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An evaluation of an inshore aquaculture park for sustainable coastal community development

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AN EVALUATION OF AN INSHORE AQUACULTURE PARK FOR SUSTAINABLE COASTAL COMMUNITY DEVELOPMENT

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agriculture and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The School of Renewable Natural Resources

by

Vanessa Maxwell
B.S., Florida Institute of Technology, 2001
M.S., Auburn University, 2003
August 2007
To my Mom and Dad, who have supported me in every way, and to my friends for keeping me on track and reminding me to have fun along the way.
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Abstract

This dissertation addresses applying industrial park concepts to the development of aquaculture parks in public waters specifically for off-bottom triploid Easter oyster, *Crassostrea virginica*, culture. The objectives are to identify the permitting process, relevant agencies, and legislation needed to facilitate development of aquaculture parks in the Gulf of Mexico states, and test and analyze off-bottom oyster culture for commercial production of triploid oysters. Off-bottom culture can increase oyster production, but fouling organisms can reduce growth and survival rates. The Adjustable Longline System (ALS), commercially used in Australia, allows oyster bags to be suspended in the water column and positioned for aerial drying to deter fouling. This study evaluates means of controlling fouling organisms for off-bottom culture of diploid oysters by measuring 1) growth rate, 2) survival rate, and 3) fouling rates. This study shows that routine aerial exposure reduces the amount of fouling organisms without significantly affecting growth or survival. The oysters in all treatments reached market-size in twelve months and had survival rates greater than 80%.

Advances in oyster genetics research are creating superior candidates for culture and needs to be coupled with advanced grow-out methods to reach full potential. Triploid oyster culture is a viable alternative to natural oyster production but requires investment in seed. This study analyzed the capital, operating costs, and break-even prices of a 0.40-hectare ALS for triploid oyster culture. The analysis assumes that seed is purchased from a hatchery and that the culturist harvests triploid oysters during the months when on-bottom oysters have a lower meat yield. The break-even costs are determined for a 100-count box of oysters. Once importation and permitting costs are determined, areas of the budget can then be adjusted to reduce the break-even price. This will include such factors as domestic system components, labor hours, or stocking density. The results will determine if off-bottom culture of triploid oysters is a good
investment for the Louisiana oyster industry. In addition, an operational plan was also prepared for the ALS to meet the International Shellfish Sanitation Council requirements for shellfish culture facilities.
Chapter 1

Foreword

The Louisiana oyster industry has been declining in the last few decades due to disease, predation, habitat lost, and pollution. Similar declines have occurred in oyster in other oyster producing regions of the U.S., and to overcome these issues they have turned to new technologies, such as hatcheries and off-bottom culture techniques (Anon. 1990). Ploidy experiments with shellfish began with making triploid Eastern oysters, *Crassostrea virginica* (Figure 1.1), and Pacific oysters, *C. gigas*, in the 1980s (Stanley et al. 1981, Guo et al. 1996). Triploid oysters have an additional set of maternal chromosomes from unique hatchery protocol causing sexual sterility. Because glycogen reserves are not used during spawning, higher meat yields are achieved during the spawning season (i.e., June-October in the gulf region) because more energy goes into growth than into reproduction (Stanley et al. 1981). Triploid oysters also grow to market-size before significant mortalities from disease (e.g., Dermo) and represent the potential to produce a larger Dermo-resistant oyster by breeding with Dermo-resistant diploid oysters (Allen et al. 1993). Sterility also reduces the concerns of genetic pollution (Guo et al. 1996).

Triploid oysters involve a large investment of time and resources to create a highly valuable “summer crop” for industrial application. Yet, extensive oyster culture (i.e., on-bottom) makes up the majority of the regional production. On-bottom predation, especially from oyster drills (*Strominata haemostoma*) and black drum (*Pogonias cromis*); can cause 50% to 85% mortalities on oyster leases in Louisiana (Gulf States Marine Fisheries Commission 1991). Because triploid oysters are an increased
Scientific name: *Crassostrea virginica*
Class: Bivalvia
Order: Ostreoida
Family: Ostreidae
Common name: Eastern oyster
Other names: American oyster

**Figure 1.1 Nomenclature and taxonomy**
investment, they need to be protected from high mortalities by coupling the triploid technology with off-bottom culture technology.

Triploid oysters involve a large investment of time and resources to create a highly valuable “summer crop” for industrial application. Yet, extensive oyster culture (i.e., on-bottom) makes up the majority of the regional production. On-bottom predation, especially from oyster drills (*Strominata haemostoma*) and black drum (*Pogonias cromis*); can cause 50% to 85% mortalities on oyster leases in Louisiana (Gulf States Marine Fisheries Commission 1991). Because triploid oysters are an increased investment, they need to be protected from high mortalities by coupling the triploid technology with off-bottom culture technology.

One way to integrate new technologies into an existing industry is an aquaculture park such as those at Harbor Branch Oceanographic Institute and Mote Marine Laboratory. Industrial parks are areas where resources, such as land, are used for certain enterprise activities (La. R.S. § 33.130.51). Similar to an industrial park, a public aquaculture park would be zoned for certain activities with exclusive use of public water column and water bottoms for mariculture. This is a different concept for such a venture, as many aquaculture facilities in the Gulf of Mexico states are located on private land and water bottoms leased for private use. An aquaculture park allows one or multiple individuals to conduct mariculture using similar resources and infrastructure. Following the industrial park model, an aquaculture park would delineate an area of coastal waters for allocation of mariculture activities, in essence, zoning an area of the coast for aquaculture activities.

Zoning is not new to coastal waters. Many areas are already designated according to their use, such as fishing zones (Fletcher and Neyrey, 2004). In addition, the surface and water column around oil and gas platforms and other structures are areas exclusively used by the industry. For example, the U.S. Coast Guard establishes safety perimeters around oil and gas
platforms, thereby establishing zones for the exclusive use by the industry (Fletcher and Neyrey, 2004). Another example of marine zoning is in Hawaii; they manage their jurisdictional water as land zoned for conservation (Marine Aquaculture Task Force, 2007).

The benefit of having a public aquaculture park is that it allows entrepreneurs to test out new technologies before making large investments. The ultimate goal of this project was to review the permit and policies of an aquaculture park in the Grand Isle, LA area for the specific use of testing the Australian Adjustable Longline System (ALS) for off-bottom culture of triploid Eastern oysters. This project provides a framework for permitting and policies for public aquaculture parks in the coastal zones of all of the Gulf of Mexico states, as well as producing an economic analysis and operational plan for using the ALS for triploid oyster culture as a summer crop for the Louisiana oyster industry. The specific objectives were to: 1) identify the number of permits, the agencies with jurisdiction, the existing regulations, and the policies that may need to be changed or developed to allow for an aquaculture park in the Gulf of Mexico state waters; 2) compare the permitting, and the regulatory issues of establishing an aquaculture park sited in public and private waters in the state of Louisiana; 3) develop a fouling control strategy for off-bottom culture; 4) produce an enterprise budget for off-bottom oyster culture using the ALS; and, 5) develop an operation plan following the guidelines of the National Shellfish Sanitation Program.

The results of this project reflect large variations in permitting and policy for aquaculture parks between each of the Gulf of Mexico States. Florida has existing private aquaculture parks and a public leasing program that is managed similarly to how a public aquaculture park would be managed. However, in Louisiana, no regulations for aquaculture parks exist and the permit application for the demonstration project in Grand Isle, LA is still in the review process. Preliminary studies conducted at the Louisiana Sea Grant Oyster Hatchery in Grand Isle, LA
showed that routine aerial exposure significantly reduced the fouling organism without significantly reducing growth or survival (Maxwell and Supan, in review, Chapter 4). The results of the preliminary studies were used to determine the management strategies that were most economical for commercial production of triploid oysters in the months of June to October. The economical analysis showed that a 100-count box of triploid oysters could be produced using the ALS with a break-even price between $22.76 and $57.00 (Maxwell and Supan, in preparation, Chapter 5). Current cost to produce a 100-count box of diploid oysters on-bottom is between $13 and $18 sold to retailers from producers not including freight costs (*fide* Al Sunsari, P&J Oyster Co.; *fide* Kevin Voisin, Motivatit Seafood, Inc.). The increased price for triploid oysters will be dependent on the demand for the higher quality meat yield provided by them during the spawning season when on-bottom cultured diploid oysters have poor meat yields.

The results of this project represent a collaborative effort between the Louisiana Sea Grant College Program, and the Grand Isle Port Commission (GIPC). The GIPC is the permit applicant for the Coastal Use Permit (CUP) and the Section 10 permit from the United States Army Corps of Engineers (USACE). They are responsible for providing security and managing the aquaculture park. The Louisiana Sea Grant Oyster Hatchery at Grand Isle, LA is responsible for providing triploid oysters. The Louisiana Sea Grant College Program purchased the ALS, installed it, and manages the system to produce market-size oysters. Jules Melancon of Island Oyster Co. Grand Isle, LA, is the planned commercial collaborator to manage and harvest the oysters from the ALS. Due to delays in permitting and Hurricane Katrina, however, he was unable to participate in the project. The policy and permitting review was a collaborative effort between the Louisiana Sea Grant Legal Program, the National Sea Grant Legal Program, and the Texas Sea Grant College Program.
This work was supported by the National Oceanographic and Atmospheric Administration (NOAA) Gulf Oyster Industry Program (GOIP), and by BP America, Inc. The results of this project have been presented at several scientific meetings (Table 1.1). In addition, four papers related to this project, Chapter 3 (Maxwell et al., 2007 in press) has been published. Chapters 4, 5, and 6 have either been submitted for review or are being prepared for submission for publication in peer-review journals (Table 1.2). For consistency, all chapters of this dissertation have been presented in the format of the *Journal of the World Aquaculture Society* with specific formatting required to meet LSU dissertation format and style.

