From temperatures of 5^0C to 20^0C the parasite multiplies faster than the oyster can control it. Above 20^0C, resistant oysters can overcome the parasite while susceptible oysters are killed. Salinity within an estuary is an important factor in the occurrence of MSX. Salinities over 15 ppt are necessary for this parasite to survive. A level of 20 ppt is necessary for rapid and high mortality. At a temperature of 20^0C and salinity levels of 10 ppt or less the parasite cannot survive.

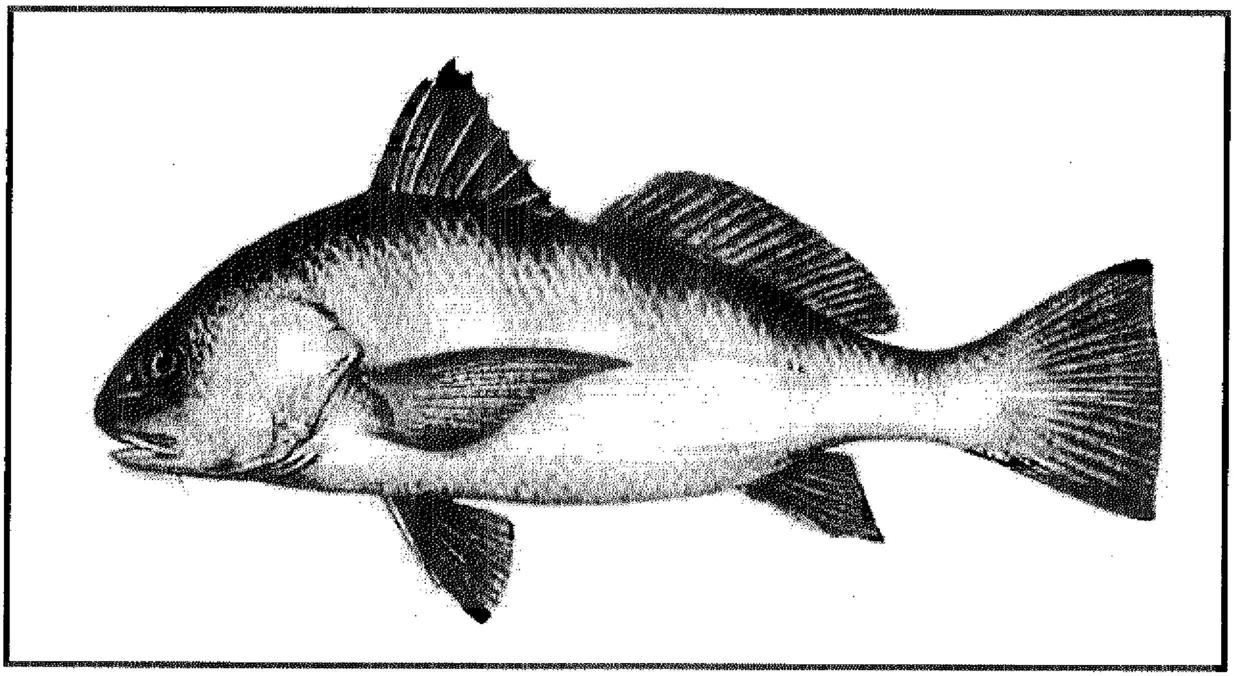
MSX is not present in Mobile Bay at this time. One factor may be a lower salinity level than is necessary for the MSX parasite to exist. The Department of Conservation and Natural Resources – Marine Resource Division is very careful not to allow non-native oysters to be imported or planted in Mobile Bay.

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, crushing teeth used to crush the oyster's shell. 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.

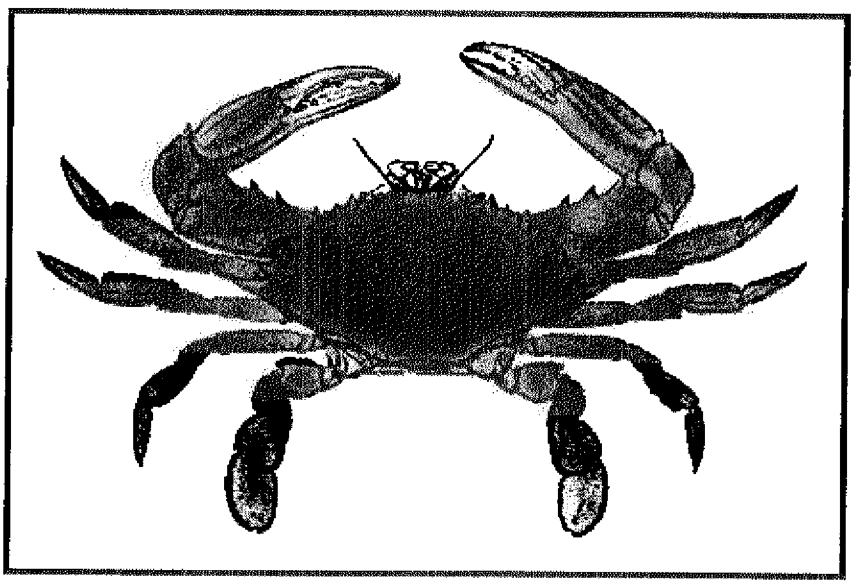


Blue Crab Fact Sheet

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.

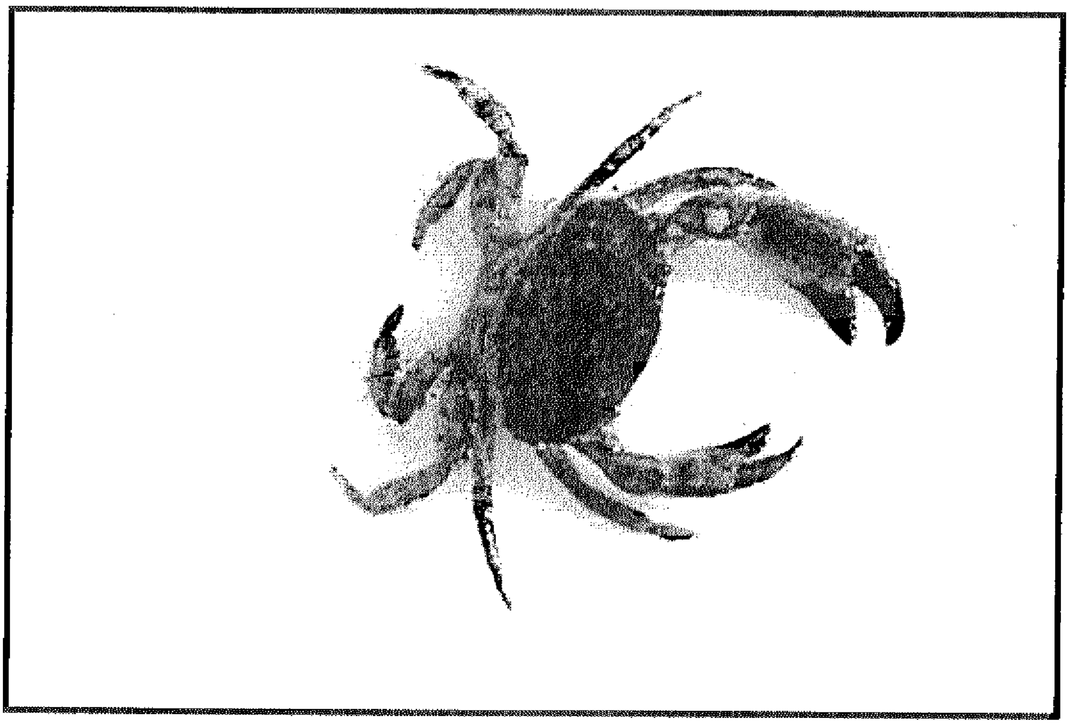


Mud Crab Fact Sheet

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. 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: *Styloachuis 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.

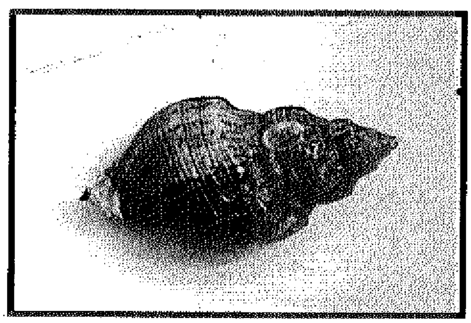
Oyster Drill Fact Sheet

Scientific Name: *Stromonita haemastoma*
Common Name: Oyster Drill

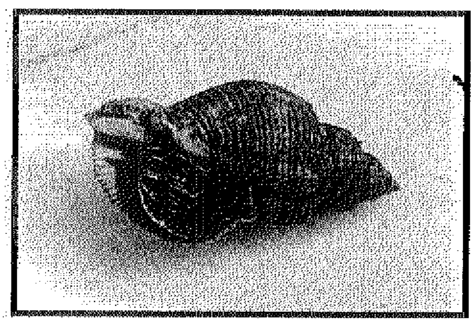
Geographic Distribution: Found along the Atlantic and Pacific coasts as well as the Gulf of Mexico.

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.

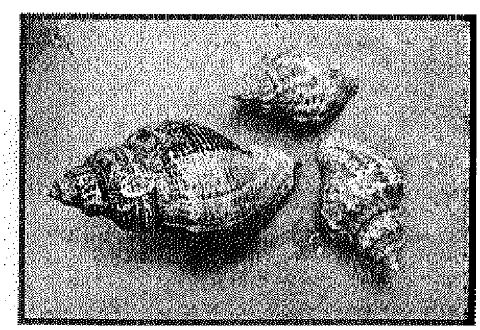
The greatest density of oyster drills will be found where the water is the most saline, usually near the mouth of the bay. The range of oyster drills is limited by salinity. Salinity greater than 15 ppt is need for its survival. During the late 1960's, the oyster drill in Mobile Bay killed 80% of the 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 in great amounts of freshwater will eliminate the oyster drill.



Dorsal View



Ventral View

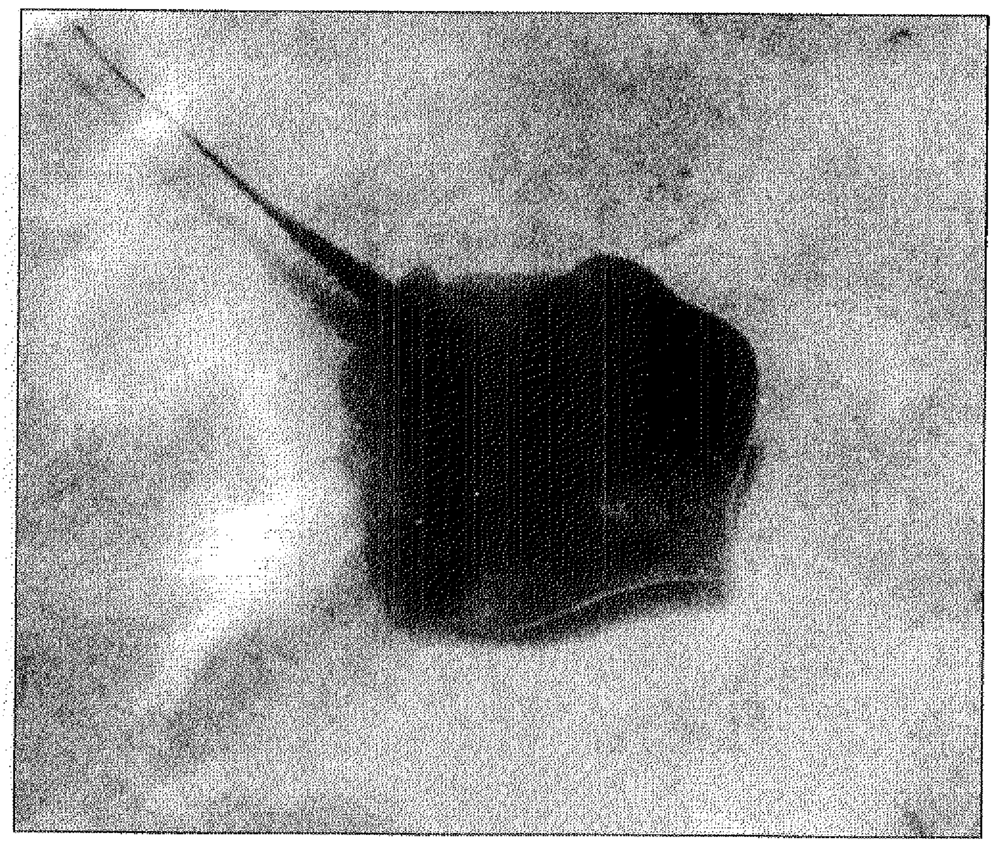


Atlantic Stingray Fact Sheet

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 50cm. 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.

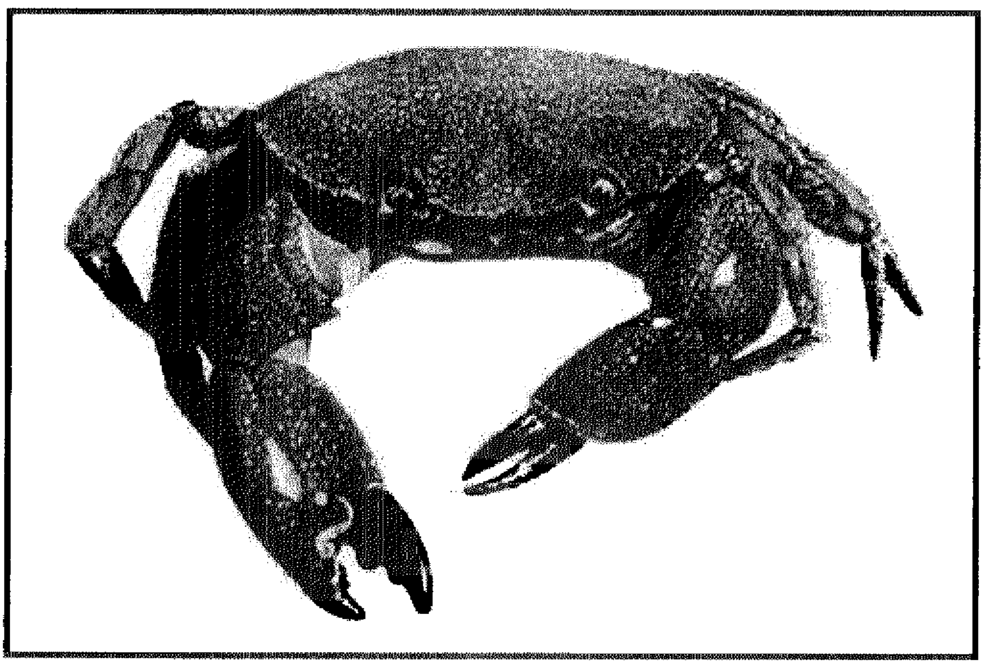


Stone Crab Fact Sheet

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.



Holly K. Hall
Mobile Bay National Estuary Program
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Mobile, AL 36615
(251) 431-6409

Regulations

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DON SIEGELMAN
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COMMISSIONER
RICHARD LILES
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R. VERNON MINTON
DIRECTOR

March 2000

ALABAMA COMMERCIAL/RECREATIONAL OYSTER HARVEST INFORMATION
Alabama Marine Resources Division

THIS IS NOT AN OFFICIAL COPY OF THE LAWS OR REGULATIONS IN EFFECT AND SHOULD NOT BE UTILIZED OR RELIED UPON AS SUCH. IT IS THE FISHERMAN'S RESPONSIBILITY TO KNOW THE LAWS AND REGULATIONS IN EFFECT AT ANY GIVEN TIME.

I. OPEN AND CLOSED HARVEST AREAS

The Department of Conservation and Natural Resources and the Department of Public Health are authorized to open and close harvest areas for management or public health purposes. Before taking oysters from any area for any reason, it is advisable to check with the Marine Resources Division (MRD) at Dauphin Island (334-861-2882), Gulf Shores (334- 968-7576) or Bayou La Batre (334-824-2161). Taking oysters from a closed area for any reason is prohibited. Transporting oysters at night through closed areas is prohibited.

II. LICENSE REQUIREMENTS

- All licenses expire September 30th of each year.
- Persons are allowed to take up to but no more than 100 oysters per day for personal consumption without a Commercial Oyster Catcher's License.
- **COMMERCIAL OYSTER CATCHER'S LICENSE (\$26.00)**
  All persons taking oysters for commercial purposes, or more than 100 oysters for personal consumption, must have in possession a commercial Oyster Catcher's License (may sell catch only to a licensed Alabama Seafood Dealer).
- Nonresidents shall pay the same fee as that charged Alabama residents to conduct the same activity in the applicant's state of residence, but not less than twice the cost that Alabama residents pay. Nonresident licenses are sold only by the Marine Resources Division offices.
- **OYSTER TAG (\$0.25)** All oysters taken from public or private reefs for commercial purposes must be sacked and tagged.
- **OYSTER DREDGE LICENSE (\$26.00)** Use of oyster dredges strictly regulated. Specific laws and regulations apply. Licenses are presently issued only to owners/lessees of private oyster reefs. Contact the Dauphin Island Office (861-2882) for further information.

III. HOW OYSTERS MAY BE TAKEN

Oysters may be taken from the public reefs and water bottoms by hand or oyster tongs only.

continued ...

IV. TIME FOR TAKING, LEGAL SIZE, AND COMMERCIAL CATCH LIMITS OF OYSTERS

The taking of oysters is permitted Monday through Friday, only. Reefs open and close daily at times set by regulations of the MRD and/or Alabama Department of Public Health.

All oysters harvested must be a minimum of 3 inches in length, with an allowance of not more than 5 % for undersized oysters.

For current commercial catch limits and daily harvest hours contact any MRD office. Bayou La Batre (334-824-2161), Dauphin Island (334-861-2882) or Gulf Shores (334-968-7576).

It is unlawful to land any oysters for commercial purposes not sacked according to the standard Alabama measure of one-quarter (1/4) Alabama barrel per sack. Each sack shall be tagged and harvest information portion of tag completed prior to landing. Tag shall remain attached to each sack until the sack is emptied.

All oysters taken from the public oyster bottoms must be culled and sacked by the time* of public water bottom closure each day. Any unculled or unsacked oysters on board a boat at the time of public water bottom closure, must be immediately replaced and scattered upon the reef from which they were taken and the boat must then immediately leave the public reefs and proceed to a landing.

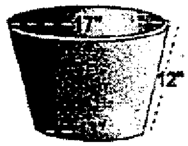
It is unlawful to transfer oysters from one boat to another for purposes of avoiding the requirements set forth in any laws or regulations, or to transfer any oysters to any unlicensed oyster boat or unlicensed oyster catcher. Any person cited for exceeding the limit (as provided by law or regulation) must immediately transport and redistribute any said excess oysters on the nearest public reef.

1/4 Alabama barrel = tub or other container measuring 1.23 cubic feet in volume.

* Daily harvest hours change seasonally (call for current info).

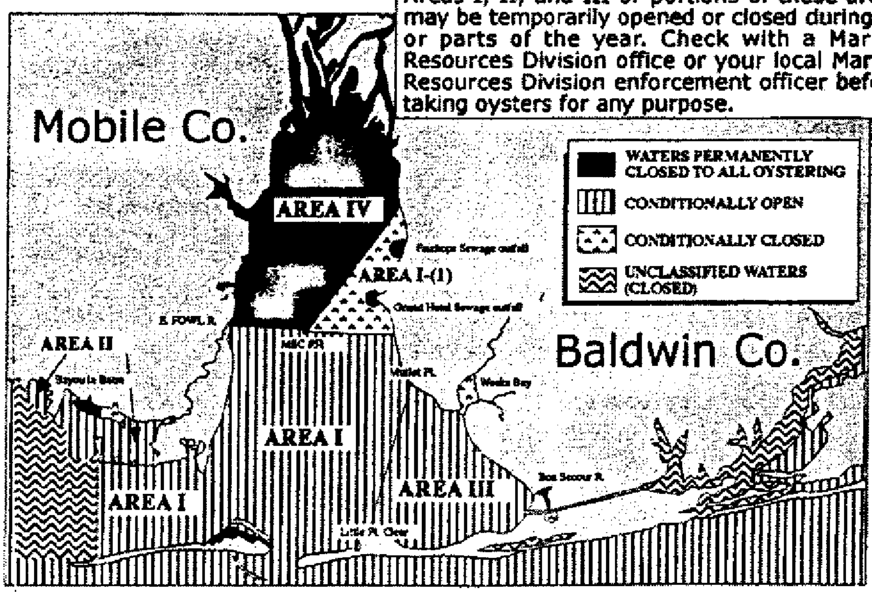
MRD Enforcement Tub Dimensions:

Diameter inside at the top	= 17"
Diameter inside at the bottom	= 13"
Inside height from top to bottom	= 12"



AREAS PERMANENTLY CLOSED TO OYSTERING

Areas I, II, and III or portions of these areas may be temporarily opened or closed during all or parts of the year. Check with a Marine Resources Division office or your local Marine Resources Division enforcement officer before taking oysters for any purpose.