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Chapter 2

Introduction

Activities in the coastal zone have a different permitting process than those on land. Activities such as mariculture are highly scrutinized by state and Federal agencies. Under the Coastal Zone Management Act, states are required to have existing guidelines for priority activities in the coastal zone in order to receive the benefits of this volunteer program (Beatley et al. 1994). Currently, there are four permits needed for mariculture activities in the coastal zone of Louisiana: a coastal use permit (CUP) from the Louisiana Department of Natural Resources (DNR), a mariculture permit from Louisiana Department of Wildlife and Fisheries (LDWF), an discharge permit from the Department of Environmental Quality (DEQ), and a Section 10 permit from the United States Army Corp of Engineers (USACE). Other agencies that would be involved in the permitting process include the Louisiana State Lands Office (SLO), which has jurisdiction over state-owned water bottoms, the Coast Guard, and local authorities in the area of a proposed mariculture site. The biggest issues when permitting mariculture activities has been liability and user conflicts. Designating areas for mariculture would allow for testing of mariculture technology while reducing site selection effort and reduce the user conflicts through local community review and involvement. A designated park would allow individual entrepreneurs to apply for liability insurance as a group, reducing the costs per individual. User conflicts can be reduced by carefully locating the park to minimize the number of boaters and anglers that could be impacted. Having an area that has the appropriate water flow and depth, bottom characteristics, and proximity to shore-based infrastructure will foster mariculture projects and reduce user conflicts in each area through coastal zone management. In 1992, Fridley reviewed mariculture conflicts and recommended that a regulatory framework be developed to determine how to best allocate the coastal resources. Development of new
technologies has been hindered by a lack of regulatory framework, which would be improved by recognizing aquaculture as a part of coastal zone planning (DeVoe et al., 1992; Duff et al., 2003). He determined that because of the strong number of conflicts, mariculture would only be successful if conducted onshore or offshore away from recreation, fishing, navigation, and landowners (Fridley, 1992). The current lack of a policy framework is leading to a loss in potential economic development (Cicin-Sain et al., 2005).

The main concerns of the permitting agencies has not been about permitting mariculture, but liability and restricting use of a public good. Under the public trust doctrine, the State has the responsibility of managing all common resources in trust for the benefit of the public (Archer et al. 1994). Although the public could benefit from the economic development of the aquaculture operation, the question is will it out weigh the public’s right to fish and boat in the area. The other concern is the liability in the event of an accident; the biggest liability deemed by this proposed research is the submerged longlines of the ALS. However, the park and its structures would be a public entity similar to a bridge or pier. In cases where boats have struck piers, weirs, or bridges, the captain of the vessel or the vessel owners were held liable for the damages and injuries (Hochstetler V. Board of Pilot Commissioners from the Bays of San Francisco, San Pablo, and Suisun 1992). In Chalmette Terminal L.L.C et al. Vs. M/V Tzanetis, et al. (1998) the U.S. District Court of the Eastern District of Louisiana found that without proof of an accident being the fault of a stationary object, the fault and therefore liability falls on the moving vessel. The Oregon (1895), Delta Transload, Inc. v. M/V Navios Commander (1987), and United States v. T/B Arcadian (1983) are all cases where the moving vessel was held at fault for colliding with a stationary object, following the logic that a moving vessel does not hit a stationary object unless it is not managed properly.
The concept of an aquaculture park is conducive with oyster culture because oysters are a highly successful culture species and filter-feed on naturally occurring phytoplankton. Thus, no feed and its resulting nutrients will be added to the water, eliminating the need for a point source pollution permit from the DEQ. This addresses the Ninth Circuit court’s decision in the *Totten Inlet vs. Taylor Resources* case in which a mussel farm was sued for being a point source of pollution; the resulting judgment found that because no feed was added, then there was no net increase in nutrients (i.e. no effluent) (Helle 2004). Currently, mariculture facilities are using bivalve culture to act as a means of treating the effluent from finfish culture and environmental agencies are using bivalves as pollution indicators (Langan 2005, Lee et al. 2004, and Lee et al. 2003). The park will also serve as an area for technology transfer of university research. The park’s first application of research results will be to test commercial-scale growth of triploid oysters.

There are several methods for creating a triploid oyster, including pressure, thermal, or chemical shock (Nell 2002). The most commonly used treatment is treating fertilized oyster eggs with Cytochalasin B (CB). Timely application suppresses the release of the second polar body during meiosis and causes a set of chromosomes that would normally be release to be retained in the embryo. Cytochalasin B is a cytokentic-inhibiting antibiotic that causes reduced larval survival, and does not produce a 100% triploid brood (Allen 1983, Stanley et al. 1981). The percentage of triploids and the amount of mortality varies due to temperature, egg quality, and CB dosage and exposure. The suggested method is to use stripped eggs to synchronize fertilization and treat with a dose of 0.25 to 0.5 mg CB/L for ten to fifteen minutes at 25°C when 50% of the eggs are at polar body I (PBI). The longer and higher dosages will result in a higher number of triploids, but also a higher mortality (Stanley et al. 1981, Shatkin and Allen 1990, Supan et al. 2000). Cytochalasin B is a toxic chemical that poses health risks to hatchery
personnel, addressed by adequate training, supervision, and wastewater handling and removal (Nell 2002, Guo et al. 1994).

Triploid oysters involve a large investment of time and resources to create a highly valuable “summer crop” for industrial application. Yet, extensive oyster culture (i.e., on-bottom) makes up the majority of the regional production. On-bottom predation, especially from oyster drills (*Strominata haemostoma*) and black drum (*Pogonias cromis*); can cause 50% to 85% mortalities on oyster leases in Louisiana (Gulf States Marine Fisheries Commission 1991). Triploid oyster utilization needs to be coupled with technically advanced grow-out methods to reach full potential. Because the triploid oyster seed is more expensive to produce, they are a viable candidate for using off-bottom culture techniques that will reduce predation mortality.

Off-bottom culture of oysters is common throughout Asia, Australia, and parts of Europe, but is limited in the United States primarily to tray culture due to the expense of equipment. Therefore, Only a small segment of the industry can afford to use off-bottom culture techniques (Hugenin and Hugenin, 1982). In Louisiana, oysters are still cultured extensively using the traditional on-bottom leases and wild seed harvested from public seed grounds rather than hatchery-produced seed commonly used on the East and West coasts. Because of the availability of wild seed and expansive suitable oyster grounds, using off-bottom culture techniques would not be necessary. To produce oysters genetically improved through hatchery techniques, however, off-bottom culture will reduce the mortality and protect the investment in the higher valued seed.

Organisms such as barnacles, bryozoans, and oyster spat will foul oysters during both on-bottom and off-bottom culture, slowing the growth rate by competing for food and creating a less desirable market oyster (Supan 1983; Adams et al. 1989). However, fouling can be treated in off-bottom culture. Several methods have been studied for treating fouling organisms in oyster
culture including brine or hydrated lime baths, pressure washing, and changing oyster bags
(Rikard et al., 1997).

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Chapter 3

Aquaculture Parks in the Coastal Zone: A Review of Policy and Permitting in the Gulf of Mexico States

Mariculture, the farming of aquatic organisms in the marine environment, is both one of the newest and oldest uses of the coastal zone (Marine Aquaculture Task Force, 2007). However, the U.S. is not a major aquaculture producer, producing less than one percent of the world's total aquaculture product (FAO 2000). While oyster culture has existed for centuries, the use of net pens and sea ranching has developed only recently. With advances in technology, mariculture has the potential to subsidize existing fisheries (Fridley, 1992). One of these advances in technology is aquaculture parks. Aquaculture parks can facilitate research and the development of culture techniques to increase production. A nearshore, within the 3 miles of the shore in shallow waters, aquaculture park would allow researchers to test new technologies and methods to determine the benefit to commercial application, while reducing user conflicts with fisheries, shipping and navigation, and recreation. An aquaculture park will also allow entrepreneurs to test new technologies and adapt culture techniques based on their own results (Costa-Pierce, 2002). Proper sitting of a park will allow potential user conflicts to be addressed before the park is developed. Aquaculture and fisheries are constantly in conflict over resources such as fish and water. Designating specific areas for aquaculture can reduce some of these user conflicts and create an area for aquaculture to help subsidize fisheries and bring economic development to the local community (Fridley, 1992; Nash, 1995).

A nearshore aquaculture park, if sited properly, can reduce the number of conflicts with other user groups. However, limitations would have to be applied according to the type of aquaculture. This would include restrictions on feed (i.e., limiting it to species that require little or no feed or extensive practices), as well as limiting the species that can be cultured to those indigenous to the area. Even limited aquaculture parks can create areas for research groups and
industry to develop new technologies. The aquaculture park concept is meant to be a beginning in the development of a regulatory framework for mariculture. Because the kind of aquaculture park described in this article would be located nearshore, net pens and large-cage finfish culture will not be suitable due to depth and water quality issues.

This study examines the concept of an aquaculture park within the framework of an oyster-culture demonstration project in Louisiana. The oyster was chosen for the demonstration project because it is a successfully cultured native species, filter-feeds on naturally occurring phytoplankton, and off-bottom culture can be used for growing genetically enhanced oysters, such as disease resistant and triploid oysters. Oyster culture was also chosen because one of the project’s stipulations is that no feed be added to the water, thereby eliminating the need of point source pollution permits (Marine Aquaculture Task Force, 2007).

In Association to Protect Hammersly, Eld, and Totten Inlets (APHETI) vs. Taylor Resources, Inc. (hereinafter Taylor Resources), the Ninth Circuit Court of Appeals held that mussel farming does not violate the Clean Water Act (CWA) because: 1) the discharge is not created by a human activity; and, 2) shellfish enhance the water quality in the surrounding area (2002). Taylor Resources was a landmark case for two reasons: 1) it held that an organization could sue a facility for not obtaining a permit even if a State determines a permit is not necessary; and, 2) mussel culture waste does not qualify as a pollutant under the CWA because the waste is a natural byproduct of a biological process. Three subsequent cases have cited Taylor Resources negatively So far, no case has overturned the ruling in Taylor Resources.

The EPA guidelines exempt shellfish culture facilities from requiring National Pollution Discharge Elimination System permit (NPDES), unless the facility is deemed to have a significant impact, defined by Regulations as a facility that produces more than 350,000 pounds of shellfish annually (EPA 2006). In fact, mariculture facilities can provide beneficial
environmental services. For example, some bivalve culture is used as a means of treating effluent from finfish culture, and environmental agencies are using bivalves, such as oysters, as pollution indicators (Langan, 2005; Lee et al., 2004; Lee et al., 2003).