OYSTER HARVESTER TAG INFORMATION

1975 CODE OF ALABAMA 9-12-67
RULE 220-3-.02 (Marine Resources)
ALABAMA STATE BOARD OF HEALTH REGULATION

1. All oysters taken for commercial purposes from the public or private oyster bottoms of the State of Alabama shall be sacked in burlap, or similar material sacks containing not more than one-quarter Alabama barrel of oysters.

2. Prior to landing, each sack must be tagged and harvest information portion of tag legibly completed using indelible ink.

3. Tag is considered void and sack improperly tagged if information on tag is incomplete, illegible, or altered in any manner. Untagged or improperly tagged sacks of oysters may be confiscated and disposed of as provided by law.

4. The tag shall remain attached to the sack until a certified dealer empties or retags the sack of oysters, or until emptied by a restaurant, other establishment, or by the final consumer.

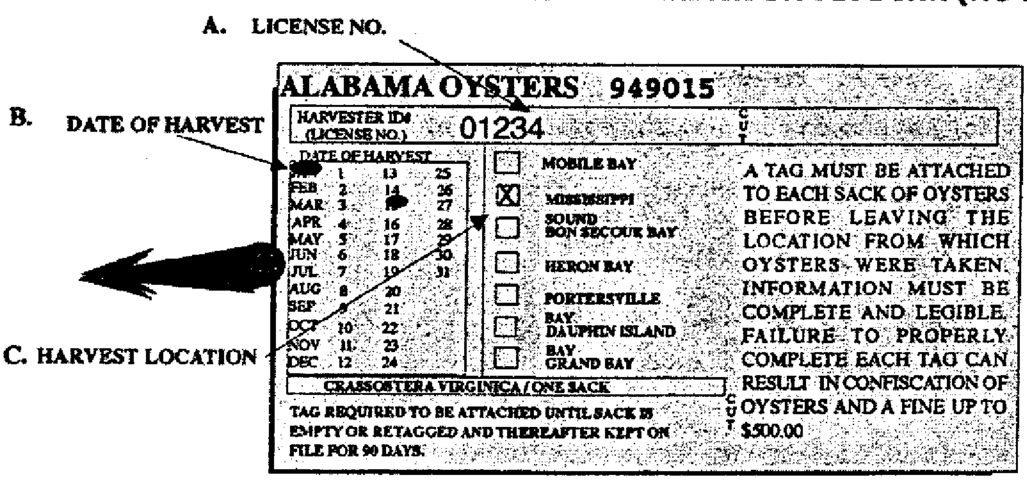
5. It is unlawful to possess empty sacks with Alabama oyster tags attached thereto.

6. Tags can be purchased at a cost of twenty-five cents ($.25) per tag from the Department of Conservation, Marine Resources Division, or its duly authorized agents.

TO COMPLETE THE TAG, HARVESTER MUST:

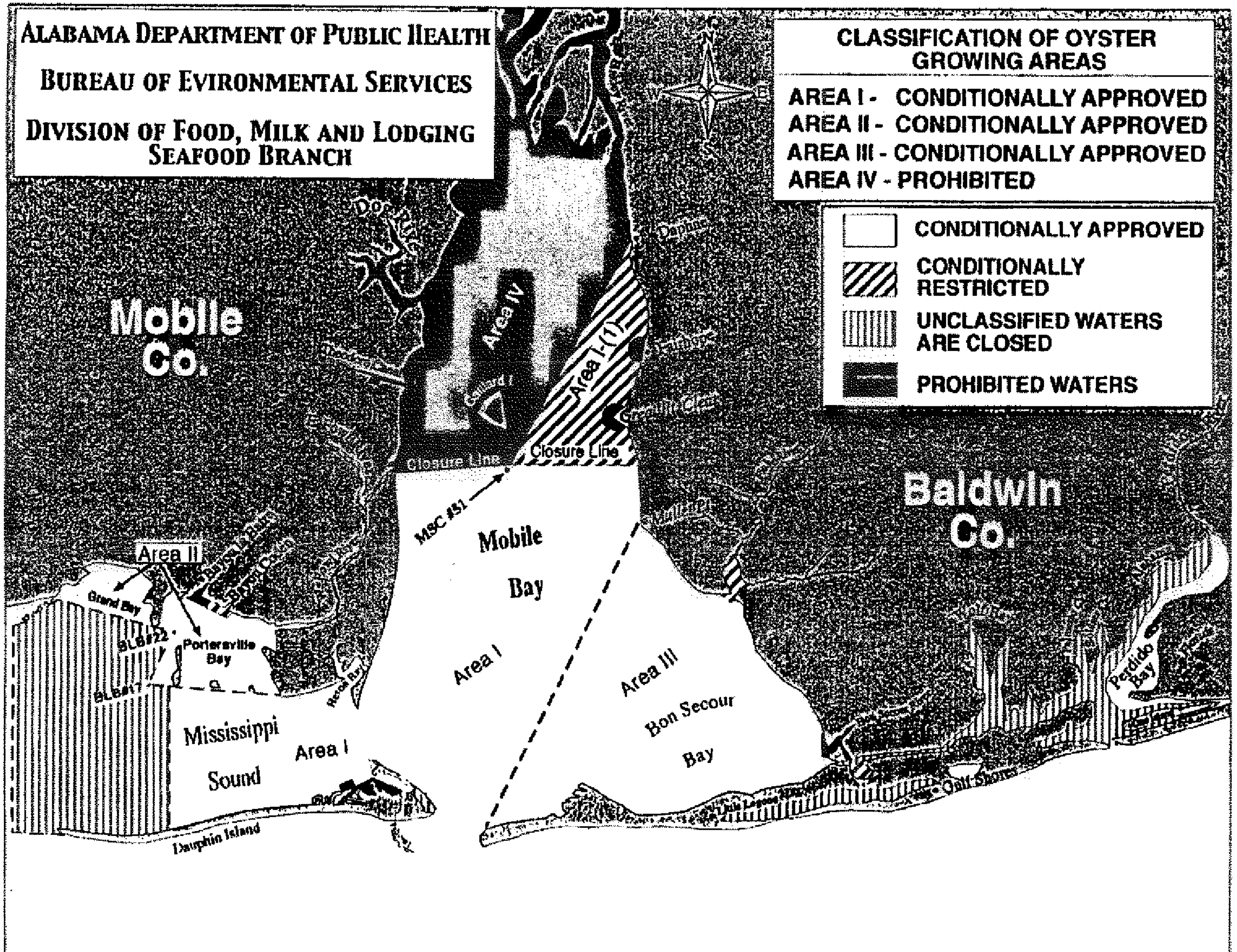
A. ENTER LICENSE NUMBER IN APPROPRIATE SPACE.
B. CIRCLE AND BLACK OUT MONTH AND DAY UNDER DATE OF HARVEST.
C. CHECK HARVEST LOCATION

INFORMATION MUST BE COMPLETED WITH BLACK OR BLUE INK (NO PENCIL)

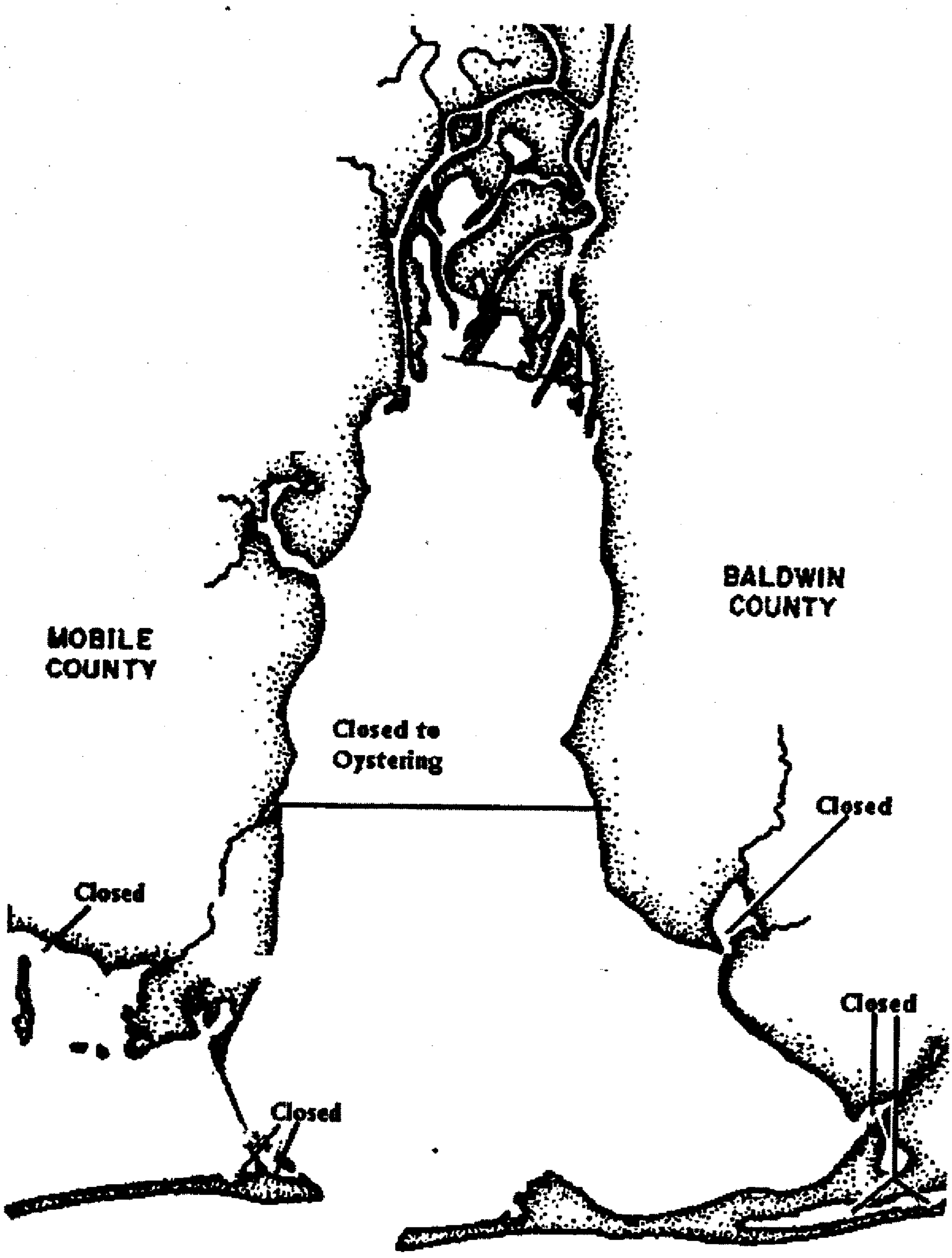


EXAMPLE

REVERSE SIDE OF TAG TO BE COMPLETED, WHEN APPROPRIATE, BY CERTIFIED DEALER.



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 APPROVED
AREA II - CONDITIONALLY APPROVED
AREA III - CONDITIONALLY APPROVED
AREA IV - PROHIBITED
CONDITIONALLY APPROVED
CONDITIONALLY RESTRICTED
UNCLASSIFIED WATERS ARE CLOSED
PROHIBITED WATERS
Mobile Co.
Baldwin Co.
Area IV
Area I-(1)
Closure Line
Closure Line
MSC #51
Mobile Bay
Area I
Area III
Bon Secour Bay
Area II
Grand Bay
Portersville Bay
Mississippi Sound
Area I
Dauphin Island
Perdido Bay


MOBILE
COUNTY
BALDWIN
COUNTY
Closed to
Oystering
Closed
Closed
Closed
Closed

Oyster Product Safety Guidelines for Alabama Commercial Oyster Harvesters

Producers, harvesters and processors of many varieties of foods all over the world have lived by the words, "Keep it cool, keep it clean and keep it moving," for years. These words of guidance are especially important for commercial oyster harvesters. Consumer confidence can be destroyed by a single disease outbreak in another part of the country. Consumer confidence in your product means better sales and better prices for you the harvester. You only need to remember what happened in New Orleans during Christmas week of 1996 to understand why good hygiene and handling practices are so important.

Dozens of football fans who ate raw oysters on the half shell ended up with an intestinal disease called Norwalk Virus. Even though the individuals affected with the virus had eaten at numerous restaurants, all of the oysters that caused this outbreak came from either Black Bay or Lake Fortuna in Louisiana.

Diseases Transmitted By Oysters Contaminated With Human Feces

There are a number of diseases that are caused by the transfer of fecal bacteria or viruses from infected humans to raw oysters. These diseases often result from poorly functioning or illegally installed onsite sewage systems with positive outlet discharges emptying into coastal waters near oyster growing and harvesting areas. A significant number of illness cases are also caused by harvesters infected with these diseases who dump their feces overboard onto oyster reefs. While these diseases do not directly infect oysters or other molluscan shellfish, oysters filter the disease-causing organisms out of affected waters and can accumulate enough of them to make consumers of raw oysters ill. The following list provides brief descriptions of the origins of some of these diseases and the symptoms that result from them.

Campylobacter jejuni – Widely distributed in the intestinal tracts of poultry, livestock and warm-blooded domestic animals. It is a very common (possibly the most common) cause of diarrheal illness in humans, and can result in profuse (sometimes bloody) diarrhea, abdominal pain, headache, weakness and fever.

Escherichia coli – Also known as E.coli, this bacterium is one of the fecal coliforms. Most types of E. coli are essential inhabitants of the human large intestine. Their purpose is to prevent dehydration by de-watering solid waste before it exits the body. Harmful (pathogenic) forms of E. coli can cause abdominal cramping, watery or bloody diarrhea, fever, nausea and vomiting, and can cause death among the very young or elderly.

Hepatitis A Virus – Man is the only natural reservoir of the Hepatitis A virus in North America. Symptoms include weakness, fever and abdominal pain early on, followed by development of yellow jaundice. Although rare, death from Hepatitis A can occur among the elderly and others with underlying diseases.

Norwalk Virus – The main reservoir is man. Symptoms include nausea, vomiting, diarrhea, abdominal cramps and fever.

Salmonella – Several species of Salmonella are naturally found in the intestines of mammals, birds, amphibians and reptiles, but they are not normally associated with mollusks. However, Salmonella can be transferred to oysters by sewage pollution of coastal waters or contamination after harvest. Salmonella infections cause nausea, vomiting, abdominal cramps and fever.

Shigella – Methods of transfer and illness symptoms very similar to Salmonella. The major difference is that Shigella is found only in the human intestinal tract.

Vibrio cholerae – A naturally-occurring bacterial resident of coastal estuaries, bays and brackish waters that is not necessarily associated with sewage contamination. There are two basic forms of this bacterium: Type 01 and non-01. Vibrio cholerae 01 is an extremely dangerous organism that can cause death as a result of dehydration from severe vomiting and diarrhea. Vibrio cholerae non-01 causes mild to moderate cases of diarrhea, abdominal cramps and fever.

Yersinia enterocolitica – Naturally found in soil, water, and domesticated and wild animals. Yersinia causes diarrhea, vomiting, fever and abdominal pain, often mimicking appendicitis.

Other Diseases Transmitted By Oysters

Unfortunately, oysters can accumulate and transmit other biological and chemical hazards in addition to fecal bacteria and viruses. The following list provides brief descriptions of several of them.

Red Tide – Blooms of the algae, Gymnodinium breve, produce three toxins (called brevetoxins) that can result in fish kills and make shellfish toxic to humans. All filter-feeding mollusks, including oysters, can accumulate Red Tide brevetoxin. Among the symptoms of brevetoxin poisoning most frequently experienced are: tingling of the face or other body parts; cold-to-hot sensation reversal; dilation of the pupils; and, a feeling of inebriation.

Vibrio parahaemolyticus – Occurs naturally in estuaries and other coastal areas throughout the temperate zones of the world. As is the case with other marine Vibrio species, this bacterium is more numerous during the warmer months. Thus, most outbreaks occur during the summer and early fall. Symptoms include diarrhea, abdominal cramps, nausea, vomiting and headache. Fever and chills may also be experienced.

Vibrio vulnificus – Thought to be the most prevalent naturally occurring estuarine bacterium in the Gulf of Mexico. Vibriosis, the disease caused by Vibrio vulnificus, can be acquired either by sustaining a puncture wound in the marine environment or by eating raw oysters that have filtered enough bacteria to cause illness.

Vibriosis can cause symptoms like nausea, vomiting and diarrhea similar to (and commonly mistaken for) many of the previously-mentioned fecal-borne bacterial and viral illnesses. In severe cases, this extremely invasive bacterium can cause life-threatening primary septicemia (invasion of the bloodstream and transfer of the infection to other parts of the body not originally affected).

Several factors make certain persons more likely to develop vibriosis. Among them are: Achlorhydria (reduced stomach acidity); AIDS; Alcohol abuse; Cancer (especially patients undergoing chemotherapy); Diabetes; Diseases requiring immunosuppressive drugs; Kidney disease; Liver disease (including cirrhosis); and, Steroid dependency.

Heavy Metal Contamination – Elements like arsenic, cadmium and lead can be toxic if consumed in sufficient quantities. Because oysters filter heavy metals from the water that they pump through themselves, they can actually accumulate enough of those hazardous elements to become toxic to humans. Arsenic is thought to promote cancerous tumors. Excessive amounts of cadmium can cause liver and kidney damage. And, too much lead can cause permanent damage to the nervous system.

Control Measures

The large number and varied nature of the potential hazards associated with oysters requires that adequate control measures be put in place to protect consumers. Some controls like the National Shellfish Sanitation Program (NSSP) are managed by federal and state shellfish authorities. Other methods of control can be practiced by individuals oyster harvesters. Following are some examples of those controls.

Permanently Closed Areas – Portions of Mobile Bay, particularly the Upper Bay, remain permanently closed to oyster harvesting due to the presence of heavy metals in bottom sediments. Much of the heavy metal concentration in Mobile Bay is the result of Liberty Ship building activities during World War II. While that was over 50 years ago, the chemical nature of the clay and silt that make up much of the Bay's sediment is such that it bonds tightly to the heavy metals. There appears to be little likelihood that these heavy metals will ever be released by Mobile Bay's sediment, making it unlikely that these Permanently Closed Areas will reopen to oyster harvesting.

Other areas of Alabama's coastal waters remain permanently closed, but for different reasons. For example, a portion of Portersville Bay from the Eastern Shore of the mouth of Bayou La Batre to the Western Shore of the mouth of Bayou Coden and out 1,800 feet is permanently closed due to several known point sources of fecal pollution being located there. This are will remain permanently closed as long as the known point sources are located there.

Temporary Closures – Occur when the water level at the Barry Steam Plant reaches 8 feet, usually following significant upstate rainfall events. When the water level at Barry Steam Plant falls below eight feet, the Alabama Department of Public Health – Seafood Branch samples the test stations. When the water and oyster meat samples meet the NSSP guidelines, the growing waters are re-opened for harvesting.