Aquaculture is regulated differently in each state. Every Gulf of Mexico state requires at least four permits to develop an aquaculture park: 1) a coastal use permit (CUP); 2) a Rivers and Harbors Act Section 10 permit (Section 10); 3) Water Quality Certification, pursuant to the CWA; and, 4) a water bottoms/column lease. How these permits and leases are issued differs according to state. In addition, different state agencies may take the lead during the permitting process, and the number of agencies involved in the review process varies. However, the application process is streamlined in some states by joint applications for the various permits. Some states may require more than the aforementioned four permits, such as “aquaculture certification” in Florida, and a permit for the handling of certain organisms, such as commercial fishing licenses. Currently, reviews of Nationwide Permits are being made that might affect and change how the Section 10 and CWA permits apply to the shellfish industry; the USACE is proposing a nationwide permit for aquaculture (fide, Susan Bunsick, NOAA Aquaculture).

This study begins with a pertinent review of the existing regulations in Florida, Alabama, Mississippi, Louisiana, and Texas and then discusses what permits would be necessary for a nearshore aquaculture park. Some Gulf of Mexico states have a clear aquaculture-permitting program and regulations addressing aquaculture parks, whether they are private or public. However, to date, no Gulf of Mexico state has permitted a public nearshore aquaculture park. This study will also review what can be learned from these existing regulations, analyze in which Gulf of Mexico states it is feasible to develop public aquaculture parks, and finally, recommend changes to existing laws that would allow their development.
Existing Laws and Regulations

Florida

In Florida, the state permits private onshore aquaculture parks. Harbor Branch Oceanographic Institution and Mote Marine Laboratory are two such examples. Although there are no regulations directly regulating the development of a public aquaculture park, existing regulations permit aquaculture through submerged lands leases, aquaculture use zones, and high-density aquaculture lease areas that give the lessee the exclusive right to use the water bottom for clam or oyster cultivation (Fla. Stat. Ann. §370.03, 597.010). The Florida Aquaculture Policy Act (FAPA) declared aquaculture a form of agriculture, vesting authority within the Florida Department of Agriculture and Consumer Services (FDACS) to issue aquaculture permits and to coordinate with other state agencies during the permitting process (Fla. Stat. Ann. § 597.002). Moreover, Florida has a state aquaculture plan that requires all aquaculture producers to become certified in order to operate within the State and provides technical assistance to those within the industry in applying for permits (Fla. Stat. Ann. §597.002, §597.004).

Florida’s high-density aquaculture lease area, mostly in the west coast of Florida, is similar to the concept of an aquaculture park, and state and local authorities have the authority to lease sovereign submerged lands within their jurisdiction for the purpose of aquaculture (Fla. Stat. Ann. §253.68). These leases grant the exclusive use of the water bottoms and water column for aquaculture activities (Fla. Stat. Ann. §253.67-253.75).

Alabama

There are no existing private or public aquaculture parks in Alabama. However, county commissions in Alabama have the authority to establish industrial parks within their respective counties, subject to the approval of the property owners (Ala. Code §11-23-1). Any person or corporation may petition a county commission to designate an area as an industrial park. A
county commission, therefore, could establish an industrial park on land to be used for aquaculture activities. However, it is less clear whether a county commission could designate an area in coastal waters as an industrial/aquaculture park. The State owns the submerged lands beneath coastal waters, but the counties’ coastal boundaries are co-terminus with the state (i.e., extend three miles offshore) (Ala. Const. Amend. 543). In theory, a county commission, with the approval of the state (i.e., the property owner) might be able to permit an aquaculture park.

Mississippi

In Mississippi, the majority of industrial parks are established and managed by the counties or other local political subdivisions. Aquaculture parks have already received legislative approval; therefore, land-based aquaculture parks could be permitted in Mississippi under existing law. Under the Mississippi Aquaculture Act of 1988, the Mississippi Department of Agriculture and Commerce (MDAC) is authorized, subject to available funding, to develop an Aquatic Ventures Center (Miss. Code §79-22-25). Through the Center, the MDAC may develop programs to:

Encourage and authorize the establishment of commercial aquaculture parks where a number of entrepreneur aquaculturalists can establish aquatic ventures. All Mississippi government entities, universities and colleges shall provide coordinated support for investors who are citizens of the United States and would like to establish a commercial aquaculture park in Mississippi and who intend to provide for innovative and effective coordinated efforts within the park, as well as among other parks, relative to water resources utilizations, production, processing and marketing applicable to cultured aquatic products (Miss. Code § 79-22-25).

Unfortunately, the Aquatic Ventures Center has yet to be funded by the State of Mississippi.

Even without the Aquatic Ventures Center, however, a land-based aquaculture park could be built in Mississippi at a port or harbor. The County Board of Supervisors, in any county with a county port authority or development commission acting through that authority or commission, “may establish industrial parks with defined boundaries to develop and utilize lands for industrial operations” (Miss. Code §59-9-23). “Industrial operations” in regards to ports and harbors:
Shall include *but not be limited to* any enterprises, the operation of which will *aid in the development of* fisheries, shipyard operations, *commerce*, navigation, or shipping in the port, as well as all forms of manufacturing enterprises, tourism enterprises, and service enterprises (Miss. Code § 59-9-5(1) (emphasis added)).

**Louisiana**

Louisiana, like Alabama, has no precedent or current legal authority that would permit public or private aquaculture parks. Parishes (i.e., counties) do have the authority to develop industrial parks, but they do not have the authority to lease water bottoms or the water column because that authority is vested to the State (La. R.S. §2:331). While the State leases water bottoms for the oyster, and oil and gas industry, it does not lease the water column (*fide* Karen Foote, Louisiana Department of Wildlife and Fisheries). Mariculture is permitted by the Louisiana Department of Wildlife and Fisheries (LDWF), but mariculture permits are only issued for mariculture on private lands and private water bottoms (La. R.S. §56:579.1). Few have applied for permits, and most who have applied have been denied due to conflicts with various agencies, or the applicant rescinded the application (Louisiana Sea Grant College Program, 2001).

**Texas**

In Texas, mariculture is regulated by the Texas Department of Agriculture (TDA), Texas Parks and Wildlife Department (TPWD), and the Texas Commission on Environmental Quality (TCEQ). A Memorandum of Agreement requires all three state agencies to work together in permitting aquaculture, which went into effect in 1999 (Treece, 2005). Before an aquaculture operation can legally begin, an aquaculture permit is required from the TDA, and a discharge permit or exemption is required from TCEQ (Texas Agriculture Code §134.011; Texas Water Code §11). The Texas Department of State Health Services (TDSHS) is authorized to regulate molluscan shellfish, including oysters, clams, mussels, and scallops under the Texas Aquatic Life Act (Texas Health and Safety Code § 436.001 *et seq.*). TDSHS's regulatory authority extends to
ensure the shellfish are harvested from approved growing waters. Counties can lease tracts of submerged land within their jurisdiction, but water bottoms and water columns are leased separately. All leases of submerged lands are regulated by the Texas General Land Office (TGLO) (Texas Natural Resources Code § 51). State and Federal regulations presently in place are not conducive to offshore aquaculture of any kind, and there are presently no operations fully permitted to grow product offshore in either state or Federal waters. A nonprofit research institute has been in the process of obtaining permits to conduct mariculture on an offshore platform in state waters since 1998. On January 3, 2005, the offshore aquaculture group won a lawsuit against the TGLO, over long-term lease ownership (Treece, 2005). There was also a dispute between TCEQ and the U.S. Environmental Protection Agency (EPA) about discharge permit requirements. The TCEQ claimed it had authority out to state boundary at 10.3 miles offshore, where the operation is located, but EPA claimed that TCEQ had no authority to issue discharge permits beyond 6 miles offshore, the state yielded to the EPA. However, both permits may still be required because there is overlap in Federal and state offshore regulations and much confusion regarding which agency has the authority (Treece, 2005).

**Permitting and Leasing**

**Florida**

Although Florida regulates aquaculture through the FDACS Division of Aquaculture (DOA), the CUP is issued by the Florida Department of Environmental Protection (FDEP) (Fla. Stat. Ann. §597.004). Due to the Florida Aquaculture Policy Act (FAPA), however, a CUP may not be required if the park is sited in an area designated as an aquaculture use zone (Fla. Stat. Ann. §253.69, §597.004). Furthermore, the submerged lands lease, which includes the water column, must be obtained from a political body known as the Board of Trustees of the Internal Improvement Trust Fund. This board, comprised of representatives of the Governor and
Cabinet, reviews all aquaculture permits and provides oversight to ensure compliance with permits and submerged lands leases ( Fla. Stat. Ann. §253.68). The DOA manages the submerged lands lease program, and under FAPA, each leaseholder must obtain an aquaculture certification from the DOA before operation can begin. Aquaculture certification applications are reviewed by the DOA, FDEP, and the Florida Fish and Wildlife Conservation Commission, as well as the local water districts and any user group that might have conflicts (Fla. Stat. Ann. §597.004).

In addition to the aquaculture certification, the Federal Section 10 permit would be required to install any equipment and/or obstructions to navigation (33 U.S.C. §403). The U.S. Army Corps of Engineers (USACE) is responsible for issuing these permits regardless of whether the project is in state or Federal waters. Water quality certifications and NPDES permits will be required if the aquaculture park was to culture species other than bivalves. These permits are issued by the FDEP (33 U.S.C. §1344).

Alabama

Alabama does not have an aquaculture certification program or an aquaculture permit program. Aquaculture is regulated by the Alabama Department of Environmental Management (ADEM). Together with the USACE, it reviews proposed projects and addresses the necessary permits required (Wallace and Fitzgibbons, 1997). The ADEM also issues the CUP and submerged land lease. One application will take care of the project review, the CUP, and the submerged lands lease. In Alabama, the Section 10 permit application is submitted separately from the CUP, and the USACE Mobile District has a joint application for Section 10 and Section 404 permits, which would cover dredging and filling activities.
Mississippi

To establish an aquaculture park in coastal waters, additional permits would be needed. Individuals who wish to cultivate oysters must file a lease application with the Mississippi Department of Marine Resources (MDMR) (Miss. Code § 49-15-27). Mississippi Dept. of Marine Resources “may lease to political subdivisions of the State of Mississippi up to one thousand (1,000) acres of water bottoms for development of oyster reefs and those political subdivisions may permit residents of the State of Mississippi to harvest oysters from the reefs” (Miss. Code § 49-15-40(3)).

In addition to the public trust tidelands lease, a number of permits are needed to conduct aquaculture activities in state waters, the most important of which is a coastal zone wetlands permit. Under a Memorandum of Agreement with the USACE, all permit applications for wetland activities in the coastal zone are submitted to MDMR. This joint permit application not only covers the MDMR wetland permit and the USACE’s Section 10 permit for obstructions to navigation, but also the Mississippi Department of Environmental Quality (MDEQ) state water permit and CWA Section 401 water quality certification.

Under Mississippi MDMR Ordinance 13.001, MDMR prohibits the discharge of “any waste material including, but not limited to, solids, debris, sanitary and kitchen wastes, oil and grease by excluding fouling organisms, the excrement of the cultured species, and commercially prepared feeds fed to them” (2000). Aquaculturists are also required to perform a pre-operation environmental survey, and develop and implement a Marine Aquaculture Environmental Monitoring Program consisting of four principle elements: a hydrographic survey, sediment chemistry, water quality, and benthic survey (MDMR, 2000).

A county authority or private corporation would be able to secure an umbrella wetlands permit for the entire aquaculture park. Success will likely depend on the level of information
provided during the application process about the activities that will be conducted at the site. If the application contains detailed information about the types of species to be cultured by the various tenants, the MDMR, USACE, and MDEQ will be able to evaluate the potential impacts of the project on the environment and on the local economy. If the park tenants are unknown at the time of the application or if tenants will be growing many different species and frequently changing the species grown, the agencies may require individual wetlands permits for each tenant because it would be impossible to evaluate the environmental impacts of the park.

**Louisiana**

In Louisiana, the CUP is part of a joint application that is reviewed by the Coastal Management Division of the Louisiana Department of Natural Resources. This review determines which permits are necessary, and comments are submitted by other State and Federal agencies with jurisdiction over the proposed project. In Louisiana, this would include the USACE New Orleans District for the Section 10 permit, the Louisiana Department of Environmental Quality for water quality certification, LDWF for the mariculture permit, and the State Lands Office for the submerged lands permit (which excludes the water column). Comments from agencies such as the U.S. Coast Guard, U.S. Fish and Wildlife Service, and the local port authority will be obtained if issues involving these agencies arise during the permitting process.

**Texas**

In Texas, the CUP, submerged lands lease, and Section 10 permit are all reviewed by TGLO through one application. Each permit application is reviewed by a different division within the TGLO. The State CUP and Federal Section 10 permit are primarily reviewed by the Natural Resource Division, with supplemental reviews by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, the TPWD, and the Texas Antiquities Committee before final
the USACE will grant the Section 10 permit. There are also plan and facility approvals required from the TPWD and the TDSHS. If oysters will be grown onsite, a license from the TDA is required for processing and selling the cultured oysters. In addition, a permit from the TPWD for transporting oysters to market and a seafood safety permit from the TDSHS is required. Moreover, the TDSHS is responsible for licensing and inspecting seafood processors and distributors, pursuant to the Texas Health and Safety Code, subchapters A, B, and C and the Federal Food, Drug, and Cosmetic Act (21 U.S.C. §301 et seq.).

In order to lease an area of submerged land, two leases are required. There are separated leases required for the water bottoms and the water column. As well as, separate permits for research and commercial activities. In addition, a coastal lease may be issued by the TGLO to local authorities to allow for limited exclusive use of the area (Texas Natural Resources Code §33.103(1) and §33.105). This would allow the local authorities to use this lease for mariculture purposes.

**Conclusions**

Currently there is no clearly defined legal process for permitting mariculture in public waters (Marine Aquaculture Task Force, 2007). Aquaculture parks, although not a novel idea, can play an important role to encourage further development of aquaculture in the coastal zone (National Resource Council 1992; Fletcher and Neyrey, 2004). Although no public nearshore (i.e., not land-based), aquaculture parks are currently in operation in the U.S., there is potential for their development. However, this development may be easier in some Gulf of Mexico states than in others. In states such as Florida and Mississippi, where regulations permit aquaculture exclusive use of the public water bottoms and the column, an aquaculture park will only need to go through the statutorily required review process. In states where there are currently no aquaculture permitting programs, such as Alabama, it will be more difficult. In this case, state
legislation is necessary to authorize coastal authorities to lease submerged lands for the exclusive use of aquaculture. Port commissions, county marine advisory boards, and any other body with jurisdiction over the waters in their counties would be the ideal candidates to manage the park by providing the proper navigational markings and security for the park users. In other states, simply acknowledging mariculture as a reasonable use of public resource, or making mariculture a priority over other uses of the land, such as mineral exploration, would facilitate development (Eichenberg and Vestal, 1992).

While Louisiana is among the Gulf of Mexico states with no legal mechanism in place for aquaculture parks, the state is slowly moving in that direction. In June 2005, the Louisiana Legislature passed Act 57. Act 57 vested the Grand Isle Port Commission with authority over a 5-acre plot of water bottom to use for a demonstration aquaculture park. The aquaculture park is still in the permitting phase as of March 2007, as it has been since July 2003. Act 57 was the result of comments on the CUP application by the LDWF, questioning if the Grand Isle Port Commission had the authority to manage the water bottoms and columns in the area surrounding the town of Grand Isle.

Creating an aquaculture park in other states may be easier using existing regulations, but laws and regulations are not the only barriers. In Florida, the existing aquaculture parks are so successful at collaborating with state agencies for research, development, and training in aquaculture that a public aquaculture park may not be considered necessary. In Mississippi, funding is an issue in the development of mariculture. In Alabama, a regulation for permitting mariculture is needed. In Texas, aquaculture would need to be a priority above other activities, such as oil and gas exploration. In addition, Texas has fewer areas that are nearshore and classified as approved shellfish growing waters. Thus, an aquaculture park for oyster culture in Texas may not be feasible.
Aquaculture parks could facilitate research and development and provide economic benefit to local communities. Community consensus aside, the biggest hurdle so far, in Louisiana, has been getting the park permitted. Not only may states need to amend existing laws regarding aquaculture, changes also would need to be made at the national level to make policies uniform throughout the states. There needs to be clear lead agencies for addressing mariculture development.

Florida would be an appropriate model for other states to use in order to develop their own aquaculture permitting programs because Florida’s aquaculture certification program provides a streamlined permitting process to obtain all required permits and licenses. Florida’s program has been successful mainly due to that state’s commitment to aquaculture development, the financial resources it dedicates to its aquaculture program, and a history of allowing private aquaculture parks (Metcalf, 2001). Furthermore, these private aquaculture parks have provided benefits to local fishermen. For example, the Harbor Branch Oceanographic Institute Aquaculture Park trained gillnet fishermen in the practice of clam farming when an amendment to the Florida Constitution banned gillnet fishing in 1995 (Philippakos et al., 2001). This led to an increase in demand for aquaculture permits nearshore rather than inland. Florida has also been ahead of development by developing best management practices (BMPs) for offshore aquaculture before any offshore aquaculture facility has been permitted (Marine Aquaculture Task Force, 2007).

Developing a public aquaculture park in states without existing programs could create a demand similar to that in Florida, and a program could eventually develop to meet this demand. Proper placement of an aquaculture park during the permitting process could resolve many of the potential user conflicts and permit obstacles, such as other projects and agency concerns, before the park is established. Hawaii’s Natural Energy Laboratory is an example of how an
aquaculture park can bring together both commercial and research groups to the benefit of the local economy; it includes not only commercial aquaculture industry and research, but also energy research and commercial water desalinization (Natural Energy Laboratory of Hawaii Authority, 2006).

**Recommendations**

There are many inconsistencies between Gulf of Mexico states in the regulation of aquaculture. Recent reports by the Pew Ocean Commission have cited a lack of a policy framework for creating confusion in the development of mariculture due to overlapping regulations and the numerous State and Federal agencies involved in the permitting process (Cicin-Sain et al., 2005; Marine Aquaculture Task Force, 2007). The recommendations included uniform one-stop permitting agencies, with NOAA as the lead agency and recommending the development of the Office of Offshore Aquaculture. These studies focused on Federal waters, but the principles used to manage offshore aquaculture can be used to manage nearshore aquaculture. Many of the same policy issues exist because nearshore aquaculture will require the same permits as offshore aquaculture, but will require the states to develop programs for managing aquaculture. Some states, such as Florida and Hawaii, have developed programs for managing offshore and nearshore aquaculture that have been successful (Cicin-Sain, 2005; Marine Aquaculture Task Force, 2007). Another recommendation is for the Federal government to recognize aquaculture is a form of agriculture rather than managing it as corollary to fisheries (DeVoe et al., 1992). This is not to say that the Fish and Wildlife agencies should not be involved in permitting and managing mariculture. However, for aquaculture techniques to develop, each leaseholder within the aquaculture park should obtain an aquaculture certification, or mariculture permit.
Leases have been the most common means of managing aquaculture and would continue to be beneficial for aquaculture parks (Eichenberg and Vestal, 1992). A permitted aquaculture park could lease space out to users based on a proposal of the type of mariculture, negating each individual entrepreneur having to obtain all of the necessary permits. The aquaculture park will allow for areas zoned for mariculture (DeVoe et al., 1992).

Aquaculture certification programs should be developed in each state to create a clear lead agency on mariculture permits for aquaculture parks to develop. To make sure that there is a clearly defined permit review process, certification boards should be developed that not only review permits, but also develop regulations for new technologies. These boards, similar to the Aquaculture Certification Review board in Florida, should be comprised of both regulatory agencies and representatives from commercial fisheries, aquaculture industries, and academia (Cincin-Sain et al., 2005). To encourage compliance with the certification programs, there should be incentives for obtaining an aquaculture certificate. In Florida, the certification program includes tax incentives that included reduced fuel costs, and reduced taxes on feeds (FDACS, 2006). However, to receive these benefits, the applicant has to agree to adhere to BMPs. These should be developed to allow for the aquaculture park, and as new technologies develop, the certification boards should develop new BMPs using information based on research from local universities and experts and from areas that have already developed new technologies (Cicin-Sain et al., 2005).