However, fecal coliforms are not the only basis for temporary closures. The presence of more than 5,000 Gymnodinium breve (Red Tide) organisms per liter in shellfish harvesting waters will trigger temporary closures. And, the presence of ANY brevetoxins in oyster meats will also cause the Seafood Branch to close oyster waters.

Tagging – Tags are the only means that processors, transporters, wholesale distributors, retailers and consumers have to identify where and when oysters were harvested. Aside from being required by federal and state rules and regulations, the real reason why all oyster sacks must display tags containing certain information is in the interest of consumer protection.

Using the 1996 Christmas week Norwalk Virus outbreak as an example, if the restaurant owners had not been able to trace their shellstock oysters back to Black Bay and Lake Fortuna, the health authorities would not have been able to prevent more cases of Norwalk Virus. If oystermen do not do their part to protect their customers from shellfish-borne illnesses, then customers are not going to continue buying and consuming oysters.

On-Board Handling – Another set of controls that oystermen can place on the safety of their products is the use of proper on-board handling procedures. Some of these procedures are mandated by state and federal rules and regulations. For example, NSSP guidelines require that shellstock oyster be shaded during the hotter months from the time they are harvested until they are placed under mechanical refrigeration to limit the growth of Vibrio vulnificus. However, common sense dictates that oysters should not be allowed to contact bilge water, battery acid or gasoline to prevent contamination with these potential biological and chemical hazards.

Personal Hygiene – Finally, oystermen have a responsibility to observe good personal hygiene and sanitation practices while on the reef. If it is necessary to use the bathroom while in shellfish harvesting areas, use an appropriate receptacle like a porta-potty or a covered plastic container, then empty it into an approved on-shore disposal facility. Fecal matter should never be dumped overboard onto the oyster reef. Even under the best conditions, this is fecal pollution, and is prohibited under state and federal law. However, if an oysterman is a carrier of a fecal pathogen, overboard dumping of infected feces into shellfish growing and harvesting waters could make people sick and, ultimately, cause the area to be temporarily closed.

In summary, there are enough other causes of temporary closures (like upstate rains or the Red Tide) that oystermen should be responsible enough not to temporarily close themselves out of an income due to improper on-board hygiene while on the reef.

Further Reading – The material in this fact sheet was complied from information contained in the following publications:

Ahemd, F.E., ed. 1991. *Seafood Safety.* National Academy Press. Washington, D.C.

Benenson, A.S. 1970. *Control of Communicable Diseases in Man.* 11th Edition. American Public Health Association. New York, N.Y.

FDA. 1995. *NSSP Manual of Operations.* Part I. Sanitation of Shellfish Growing Areas. Center for Food Safety and Applied Nutrition. Washington, D.C.

National Seafood HACCP Alliance. 1996. *HACCP: Hazard Analysis and Critical Control Point Training Curriculum.* 2nd Edition. North Carolina Sea Grant Publication UNC-SG-96-02.

Oblinger, J.L., ed. 1988. *Bacteria Associated with Foodborne Diseases.* A Scientific Status Summary. Food Technology. 42:4 (181-200).

Perkins, B.E. 1997. *Aquacultured Oysters.* Alabama Cooperative Extension System Circular ANR-1030. MASGP-97-008.

Perkins, B.E. 1991. *Seafood Safety.* Alabama Cooperative Extension System Circular ANR-578. MASGP-91-003.

Alabama Department of Public Health – Seafood Branch
Alabama Department of Conservation and Natural Resources – Marine Resources Division
Auburn University Marine Extension and Research Center
MASGP-97-013

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SRAC Publication No. 434

COOPERATIVE EXTENSION SERVICE
THE UNIVERSITY OF MARYLAND SYSTEM

Southern
Regional
Aquaculture
Center

July 1995

Aquacultured Oyster Products

Inspection • Quality • Handling • Storage • Safety

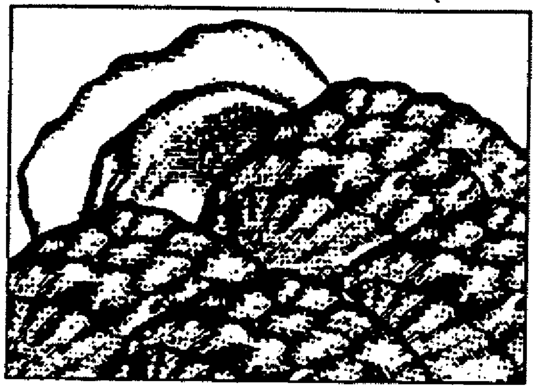
Brian E. Perkins*

Archaeologists regularly investigate oyster shell middens (piles of shucked oyster shells) to learn more about America's earliest human inhabitants. Pottery and other artifacts found in middens provide evidence that Paleo Indians inhabited the coastal areas of what is now the Southeastern United States thousands of years before the first Europeans arrived. Early European settlers in America likewise used the abundance of oysters they found along the coastlines and in the bays of the original Thirteen Colonies to provide themselves with an easily harvested dietary component.

Oysters played other important roles in the cultures of both groups. Oyster shells were used by the Paleo Indians for tools, jewelry and currency (wampum), and shell middens were sometimes used as burial sites. Seventeenth Century European settlers used oyster shells as construction materials for buildings and roads.

Today in Alabama, oysters are harvested by the old-fashioned method of tonging, which is carried out from small boats by using tongs (rakes on the ends of long wooden poles) to gather and hold the oysters until they are lifted on board. Much of the oyster tonging in Alabama is conducted on public oyster reefs, but increasing numbers of oysters are cultured in waters adjacent to privately-owned land.

Alabama law provides that owners of property fronting on the waters of the State where oysters may be grown have the right to grow oysters in front of their land to a distance of 600 yards from shore. This is referred to as the owners' *riparian* oyster right. Some owners lease the right to culture oysters on their riparian oyster bottoms to other individuals. Riparian oyster rights allow the commercial oyster industry to supplement its dependence on production from public reefs with additional production from a more managed form of aquaculture.



Biology

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 100 species of oysters are found throughout the world, and the waters of the Gulf of Mexico contain several. Of these, only the Eastern oyster (*Crassostrea virginica*) is commercially important.

Adult oysters release eggs and sperm into the water and, after fertilization, the fertilized eggs proceed through several swimming larval stages. Ultimately, the larvae become too heavy to remain suspended in the water, and sink to the bottom. Those that settle on a suitable substrate (clean, hard bottom) secrete a fluid that

*Extension Seafood Technologist, Auburn University, Marine Extension and Research Center.

cements them permanently to the bottom.

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 24 to 30 months.

Inspection

Because oysters cannot move, they are at the mercy of the surrounding environment. Along with their food (diatoms and algae), tides and currents can bring silt or sand to smother them, predators to feed on them, or microorganisms that they can accumulate and pass up the food chain. For this reason, state and federal health authorities pay close attention to molluscan shellfish.

Like all other varieties of seafood, once oysters are landed at the dock or offered for import, they may be inspected by numerous authorities. Seafood inspection is not the continuous "carcass-by-carcass" inspection associated with red meat and poultry. Seafood is routinely inspected with a frequency determined by past experience or potential for a particular commodity to cause illness.

State and county health authorities inspect all processing plants, grocery stores, and restaurants where seafood is processed, handled, or sold. The U.S. Food and Drug Administration (FDA) inspects seafood processing plants to ensure compliance with federal standards for sanitation, Good Manufacturing Practices, branding, and labeling. The FDA also checks seafood products for pesticides and other contaminants, and assures the wholesomeness of imported seafoods and products shipped across state lines.

The FDA pays particularly close attention to raw, minimally processed, and ready-to-eat seafoods. Because oysters, clams, and mussels are often eaten raw, the FDA's National Shellfish Sanitation Program (NSSP) carefully monitors them from their growing waters through processing, and ultimately to retail outlets. The NSSP *Manual of Operations* is routinely revised by the Interstate Shellfish Sanitation Conference (ISSC), a voluntary group composed of members from FDA, state health regulatory agencies, and industry. ISSC committees and task forces generate revisions and resolutions that are forwarded to FDA for approval. Once the revisions and resolutions are approved, FDA adds them to the NSSP *Manual of Operations*.

Oysters may be placed in interstate commerce only if the growing state's oyster industry and health agency practices are consistent with the NSSP *Manual of Operations*. State health agencies comply by routinely monitoring, classifying, and opening and closing shellfish growing and harvesting waters in the interest of consumer protection. Processors, in turn, attach tags to sacks or boxes of shellstock oysters (live oysters in the shell) noting oyster harvest date and location. Processors must properly label containers and maintain strict temperature controls to minimize bacterial growth.

Quality attributes and buying hints

Like most seafoods, oysters provide sound nutrition. A $3^1/_2$-ounce (100-gram) uncooked serving contains 7.9 grams of protein, 3.5 grams of carbohydrate, 2 grams of total fat, 57 milligrams of cholesterol, and 75 calories. Oysters are moderately low in sodium. A $3^1/_2$-ounce serving also provides 100 percent of the USRDA for Vitamin B_{12} and zinc, plus 65 percent of the USRDA for niacin, and about 35 percent of the USRDA for iron.

Oysters are marketed live in the shell, as fresh, frozen or canned meats, or frozen and breaded. Live oysters are sold by the dozen, by the bushel bag, or in bushel-fraction boxes. Six live oysters per person is a normal portion, although many people will eat more. Shucked oyster meats are graded and sold according to size, usually in 8-ounce and 12-ounce cups, or in pint, quart, or gallon containers. Allow $^1/_3$ to $^1/_2$ pint of shucked oyster meats per serving.

If you purchase oysters in the shell, make sure that they are alive. Live oysters hold their shells tightly closed. Tap any oysters with slightly opened or "gaped" shells. Live oysters will respond by closing their shells tightly. Oysters that do not respond are dead and should be discarded. When purchasing freshly shucked oyster meats, choose oysters that are plump and have a natural creamy color and clear liquid.

Raw molluscan shellfish should only be purchased from reputable dealers. All shellstock oysters are required to have an accompanying tag that allows the buyer to trace the oysters back to their point of harvest. Shucked oyster meats must be in sealed containers displaying the processor's permit number. Retail-sized containers ($^1/_2$-gallon or smaller) of shucked oyster meats must have a "sell by" date stamped on them. Shucked oyster meat containers larger than $^1/_2$ gallon must display the "date shucked," and cannot be offered for sale beyond 14 days after that date. In-store "dipping" of oyster meats from larger containers into smaller cups is not legal in Alabama.

Preparation

Thoroughly wash and scrub all mud and debris away from the shells. This is best done with a garden hose and scrub brush. To shuck whole oysters, use gloves and an oyster knife. An oyster knife has a heavy wedge-shaped blade and handle, often made in one piece. It is designed to withstand the pressure required to open oysters. Never use a sharp knife.

The cleanest way to open oysters is to grasp the oyster securely by the thin end or "bill," leaving the hinge (thicker portion) exposed toward the other hand. Then:

1. Insert the oyster knife into the crevice between the shells at the hinge; twist the knife while pushing it firmly into the opening to sever the hinge.

2. Once the hinge is broken, before pulling the shell apart, slide the knife along the inside of the top shell to cut the adductor muscle loose from the top shell.

3. Remove the top shell and slip the knife under the body of the oyster, being careful not to mutilate it, and cut the adductor muscle away from the bottom shell. Remove any remaining shell particles that may be attached to the oyster. Most oysters, except the very largest, can be opened by this method.

An alternate method is to make an opening by breaking part of the shell on the thin end with a hammer. Insert the knife into the opening and slide along the inside of the top shell to cut the adductor muscle. Then cut the oyster meat away from the bottom shell being careful not to mutilate the oyster meat. (This method tends to leave more shell particles on the oyster.)

Preservation

Oysters to be eaten fresh can be stored in the refrigerator by either of two methods. Shellstock (unshucked) oysters can be stored without ice in ventilated containers in the refrigerator at 35-40° F, and should remain alive for 7 to 10 days. Freshly shucked oyster meats can be placed in sanitized 1-cup or 1-pint containers or plastic freezer bags. These containers or bags should be packed in ice and placed in the refrigerator. Oysters stored by this method will keep for 7 to 10 days.

Oysters can be frozen, but they will be of lower quality than fresh oysters. The simplest method is to freeze oysters in the shell. Place the oysters in a plastic bag, press out excess air, seal the bag, and freeze. The shell and juices provide an excellent natural container for the oyster meat.

Shucked oyster meats can be frozen also. They will maintain a better flavor if frozen in their own natural juices, called liquor. Place shucked oyster meats in sanitized plastic containers or freezer bags. Leave 1/2 inch of headspace above oyster meats in plastic containers. Press freezer bags flat against oyster meats to expel excess air. Seal and freeze as quickly as possible.

Oysters frozen by either of these two methods will keep for 2 or 3 months. Do not thaw and refreeze oysters. Thaw overnight in refrigerator only. Thawing under running water washes away the flavor. It is best to use previously frozen oyster meats in preparations like oyster dressing, chowders, or stews where appearance is not so important.

Safety

Any protein food eaten raw poses a greater risk of causing illness than does the same protein food after cooking. However, commercially available oysters (and other molluscan shellfish) harvested from certified waters, packed under sanitary conditions in inspected facilities, and properly refrigerated pose little risk of causing disease when consumed raw by most healthy individuals.

Along the Gulf Coast, we hear a great deal about seafood-related illnesses resulting from the bacterium, *Vibrio vulnificus*. This free-living microbe occurs naturally in temperate brackish estuarine areas throughout the world. The numbers of *Vibrio vulnificus* in coastal waters increase during the warmer months. Thus, most cases of Vibriosis occur during late summer and early fall.

One way Vibriosis can be contracted is by a puncture wound through which the *Vibrio* bacteria gain entry to the body. The disease can also be acquired by eating raw, undercooked, or minimally processed seafoods, including oysters and other molluscan shellfish. It can range in severity from a condition similar to (and commonly mistaken for) gastroenteritis, with associated nausea, vomiting, and diarrhea, to a life-threatening primary septicemia.

Everyone who eats seafood with associated *Vibrio* bacteria will not succumb to the illness. Among the groups of people who are more at risk are those with the following conditions:

- Achlorhydria (reduced stomach acidity)
- AIDS
- Cancer (especially patients undergoing chemotherapy)
- Chronic alcohol abuse
- Chronic kidney disease
- Diabetes mellitus
- Inflammatory bowel disease (or other diseases requiring immunosuppressive drugs)
- Liver disease (including cirrhosis and hemochromatosis)
- Steriod dependency (for such conditions as chronic obstructive pulmonary disease)

To summarize oyster safety in simple terms, the commercial oyster industry and its related commodity organizations, along with county, state, and federal health agencies, assure that the vast majority of consumers will receive safe, wholesome, and nutritious oysters. Unfortunately, a certain portion of the population (listed previously) has a higher risk of succumbing to illness. Still, there are several steps that consumers can take to minimize the risk of illness:

- Since harmful microbes are killed by heat, high-risk individuals should enjoy oysters and other molluscan shellfish cooked.

- Persons who catch or harvest their own oysters should be certain that the waters from which they come are approved for harvest. County and state health authorities can provide advice about area openings and closings.
- Avoid cross-contamination between raw and cooked shellfish. Always sanitize raw product handling surfaces before placing cooked or ready-to-eat foods of any kind on the surface.
- If the oysters are to be cooked before consumption, be sure they are thoroughly cooked. Oyster meats are done when they plump and the edges begin to curl. (This occurs at a temperature of 140-150° F.)
- Refrigerate or freeze leftover, cooked oyster preparations promptly. Use refrigerated, cooked oysters within two days.

REMEMBER: All raw foods, including oysters, contain bacteria. Handle oysters as you would any perishable food. Keep oysters cold, handle oyster meats with clean hands on sanitized surfaces, and use older products first.

Purchase oysters only from reputable, properly licensed or permitted outlets.

Further reading

The material in this fact sheet was compiled from information contained in the following publications. Consult them for additional information about oyster biology, management, nutrition, preparation, preservation, production, quality, and safety.

Perkins, B.E. 1993. Alabama seafood facts. Alabama Cooperative Extension Service Circular ANR-833. MASGP-93-014.

Wallace, R.K. 1993. Oysters in Alabama. Alabama Cooperative Extension Service Circular ANR-832. MASGP-93-010.

Wallace, R.K. 1993. Oyster farming in Alabama. Alabama Cooperative Extension Service Circular ANR-805. MASGP-93-007.

Perkins, B.E. 1991. Seafood safety. Alabama Cooperative Extension Service Circular ANR-578. MASGP-91-003.

Perkins, B.E. 1990. Preparation and preservation of Alabama seafood. Alabama Cooperative Extension Service Circular CRD-53. MASGP-90-005.

Perkins, B.E. 1987. Saving your catch. Alabama Cooperative Extension Service Circular CRD-40. MASGP-87-001.

Hosking, W. and R.L. Collette. 1984. Buying and preparing oysters. Alabama Cooperative Extension Service Circular CRD-30. MASGP-84-003.

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Aquaculture

Hatchery Production of Oysters

The role of the hatchery in oyster gardening is to produce oyster larvae, set those larvae, and grow the resulting spat until they are ready to stock to open waters. The oyster species predominantly cultivated along the Gulf Coast is the eastern oyster, *Crassostrea virginica*. Production of oyster spat begins by spawning adult oysters called broodstock. Broodstock ripe for spawning may be collected from naturally occurring reefs in Mobile Bay or broodstock may be conditioned in the hatchery for spawning.

One of the more common methods of spawning oysters is by "temperature induction". Broodstock are cleaned and placed on a shallow spawning table of cool (22-24°C) flowing seawater. Once the oysters are open and pumping the temperature of the water is increased (28-30°C) to stimulate spawning. As the oysters begin to spawn, males and females are segregated into small dishes. When spawning is complete, the eggs are pooled into a single bucket with 10 L of filtered seawater. A small amount of sperm suspension is then mixed with the eggs to initiate fertilization. Samples are taken of the eggs and observed under a microscope to check for adequate fertilization and estimate the number of fertilized eggs. A single female can release as many as 170 million eggs.

Fertilized eggs are placed in large rearing tanks containing lightly aerated and filtered seawater (10-20ppt). Here they will develop into free swimming trochophore larvae within 24h. Several hours later they will develop into a straight-hinge or D-hinge larvae with the appearance of a bivalve shell. The larvae are now capable of feeding on phytoplankton (algae). The larvae are fed either cultured algae or naturally occurring algae from filtered seawater. Algae production can be one of the most time and space consuming operations in a hatchery.

Over the next several days the larvae will develop an umbo at the anterior end and are then referred to as veliger larvae. Every one to two days the tanks are drained and the larvae collected on a fine mesh sieve and placed in a new tank of clean filtered seawater. Different size sieves may be used as the larvae grow to grade out poorly developing or slow growing larvae. After 10 to 14 days the larvae have developed a muscular foot and a pigmented eye spot and are ready to set. The larvae at this stage are referred to as pediveligers or "eyed" larvae.

At this point, the larvae are sieved out of the rearing tank and transferred to setting tanks containing a suitable substrate (cultch) on which the larvae will set. The larvae will set by searching with their foot for suitable substrate and then cementing themselves to the cultch. Setting usually takes place within 48 hours after being placed in the setting tanks. Larvae prefer to set in dark locations (negatively phototaxic). For this reason the tanks are covered to provide a more suitable environment for setting. After setting, larvae metamorphose into small oyster usually called spat. Spat are fed by pumping filtered seawater through holding tanks or in some cases, fed hatchery-produced algae.

Larvae can be set on very finely ground oyster shell (0.25mm diameter) called microcultch, or they can be set on whole oyster shell contained in mesh bags. Larvae set on microcultch are intended to produce single oysters. These are good candidates for aquaculture production of oysters for the "half-shell" raw oyster market. Larvae set on whole oyster shell will eventually form clumps and are similar to oysters found on natural reefs. These oysters are more appropriate for reef restoration and reef enhancement projects like oyster gardening.