In addition to developing the permits and the BMPs for the aquaculture park, the Aquaculture Certification Boards should also help to define the terms of leases within an aquaculture park, including leaseholder property rights and what circumstances the leaseholder may be liable for their equipment and their culture organisms (Cincin-Sain et al., 2005; Marine Aquaculture Task Force, 2007). This would include deciding which particular species are
permitted in the aquaculture parks, the security measures taken to protect both the aquaculture park participants and the other resource users.

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Northern Plains Resource Council v. Fidelity Exploration and Development Company 325 F. 3d 1155 (9th Cir. 2003)


Chapter 4

Biofouling Control in Off-Bottom Longline Culture of the Eastern Oyster, (*Crassostrea virginica*)

Off-bottom aquaculture is largely used in Japan, but did not become used in the U.S. because of the available habitat for less costly on-bottom culture (Shaw, 1971). Off-bottom culture increases the amount of available growing habitat because the type of substrate is no longer a constraining factor, and increases survival by reducing mortalities from predation and siltation (Toba, 2002). There are several types of off-bottom culture: rack systems, net suspensions, floating cages, and longline suspension systems. Rack and bag systems are typically used in intertidal areas where metal racks hold bags, or trays off-bottom and are exposed at low tide to deter fouling organisms and allowing access for cleaning (Supan and Cake, 1982; Jones and Allen, 1993). Lantern nets and pearl nets can be used to suspend trays of oysters from docks and or longlines in the water. However, they require more preparation and lower stocking densities because of weight and growth (Toba, 2002). Floating trays, such as “Taylor” floats, made up of PVC and wire mesh offer easy access to the oysters, but are expensive and require high amounts of maintenance to keep the mesh clean (Luckenbach et al., 1999; Goldsborough and Merrit, 2001). The floating chub ladder is one off-bottom culture technique that has been used in the U.S. to increase oyster production, but this system has difficulties in controlling fouling organisms, which led to higher mortalities and reduced growth (Kemp and Evans, 1994). Off-bottom culture is also vulnerable to storms. However, improved design and developments of new technology can address these issues with economical methods to reduce labor costs.

The adjustable longline system (ALS), commercially used in Australia, is a combination of the rack and suspension systems. It is designed to suspend bags in the water column from a longline cable supported by numerous posts that have several “riser clips,” suspending the cable
horizontally, and can be adjusted for depth. This allows the oyster bags to be placed at any depth or raised out of the water for aerial treatment to inhibit the growth of fouling organisms. This study will determine the most efficient method of controlling fouling organisms cultured in the ALS by evaluating: 1) growth rates; 2) survival rates; 3) fouling rates.

Methods

At the Louisiana Sea Grant College Program’s Grand Isle Oyster Hatchery (29°12’30”N, 90°02’30”W), a four-line ALS (Fig. 4.1) was used to test four different treatments: weekly aerial drying for 18 hours, a monthly brine dip for 10 minutes followed by 6 hours of aerial drying (Debrosse and Allen, 1993), diurnal exposure, and a control of continuous submersion (i.e. no treatment). The experiment began on July 28, 2004. Forty bags (10 bags per treatment) were deployed each containing 75 single diploid oysters, with a mean shell length of 21.7 mm. Diploid oysters were used due to a temporary lack of availability of 100% triploid oysters at the Grand Isle hatchery. Due to the parasite Haplosporidium nelsoni (MSX) on the East and West coasts, 100% triploid oysters available from other hatcheries cannot be imported to the Gulf of Mexico region.

The oyster bags were hung on two of the four lines available at the Grand Isle study site. The oyster bags exposed at low tide were placed on a separate longline from the other treatment bags to allow them to be adjusted with the tides. The remaining treatment bags were distributed along a second longline, with each treatment located at least twice between pairs of riser post sections. Shell height of 75 oysters from each treatment was measured monthly with Venier calipers (±0.5) to determine the growth rate. Growth and survival were recorded each month when the brine dip treatment was performed. The brine-dipped bags were treated and left to dry while a single bag from each treatment was randomly selected for measurements of growth and mortality. After the oysters reached market-size, significant growth differences were determined
Figure 4.1 Photograph of the experimental ALS in Grand Isle, LA. The two lines on the far right were used in the experiment. All lines were hung on the highest riser clip to show how the bags attach to the longline and the longline attaches to the riser posts.
using ANOVA to determine the most efficient treatment (SAS 9.1 software, SAS Institute Inc. 2003).

At harvest, water displacement was used to determine the amount of fouling organisms culled from three separate oyster bags per treatment. Each bag was opened and the unculled oysters were placed into spouted buckets filled with water. The volume of water displaced from the bucket was recorded, the oysters were then culled, and the cleaned oysters placed in refilled buckets. The volume of the culled oysters was subtracted from the volume of the unculled oysters to determine the volume of the fouling organisms in each bag. The volumes of each treatment were compared to the control and each other using t-tests (SAS 9.1 software, SAS Institute Inc. 2003).

To monitor the amount of fouling exposure to the bags, fouling plates were placed on the longlines with the treatment bags. The fouling plates consist of two ceramic clay tiles placed side-by-side within a PVC frame held together with 150 lb.-test twine and attached to the longline with oyster bag clips (Fig. 4.2). Each side of the plate was treated as one sample, all fouling organism were counted and identified to the genus level. Species that were not identifiable were taken to Dr. John Fleegler at the Louisiana State University Biological Sciences Department for further identification. Ten barnacles, bryozoans, and oysters per sample were randomly measured. Algae were measured as percent coverage.

At first, 5 frames (10 plates, 20 samples) were placed on the longline, one plate for every two sections of longline. After the first month, the number of frames was reduced to three frames (6 plates, 12 samples) to reduce labor. In January 2005, the preliminary fouling data from August to November 2004 was used to determine an appropriate sample size. Using the Poisson distribution equation \( n = \frac{1}{D^2 \bar{x}} \), where \( \bar{x} \) is the mean of the fouling organism and \( D \) is the type II error, a 20% Type II error was used (Elliot 1977; Table 4.1). For each species and
each month, a Z-test was performed to test for differences in the locations of the frames. The results indicated that only three plates were needed for an adequate sample size. The frame was modified to hold three plates side by side in one frame.

Statistical differences in fouling between each month, each season (i.e. season 1, season 2), and each generation of oysters was determined using Poisson distribution and Student’s t-test using SAS 9.1 software (SAS Institute Inc 2003). There were two incidents when fouling plates were lost to hurricanes, the first was in September 2004 where 2 plates of the six were lost during Hurricane Ivan, the second was during Hurricane Katrina when all fouling plates were lost, so the fouling data set ends in July 2005 rather than August.

Results

There was no significant difference between treatments in growth or the average survival. Survival was consistently 80% or greater (Fig. 4.3). A logistic analysis resulted in odds ratios comparing each treatment to the control. The aerial weekly treatment is 4 times more likely to have less mortality than the control, and diurnal exposure is 0.8 times more likely to have less mortality than the control. However, the brine dip treatment is 7 times more likely to have mortalities higher than the control treatment. This could be due to higher mortalities caused by spat fouling crowding the oyster bags.

All four treatments reached market-size (76 mm) within one year (Fig. 4.4). The submerged and weekly aerial drying treatments were not statistically different. However, the diurnal and brine dip treatments were significantly different from all other treatments (Table 4.2). The diurnal exposure treatment had significantly less volume of fouling organisms than the control treatment, but was not significantly different from the brine dip or weekly aerial treatments (Fig. 4.5). There were differences in growth between the months, but not between the treatments in each month. Although the weekly aerial drying treatment did not have statistically
Figure 4.2 Picture of the final frame used to hold the fouling plate on the ALS next to the oyster bags.

Table 4.1 Sample size determination calculations using the results of the first four months of data from 10 fouling plates, using only barnacle counts, and the equation \( n = \frac{1}{D^2 x} \), where \( x \) is the mean of the barnacle counts and \( D \) is the type II error assumed to be 20%. Samples are one side of a plate.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean</th>
<th>Std</th>
<th>Poisson</th>
<th># samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td>5.30</td>
<td>7.14</td>
<td>4.72</td>
<td>5</td>
</tr>
<tr>
<td>September</td>
<td>418.50</td>
<td>229.86</td>
<td>0.06</td>
<td>1</td>
</tr>
<tr>
<td>October</td>
<td>16.67</td>
<td>12.15</td>
<td>1.50</td>
<td>2</td>
</tr>
<tr>
<td>November</td>
<td>4.58</td>
<td>4.70</td>
<td>5.45</td>
<td>6</td>
</tr>
<tr>
<td>Overall</td>
<td>111.26</td>
<td>204.90</td>
<td>0.22</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 4.3 Monthly survival (total number of oysters in one bag per treatment per month) of oysters held in the ALS.
significantly different growth from the control, there were physically noticeable differences in the amount of fouling organisms and the processing time of samples (Fig. 4.6a – 4.6d). Eleven types of fouling organisms were found on the fouling plates, but only four dominant genera consistently occurred throughout the year: barnacles (*Balanus sp.*), bryozoans (*Membranipora sp.*), oysters, and algae (*Enteromorpha sp.*). Other types of organisms found on the plates included tunicate larvae, fish eggs, serpulid worms, polychaetes, isopods, and amphipods (Gosner, 1971; Dawes, 1974). Genera exhibited seasonal variations, but statistically there were no significant differences in the fouling levels of each genera with each month (Fig. 4.7). Barnacles were consistently the dominant fouling organism observed. Barnacles were also the only organisms that had significant different fouling levels in different months; January through May had statistically significant greater barnacle settlement than the fall and summer months. There were no statistically significant differences in the location of the plates on the longline system. This allowed placement of all three of the plates together post sample size determination. There was also no significant difference between the smooth and rippled sides of the plates.

**Discussion**

This study provides data that supports the ALS system as a viable oyster culture method that has increased growth rates and can be easily be managed to deter fouling organisms. The results of this study show regular aerial exposure is more efficient for reducing fouling organisms than using the standard brine dip treatment. While the weekly-aerial-drying treatment had the fastest growth rate, the diurnal exposure treatment required the least amount of labor and had significantly less fouling both visibly and statistically. All of the treatment oysters reached market-size within one year. This is significant because oysters cultured on-bottom require 18 to 24 months to reach market-size (Gulf States Marine Fisheries Commission 1991). Off-bottom
Figure 4.4 The monthly growth rate measured in shell height (mm) of 75 oysters per treatment (±0.5mm) form August 2005 to harvest in August 2006.
Table 4.2  Least square means and confidence intervals for treatment growth

<table>
<thead>
<tr>
<th>Treatment</th>
<th>LS Means</th>
<th>Confidence Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial Weekly</td>
<td>55.66</td>
<td>55.13 - 56.16</td>
</tr>
<tr>
<td>Brine Dip</td>
<td>58.16</td>
<td>57.58 - 57.74</td>
</tr>
<tr>
<td>Control</td>
<td>55.64</td>
<td>55.12 - 56.16</td>
</tr>
<tr>
<td>Diurnal Exposure</td>
<td>52.75</td>
<td>52.23 - 53.27</td>
</tr>
</tbody>
</table>
Figure 4.5 The volume of fouling organisms in oyster bags at harvest measured using water displacement. Letters (a&b) indicate significant differences.
Figure 4.6a Photograph of one bag of each treatment and the oysters that were contained in the bag on July 24, 2005, 1 year post-seeding. A, control; B, brine dip, C, weekly aerial exposure, D, diurnal exposure.
Figure 4.6b Photograph of brine dip bag the oysters that were contained in the bag on July 24, 2005, 1 year after the experiment began.
Figure 4.6c Photograph of aerial exposure bag and the oysters that were contained in the bag on July 24, 2005, 1 year after the experiment began.
Figure 4.6d Photograph of diurnal exposure bag and the oysters that were contained in the bag on July 24, 2005, 1 year after the experiment began.
Figure 4.7 The monthly fouling percent coverage for the dominant species found on the fouling plates held along side the ALS. Algae was measured in percent coverage from August 2005 to July 2006.
culture with timely aerial drying can produce a single oyster with less fouling to be culled post-harvest. This system increases growth rate while decreasing labor, therefore being more efficient than on-bottom culture.

The survival of extensively cultured oysters is low; oysters cultured on-bottom are not only susceptible to disease but also to predation. On-bottom culture survival ranges from 20 to 60% (Gulf States Marine Fisheries Commission 1991). All the treatments had average survival for the year of ≥ 80%. This is a significant increase in survival where even the control had an 84% average survival for the year.

The diurnal exposure treatment significantly reduced the amount of fouling organisms on the harvested oysters as well as requiring the least amount of labor. It also produced mostly single oysters, whereas the brine-dip and no treatment (control) produced more clustered oysters. Single oysters have a higher value because they can be sold more easily for the half-shell market. Using diurnal exposure and the ALS off-bottom culture technique, a Louisiana oyster farmer can improve oyster production for half-shell sales, but it would also require a large initial investment.

Barnacle settlement and growth is more of a concern for fouling the ALS because barnacles exhibit 3-dimensional growth and can occlude mesh openings more rapidly that other organisms causing lower survival.

As triploid oysters become available in the Gulf region, the added investment into seed may justify the additional investment in off-bottom culture techniques. The ALS is the only off-bottom culture technique that can allow the system to be air-dried easily. Other techniques, such as tray culture, require the containers either to be moved or to be kept in areas where they are exposed at low tide. Trays are also susceptible to storms and surges (Michael and Chew, 1976). The experimental ALS used in this study survived at least a four-meter storm surge during Hurricane Katrina. Experimental Taylor floats that were deployed along side the ALS with a
hurricane rope securing them into place broke free with the storm surge and the oysters inside were lost. Therefore the ALS system is not only easier to treat for fouling organisms than other off-bottom culture techniques; it is also less susceptible to storms, minor or major. The next step in this study is to determine if the ALS can economically produce triploid oysters on a commercial scale using regular aerial exposures for controlling fouling organisms.

References


Chapter 5

Economic Analysis of Off-Bottom Oyster Culture Using the Australian Adjustable Longline System for Triploid Eastern Oyster, *Crassostrea virginica*, Culture in Louisiana

Off-bottom culture can occur in areas where on-bottom culture is limited by predators, increasing production areas that can be used for oyster culture. Growth rates are increased when oyster are held off-bottom because of being closer to the food source in the photic zone. However, organisms such as barnacles, bryozoans, and oyster spat will foul oysters in both on-bottom and off-bottom culture techniques, slowing the growth rate by competing for food and creating a less desirable market oyster (Supan 1983; Adams et al. 1989). The problem of fouling can be treated in off-bottom culture. There have been several methods investigated for treating fouling organisms in oyster culture, including brine baths, hydrated lime baths, pressure washing, and changing oyster bags (Rikard et al., 1997).

The floating chub ladder is one off-bottom culture technique that has been used in the U.S. to attempt to increase oyster production, but this system has difficulties in controlling fouling organisms, which led to higher mortalities and reduced growth (Kemp and Evans, 1994). The ALS is a design of off-bottom culture where numerous posts have several riser clips attached to allow adjustment of a longline of culture bags at different water depths. Adjustable depth allows the bags to be easily moved out of the water for aerial treatment to inhibit the growth of fouling organisms. However, off-bottom culture is an additional investment added to utilizing polyploidy technology. There is also no data on if there is a market preference for triploid Eastern oysters. This study will target the half-shell market during the spawning season when diploid oysters have poor meat condition. The goal is to determine the various costs involved in an ALS enterprise and identify the costs that can be reduced to lower the break-even price.
Methods

This analysis is based on the production of 100-count boxes of oysters produced by 0.40 hectare (1 acre) of the ALS to be sold specifically for the half-shell market during the summer months when oyster meat yields of diploid oysters are low. Capital costs are based on the purchasing and assembly of 0.40 hectare of the system imported from suppliers in Australia and Canada. The capital funding costs are assumed to be paid for by the standard operating loans issued by the Farm Service Agency (fide Martin Fontenot, Farm Service Agency) (Table 5.1). Fixed costs included loan principle and interest costs, and a 10% depreciation of all physical equipment (Table 5.2).

Operating costs are based on maintaining a four-line (each line 51.82 meters long) system at the Louisiana Sea Grant Oyster Hatchery in Grand Isle, LA (29°12′30″N, 90°02′30″W). This system was used to determine the cost and labor associated with seeding, maintenance, and harvesting. From this small system, we were able to determine that it takes 10 – 12 months for diploid seed oysters to reach market-size. Seed costs were based on the price of triploid Pacific oyster seed produced on the U.S. West coast. Labor hours to deploy seed and harvest were based on information provided by BST Oyster Supplies P/L (fide Ashley Turner, BST Oyster Supplies P/L 2007). Post harvest equipment, including a shed for bag storage and a pressure washer for cleaning the bags, were based on prices from local hardware stores such as Home Depot. The results from operating the four-line system were extrapolated to determine the costs for operating 0.40 hectare. Cost of labor and fuel are based on current fuel prices and wages paid to deck hands on oyster vessels. From this, four scenarios have been developed based on the following assumptions. Sensitivity analysis of loan interest rates, stocking densities, and mortality were then developed to compare the scenarios break-even prices to the current price of a 100-count box of oysters at $13 - $18 (fide Al Sunseri, P&J Oysters Co.; fide Kevin Voisin, Motivatit
Table 5.1  Capital cost for purchasing and installing 0.4 hectare (1 acre) of the Adjustable Longline System in Grand Isle, LA, importing the equipment from Canada and Australia.

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Purchases*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASL: bags (rolls of mesh)</td>
<td>13</td>
<td>273.17</td>
<td>$3,551.21</td>
</tr>
<tr>
<td>bag clips</td>
<td>3000</td>
<td>0.42</td>
<td>$1,260.00</td>
</tr>
<tr>
<td>end caps</td>
<td>3036</td>
<td>1.42</td>
<td>$4,311.12</td>
</tr>
<tr>
<td>riser clips</td>
<td>4000</td>
<td>0.4</td>
<td>$1,600.00</td>
</tr>
<tr>
<td>cable</td>
<td>4</td>
<td>510</td>
<td>$2,040.00</td>
</tr>
<tr>
<td>sheath</td>
<td>4</td>
<td>178.5</td>
<td>$714.00</td>
</tr>
<tr>
<td>reflective tape</td>
<td>44.5</td>
<td>38.40-49.75</td>
<td>$513.20</td>
</tr>
<tr>
<td>Riser posts</td>
<td>495</td>
<td>20</td>
<td>$9,900.00</td>
</tr>
<tr>
<td>Pilings</td>
<td>10</td>
<td>34.75</td>
<td>$347.50</td>
</tr>
<tr>
<td>Shipping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bags, cable, clips (Australia)</td>
<td></td>
<td></td>
<td>$3,000.00</td>
</tr>
<tr>
<td>riser posts (Canada)</td>
<td></td>
<td></td>
<td>$2,600.00</td>
</tr>
<tr>
<td>Construction &amp; Installation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seasonal labor (hrs)</td>
<td>12.5</td>
<td>100</td>
<td>$1,250.00</td>
</tr>
<tr>
<td>Supplies: nails, hammer, knives, saw</td>
<td></td>
<td></td>
<td>$500.00</td>
</tr>
<tr>
<td>Installation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor (hrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seasonal labor</td>
<td>2</td>
<td>100</td>
<td>$200.00</td>
</tr>
<tr>
<td>Supplies: winch, wire grip, pile driver</td>
<td></td>
<td></td>
<td>$300.00</td>
</tr>
<tr>
<td>Rental: hand jet</td>
<td></td>
<td></td>
<td>$100.00</td>
</tr>
<tr>
<td>Other capital equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smaller service boat</td>
<td>1</td>
<td></td>
<td>$8,000.00</td>
</tr>
<tr>
<td>Walking float</td>
<td>1</td>
<td></td>
<td>$100.00</td>
</tr>
<tr>
<td>Storage shed</td>
<td>1</td>
<td></td>
<td>$250.00</td>
</tr>
<tr>
<td>Pressure washer</td>
<td>1</td>
<td></td>
<td>$400.00</td>
</tr>
<tr>
<td>Permits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal use permit</td>
<td></td>
<td></td>
<td>$100.00</td>
</tr>
<tr>
<td>Class D state lands permit</td>
<td></td>
<td></td>
<td>$10.00</td>
</tr>
<tr>
<td>USACE section 10 permit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>$41,047.03</td>
</tr>
</tbody>
</table>
Table 5.2  Fixed costs of owning and operating 0.4 hectare of the Adjustable Longline System with a $75,000 loan and 5.125% interest rate based on Farm Service Agency information.