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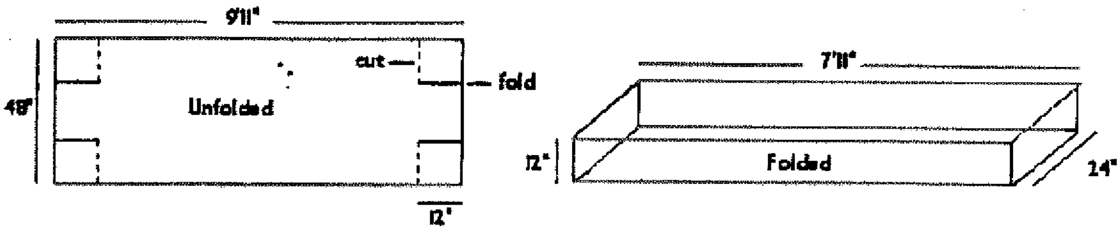
Taylor Floats and Maintenance

HOW TO BUILD A TAYLOR FLOAT

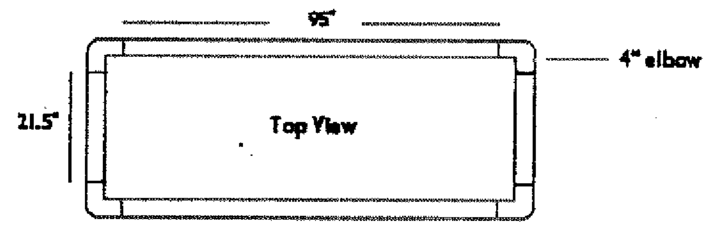
Materials	Unit Cost	Cost Per Float
10 feet 1" x 1" plastic coated wire netting	0.75/foot	$ 7.50
1- 2' x 4' piece of polyethylene netting		5.00
12 feet 4" Schedule 20 PVC pipe	0.672/foot	8.07
4 – 4" Schedule 20 PVC elbows	1.98/each	7.92
144 stainless steel rings	5.00/lb.	2.00
28 nylon Zip ties		7.00
PVC Primer	5.66/pint	1.00
PVC Cement	4.45/pint	1.00
Labor		40.00
Total Cost*		**$ 79.49**

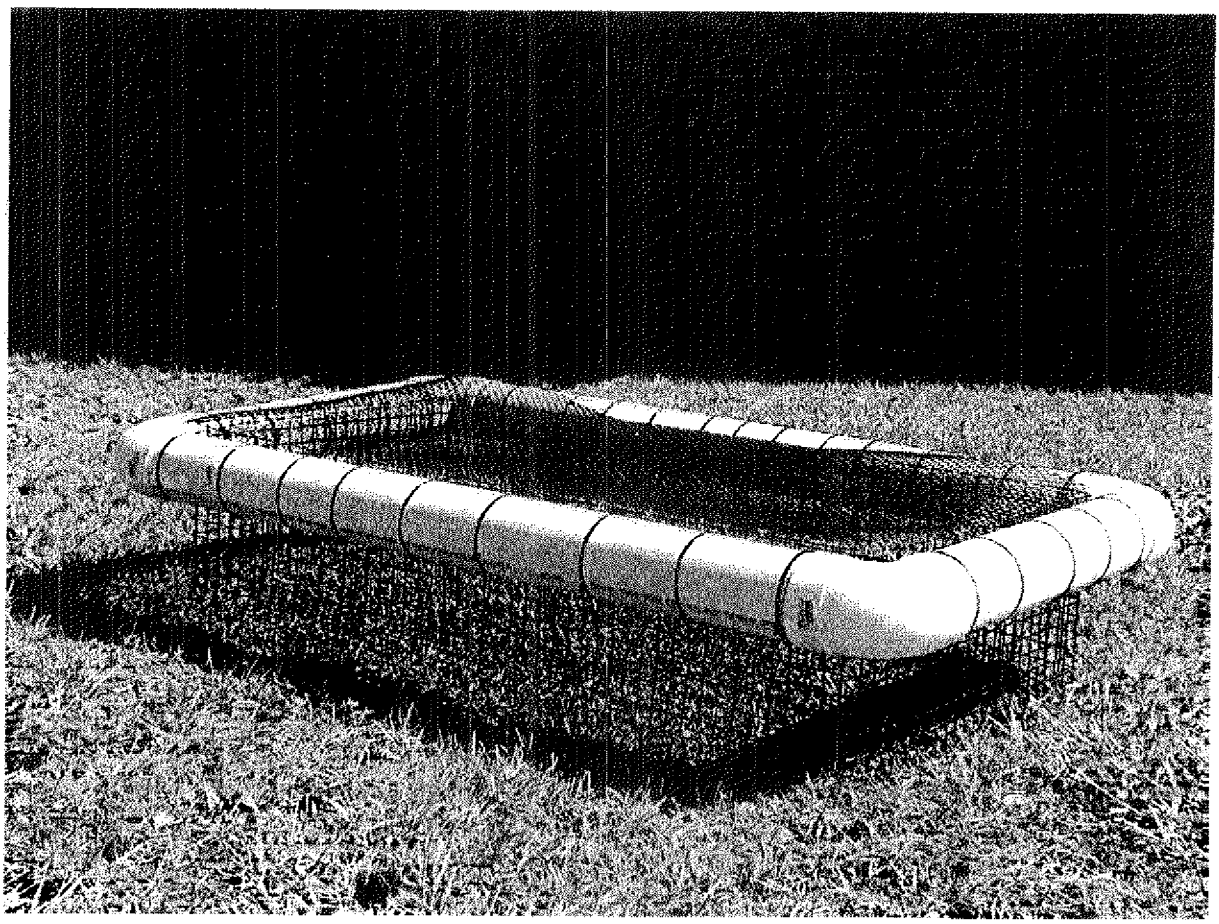
* All costs are approximate and subject to the prices of the material vendors.

1. Cut the PVC pipe into 2 four foot lengths and 2 two foot lengths. Swab the purple cleaning primer onto the outer edge of every pipe and the inside of each elbow. Wait for the primer to dry. Add the cement to the outer edge of the two foot pipe and the inner edger of two elbows. Swab the cement on to one piece of PVC at a time and put the pieces together before adding the cement to the next piece. Force the elbows all the way on the two foot piece of pipe to make sure they are square. Add cement to the outer edge of the four foot pieces and the other elbows. Quickly place all pieces onto a flat surface and push the two foot lengths with elbows all the way on the four foot length of pipe. Re-cement each seam to avoid a leak.
2. Cut one piece of plastic wire netting 12 feet long and 11 inches wide. Cut another piece of plastic wire netting 2 feet by 4 feet. Fold the 12 foot x 11 inch piece of wire into a two foot by four foot square. Attach the corners with stainless steel rings at every mesh.
3. Attach the 2 foot by 4 foot piece of netting to the bottom of the box using stainless steel rings clamped at every mesh.
4. Attach to the PVC floatation collar using the nylon zip ties, placing the cut edge of the wire at the top of the float collar. Attach the two foot by four foot piece of wire to the bottom edge of the side of cage using the stainless steel rings.
5. Make a lid by cutting a 2 foot x 4 foot piece of netting. The lid may be attached by using plastic coated wire.


9'11"
cut
fold
48"
Unfolded
12"
7'11"
12"
Folded
24"

PVC Float


95"
4" elbow
21.5"
Top View



CHECKLIST FOR TAYLOR FLOAT MAINTENANCE

ITEM	WHEN	WHAT	ACTION
Entire float	bi-monthly	control fouling and flat worms	pull float from water and dessicate fouling organisms for 6 - 12 hours depending upon temperature; replace float
Floatation collar	monthly	remove fouling	scrub with wire brush or pressure wash
		inspect for cracks or deterioration of PVC	repair cracks with PVC cement; replace flotation if deterioration is severe
		check for leaking joints	identify leaks and patch immediately with sealant
Wire basket	monthly	check for fouling of meshes	clean mesh with wire brush or high pressure spray
		check to ensure that corners are securely fastened	repair corners with hog rings
		check condition of wire for corrosion that might affect holding capacity of the unit	repair worn areas with wire patches; in severe cases, remove unit and replace entire basket
Cable ties	monthly	inspect to ensure that all are in place and in good condition	replace deteriorated or missing ties

Care and Maintenance of Oysters

There are three things that will be the most important maintenance tasks for oyster gardening: (1) keep the float clear of fouling organisms such as barnacles, mussels, and algae; (2) remove sediment and oyster feces that will collect in the float; and (3) remove predators that will invade your float and feed on the young oysters. Your float 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 mussles. This will be accomplished by pulling the Taylor float out of the water and letting it sit on the dock, exposed to the fresh air. The young oysters can survive extended periods exposed to air. Letting your oysters sit in hot, direct sunlight for more than a couple of hours is not recommended. Keeping the float shaded will help to reduce the fouling. On cloudy or rainy days, the oysters can survive for a longer period of exposure to the air. Your floats 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 the algae is to make sure it does not have a chance to grow. When you observe algae beginning to grow on your float you should begin the routine of letting your float air out in the sun. Once the algae becomes established it will grow very quickly. If the float is 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 float. This may be accomplished by covering it with an opaque cover.

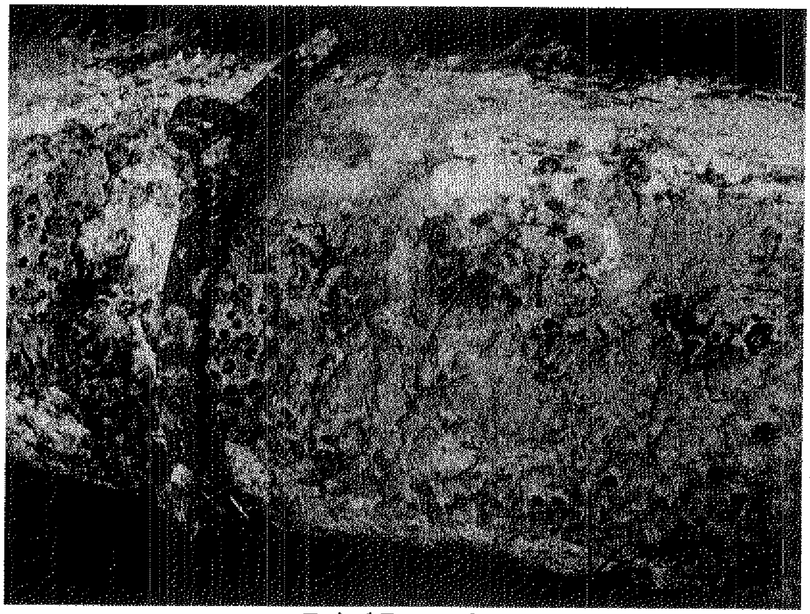
If you cannot control the growth of barnacles, mussles, or algae using the drying out method alone, you will need to take a more direct approach. Scrubbing the float with a hard bristle brush will help remove the algae. Scraping with a hoe can remove barnacles. A high pressure hose can also help to remove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

Cleaning Floats

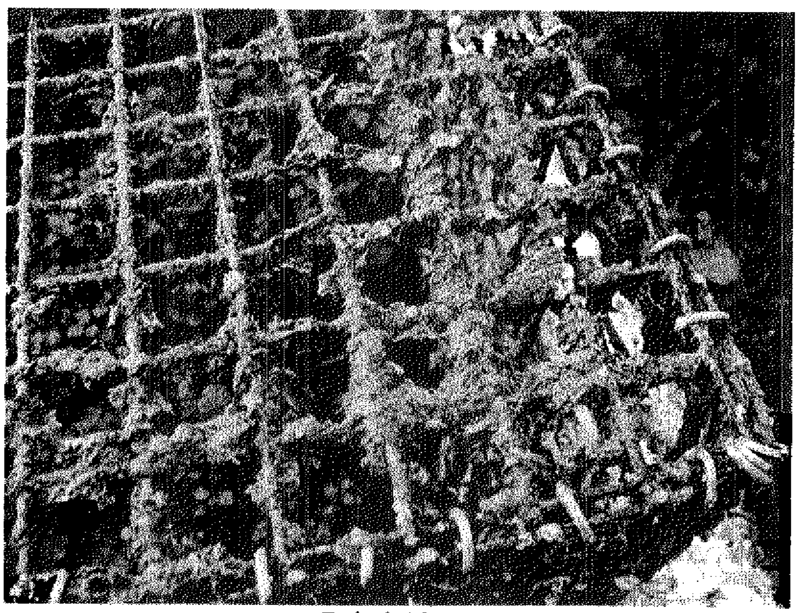
The Taylor floats will trap sediment that is suspended in the water. The problem you have with sediment will depend on where you are located. Some areas may have a high load of suspended sediments, while others may not. Examining the bottom sediments near your pier will be an indication of the problem 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. Floats located in areas where high wave activity occurs may have to clean their float after a major storm.

If your area has fine clay sediment, this will be more of a problem. The oysters in the float will catch the sediment as it falls out of the water. Oysters will also remove some of the sediment and algae through their own water filtering process. The waste product of the oyster, known as "pseudofeces" will contain some of the sediment as well as the natural oyster waste. Waste particles will be dropped and accumulate on the bottom of the float. Both the sediment and the oyster feces can be a problem with the survival of your oysters. 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 Taylor floats **must** be cleaned on a regular basis. The time between cleaning will vary depending on the location of your float and the season. All floats will need to be cleaned as often as every two weeks. Cleaning can consist of moving the float up and down in the water until all the sediment is rinsed off, or by using a hose if one is available. When cleaning your float do not remove the dead oysters from the float because they will need to be counted when collecting data on your oysters.

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



Dried Barnacles



Dried Algae

Gardener's Data

Oyster Gardening Data Sheet

Gardener's Name: ______________________________

Gardener's Location: ______________________________

Gardener's Phone Number: __________________

Date Oysters Measured: ___month ___ day ____ year

Predators	**Number removed**
Blue Crab	______
Mud Crab	______
Oyster Drills	______
Other ______________	______

Describe any problems you have had with your oysters:

____

____

____

Please sort through and count the number of dead oysters: ______

(dead oysters are open with a top shell that will not close when touched or a single shell that has lost its top shell)

Comments:

____

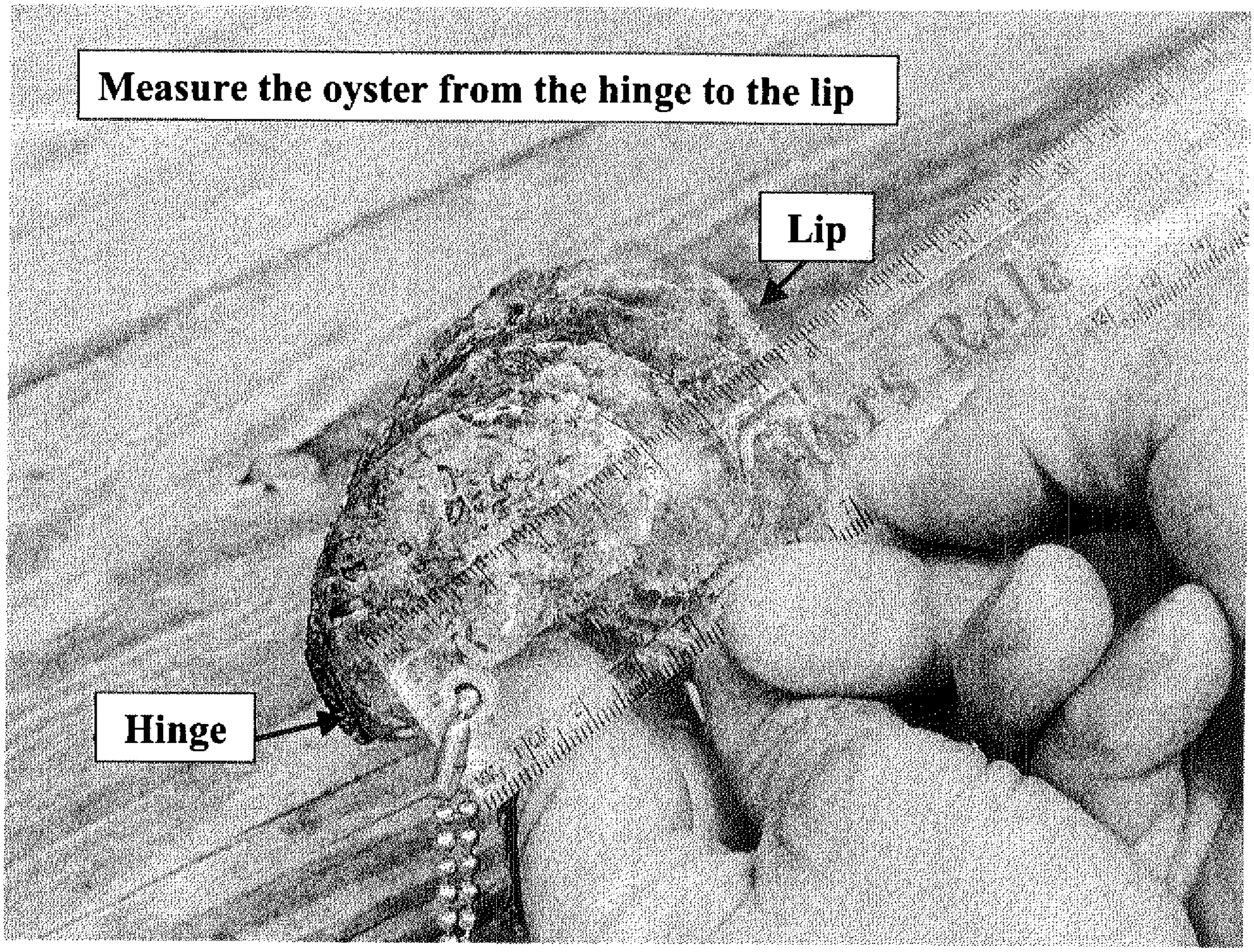
____

____

Randomly select 50 oysters. Measure each oyster, using the regulation oyster ruler, in millimeters. Measurements are taken from the hinge to the lip (see reference photograph).

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30
31	32	33	34	35
36	37	38	39	40
41	42	43	44	45
46	47	48	49	50

Instructions for submitting your data:
If you have any questions, please call the Mobile Bay National Estuary Program (251) 431-6409.



Mobile Bay Oyster Gardening Calendar

January – April: Construct Taylor Floats

April - May: Participate in an Oyster Gardening training session.
Mobile Bay National Estuary Program will provide oyster spat at 1,000 spat per Taylor float.

May – October:
Monitor growth and collect data on oysters every month. Record requested information on the Oyster Gardening Data sheets. As needed, maintain floats by removing fouling organisms. Growth of algae can add 10-50 pounds of weight to the float. A pressure washer removes algae best.

November – December:
The Mobile Bay National Estuary Program office will contact you about transporting your oysters for restoration. Oysters will be planted onto reefs in Mobile Bay approved by the Alabama Marine Resources Division and Alabama Department of Public Health. Floats must be removed from water and cleaned for winter storage.

Restoration

Reprinted from
Oyster Reef Habitat Restoration: A Synopsis and Synthesis of Approaches
Edited by M. W. Luckenbach, R. Mann and J. A. Wesson • 1999 • Virginia Institute of Marine Science Press, Gloucester Point, VA.

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 = $1{,}800 \cdot m^{-3}$) and reaches more than $7{,}000 \cdot m^{-3} \cdot sec^{-1}$ 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

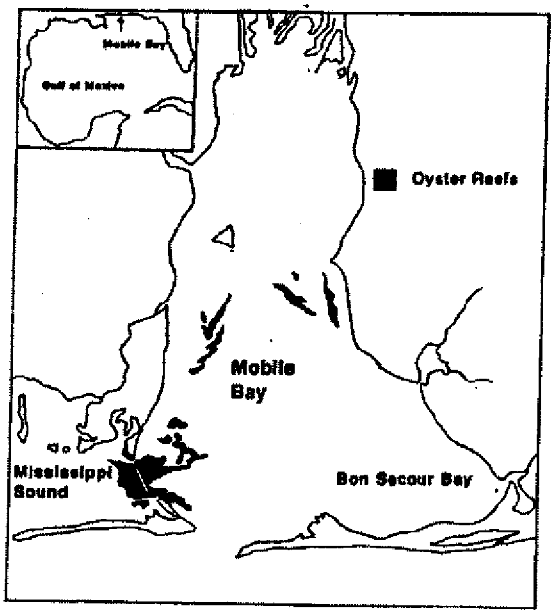

Figure 1. Location of oyster reefs in Mobile Bay, Alabama.