<table>
<thead>
<tr>
<th>Item</th>
<th>Total costs</th>
<th>Annual costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation (10% annually)</td>
<td>$33,787.03</td>
<td>$3,378.70</td>
</tr>
<tr>
<td>Principle</td>
<td>$75,000</td>
<td>$9,143.00</td>
</tr>
<tr>
<td>Loan Interest</td>
<td>5.125%</td>
<td>$3,289.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$15,810.70</strong></td>
<td></td>
</tr>
</tbody>
</table>
Seafood, Inc., 2007). The loan interest rates were based first on the 5.125% interest rate currently used by the FSA, and 6%, and 7% as conservative rates. The stocking densities were based on a 50, 75, and 100 seed per bag, assuming that enough seed is available. The mortality rates were based on the results of preliminary studies conducted at the Louisiana Sea Grant Oyster Hatchery: 75% a conservative estimate, 80% the lowest survival rate, and 90%, which was closer to the average survival seen in preliminary studies.

**Assumptions**

This analysis was based on the following assumptions:

1) $75,000 operating loan is available from Farm Service Agency;

2) The loan will be repaid in 7 years;

3) Triploid oyster seed is available at $40 per thousand;

4) The 0.40-hectare system is 3.7 km from the dock;

5) Diesel fuel cost are $12.56/hr from dock to the system (3.7 km), based on oyster vessel fuel efficiencies (Horst 1987);

6) Vessel opportunity costs of $600/day based on the lost opportunity of not harvesting traditionally grown oysters for market;

7) Labor costs of $100/day/person, based on standard Louisiana deckhand labor rate;

8) 10% depreciation of all equipment;

9) Each culture bag is stocked with 75 single seed oysters by volume;

10) Seeding starts early May and harvesting begins one year later;

11) 0.40-hectare of the system holds 1,500 bags;

12) 100 count boxes cost $1.40 each (J&M Industries 2007);

13) Prices are free on board (FOB) dockside.
Scenario 1

This scenario includes receiving one large shipment of seed and: a) seeding the system in one week; b) a fouling maintenance regime of weekly aerial drying; and, c) one-week of harvest one year post-seeding (Table 5.3).

Scenario 2

This scenario includes receiving one large shipment of seed and: a) seeding the system in one week; b) a fouling maintenance regime of diurnal exposure; and, c) a one-week of harvest one year post-seeding (Table 5.4).

Scenario 3

This scenario includes receiving several small shipments of seed and: a) seeding one longline each week for ten weeks’ b) a fouling maintenance regime of weekly drying; and, c) one line harvest each week after one year post-seeding (Table 5.5).

Scenario 4

This scenario includes receiving several small shipments of seed and: a) seeding one line each week for ten weeks; b) a fouling maintenance regime of diurnal exposure and, c) one line harvest each week after one year post-seeding (Table 5.6).

Results

There are several costs associated with off-bottom oyster culture. The investment costs are estimated to $41,047 (Table 5.1). The fixed costs ranged from $16,064 - $16,873 annually depending on the interest rate (Table 5.2). With a stocking density of 75 oysters per culture bag and an 80% survival, the sensitivity analysis on interest rates resulted in break-even prices between $30.09 and $41.97, with the diurnal exposure scenarios having the lower break-even
Table 5.3  Operating costs of Scenario 1: weekly aerial drying, one harvest and seeding, harvested on the same days as maintenance.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel fuel</td>
<td>106 trips</td>
<td>$12.56</td>
<td>$2,662.72</td>
</tr>
<tr>
<td>Oyster seed</td>
<td>112500</td>
<td>$40 per 1000</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seeding</td>
<td>2</td>
<td>$100/day</td>
<td>$200.00</td>
</tr>
<tr>
<td>maintenance - aerial drying</td>
<td>104</td>
<td>$100/day</td>
<td>$10,400.00</td>
</tr>
<tr>
<td>harvest</td>
<td>0</td>
<td>$100/day</td>
<td>$0.00</td>
</tr>
<tr>
<td>bag washing (6 bags/hr)</td>
<td>250</td>
<td>$6.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Boxes</td>
<td>900</td>
<td>$1.40</td>
<td>$1,260.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>$20,522.72</strong></td>
</tr>
</tbody>
</table>

Table 5.4  Operating costs of Scenario 2: diurnal exposure, one harvest and seeding.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel fuel</td>
<td>30 trips</td>
<td>$12.56</td>
<td>$753.60</td>
</tr>
<tr>
<td>Oyster seed</td>
<td>112500</td>
<td>$40 per 1000</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seeding</td>
<td>2</td>
<td>$100.00</td>
<td>$200.00</td>
</tr>
<tr>
<td>maintenance</td>
<td>26</td>
<td>$100.00</td>
<td>$2,600.00</td>
</tr>
<tr>
<td>harvest</td>
<td>2</td>
<td>$100.00</td>
<td>$200.00</td>
</tr>
<tr>
<td>bag washing (6 bags/hour)</td>
<td>250</td>
<td>$6.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Boxes</td>
<td>900</td>
<td>$1.40</td>
<td>$1,260.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>$11,013.60</strong></td>
</tr>
</tbody>
</table>

Table 5.5  Operating costs of Scenario 3: weekly exposure, multiple seeding and harvesting during weekly maintenance.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel fuel</td>
<td>109 trips</td>
<td>$12.56</td>
<td>$2,738.08</td>
</tr>
<tr>
<td>Oyster seed</td>
<td>112500</td>
<td>$40 per 1000</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seeding</td>
<td>5</td>
<td>$100.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>maintenance</td>
<td>104</td>
<td>$100.00</td>
<td>$10,400.00</td>
</tr>
<tr>
<td>harvest</td>
<td>0</td>
<td>$100.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>bag washing (6 bags/hr)</td>
<td>250</td>
<td>$6.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Boxes</td>
<td>900</td>
<td>$1.40</td>
<td>$1,260.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>$20,898.08</strong></td>
</tr>
</tbody>
</table>
Table 5.6  Operating costs of Scenario 4: diurnal exposure, multiple seeding and harvesting once a week for 10 weeks.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel fuel</td>
<td>39 trips</td>
<td>$12.56</td>
<td>$979.68</td>
</tr>
<tr>
<td>Oyster seed</td>
<td>112500</td>
<td>$40 per 1000</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seeding</td>
<td>5</td>
<td>$100.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>maintenance</td>
<td>26</td>
<td>$100.00</td>
<td>$2,600.00</td>
</tr>
<tr>
<td>harvest</td>
<td>8</td>
<td>$100.00</td>
<td>$800.00</td>
</tr>
<tr>
<td>bag washing (6 bags/hr)</td>
<td>250</td>
<td>$6.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Boxes</td>
<td>900</td>
<td>$1.40</td>
<td>$1,260.00</td>
</tr>
</tbody>
</table>

$12,139.68
prices than the weekly exposure scenarios (Table 5.7). With an interest rate of 5.125% and an 80% survival, the sensitivity analysis on stocking densities resulted in break-even prices between $24.16 and $58.48, again the diurnal exposure scenarios had lower prices than the weekly exposure (Table 5.8). The survival sensitivity analysis based on a 5.125% interest rate and 75 oysters per culture bag had break-even prices between $26.91 and $43.31, again the diurnal exposure scenarios having the lower break-even prices than the weekly exposure scenarios (Table 5.9).

**Discussion and Conclusion**

Currently (2007), 100-count boxes of half-shell oysters sell between $13 and $18 (fide Al Sunseri, P&J Oysters Co.; fide Kevin Voisin, Motivatit Seafood, Inc.). The break-even prices for the various scenarios show that using diurnal exposure for fouling control costs less. Therefore, an oyster farmer may sell 100-count boxes of triploid oysters using the ALS at a price close to the 2007 price of diploid 100-count boxes. Based on the sensitivity analysis, the best way to produce triploid oysters using the ALS, assuming one can obtain an FSA loan at 5.125-fixed APR, is to stock each bag with 100 oysters, use diurnal exposure for fouling control, and achieve ≥ 80% survival. This situation had annual operating costs of $12,934 per 0.4 hectares and a break-even price of $24.16 per 100-count box. There was little difference in the costs of doing a single seeding or multiple seeding; there was only approximately $1,000 difference between stocking and harvesting once verses multiple harvests. These costs will be greatly dependent on the availability of seed. Multiple seeding and harvesting increases trips to the culture site, but also allows the operator to regularly check on the system.

The benefits to using the weekly exposure treatment is physical presence near the system, allowing for added security as well as to allow the operator to conduct any maintenance on the system, such as any necessary clip replacement, or removing flotsam caught on the system.
Table 5.7  Sensitivity analysis on interest rates, assuming 75 oysters per culture bag and a 80% survival rate.

<table>
<thead>
<tr>
<th>Interest Rate (% fixed APR)</th>
<th>Fixed costs</th>
<th>Scenario</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.125%</td>
<td>$16,604</td>
<td>1</td>
<td>$40.65</td>
</tr>
<tr>
<td>6%</td>
<td>$16,436</td>
<td>2</td>
<td>$30.09</td>
</tr>
<tr>
<td>7%</td>
<td>$16,873</td>
<td>3</td>
<td>$41.07</td>
</tr>
<tr>
<td>Break-even price</td>
<td></td>
<td>4</td>
<td>$31.34</td>
</tr>
</tbody>
</table>

Table 5.8  Sensitivity analysis on stocking density, assuming 80% survival and a 5.125% fixed APR operating loan from FSA.