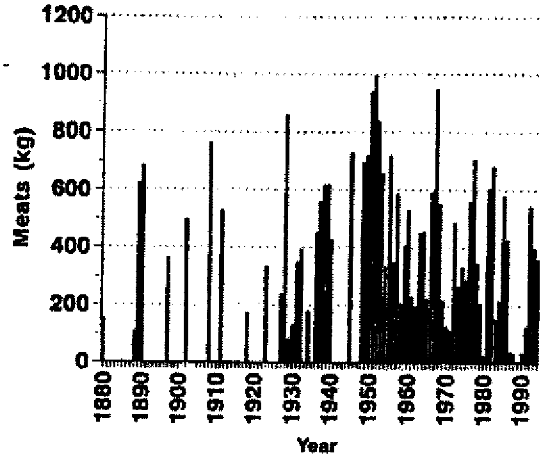

Figure 2. Alabama Oyster Landings, 1880 - 1994.

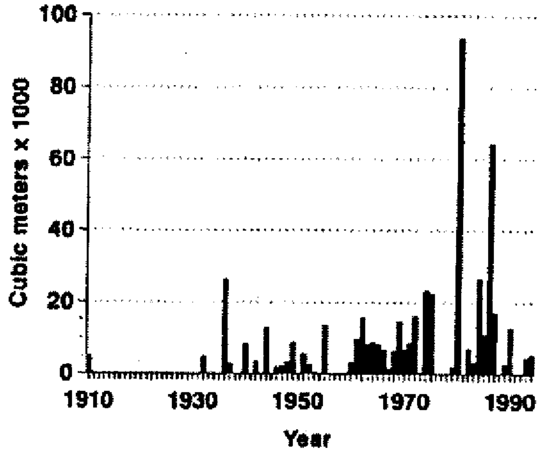

Figure 3. Public Shell Planting in Alabama, 1910 - 1994.

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.

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 ($<1\text{-}2 \cdot m^{-2} \cdot d^{-1}$) in the southeastern and central part of Mobile Bay, higher sets ($5\text{-}10 \cdot m^{-2} \cdot d^{-1}$) in the southwestern area of the Bay and eastern Mississippi Sound. High spat sets ($100\text{-}200 \cdot m^{-2} \cdot d^{-1}$) 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.

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

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

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.

Literature Cited

Bell, J. O., 1952. A study of oyster production in Alabama waters. M. S. Thesis, Texas A&M College, College Station, TX, 81p.

Durrenberger, P. E., 1992. It's all politics: South Alabama's seafood industry. University of Illinois Press, Urbana, 216p.

Eckmayer, W. J., 1979. The oyster fishery in Mobile Bay, Alabama. pp. 189-200 *In*: H. A. Loyacano, Jr. and J. P. Smith (eds), Symposium on the Natural Resources of the Mobile Estuary, Alabama. U. S. Army COE, Mobile District, Mobile.

Eckmayer, W. J., 1983. Growth and survival of hatchery-related American oysters set on three types of cultch and in Bon Secour Bay, Alabama. N. Am. J. Fish. Manage. 3:171-175.

Hoese, H. D., Nelson, W. R., and Beckert, H., 1972. Seasonal and spatial setting of fouling organisms in Mobile Bay and eastern Mississippi Sound, Alabama. Ala. Mar. Res. Bull. 8:9-17.

May, E. B., 1969. Feasibility of off bottom oyster culture in Alabama. Ala. Mar. Res. Bull.3:1-14.

May, E. B., 1971. A survey of the oyster and oyster shell resources of Alabama. Ala. Mar. Res. Bull. 4:1-53.

Ritter, H. P., 1896. Report on a reconnaissance of the oyster beds of Mobile Bay and Mississippi Sound, Alabama. Bull. U.S. Fish Comm. for 1895:325-339.

Rouse, D., Wallace, R. K., and Rikard, S., 1993. Growth of microcultched and remote set oysters in coastal waters of Alabama. J. Shellfish Res. 12(1):134.

Schroeder, W. W. and Lysinger, W. R., 1979. Hydrography and circulation of Mobile Bay. pp 75-94 *In*: H. A. Loyacano, Jr. and J. P. Smith (eds), Symposium on the Natural Resources of the Mobile Estuary, Alabama. U. S. Army COE, Mobile District, Mobile.

Swingle, H. A. and Hughes, E. A., 1976. A review of the oyster fishery of Alabama. Ala. Mar. Res. Bull. 11:58-73.

Tatum, W. M., Heath, S. R., Van Hoose, M. S. and Duffy, J. J., 1994. Archaeological coral for cultch material to catch oyster spat. Project Completion Report. Ala. Mar. Res. Div., Dauphin Island, AL.

Wallace, R. K. and Rouse, D. B., 1993. Growth and survival of the eastern oyster cultured in an earthen pond. World Aquaculture 24(2):82-83.

Wallace, R. K., Hosking, W., and Rouse, D. B., 1994. Oyster culture demonstration projects in Alabama. World Aquaculture Soc., Book of Abstracts, World Aquaculture '94:77.

Restoring Oysters to U.S. Coastal Waters

A NATIONAL COMMITMENT

Sea Grant OYSTER DISEASE RESEARCH PROGRAM
NATIONAL SEA GRANT COLLEGE PROGRAM

Restoring Oysters to U.S. Coastal Waters: A National Commitment

A REPORT FROM THE NATIONAL SEA GRANT COLLEGE PROGRAM

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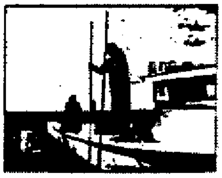
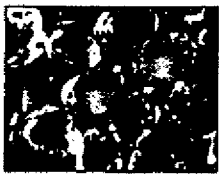




The Oyster Disease Research Program (ODRP)

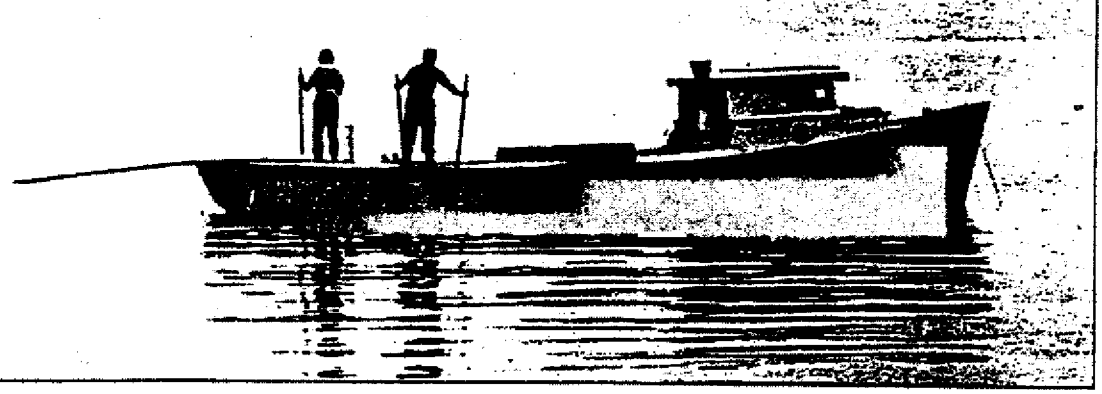
A Congressionally-mandated program to support research, outreach and management efforts to better serve restoration of healthy populations of oysters in the nation's coastal waters. ODRP began in 1990 with oversight by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and its Chesapeake Bay Office; it is now administered by the National Sea Grant College Program.

Through competitive proposals, ODRP supports research to develop the following: (1) optimal strategies for managing around disease; (2) better understanding of the processes of parasitic infection; (3) improved understanding of the oyster's immune system; (4) hatchery techniques for producing disease-resistant strains; (5) molecular tools to better monitor the onset and presence of disease.

For more information about research findings and current projects, contact the National Sea Grant College Program, 1335 East-West Highway, Silver Spring, Maryland 20910 or visit the ODRP website:
http://www.mdsg.umd.edu/NSGO/research/oysterdisease/

The Nation's Oysters *Beleaguered by Disease*

Whether wild caught or cultured, oysters face an onslaught by parasites, bacteria and loss of habitat



For more than a century, commercial oyster harvests have had a major economic influence on many of the nation's coastal communities with annual dockside values totaling in the tens of millions of dollars. These numbers rise significantly when support industries are included — processing plants, boat building, equipment manufacturing and other services that range from retailing to food service. All told, the oyster business has employed thousands of workers. Along the Atlantic coast, in particular, this is no longer the case.

The wild oyster fishery, which has helped define a way of life in the mid-Atlantic and Gulf Coast regions, saw the first signs of decline in 1956 when a mysterious parasite — it was initially referred to as MSX because of its multispherical appearance — killed more than 90 percent of the oysters in Delaware Bay. By the next year, MSX began making its way up the lower Chesapeake Bay, and over the next several years, it spread farther up the Bay into Maryland waters.

On the west coast, where the industry is based primarily on aquaculture, growers do not depend on natural sets of oysters; rather, oysters are spawned in the hatchery and then planted on private grounds. While growers in Washington state, Oregon and California have been successful in developing an industry based on a non-native species (the Pacific oyster, *Crassostrea gigas*), intensive production has also resulted in increased prevalence of many infectious diseases known as "summer mortality" — these diseases now threaten the future of the industry.

Early in the 1940s, oysters in Gulf Coast waters began falling to a protozoan parasite, *Perkinsus marinus* (more familiarly known as Dermo because it was originally classified as a fungal species, *Dermocystidium*). In the mid-80s, Dermo began killing oysters in the Chesapeake Bay — over the next decade, the parasite spread throughout the Chesapeake, sometimes inadvertently transported by replenishment programs and commercial operations that moved oysters from reproductively rich bottom grounds to areas more favorable for growout. By the early 90s, Dermo had infested virtually every major oyster bottom in the Bay. A resilient parasite, Dermo has continued to move up the Atlantic coast; it has struck Delaware Bay and been seen as far north as Maine oyster grounds.

Harvest records tell part of the story. In Maryland, for example, the annual catch fluctuated between two and three million bushels a year from the 1960s through the 1980s. Over the last eight years, the annual catch has averaged a mere 150,000 bushels, a 90 percent decline. With declining oyster harvests has come

Left: Oysters form the base of important habitats and help to sustain biological diversity. Opposite page: The processing industry and related businesses have also suffered with the decline of oysters in coastal waters.

a diminished industry infrastructure: shucking houses, businesses that served harvesters and processors in the fall and winter months, economic changes and something more elusive — a way of life in which social and work patterns that were clearly tied to the region's historical past and ecological present.

A Keystone Species

The heavy loss of oysters to disease and the dismantling of habitats through more than a century of harvesting and landborne pollution have also impacted water quality that depends, at least in part, on robust oyster populations and the bottom-dwelling communities that form around them. Only in recent years have we begun to appreciate what the loss of oysters and their reef structures have meant to coastal sounds and estuaries from Maine to the Gulf of Mexico.

Oysters are keystone species in a number of aquatic ecosystems, meaning that they play a significant role in converting organic matter, namely single-celled algae, to energy. An adult oyster, for example, can filter 40 to 50 gallons of water daily in warm months — in so doing, they ingest algae, thus removing that living matter from the water. Though algae (also called phytoplankton) form the base of the food chain and are critical for organisms higher up in the chain, too many algae can present a problem for ecosystems that cannot assimilate them.

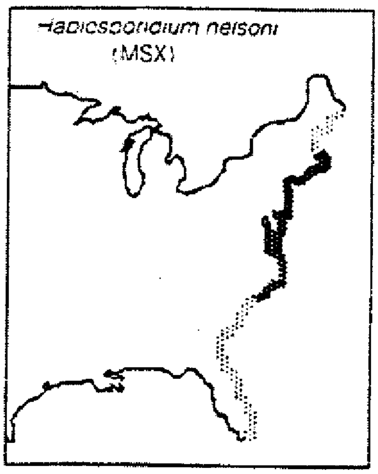
A major problem in many estuaries like the Chesapeake is two-fold: nutrients flooding in by land and air and a lack of assimilative organisms to handle them. The result is excessive growth of phytoplankton. Without enough filter feeders like oysters, the algae that go uneaten are left to decay. The dead algae, when metabolized by microbes, contribute to oxygen depletion, a major cause of poor water quality, especially along the bottom, where many species live.

Clearly, more oysters and improved habitat in the Chesapeake could help remove algae and contribute to improved water quality; meanwhile, improved water quality could also lead to an invigorated oyster fishery, based on sustainable harvesting.

Until recently, the prospects of any restoration were hardly conceivable in the mid-Atlantic region. Not only had Dermo and MSX dec-

A resilient parasite, Dermo was first observed in Gulf Coast waters and has been moving up the Atlantic coast.

In these maps dark shading indicates regions where Dermo and MSX diseases are epidemic among a large number of organisms (epizootic) or have occurred in particular localities (enzootic); light shading indicates regions where parasites have been reported, but are not causing recognizable mortalities.

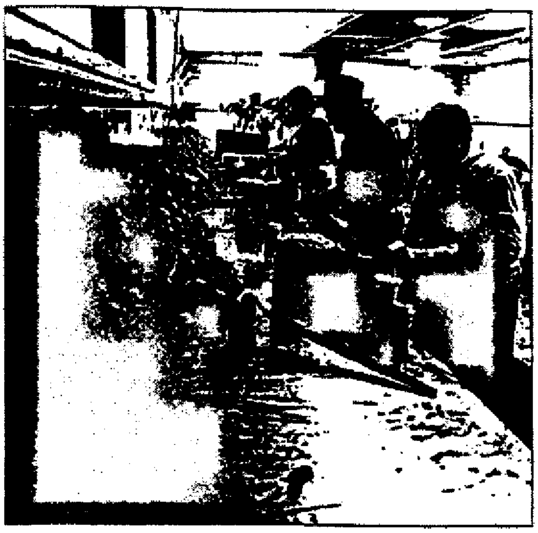


imated virtually every major oyster ground in Chesapeake and Delaware bays, but except for ad hoc actions to try and manage around disease, a full-scale plan to combat these diseases was virtually nonexistent. Such a comprehensive plan is essential. Scientists have lacked a fundamental understanding of the biology of the parasitic organisms, let alone knowledge about the factors that make oysters so vulnerable. Though researchers at the Rutgers University Haskin Shellfish Laboratory had bred oysters resistant to MSX, these oysters were not resistant to Dermo. When Dermo began spreading through mid-Atlantic waters, the Rutgers oysters proved to be vulnerable, thus precluding their use in commercial hatchery operations.

A Coordinated Counterattack

While research on oyster disease through the 70s and 80s increased the scientific understanding of such issues as the oyster's immune system, that research was piecemeal, consisting of individual studies largely funded by the National Science Foundation and individual Sea Grant programs. There was no coordinated, nor consistent long-term support that would enable scientists to develop innovative research efforts — nor did those piecemeal efforts focus on the critical relationship between scientific findings and their practical application by growers and management agencies.

In 1989, however, Congress enacted legislation which recognized that if there was to be any real chance of returning oysters to coastal ecosystems, then it would take consistent support for research and, equally important, education efforts to demonstrate the application of that research. The Oyster Disease Research Program (ODRP) is the result — its aim, the development and application of a body of knowledge to help restore oysters to coastal systems in the United States.



Over the past five years, this research has made enormous progress that has already put surviving oysters back in the water — ODRP has significantly improved approaches to managing around disease and has furthered the scientific understanding of the dynamics of disease. In addition, new molecular probes are now coming on line that will soon give east coast oystermen a rapid means to test for threats of Dermo and MSX and west coast growers diagnostic tools to detect Pacific oyster nocardosis, the widespread disease that periodically causes significant mortalities, especially in cultured species during periods of warm temperature.

Scientists have been breeding oysters that are more tolerant of both MSX and Dermo — several seasons of field trials are pointing to new directions that commercial growers, private and public, are already beginning to employ.

Will we see successes in oyster restoration in the next several years? The answer is yes. In addition to improved prospects for disease-resistant oysters, educational efforts by public agencies, citizens groups and Sea Grant programs focusing on the key role of oyster habitats for aquatic health have excited public participation in oyster gardening in the mid-Atlantic. Citizens in Maryland and Virginia are growing oysters along docks and on leased grounds that can then be planted and used as broodstock for new generations of oysters.

Over the past five years, research on oyster disease has made enormous progress.

Will these and other efforts restore oysters to levels of the mid-80s in Chesapeake Bay, let alone to what they were fifty years ago? The answer is no. It has taken more than a century of steady harvesting and rising pollution to eliminate oysters — it may take decades more to even approach large-scale restoration.

While restoration capabilities will depend on laboratory and field research, such as those supported by the Sea Grant Oyster Disease Research Program, widespread restoration will also depend on other actions, from rebuilding oyster habitats to ongoing efforts to slash contaminant and sediment runoff from the land. Even more, bringing back the eastern oyster will take continued public recognition that oysters are keystone organisms and an understanding that if there is to be any chance of sustaining the health of coastal systems, oyster restoration will be critical.

Aquaculture and Restoration

By Merrill Leffler

Not only is aquaculture bringing more farmed seafood to the table each year, it is also bringing assistance to resource and habitat restoration programs. In the Chesapeake Bay, for instance, hundreds of thousands of striped bass were released annually by public and private agencies — this was part of the successful program to restore the species throughout the East Coast. Populations of striped bass appear to be back to historical levels and agencies only have a limited need to release them now. Research and management agencies are currently looking at how aquaculture can help restore other species, among them, severely diminished shad populations and the nearly extinct sturgeon that used to roam the bottom waters of Chesapeake rivers.

But the greatest restoration challenge for aquaculture in the Chesapeake is its once-renowned oyster populations, which are at historical lows. The heavy loss of oysters to two parasitic diseases — Dermo (caused by *Perkinsus marinus*) and MSX (caused by *Haplosporidium nelsoni*) — has combined with a century of steady harvesting pressure and an increase in landborne pollution, especially sedimentation, to decimate the species.

Not only has the oyster industry suffered — watermen, suppliers, seafood processors and distributors — but so apparently has Bay water quality which depends, at least in part, on robust oyster populations and the communities that form around them. Only in recent years have we begun to appreciate how oysters and their habitats contribute to improving water quality by filtering algae, which remove some of the excess nutrients that are plaguing the Bay.

Despite their decline, oysters are resilient animals — this past summer, for example, the Chesapeake had a record spat set, new young oysters that settled on shells and other substrates throughout the Bay. Because of Dermo and

MSX, however, most of these oysters are not likely to survive to harvestable size in the three years it generally takes oysters spawned in the wild. The poor prospect for survival is one reason restoration plans have been looking to the controlled spawning of oysters in hatcheries: hatchery operators can spawn oysters earlier than under natural conditions and give young oysters a big headstart in growing to maturity. Moreover, as specially-selected stocks are developed that are more resistant to disease, hatcheries can be used to get these oysters to growers for restoration purposes (see *Maryland Marine Notes*, January-February 1997). Such efforts are making it possible to better manage around disease by giving resource managers and commercial operations more flexibility.

For more than 20 years, Maryland Sea Grant Specialist and researcher Don Meritt of the University of Maryland Center for Environmental Science has been operating the hatchery at Horn Point Laboratory (HPL) and working with watermen to set their own oysters and plant them on privately-leased beds. With Dermo now entrenched on oyster beds throughout the Bay, Meritt has teamed with other researchers, including those at the Maryland Department of Natural Resources (DNR) and in the Maryland Oyster Recovery Partnership — a coventure of watermen, aquaculturists and environmentalists — to spawn disease-free oysters in the hatchery and grow them to maturity in lower-salinity areas. While optimum growth in oysters favors higher salinities, disease pressure is generally less intense at lower salinities and the hope is that oysters can survive to maturity there.

The Partnership grew out of a unique consensus agreement in Maryland, says its executive director Robert Pfieffer, among watermen, aquaculturists, resource managers, legislators, scientists and environmentalists — its long-range goal is restoration of oyster populations. The agreement divided the Bay system into three zones, A, B and C. In the upriver and low salinity waters of Zone A, certified disease-free spat can be planted; furthermore oyster harvesting is not allowed in these areas.

Is it possible to bring these oysters to harvest before disease kills them? Further, asks Meritt, can we bring them to harvest under different climatic conditions, particularly when salinities are higher because of drought-like weather and disease intensity is therefore greater? So far the prospects are promising, says Pfieffer, though we need several more seasons of differing weather conditions to have a clearer idea.

In 1997, Meritt produced more than 20 million oyster spat at HPL — still only enough to plant some 20 to 30 acres of bottom ground. While DNR is also growing and planting disease-free seed, sustainable restoration could be lifetimes away. Consider that Maryland has some 270,000 acres of designated public oyster grounds (though most no longer produce harvestable oysters), says Meritt — our efforts are a measure of the task ahead of us.

Important inroads are being made in the effort to bring back the oyster in the Chesapeake Bay, but it will take more than aquaculture to restore what has taken a century to nearly destroy. It will take major efforts to maintain reductions of pollution from the land along with progress in ongoing research to develop oysters that are resistant to disease. But we have made a start, says Meritt. "They may be small steps, but at least they are steps."

Chesapeake Bay Oyster Restoration

Consensus of a Meeting of Scientific Experts
Virginia Institute of Marine Science
Wachapreague, Virginia

"The abundance of oysters is incredible. There are whole banks of them so that the ships must avoid them. They surpass those in England by far in size, indeed they are four times as large."

Francis Louis Michel
after a visit to Virginia in 1701

CRC

Chesapeake Research Consortium
June 1999

Executive Summary

A small group of oyster experts from Maryland, Virginia and North Carolina met at the Virginia Institute of Marine Science Eastern Shore Laboratory, Wachapreague, VA on January 18, 1999 to recommend measures to restore and protect the oyster resource of the Chesapeake Bay.

Restoration Philosophy

- The goal for Chesapeake Bay oyster restoration should be to restore and manage oyster populations for their ecological value in such a way that a sustainable fishery can exist while maintaining the essential ecosystem functions of oyster reefs.

Protection Philosophy

- The oyster fishery should be managed regionally based on stock assessments.
- Proper disease management means minimizing, or even prohibiting, movement of infected oysters.

Essential Components of Oyster Restoration Efforts

- Three-dimensional reefs, standing substantially above the bottom, are essential for oyster reproductive success, for predator protection and to create habitat for other organisms.
- Permanent reef sanctuaries permit the long-term growth and protection of large oysters that provide increased fecundity and may lead to development of disease resistant oysters.
- For success, both components, three dimensional reefs as permanent sanctuaries, are necessary; neither component alone will be sufficient.

Reef Siting and Design

- Sanctuary reefs must be placed on hard bottom in areas of natural spatset. Three-dimensional structure equal to at least one-half the water depth is recommended.
- Adult oysters may need to be added to reefs to "jumpstart" recruitment.
- Oyster shell is a limiting resource in all areas and availability may affect recruitment around reefs.

Goals

- Long-term goals are to set aside and restore 10% of historic productive oyster reef acreage for its habitat and ecological value and to restore a sustainable public fishery that would not require additional public monies.
- Short-term goals are to increase spatset, increase the number of adult oysters and to increase habitat and fish utilization of that habitat in tributaries where reef sanctuaries have been established.
- Intermediate goals (4-8 years) are to demonstrate the effectiveness of reef sanctuaries in selected tributaries in Maryland and Virginia.

The Consensus

Restoration Philosophy

Overfishing in the late 1800s and early 1900s reduced Chesapeake Bay market oyster landings from a peak of about 24 million bushels in 1887 to a more-or-less steady state of about 5 million bushels by 1930. This high harvest pressure also mined the oyster reefs themselves, greatly reducing the reef habitat in the Bay. In the last four decades two protozoan diseases (MSX disease caused by *Haplosporidium nelsoni* and Dermo disease caused by *Perkinsus marinus*) have combined to further reduce oyster populations throughout Chesapeake Bay to about 1% of historical levels.

Restoration and proper management of oyster populations in the Chesapeake Bay are critical, but we must move away from the concept of restoring and managing oysters strictly to support an industry. The primary impetus for oyster restoration should be because their filter-feeding lifestyle is an important ecological component in the Bay ecosystem and because their reef-building nature provides valuable habitat for oysters themselves and for other organisms. Oysters can improve water quality because they consume phytoplankton that contribute to anoxia in bottom waters and they also reduce suspended particulate matter, thereby improving water clarity and light penetration critical for aquatic plants. Oyster reefs support a diverse macrofaunal community that provides shelter and food for crabs and fish. An increase in oyster reefs will increase habitat and food for other important species in the Bay.

The restoration philosophy must be to restore and manage oyster populations for their ecological value, but in such a way that a sustainable fishery can exist. The restoration philosophy must not be to manage oysters just to support a fishery. Oysters should be managed on a regional basis with regional quotas established for a fishing season based on stock assessments.

Essential Components of Any Restoration Effort

1. Permanent Reef Sanctuaries

There are really two parts to this component—reefs and permanent sanctuaries. It is clear from historical documents that three-dimensional oyster reefs were a dominant feature of the Chesapeake Bay when colonists arrived in the New World. Oyster reefs provide aggregations of oysters that maximize reproductive success and the resulting structure enhances recruitment and growth of young oysters and provides protection from predators. In Chesapeake Bay, oyster densities are currently so low at most historical reef sites that reproductive success is likely low. Further, the lack of reef structures results in sub-optimal habitat for oyster growth and survival. Three-dimensional reefs are critical for reproductive success, predator protection and, of course, for the habitat they provide for other estuarine fauna.

Permanent sanctuaries are critical for a number of reasons. Permanent sanctuaries will allow for the development and protection of large oysters. It is well documented that fecundity in oysters increases exponentially with length. Thus, a small number of very large oysters can produce many more eggs than a large number of small oysters. In addition, large oysters in disease-endemic areas have a demonstrated ability to survive diseases, a characteristic that is, at least in part, inherited by their offspring. Natural disease resistance has not developed in Chesapeake Bay for two reasons. First, there has been historically a large unselected gene pool in ow salinity that diluted any selected gene pool. Second, the fishery harvested all the large oysters that were surviving in disease-endemic areas and that may have been disease resistant. We cannot guarantee that disease resistant oysters will become widespread in the Bay with the protection of large oysters, but certainly disease resistance will never become widespread without the protection of large oysters.

Reef sanctuaries are also critical for habitat and ecological value. The reef structure provides important habitat for myriad organisms that contribute to the overall health of the Bay and provide food for recreationally and commercially important fish and shellfish species. In short, reef sanctuaries contribute to ecosystem restoration. Large oysters may be important for the structural integrity of a reef and it has been documented that a range of oyster sizes, including large individuals, is important for the ecological role of reefs (e.g. nesting sites for small fishes). Reefs must be considered "ecological sanctuaries." Harvesting must not be allowed on reef sanctuaries or the community of organisms important for reef structure and function will never fully develop.

Thus, the combination of restored three-dimensional reefs and permanent sanctuaries is critical to the success of oyster restoration. Restored reefs where harvesting is allowed will be unsuccessful as will sanctuaries alone. It is the combination of the two concepts that is important.

Areas around reef sanctuaries can be managed for harvest. Shells planted around reefs to catch spat can be harvested eventually in place or the small oysters can be moved to other areas for growout and harvest. However, a long-term goal should be to create a sustainable regional fishery and thereby reduce the necessity to move oysters. Properly placed reef sanctuaries will likely reduce or eliminate the need to move oysters for harvest because the reefs will be a source of larvae that will settle on local harvestable beds.

2. Proper Disease Management

One of the basic tenets of disease management is that infected organisms should not be moved into areas where the disease is not present or is present at lower levels. Much of the spread of Dermo throughout the Bay resulted from moving infected oysters. Managers argue that because Dermo is now present throughout the Bay it doesn't hurt to move infected seed oysters into low salinity because the disease is already there. However, the historical distribution of Dermo was restricted to the lower Bay and the mouths of major tributaries. Prior to the severe droughts of the late 1980s Dermo was not present in most Maryland tributaries and there is reason to expect that if rainfall patterns return to normal Dermo will eventually return to its historical range. It is well documented that Dermo is not pathogenic below about 12 ppt, so managers argue that it doesn't make any difference if infected seed oysters are moved to salinities below that level. However, if a drought occurs Dermo will multiply rapidly, kill oysters and spread to other oysters, thereby perpetuating the disease in the area.

At the very least, a policy must be established against moving any infected oysters into salinities lower than where they set or into areas where disease levels are low. However, there was strong sentiment among most committee members that infected oysters should not be moved at all.

Issues

There are many other issues involved with the successful implementation of a reconstructed oyster reef sanctuary program. Issues that the committee felt were important are discussed briefly below.

1. Reef Siting

Reef sanctuaries should be placed in areas that historically supported productive oyster bars if there has been no subsequent change in hydrography or sedimentation patterns. To be self-sustaining they must be placed on stable, hard bottom and in areas where natural spatset occurs. If reefs are to be a source of spat for shell plantings, and for sustainability of the reef itself then salinity, flow regime and basin morphology will be important considerations. Hydrodynamic models or drifter studies will be useful in determining fate of larvae from any proposed reef site.

2. Reef Design Criteria

A reef is defined here as a three-dimensionally-complex biogenic structure that rises substantially from the seafloor. Verticality is critical and reefs should have sufficient vertical relief that recruitment and growth of the reef will outpace sedimentation. Substantial three-dimensional structure equal to at least one-half the water depth is recommended. Historically, some reefs may have broken the surface at low water and the goal should be to reproduce historical reefs to the best of our ability.

The core of the reef may be composed of any substrate that will provide stability to the vertical structure. There should be a veneer of oyster shell or other suitable substrate for spat settlement. The veneer must have a three-dimensional matrix sufficient to allow spat settlement and provide protection for the spat from predators.

Optimal size of reef sanctuaries has not been determined and will likely be dictated by funding constraints. In Virginia, reefs as small as one acre have substantially increased spat set in the surrounding area. An archipelago of small reefs may be more effective than a single large reef.

3. Reef Protection

It is critical that reef sanctuaries be protected from poaching. They should be sited such that enforcement of the sanctuary will be feasible. Community awareness can be important for enforcement so reefs should be sited, if possible, in areas where community oversight can develop.

4. Broodstock Supplementation on Reefs

It will probably be important to add adult oysters to some restored reefs to enhance recruitment to the reef and to the surrounding area. Large natural oysters can be harvested and aggregated on reefs to enhance fertilization success. This strategy worked successfully in Virginia where large, but scattered, oysters from Tangier Sound were aggregated on a reef in the Great Wicomico River. Spatset on and around the reef increased dramatically the following year. If natural recruitment is low then it may be necessary to add adults to a reef in high density to "jumpstart' recruitment.

Where possible and when available, progeny from genetically selected oysters could be stocked on reefs. There are a number of programs underway to select oysters for a variety of traits including growth in low salinity, fast growth, or disease resistance. These strains will require evaluation for their effectiveness for use on reef sanctuaries.

5. Shellplants Around Reefs

An important component of the restoration strategy will be to plant shell around reef sanctuaries to enhance spatset, although the need for shell planting will likely be site specific. Good quality oyster shell is a limiting resource for spatset around reefs in all areas. Shallow buried and fossil shell are currently available, but more emphasis needs to be placed on returning harvested shell to the Bay. After spatfall, the shell could be left in place for future harvest or it could be moved to other areas to develop sanctuaries or for future harvest. The oysters moved to other areas would contribute ecological value until they were harvested. However, as stated above, a long-term goal is to use reef sanctuaries to provide a sustainable regional source of spat to reduce or eliminate the need to move seed oysters.

Siting of shellplants will be important to maximize spatset. Circulation models may help determine current patterns and where best to plant shell.

Restoration Goal

The long-term restoration goal should be to construct and protect a sufficient number of reef sanctuaries bay-wide such that 1) habitat and ecological function will be restored, 2) water quality will improve and anoxia will decrease, and 3) a sustainable fishery can exist with no addition of public funds. In lieu of specific data on the required sanctuary area necessary to meet this goal, we recommend that 10% of traditional oyster bar acreage in formerly high-yielding harvest locations be set aside and restored as permanent sanctuaries. As additional data become available it may be possible to refine this estimate.

The short-term goal will be to increase spatset, increase the number of adult oysters, and increase habitat and fish utilization of that habitat in specific tributaries where reef sanctuaries have been constructed.

Over the next four to eight years the intermediate goal should be to demonstrate effectiveness of reef sanctuaries for ecological improvement in one or two selected tributaries in each state. The tributaries will have to be monitored to evaluate success, using criteria listed above under short-term goals.

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Appendix

ALABAMA MARINE RESOURCES BULLETIN

NUMBER 11

Alabama Marine Resources Laboratory
Dauphin Island, Alabama 36528
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STATE OF ALABAMA

George C. Wallace, Governor

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Claude D. Kelley, Commissioner

MARINE RESOURCES DIVISION

Wayne E. Swingle, Director

ALABAMA MARINE RESOURCES LABORATORY

Hugh A. Swingle, Chief Marine Biologist

A REVIEW OF THE OYSTER FISHERY OF ALABAMA[1]

HUGH A. SWINGLE AND EDGAR A. HUGHES

Marine Resources Division
Dauphin Island, Alabama 36528

ABSTRACT

Historical data on the Alabama oyster fishery are presented. Legislation affecting the fishery since 1852 and management and research activities during the 1900's are reviewed.

INTRODUCTION

Oysters have been a significant part of man's diet along the Alabama coast since the first Indians visited the area some 3,500 years ago but were a local commodity until improvements in transportation systems and construction of canneries in the late 1800's and early 1900's. Early management of state oyster bottoms consisted solely of restrictions on harvest methods. The first Alabama Oyster Commission (1909-1915) and the second Alabama Oyster Commission (1935-1939) established by the State Legislature were the first state agencies concerned solely with oyster management. Both commissions liberalized harvest methods, established leasing of state bottoms and had extensive planting programs. Both commissions were apparently unpopular locally and were abolished by the legislature soon after their creation. The present Department of Conservation and Natural Resources assumed authority over oysters in 1919, but activities were primarily regulatory in function until the late 1940's. Oyster management has been a major activity of the present Marine Resources Division since 1967.

HISTORY OF THE FISHERY

Prehistoric Indian cultures harvested oysters from the coastal waters of Alabama over 3,500 years ago (May, 1971). Numerous middens consisting almost entirely of oyster shells located along the shores of Bon Secour Bay, Mississippi Sound and Dauphin Island indicate the importance of oysters in the diet of these early cultures. Early Spanish and French explorers and settlers made use of the abundant oysters along our coast as early as the 16th century. By 1732, what is now known as Cedar Point had been named Oyster Point because of the large reef there. It is the major reef fished today. Oysters have had a significant influence on inhabitants of coastal Alabama, having provided a readily accesible and stable source of food and income since man first settled in the area.

Methods of Harvest

Throughout the history of the oyster fishery hand tongs have been the only legal method of taking oysters from the public reefs with the exception of a period between 1909 and 1915 when dredging was allowed on White House, Point Clear and Klondike Reef in the

[1]This study was made in cooperation with the U.S. Department of Commerce, NOAA, NMFS, under P.L. 88-309(Project 2-216-R)

mid-region of Mobile Bay, from 1933 to 1939 and a brief period during the 1950's. Legislation permitting dredging was established by the first Alabama Oyster Commission (1909-1915), the Department of Game and Fisheries, and the second Alabama Oyster Commission (1935-1939) and was apparently very unpopular with the majority of fishermen as the acts were repealed when the Commissions were abolished by the State Legislature. Dredging is now allowed only for taking seed oysters for replanting under supervision of the Department of Conservation and Natural Resources and for harvest on private beds.

Harvest Statistics

Statistics on the Alabama oyster fishery have been collected by federal agencies since 1880 but are complete only from 1948 (Table 1). Annual fluctuation in harvest is common to the fishery due to both natural and man-made reasons. The average harvest per decade since 1880 based on available records has been about 1 million pounds of meats annually (May, 1971). During the early 1880's records indicate that harvest was only about 300 thousand pounds of meats annually, most of which was presumably consumed locally although oyster canneries were in operation in Mississippi at this time. Only Alabama citizens could engage in the fishery from 1882 until legislation was passed in 1901 allowing nonresidents fishing privileges but only if they sold to Alabama canneries. Legislation in 1915 repealed this, allowing only citizens fishing rights. In 1919, nonresidents were again given fishing rights after paying a double license fee.

Legislation regulating out-of-state shipment of oysters in the shell was passed 1891. This act allowed out-of-state shipment only from the middle of December to the middle of January, which coincided with the start of the oyster canning season in Mississippi. In 1909, legislation prohibited all out-of-state sale of raw oysters unless Alabama canneries paid less than the price paid in neighboring states. Legislation in 1919 allowed out-of-state shipment only to states allowing Alabama fishermen to take and transport oysters from that state.

TABLE 1. Alabama Oyster Landings.

Year	Pounds of Meats	Year	Pounds of Meats
1880	327,085	1950	2,070,300
1888	238,271	1951	2,191,400
1889	1,372,270	1952	1,842,000
1890	1,505,749	1953	1,449,700
1897	798,316	1954	739,300
1902	1,087,550	1955	1,580,600
1908	1,677,680	1956	769,900
1911	1,162,592	1957	1,291,200
1918	376,360	1958	457,600
1923	729,559	1959	894,800
1927	520,804	1960	1,169,300
1928	1,886,104	1961	508,500
1929	178,823	1962	442,700
1930	286,794	1963	995,400
1931	768,721	1964	1,005,300
1932	859,217	1965	492,400
1934	391,800	1966	1,304,500
1936	991,800	1967	2,087,900
1937	1,235,200	1968	1,211,800
1938	1,358,700	1969	480,700
1939	1,357,700	1970	279,000
1940	936,000	1971	250,000
1945	1,605,700	1972	1,069,515
1948	1,531,200	1973	590,118
1949	1,585,800	1974	732,776

In 1891, legislation set the oyster season from 1 September to 30 April, the "r-months" common elsewhere. This was in effect for many years. The Department of Conservation and Natural Resources presently sets the season by regulation.

In 1901, catchers were restricted to 3,500 barrels of oysters per week which had to be at least 2½ inches in length. Legal size was changed to 3 inches and the quantity restriction was repealed in 1909. The legal size was changed back to 2½ inches in 1915 and in 1937 the present law establishing 3 inches as legal size was passed. It was amended in 1963 allowing the Department to reduce the legal size to 2⅝ inches by regulation.

Leases and Riparian Rights

The act giving owners of waterfront property the right to plant and harvest oysters from waterbottoms adjacent to their property was passed in 1872. These riparian rights extended 600 yards from shore, or halfway between points less than 1200 yards apart (1879 amendment). Unculled oysters could be taken from the public reefs only during certain months of the year and planted oysters could not be harvested for varying lengths of time up to 2 years depending upon various legislative acts. Private planting on riparian bottoms was extensive during the late 1890's especially in Bon Secour Bay and along the northern shores of Mississippi Sound (Ritter, 1896). Nelson (1914) lists 50,000 barrels of seed oysters as being transported from Scranton, Mississippi and planted on riparian bottoms in Grand Bay about 1897 and numerous other plantings from Alabama reefs in the early 1900's.

The first Alabama Oyster Commission established a leasing system whereby citizens would lease state-owned bottoms for oyster cultivation. It also authorized dredging for seed oysters on certain reefs in Mobile Bay. The Alabama Oyster Commission (1914) reported that 4,000 acres of bottoms had been leased by 1914. Revenue from leases between 18 April 1911 and 31 December 1914 totaled $5,057.97. Legislation in 1923 prohibited leasing of state bottoms and gave lessees 5 years to remove oysters from leased areas. Leasing was again authorized in 1937. About 70 acres were leased annually from 1948 to 1959, about 1,700 acres from 1960 to 1968 and 924 acres were leased in 1969 (May, 1971). Management of these leases became of little significance after about 1950 due to the lack of seed oysters, reef closures by the Alabama Health Department and restrictions on harvest.

Oyster Canneries

The first oyster cannery was built about 1890. According to the report of the first Alabama Oyster Commission (1914) this cannery was soon forced out of business when Mississippi canneries greatly increased their price paid for oysters. The Bayou La Batre Packing Company, Torch Packing Company and Kidwell Packing Company were likewise forced out of business by the Mississippi canneries prior to 1909. Boyle Canning Company was built *ca.* 1902 at Alabama Port. A long wharf extended out into Mobile Bay and oysters were loaded into sail propelled carts that carried the oysters to the factory on the mainland. The factory was destroyed by the 1906 hurricane although the well pipe of the artesian well is still found off Alabama Port. When the Alabama Oyster Commission was established by the legislature in 1909 only the Alabama Canning Company at Coden was in operation. During 1910, this cannery packed 66,261 barrels of oysters while 20,291 barrels of raw oysters were consumed locally and 2,618 barrels were sold to out-of-state canneries. One cannery was located on Dauphin Island but moved to Mobile *ca.* 1919.

From the 1920's through the 1950's several canning companies operated in Alabama. Dunbar and Ducate Packing

Company, Grahams Seafood Company, Hidenheim Company, McPhillips Packing Company, Marco Skremetti, Coffee Island, and others operated at Bayou La Batre or Coden. In 1926, there were five companies in Bayou La Batre packing shrimp and oysters (Ann. Rep. 1922-1926) but by 1938 only two were in operation in Alabama (U. S. Dep. Interior, 1941). According to Fisheries Statistics of the U. S., there were three canneries in operation in the 1950's and two in 1960. One operated through 1967 with the exception of 1965 and 1966. Some companies canned vegetables as well as seafood. A typical operation would can oysters from January until May, vegetables (beans and potatoes) during the late spring and summer and shrimp from August through late fall or early winter depending upon their availability. Crab meat was canned also by some canneries.

In 1923, a survey made of raw oyster consumption in Birmingham, Montgomery and Mobile stated that 100%, 97% and 90% of the raw oysters consumed in the respective cities came from out of state (Dep. Game and Fisheries, 1930). The canneries were apparently consuming the bulk of the Alabama harvest. The decline of the canneries from their peak years of the 1920's was largely due to loss of productive oyster bottoms in Portersville Bay. Periodic closure of the reefs by the Alabama Department of Health since 1952 and restrictions on harvesting oysters from leased and riparian beds also contributed to their demise.

HISTORY OF MANAGEMENT

Responsibility for management of Alabama's oyster fishery and enforcement of laws and regulations has been under various agencies since the 1800's when the first legislation concerning oysters was enacted by the State Legislature. The agencies and periods of responsibilities follow:

18??-1891	County Law Enforcement Agents
1891-1909	Oyster Inspector appointed by Governor
1909-1915	First Alabama Oyster Commission
1915-1919	Secretary of State through the Chief Inspector
1919-1923	Department of Conservation through the Chief Oyster Inspector
1923-1935	Department of Game and Fisheries through the Chief Oyster Inspector
1935-1939	Department of Conservation of Game, Fish and Seafoods through the Second Alabama Oyster Commission
1939-1951	Department of Conservation through the Division of Game, Fish and Seafoods
1951-1971	Department of Conservation through the Seafoods Division
1971-	Department of Conservation and Natural Resources through the Marine Resources Division

The Department of Game and Fish was established by the State Legislature on 27 February 1907 but did not assume responsibility over the oyster fishery and other seafoods until 1919 when the name of the department was changed.

State management during the 1800's consisted solely of laws passed by the legislature. There was no state agency in any way concerned with oyster management, and enforcement of the few laws concerning oysters was by the county sheriff. The earliest law at hand concerning oysters, dated 1852, made it unlawful to take oysters from any waters of the state by any methods other than hand tongs and authorized the sheriff of any county "bordering the waters of this state" to confiscate boats and equipment of persons violating this law. Legislation in 1872, amended in 1879, granted riparian owners the right to plant and harvest oysters for a maximum distance of 600 yards offshore as long as it did not interfere with navigation. In 1882, the State Legislature passed a law regulating buying and selling oysters in the shell in measurements other than described by law. This one-third barrel was described as being 16 inches across the bottom, 18 inches across the top and 9½ inches high. In 1887, a culling law was passed by the State Legislature. All oysters "that are too small or unfit for market" were required to be returned to the reef from which they were taken.

The first oyster management legislation was passed in February 1891. An Oyster Inspector and Deputy Inspector appointed by the Governor for a two-year term were authorized to enforce a new culling law (2½ inches), seasons for taking oysters from public and private reefs (September - May) and restrictions on out-of-state shipment of oysters in the shell (restricted to the middle of December to the middle of January). Oystering on private beds was excluded from the season restriction only if oysters were taken for the owners use. Sheriffs, constables and other police officers were also authorized enforcement agents under this legislation. The Oyster Inspector and Probate Judge of Mobile County were authorized to collect oyster boat licenses based on $0.10 per barrel capacity and a tax of $0.10 per barrel of oysters taken from both public and private beds. All receipts were deposited with the State Treasurer. Only citizens of Alabama were allowed fishing privileges. The Oyster Inspector was required to live either on Dauphin Island or at Cedar Point and the Deputy Inspector was required to live in Mobile, unless filling the duties of the inspector. The two officials were actually under the control of the Mobile County Grand Jury which was given authority by the Governor for their dismissal.

Legislation in 1892 and amended in 1894 provided that the Oyster Inspector live in Mobile and that one deputy live in Mobile County and an additional deputy live in Baldwin County. The inspectors enforced the culling laws, collected taxes and patrolled the reefs during the closed season. In 1902, a law was passed limiting weekly catch to 3,500 barrels.

Although the Department of Game and Fish was established by the legislature in 1907, the oyster fishery was still controlled by the Oyster Inspector.

The first oyster and shell planting in Alabama by other than private individuals was done by the first Alabama Oyster Commission about 1910. This commission was established by the State Legislature in August 1909 and was the first attempt at management of the public reefs. The commission received no appropriations from the state and expenses prior to collection of annual oyster taxes, licenses, lease fees and other revenue were advanced by members of the commission. Between 1909 and February 1915, when the commission was abolished by the State Legislature, the commission planted 35,000 barrels of shell at a cost of $1,559.56 and transported an unreported number of seed oysters at a cost of $1,147.50 to an experimental plot in Portersville

Bay to demonstrate oyster management. When the federal government dredged Pass aux Herons channel, *ca.* 1912, the commission persuaded the government to change the course of the channel and to deposit the spoil some distance away to minimize damage to Cedar Point Reef. The present ½-barrel measure was established in 1909. In 1910, the commission obtained the services of Dr. H. F. Moore (1913), U. S. Bureau of Fisheries to survey the oyster reefs and the potential oyster bottoms and to make recommendations on oyster management. The shell and seed oysters planted by the commission were not successful and the commission obtained the services of T. C. Nelson in 1914 to determine the cause of mortality on planted areas in Portersville Bay. Nelson (1914) found that many of the planted areas were on soft mud or on unstable bottoms. The Alabama Oyster Commission was attempting a scientific approach to oyster management but was abolished by the State Legislature in February 1915 before it became truly effective. The Secretary of State assumed control of the oyster fishery from 1915 to 1919.

In 1919, the Department of Game and Fish was changed to the Department of Conservation and assumed jurisdiction over the oyster fishery and other saltwater species. This legislative act also established the Game and Fish Protection Fund and the Oyster Fund. A one dollar oyster license was established. The Oyster Fund consisting of licenses and taxes on both oysters and shrimp paid the salaries and expenses of the Chief Oyster Inspector and two Assistant Inspectors. Receipts of the Oyster Fund during FY 1920 totaled $5,662.00 of which $2,880.42 was spent on salaries and expenses. The Chief Oyster Inspector was under the direct supervision of the Commissioner of the Department of Conservation. Oyster management consisted solely of law enforcement.

In 1923, the Department of Conservation was renamed the Department of Game and Fisheries. During 1925, the Department planted 35,000 barrels of seed oysters on public reefs which was the first plantings on public reefs since the planting by the first Alabama Oyster Commission in 1910. During 1926, 10,000 barrels of seed oysters were planted. During 1923, legislation was passed allowing dredging of oysters by the Department north of a line from Alabama Port in Mobile County eastward to Mullet Point in Baldwin County. This provided a more readily available supply of seed oysters to the state. The legislation was very unpopular among most fishermen. During the period 1923-1926 receipts of the Oyster Fund varied annually from $6,658.51 (1924) to $9,466.26 (1925), about two-thirds of which was spent on salaries and expenses of the Chief Oyster Inspector and three assistants. During 1933 and 1934, federal funds under Civil Works Administration and Federal Emergency Relief Administration programs were used to plant 41,000 barrels of seed oysters and shells in Isle of Dames, Portersville and Dauphin Island bays. Approximately 350 acres were planted with 26,795 barrels of seed oysters obtained from Mississippi Sound, Bayou La Batre and Bayou Coden (Dep. Game and Fisheries, 1934). Legislation in 1933 allowed dredging on Cedar Point Reef, King's Bayou Reef, Buoy Reef, White House Reef and Fowl River Reef and gave riparian owners broader privileges in developing private beds.

In August 1935, the Department of Game and Fisheries was reorganized.

The Swift Act created the Department of Conservation of Game, Fish and Seafoods; created a State Conservation Board advising the Commissioner; and made the office of Commissioner an appointee by the Governor rather than an elected official as it had been since 1907. The McPhaul Act (July 1935) created the second Alabama Oyster Commission. The Alabama Oyster Commission obtained a federal grant of $92,365 and $17,635 state funds and equipment for oyster reef rehabilitation. The members of the commission were N. J. Gonzales of Mobile, A. B. McPhaul of Seminole, C. H. Wakefield of Bon Secour, and A. L. Staples of Mobile. Mr. I. T. Quinn the Conservation Commissioner was Chairman of the Oyster Commission. The state, through the Oyster Commission was empowered to buy and sell property, conduct economic surveys of the seafood industry, lease oyster bottoms, plant and remove seed oysters and shells and purchase seed oysters and shell for planting. The Chief Enforcement Officer and assistants enforced the regulations of the Oyster Commission. The annual report of 1936 was the first to mention a "Seafoods Division", which consisted of the Chief Enforcement Officer, the Chief Oyster Inspector and two Assistant Inspectors. The 1938 annual report listed the following divisions of the Department of Conservation of Game, Fish and Seafoods: Division of Fish Culture, Division of Law Enforcement, Division of Research and Statistics, Division of Game Propagation, Division of Game Management, and Division of Seafoods. The Division of Seafoods consisted of the Chief Enforcement Officer and four assistants which enforced regulations of the Alabama Oyster Commission. Oyster planting was done by the federal Works Progress Administration (WPA) and by the Alabama Oyster Commission. Total receipts of the Oyster Fund during FY 1937 was $11,262.02.

In March 1939, the Department of Conservation of Game, Fish and Seafoods was reorganized into the Department of Conservation which consisted of the Game, Fish and Seafoods Division; Forestry Division; Parks, Monuments and Historical Sites Division; and Statistical Division. The legislation abolished the Alabama Oyster Commission, Forestry Commission, Alabama Conservation Board, Office of State Forester, and the Alabama Monument Commission. It established the present Conservation Advisory Board and changed the title of department head to Director, replacing Commissioner used since 1907. The seafoods branch of the Division of Game, Fish and Seafoods consists of Chief Enforcement Officer and five assistants who were responsible for enforcement of seafood laws and collecting license and taxes on seafoods. No shell planting was done by the Division during its first year of existance. Revenue from the oyster fishery during FY 1938 was $140.25 from oyster leases and $455.31 from oyster taxes. Seafoods ranked such low importance that it was omitted in two instances from the Division of Game, Fish and Seafoods in the Department of Conservation annual report of FY 1939; being referred to on page 64 of the report as "The seafoods unit of the Game and Fish Division" and on page 7 being omitted completely from the Division title. Through the effort of WPA, Alabama oyster canneries and local oyster fishermen a total of 60,000 barrels of shell were planted on public reefs. The receipts from seafood industry totaled

$12,583.34 during FY 1940 or slightly more than twice that received during FY 1910. Little oyster management was done by the Division of Game, Fish and Seafoods until FY 1943 when general fund appropriations allowed planting of 92,426 barrels of shell on the public reefs. The Division of Game, Fish and Seafoods had separate accounts for receipts from seafoods and receipts from fishing and hunting until FY 1945 and receipts from seafoods was always insufficient for enforcement and much needed management and research.

Legislation in FY 1944 allowed oysters of any size to be dredged from private oyster reefs for the first time. The Mobile Bay Seafood Union directed seed oyster planting of 6,000 barrels in FY 1944. The union was composed of members of the crew of the vessel that dredged seed oysters from Buoy Reef for the state and was apparently the first unofficial advisory committee. During FY 1945 the Division of Game, Fish and Seafoods had a budget carry-over to FY 1946 of more than $216 thousand. Even with this surplus no shell was reported planted in the annual report of that year.

The FY 1946 annual report separated the Division of Game and Fish and the Division of Seafoods into staff divisions although the two divisions were not separated by legislature until 1951. The Division of Game, Fish and Seafoods contracted with McPhillips Packing Company of Bayou La Batre for planting 40,000 barrels of seed oysters in Mobile Bay and Bon Secour Bay. Land was purchased in Bayou La Batre for construction of a seafood office, dock, boathouse and warehouse. Arrangements were made with the University of Alabama to provide biological services in matters dealing with seafoods. Attempts were made to obtain reciprocal fishing agreements with Mississippi and Louisiana similar to the one obtained with Florida in 1946. The revenue from the new shell dredging contract ($5,443.26) was used for seafoods management.

During FY 1947 biological studies of the oyster reefs were made by the Geological Survey of Alabama and the Alabama Museum of Natural History at the request of the Department of Conservation. The "Seafoods Division" became self-sustaining for the first time in history with revenues of $135 thousand composed of $47 thousand from shell dredging, $45 thousand from a legislative appropriation and the remaining $43 thousand from seafood revenue. The State Ecologist with the Alabama Museum of Natural History made recommendations for management of seafoods and the enforcement personnel were increased to eleven. Air patrols were made to check shrimp and oyster fishermen for violations. The activities of the "Seafoods Division" covered eight pages in the annual report of FY 1947, or more than the total coverage for the past decade or more. Recommendations for more research, hiring a full time marine biologist, construction of a seafoods laboratory and installation of laboratory equipment and a larger patrol force were made by the Chief Oyster Inspector. Legislation was passed in 1947 authorizing formation of the Gulf States Marine Fisheries Commission. The organization meeting was held in Mobile on 16 July 1949 and Governor Folsom of Alabama was the first to sign the compact and Mr. Bert Thomas, Director, Alabama Department of Conservation, became the first Chairman.

In January 1950, the Marine Laboratory at Heron Bay Cutoff was officially opened. The laboratory provided office and laboratory space for Senior Biologist F. X. Leuth and some enforcement personnel. Studies of oyster spat set, oyster growth and survival were initiated on planted areas and hydrological data were collected to improve management techniques. The receipts of the Game, Fish and Seafoods Fund during FY 1949 was slightly over $900 thousand.

On 1 October 1951, upon recommendation of the Director of Conservation, legislation was signed separating the Division of Seafoods from the Division of Game, Fish and Seafoods. The Game, Fish and Seafoods Fund was separated with seafood revenues and revenue from dredging buried reef shells going to the new Seafoods Division. Receipts from 1 October 1951 to 30 September 1952 totaled $256 thousand. The Division moved to a new office building in Bayou La Batre on 15 May 1952. Enforcement consisted of six officers, three boats, and one amphibian airplane. Shell and seed oysters were planted by the Division and by packers and dealers which were required to return 30% of the shells back to the reefs under the supervision of the Seafoods Division. The Division dredged a 9-foot channel into Bon Secour to aid the seafood industry of that area.

During the early 1950's, injunctions were placed against the Division prohibiting the opening of public reefs for seed oysters. One such decision went as far as the Alabama Supreme Court where it was reversed in 1955. After this ruling seed oysters were made available from reefs located in water too deep for tonging. During the early 1950's the biological staff consisted of one division biologist and consultant biologists from Texas A & M, Mississippi and the federal laboratory at Gulf Breeze, Florida. The Department of Conservation Annual Report for FY 1959 stated that "The Seafoods Division was completely re-organized during the past year. A new division director was appointed, together with new enforcement men". Biological work was now contracted to the Biology Department, University of Alabama, and Dr. Gordon Gunter of Mississippi. The Division had apparently become ineffective during the late 1950's as the report stated that "there was very little activity in the form of constructive development, enforcement, research or administration". The oyster shell dredge was shut down during 1959 causing financial distress within the Division which received as much as 89% of its revenue from this single source. After the reorganization the Division renewed shell and seed oyster planting efforts.

Financing through the Mobile Area Public Higher Education Foundation, Inc. permitted construction of the present Alabama Marine Resources Laboratory on Dauphin Island which was completed in 1963. The facility originally provided office space for the Division Chief and enforcement personnel of the Seafoods Division and office and laboratory space for biological and teaching staff of the University of Alabama which did research under contract for the Seafoods Division. The Division of Seafoods began to obtain its own biological staff in 1966, hiring a laboratory director and a biologist to work on oyster management. The contract with the University of Alabama was terminated in 1967 and university personnel moved into facilities at Point aux Pins. When the 1971 State Legislature changed the name of Department of Conservation to Department of Conservation and Natural Resources and the Seafoods Division to Marine Resources Division, the Division staff consisted of Division Director, Chief Biologist, 5 biologists, 14 enforcement officers, 3 biologist aides, 4 laborers and 5 clerk typists. Offices were maintained at Dauphin Island, Bayou La Batre and Gulf Shores. From 1967 oyster management has consisted of intensified oyster research and shell planting. Approximately 40% of the 1,899,351 barrels of shell planted between 1910 and 1975 (Table 2) were planted from 1967 to 1975. Revenue is presently obtained from the seafood industry, oyster shell dredging (since 1946), marine gas tax (1962), Commercial Fisheries Research and Development Act, P.L. 88-309 (1966), Anadromous Fish Act P.L. 89-304 (1967) and, rarely, appropriations from the State General Fund. Revenue has not increased significantly since the mid 1960's and the greatest source of revenue (shell dredging) is a nonrenewable resource which will eventually become depleted.

TABLE 2. Barrels[1] of oyster shells and seed oysters planted on public reefs in Alabama since 1910.

Year	Oyster Shells	Seed Oysters	Year	Oyster Shells	Seed Oysters
1910-1914	35,000	—0—	1955	97,707	—0—
1925	—0—	35,000	1956	—0—	40,000
1926	—0—	10,000	1957	—0—	50,000
1928	—0—	30,000	1958	—0—	59,860
1929	—0—	10,000	1959	—0—	—0—
1932	33,382	—0—	1960	23,534	15,000
1936	189,554	[2]	1961	70,000	—0—
1937	20,045	[2]	1962	115,000	39,839
1940	60,000	—0—	1963	60,000	30,000
1942	25,000	—0—	1964	65,000	36,000
1944	92,426	—0—	1965	60,000	65,698
1945	—0—	6,000	1966	50,000	60,000
1946	12,743	19,040	1967	11,400	8,660
1947	15,000	18,950	1968	46,470	—0—
1948	25,000	40,000	1969	105,325	—0—
1949	63,215	33,409	1970	51,296[3]	—0—
1950	—0—	40,713	1971	61,982	—0—
1951	40,000	—0—	1972	117,346[3]	—0—
1952	17,749	54,000	1973	3,157[3]	—0—
1953	2,431	—0—	1974	167,330[3]	5,451
1954	—0—	7,500	1975	162,259[3]	—0—

TOTAL — Oyster Shells — 1,899,351
TOTAL — Seed Oysters — 715,120

[1] An Alabama barrel = 4.9 ft.[3] or 3.9 U. S. Standard bushels
[2] Figure for seed oysters combined with that for oyster shells this year
[3] Combined figure for oyster shells and clam shells

HISTORY OF RESEARCH

The prehistoric Indian cultures were aware of the locations of Alabama oyster reefs more than 3,500 years ago as evidenced by the numerous shell middens in coastal Alabama. The Spanish expedition of 1519 led by Pineda possibly explored the Alabama coastal area and recorded the position of some oyster reefs. The first U.S. Coast Survey map of coastal Alabama published in 1851 showed locations of certain reefs although the first specific effort to map the oyster reef was done by Boudouquie in 1883 (May, 1971).

In 1894, Homer P. Ritter (1896), Assistant, U. S. Coast and Geodetic Survey, made a survey of the oyster reefs from Cedar Point eastward to Bon Secour Bay and northward throughout Mobile Bay. Besides mapping the oyster reefs he described the general areas and recorded water temperatures, densities, depths, bottom types and the quality of oysters. Having begun the survey on February 10 during a period of freshets, he returned in December to take additional water densities under low flow conditions. Ritter obtained the approximate locations of reefs from oystermen but used triangulation points established by the Coast Survey records during mapping. The extent of the reefs were determined by dragging a chain over the reefs. He found the northern limits of oyster growth in Mobile Bay to be along a east-west line from Great Point Clear to East Fowl River. The oyster reefs along the eastern shore were few in number and Ritter concluded that depletion of these reefs was probably due to excessive fishing. He mapped 3,105 acres of oyster bottoms in Mobile Bay, Bon Secour Bay and extreme eastern portion of Mississippi Sound. He did not map the reefs in Mississippi Sound but stated "oysters were growing in all parts" of the northern portion of the sound west to the Mississippi line.

During 1910-1911, Dr. H. F. Moore (1913) of the U. S. Bureau of Fisheries examined the oyster bottoms of Mobile Bay and Mississippi Sound. His study was done at the request of the newly appointed Alabama Oyster Commission created by the Alabama Legislature on August 27, 1909. Moore used chains dragged behind a boat to locate the reefs. A launch tonged oysters for counting and measurement. Grabs were also taken to determine the density of oysters. The survey covered 93,000 acres including 4,000 acres of oyster beds. A general summary of all the beds were made in terms of relative productivity. More than 24,000 acres surveyed were considered suitable for oyster culture and Moore recommended removal of small oysters from crowded bottoms to other suitable areas.

In July 1914, Thurlow C. Nelson (1914) of the University of Wisconsin came to Alabama at the request of Mr. Joullian, Secretary of the Alabama Oyster Commission, to study mortality of planted seed oysters in Alabama waters, principally those in Portersville Bay. He examined both private leases and public reefs recording dates and amounts planted, condition of oysters and other data. He concluded that in every area where oysters died the bottom was either too soft or that the bottom was unstable or shifting in nature and that oysters planted on suitable bottoms were not affected by the mortality observed during February and March 1914. He completely dismissed the oyster drill as playing any part in the mortality.

In May 1929, Dr. Paul Galtsoff (1930) of the U. S. Bureau of Fisheries made a study of the oyster reefs of Alabama following the 1929 flood. He used oyster dredges to sample the reefs to determine mortality. His study showed that between 55% and 100% of the oysters on the reefs in Mobile Bay and Mississippi Sound were destroyed by the flood. He concluded that all commercially important oyster bottoms in Mobile Bay were destroyed and that the reefs could be rehabilitated only by establishing "spawning beds", planting shell near the spawning beds and planting seed oysters. He recommended that state law prohibit leasing of public oyster bottoms and that development of public reefs should be a state responsibility.

During November and December 1943, James B. Engle (1945) of the U. S. Fish and Wildlife Service made a survey of the oyster bottoms of Alabama to determine the conditions of the reefs to improve rehabilitation of depleted reefs and improve cultivation methods. This survey followed an examination of the reefs by the Department of Conservation in 1941-1942 which revealed heavy mortality. Engle recommended planting shell and seed oysters and enforcement of the culling law. During December 1947 Engle (1948) made another survey following the hurricane of 1947. He found damage restricted mostly to the northern area of Mississippi Sound where oysters had been covered by soft mud to depths up to 1 foot. Most of the producing bottoms in Mobile Bay were unaffected. He recommended that bottoms in much of the Mississippi Sound area were too soft to support oysters or shell and that plantings should be done only on suitable bottoms. He also observed that considerable damage to oysters was caused by oyster drills along the northern shores of Mississippi Sound. Ritter (1896) had commented upon the freshness of the waters of the northern portion of the Sound. In an addendum to Ritter's paper, a note by Mr. John J. Delchamps stated that "whelks" have become a problem and that "This is the first year (1894?) that I have heard complaints of their destructiveness". Increased salinity and oyster drill activity apparently became prevalent between the early 1900's and the 1940's presumably due to migration and widening of the pass between Dauphin and Petit Bois islands.

Bell (1952) surveyed the oyster reefs during the summer of 1951 in fulfilling requirements of a M.S. thesis for Texas A & M University. He surveyed 5,912 acres of public oyster beds of which 3,284 acres were considered to contain a fishable density. The oyster beds were found generally to be in good condition with good spat set. He encouraged increasing the area under private lease.

May (1971) surveyed both the public oyster reefs and the buried shell deposits during 1968 and 1969. He surveyed 3,064 acres of natural oyster bottoms. He stated that there were 924 acres of leased bottoms and 1,050 acres of riparian bottoms which ocassionally produced oysters. He did extensive sampling on the reefs using scuba to determine the density of oysters, spat, boxes, mud crabs and oyster drills and presented data on the commercial fishery and factors affecting oyster production. Oyster density was considerably lower in 1969 than during earlier surveys and he concluded that there were about 60 thousand acres of bottoms in Alabama which are firm enough to support oysters. The buried shell deposits totaled more than 93 million cubic yards of which approximately 46 million were recoverable. He contributed significantly to the knowledge of the Alabama oyster fishery in papers dealing with summer oyster mortalities (May, 1968), oyster culture (May, 1969), oyster survival (May and Bland, 1970), surveying oyster deposits (May and McLain, 1970), effect of floodwaters (May, 1972a), oyster fishery (May, 1972b), diseases (Beckert, Bland and May, 1972), dredging (May, 1973a), oxygen depletion (May, 1973b) and mud crab abundance on oyster reefs (May, 1974).

Other research concerning oysters in Alabama include Casper et al. (1969), Engle (1936), Gallagher et al. (1969), Hoese, Nelson and Beckert (1972), and McClellan (1965).

PROBLEMS IN OYSTER MANAGEMENT

Biological and socioeconomic problems have plagued the oyster fishery during historical times. Spring floods, pollution, low dissolved oxygen, oyster predators and diseases together with insufficient funding, indifferent fishermen and administration, and bi-county bickering have all had effects on the fishery.

A total of 73,584 acres of Alabama waters are permanently closed to shellfish harvest (May, 1971) and almost all of the remainder is temporarily closed due to bacterial contamination during winter and spring flood periods. While there are only two small reefs within the permanently closed areas, the temporary closures of the major reefs caused an estimated loss to the fishermen of $2,000 per day or an estimated total of $282 thousand during 1968 and 1969 (May, 1971). Closures last from a few weeks to 4 months or longer depending upon the magnitude of the winter and spring flooding. Winter floods have also caused extensive oyster mortalities in Alabama. During the 1929 flood, mortalities ranged from 100% in upper Mobile Bay and from 54% to 84% in the lower bay (Galtsoff, 1930). Other extensive mortalities were recorded in 1912, 1953, 1961 and in 1973 when 42% of all oysters in the state were killed (Hughes and May, 1975).

Within limits decreased salinity is beneficial in that the oyster drill, *Thais haemostoma*, is salinophilic. In the spring and summer of 1967, 80 to 95% of the oysters less than 2 inches were killed on some Alabama reefs by drills (May, 1971). Spat set in Alabama is highest in the saline waters of Mississippi Sound but survival is negligible due to oyster drills (Hoese, Nelson and Beckert, 1972). The number of drills on some Alabama reefs outnumber oysters and spat combined (May, 1971). Mud crabs are also predators on small oysters and spat and may transmit oyster diseases. May (1974) found that the number of mud crabs ranged from none per acre on some of the more northern reefs to 62,000 per acre in the lower bay. Low salinities also inhibit development of *Labyrinthomyxa marina*, a parasitic fungus affecting oysters (Ray, 1954).

The effects of small amounts of pesticides upon oysters is not fully understood. Levels of certain pesticides as low as 10 parts per billion (ppb) may inhibit growth of oysters (Butler, 1969) and oysters can concentrate pesticides within the tissues to levels much higher than found in surrounding waters (Butler, 1966). The levels of DDT residues in mollusks, however, has declined markedly in most estuaries (Butler, 1973) and residues in Alabama oysters are far below levels considered harmful from a public health standpoint (Casper et al., 1969).

Low dissolved oxygen in certain areas of Mobile Bay has caused oyster mortalities as high as 100% and is responsible for poor spat set (May, 1973b). During 1967, approximately 1,000 acres of oysters valued at $500 thousand were lost due to low dissolved oxygen and during 1971 more than 2.6 million oysters were lost due to the same cause (May, 1973b). Reefs in the middle portion of Mobile Bay and Bon Secour Bay have a long history of poor spat set (Ritter, 1896; Bell, 1952) which is likely due in part to low dissolved oxygen (May, 1973b). This low dissolved oxygen phenomenon has been known locally for more than a century as "jubilees" (Loesch, 1960; May, 1973b). Other contributing factors to poor spat set are thought to be spring freshets (May, 1972a) and existing current patterns (Hoese, Nelson and Beckert, 1972).

Current patterns have changed somewhat due to spoil deposition adjacent to the Mobile Ship Channel. The channel has also caused saltwater penetration inland from the Gulf (Ryan, 1969). May (1971) considered changes in salinity and current patterns more detrimental to oyster resources than siltation or physical destruction due to channel construction. Physical destruction of oysters has occurred during construction of Grants Pass in 1838, Pass aux Herons (ca. 1912) and the Gulf Intracoastal Waterway in the late 1930's. Spoil from these channels was placed in some instances on nearby oyster reefs. Increased salinity in Portersville Bay resulting from the natural westward migration of Dauphin and Petit Bois islands has destroyed the oyster resources in Portersville Bay. The width of the pass between the two islands has increased from 1.5 nautical miles in 1851 to about 5 nautical miles (May, 1971) increasing the salinity throughout Mississippi Sound.

Socioeconomic problems also affect the industry. Overfishing was mentioned by Ritter (1896) as the cause of depletion of certain reefs in Alabama. Nelson (1914), Galtsoff (1930) and Engle (1936) also considered overfishing of the more accessible reefs, failure to return shells to the reefs, and use of oyster dredges as major factors in depletion of the reefs. These conclusions must be considered; however, many biological factors affecting oysters were unknown at those times. While the effects of high fishing pressure is not fully understood, continued fishing of the more accessible reefs and little or no utilization of less accessible reefs is a poor method of exploiting a resource. At least 90% of the fishing pressure is expended on Cedar Point Reef even though less accessible reefs such as Sand Reef, Buoy Reef, King's Bayou and others periodically have oyster densities equally as high. One valid example of overfishing was during the 1966-1967 steam oyster season. The size of legal oysters was reduced and thousands of barrels of small oysters were taken to the canneries in Mississippi. The oyster harvest was considerably reduced for several years following the steam season (May, 1971).

Bickering between oyster fishermen of Baldwin and Mobile counties and among fishermen within each county sometimes has hampered effective management and improvement of the fishery. The eastern shore historically has had a poor oyster set (Ritter, 1896; Hoese, Nelson and Beckert, 1972) and production there is sporatic. The Mobile County fishermen greatly resent attempts by Baldwin County fishermen to obtain seed oysters from reefs in Mobile County. This led to an armed confrontation between the two groups in the 1960's. Also, most shell planting by the state has historically been on the better producing reefs of Mobile County which has caused resentment among the Baldwin County fishermen. During 1975, seed oysters in two locations in Mobile County were made available to a small group of Mobile County fishermen for planting on their leased bottoms. Both areas were in polluted, permanently closed areas and considerable effort was made by the Marine Resources Division to obtain authorization from the Department of Health to move these oysters. The lessees were indifferent to obtaining oysters from one location and permission to obtain oysters from the other was withdrawn after a petition was circulated by other Mobile County fishermen objecting to removal of oysters from public bottoms (even though permanently closed) to a private lease.

The oyster fishery itself contributes almost nothing to reef improvement and, as in all coastal states, is heavily subsidized by the state. During the period from 1960 to 1968 the Marine Resources Division planted 454,934 barrels of shell and 254,499 barrels of seed oysters on the public reefs of Alabama. During this same time revenue received from the oyster fishery amounted to about $9,000 per year, or 2% of the dockside value of the fishery (May, 1971). During 1968, 1970, 1972, 1974 and 1975 a total of $396 thousand was spent by the Marine Resources Division to plant shell following extremely high mortalities on the oyster reefs. These funds were made available by the U. S. Department of Commerce under Public Law 88-309, Section 4(b) for fisheries disaster relief. Were these funds not available, it would have been impossible for the state to fund shell planting programs of this scope. Lack of funds historically has been a cause of little development of suitable bottoms, but it is questionable whether governmental subsidies except following natural disasters are the solution. Lack of seed oysters has reduced interest in developing leases and riparian bottoms but the recent development in producing cultchless seed oysters in hatcheries may provide needed stimulation to private development of the fishery. However, closures due to pollution have become more frequent and of longer duration since the 1950's and have certainly decreased interest in extensive development of the fishery by either private enterprise or governmental agencies.

LITERATURE CITED

Alabama Department of Conservation and Natural Resources. Annual Reports for 1908 through 1971. Montgomery, Alabama.

Alabama Oyster Commission. 1914. Report to the Governor and General Assembly. 24 p.

Beckert, H., D. G. Bland and E. B. May. 1972. The incidence of **Labyrinthomyxa marina** in Alabama. Alabama Mar. Resour. Bull. 8:18-24.

Bell, J. O. 1952. A study of oyster production in Alabama waters. M.S. Thesis, Texas A & M College. 81 p.

Butler, P. A. 1966. The problem of pesticides in estuaries. Amer. Fish. Soc. Spec. Rep. 3:110-115.

Butler, P. A. 1969. Bureau of Commercial Fisheries pesticide monitoring program. U. S. Public Health Service, Dauphin Island, Alabama.

Butler, P. A. 1973. Residues in fish, wildlife and estuaries. Part I. General Summary and Conclusions. Pesticides Monitoring J. 6(4):238-246.

Casper, V. L., R. J. Hammerstrom, E. A. Robertson, J. C. Bugg and J. L. Gaines. 1969 Study of chlorinated pesticides in oysters and estuarine environment of the Mobile Bay area. U. S. Public Health Service, Dauphin Island, Alabama. 47 p.

Engle, J. B. 1936. Effects of dredging on natural oyster reefs and planted bottoms in Alabama. A report to the U. S. Bureau of Fisheries. 6 p.

Engle, J. B. 1945. The condition of the natural oyster reefs and other oyster bottoms in Alabama in 1943 with suggestions for their improvement. U. S. Fish. Wildl. Ser., Spec. Sci. Rep. 29. 42 p.

Engle, J. B. 1948. Investigations of the oyster reefs of Mississippi, Louisiana, and Alabama following the hurricane of September 19, 1947. U. S. Dep. Interior, Fish. Wildl. Ser., Spec. Rep. 59. 70 p.

Gallagher, T. P., F. J. Silva, L. W. Olinger and R. A. Whatley. 1969. Pollution affecting shellfish harvesting in Mobile Bay, Alabama. Fed. Water Pollution Control Admin., Athens, Georgia. 46 p.

Galtsoff, P. S. 1930. Destruction of oyster bottoms in Mobile Bay by the flood of 1929. U. S. Bureau Fisheries, Rep. of the Comm. of Fisheries for fiscal year 1929, append. 11 (Doc. 1069). 741-758.

Hoese, H. D., W. R. Nelson and H. Beckert. 1972. Seasonal and spatial setting of fouling organisms in Mobile Bay and eastern Mississippi Sound, Alabama. Alabama Mar. Resour. Bull. 8:9-18.

Hoese, H. D. 1964. Studies on oyster scavengers and their relation to the fungus **Dermocystidium marinum.** Proc. Nat. Shellfisheries Ass. 53:161-174.

Hughes, E. A. and E. B. May. 1975. Factors affecting the life of the Alabama oyster. Alabama Conserv. 45(2):6-7.

Loesch, H. 1960. Sporadic mass shoreward migrations of demersal fish and crustaceans in Mobile Bay, Alabama. Ecology 41(2):292-298.

May, E. B. 1968. Summer oyster mortalities in Alabama. Progressive Fish-Culturist. 30(2):99.

May, E. B. 1969. Feasibility of off bottom culture in Alabama. Alabama Dep. Conserv., Dauphin Island, Alabama. Alabama Mar. Resour. Bull. 3:1-14.

May, E. B. 1971. A survey of the oyster shell resources of Alabama. Alabama Mar. Resour. Bull. 4:1-53.

May, E. B. 1972a. The effect of floodwater on oysters in Mobile Bay. Proc. Nat. Shellfish. Ass. 62:67-71.

May, E. B. 1972b. Alabama oyster fishery. Proc. Symposium of the Oyster Fishery of the Gulf States. Gulf Coast Research Lab., Ocean Springs, Mississippi. p. 12-13.

May, E. B. 1973a. Environmental effects of hydraulic dredging in estuaries. Alabama Mar. Resour. Bull. 9:1-85.

May, E. B. 1973b. Extensive oxygen depletion in Mobile Bay, Alabama. Limnol. Oceanogr. 18(3):353-366.

May, E. B. 1974. The distribution of mud crabs (Xanthidae) in Alabama estuaries. Proc. Nat. Shellfisheries Ass. 64:33-37.

May, E. B. and D. G. Bland. 1970. Survival of young oysters in areas of different salinity in Mobile Bay. Proc. Southeastern Ass. Game and Fish. Comm. 23. 519-521.

May, E. B. and K. R. McLain. 1970. Advantages of electronic positioning and profiling in surveying buried oyster shell deposits. Proc. Nat. Shellfisheries Ass. 60:72-74.

McDermott, J. J. 1960. The predation of oysters and barnacles by crabs of the family Xanthidae. Proc. Pennsylvania Acad. Sci. 34:199-211.

Moore, H. F. 1913. Condition and extent of the natural oyster beds and barren bottoms of Mississippi Sound, Alabama. Dept. Com. and Labor, Bur. Fisheries Doc. 769.60 p.

Nelson, T. C. 1914. Report on an investigation of the causes of mortality among planted oysters in Portersville Bay and other Alabama waters. Univ. Wisconsin. 59 p.

Ray, S. M. 1966. A review of the culture method for detecting **Dermocystidium marinum**, with suggested modifications and precautions. Proc. Nat. Shellfisheries Ass. 54:55-69.

Ritter, H. P. 1896. Report on a reconnaissance of the oyster beds of Mobile Bay and Mississippi Sound, Alabama. Bull. U. S. Fish. Comm. for 1895. 325-339.