<table>
<thead>
<tr>
<th>Stocking (oysters/bag)</th>
<th>Scenario</th>
<th>Price (100 count box)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1</td>
<td>$58.48</td>
</tr>
<tr>
<td>75</td>
<td>2</td>
<td>$41.93</td>
</tr>
<tr>
<td>100</td>
<td>3</td>
<td>$58.40</td>
</tr>
<tr>
<td>Production (100 count box)</td>
<td>Break-even price</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.9  Sensitivity analysis on survival, assuming 75 oysters per culture bag and a 5.125% fixed APR operating loan from FSA.

<table>
<thead>
<tr>
<th>Survival (Market Size)</th>
<th>Scenario</th>
<th>Price (100 count box)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>1</td>
<td>$43.31</td>
</tr>
<tr>
<td>80%</td>
<td>2</td>
<td>$32.03</td>
</tr>
<tr>
<td>90%</td>
<td>3</td>
<td>$45.21</td>
</tr>
<tr>
<td>Production (100 count box)</td>
<td>Break-even price</td>
<td>4</td>
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</tbody>
</table>
There are benefits to this extra cost, but it will need to be determined if a higher quality oyster in using the ALS. The capital costs can be reduced by obtaining the materials for the system domestically or using less expensive materials. For example, the riser posts made of recycled plastic imported from Canada totaled $12,500. Purchasing saltwater emersion-treated wooden riser posts from a local lumber store and delivered to Grand Isle would cost approximately $5,000. Fast growth with thinner shells and high meat yields are characteristic of off-bottom oyster culture in Louisiana based on preliminary studies. Therefore, it is advantageous to sell such oysters by the count rather than by volume. The 0.4 hectare of the ALS is capable of producing 600 – 1200 100-count boxes of oysters, depending on stocking density and mortality based on the preliminary studies. According to the industry interviews, a restaurant that specializes in oysters, such as Drago’s in Metairie, LA, will use approximately 375 boxes a week (fide Al Sunseri P&J Oyster Co.). Therefore, 0.40 hectare of the ALS will only be able to produce enough to supply one restaurant for one approximately one month.

This evaluation of ALS and triploid oyster culture does not suggest replacing existing traditional Louisiana oyster culture, but as a means of supplementing the industry. This proposal suggests producing high quality meat yield during the times that traditional Louisiana oyster culture results in low meat yields. It may not be economically feasible to raise diploid oysters in this system or to harvest triploid oysters year-round because there is still an abundance of oysters produced naturally. Should natural production decline, off-bottom culture might become a commercially viable alternative as it has on the U.S. West Coast (Anon. 1990).

References


Fontenot, Martin (Farm Loan Manager, Farm Services Agency, Addis, LA). Phone conversation January 2007.


Sunseri, Alfred (President of the P&J Oyster Co.). Phone conversation, March 2007.


Turner, Ashley (CEO/Director; BST Oyster Supplies P/L). E-mail communications. February 2007.

Voisin, Kevin (Sales Manager, Motivatit Seafood, Inc.). Phone conversation, March 2007.
Chapter 6

An Operational Plan for an Adjustable Longline System in a Nearshore Aquaculture Park

Under the National Shellfish Sanitation Program Model Ordinance IV 2003, all aquaculture operations are required to develop an operational plan. The operational plan includes a description of the system design, activities, location, and identification of structures such as rafts, pilings, and floats. In addition to the descriptions, an operational plan is required to have procedures and programs for addressing poisonous substances, sanitation, maintenance, supervision, stocking, harvesting, and processing. Microbial water quality analysis and record keeping are also requirements of an operational plan by the state shellfish control authority (SSCA). In Louisiana, the SSCA is the Louisiana Department of Health and Hospitals.

The Adjustable Longline System (ALS) is an off-bottom oyster culture system that is commercially successful in Australia. This system is designed to work in shallow water areas similar to that in the Gulf Region, to allow for control of biofouling organisms by diurnal exposure. The oysters survive the small intervals of exposure while organism such as barnacles and bryozoans do not. In preliminary studies at the Louisiana Sea Grant Oyster Hatchery on Grand Isle, LA, oysters cultured using the longline system and a diurnal exposure reached market-size in one year.

Aquaculture parks can facilitate research and the development of culture techniques to increase production (Fridley, 1992; Nash, 1995). A nearshore aquaculture park would allow researchers and entrepreneurs to test new technologies and methods to determine the benefit to commercial application, while reducing user conflicts with fisheries, shipping and navigation, and recreation. Proper sitting of a park will allow any potential user conflicts to be addressed before the park is developed. Aquaculture and fisheries are constantly in conflict over resources such as fish and water. Designating specific areas for aquaculture can reduce some of these user
conflicts and create an area for aquaculture to help subsidize fisheries and bring economic development to the local community.

Similar to an industrial park, a public aquaculture park would be zoned for certain activities with exclusive use of public water column and water bottoms for mariculture. This is a different concept for such a venture, as many aquaculture facilities in the Gulf of Mexico states are located on private land and water bottoms. Industrial parks are areas where resources, such as land, are used for certain enterprise activities (La. R.S. § 33.130.51). An aquaculture park allows one or multiple individuals to conduct mariculture using similar resources and infrastructure. Following the industrial park model, an aquaculture park would delineate an area of coastal waters for allocation of mariculture activities, in essence, zoning an area of the coast for aquaculture activities.

In the aquaculture park, triploid Eastern oysters will be cultured using off-bottom culture techniques. The preliminary method will be to use the ALS to determine if off-bottom aquaculture of triploid oysters is an economically feasible in Louisiana. This park will determine if the added investment in intensive culture techniques can benefit the Louisiana oyster industry. The Grand Isle Port Commission will administer the aquaculture park, while the system operator, a commercial oysterman, will maintain the ALS with Sea Grant personnel. The Louisiana Sea Grant Oyster Hatchery on Grand Isle, LA will supply the oyster seed. All sources of seed used for aquaculture in Louisiana waters shall be sanctioned by the state shellfish control authority.

**System Design**

The Adjustable Longline system is comprised of three main components: the poles, the cables, and the bags (Figure 6.1). Each grid comprise three pairs of pilings (15 cm diameter, 3 m long) separated 91 m apart, with riser posts (10 cm x 10 cm x 3 m) at 3 m intervals. Each is jetted into the water bottom 2 m deep. The opposite end of each riser post will have seven
plastic riser clips nailed to the same post side with reflective material (Figure 6.2). The specialized 10.5 mm diameter longline cable is covered in a sheath that protects the cable from chafing. The specialized oyster culture bags are designed to hang horizontally from the cable from a pair of specialized clips, called duck clips.

**Permit Requirements**

In order to deploy this system, the appropriate permits must be obtained. There are four permits required in the State of Louisiana: 1) Coastal Use Permit from Louisiana Dept. of Natural Resources, 2) Class D submerged lands lease form State Lands Office, 3) Section 10 of the Rivers and Harbors Act permit form the U.S. Corps of Engineers, and 4) Mariculture permit from Dept. of Wildlife and Fisheries. Because the ALS is for bivalve culture, no feed will be added and, therefore, no Water Quality Certification is required from the Dept. of Environmental Quality. This is a stipulation that will be held for any organisms culture in the park. Any person who performs open water aquaculture or operates an aquaculture facility to raise shellfish for human consumption shall obtain:

1) a permit from the Authority for the activity or for construction and functioning of his facility;
2) a harvester’s license; and 3) certification as a dealer, where necessary.

**Site Selection**

This system has a few requirements when it comes to the area that it can be deployed. All off-bottom molluscan shellfish culture systems should be placed in approved shellfish growing waters, classified by the SSCA, to allow direct harvest to market. For the ALS, placement in an area where there is enough tidal influence for daily diurnal exposure will help it achieve full potential. The system can be operated by walking the lines or by boat, so the substrate may not have to be hard if operating by boat. The site selected for the Grand Isle Aquaculture Park (Figure 6.3 and Figure 6.4) has been chosen because it has the right substrate,
**Figure 6.1** ALS Schematic

**Figure 6.2** Riser posts with riser clips, and reflective tape.
the right tidal influences, is in approved shellfish growing waters, and has limited user conflicts with local fishermen.

System Operation

The first step in the installation is to jet pilings into the water bottom 30 days prior to deploying additional components. The longline cable is then attached at one end to a piling by wrapping the cable around the piling with a special knot. The opposite end of the longline is attached to a winch and tighten until taunt, but with enough flexibility to adjust for depth. This end is then attached to the opposite piling and tied in the same manner. The rizer poles are then jetted into the sediment using a 9 ft long sliding spacer. The longline bags have to be assembled from their parts, but once assembled they are ready for immediate deployment (Figure 6.5a-6.5c). The system is passive (i.e. no pumping or filtration), meaning that once in the water nothing is required except for occasional maintenance of the system components. The system is designed to be able to move the oyster bags out of the water for aerial exposure to reduce fouling organisms.

Sanitation, Maintenance, and Supervision

Because the ALS is a passive system there is no means of controlling water quality other than site selection. Therefore, the ALS needs to be sited in areas that are classified as approved shellfish growing waters by the SSCA, which monitors monthly water quality. In the event the area is placed in closed status, conditionally approved status, or restricted status, any shellfish raised in aquaculture shall be subjected to depuration or relaying prior to direct marketing. The ALS will also be maintained to prevent fouling or the culture oysters and the oyster bags by routine aerial drying, which will allow the system operator to observe the system for any indications of maintenance requirements, such as broken riser or bag clips, chaffing lines, or debris/flotsam caught on the longlines.
Figure 6.3  Site map of Caminada Bay in Grand Isle, LA.
Figure 6.4 Certified plat of the proposed Aquaculture Park site.
Figure 6.5a The ALS is a series of cylindrical mesh bags suspended horizontally on a longline.

Figure 6.5b Special bag suspension clips enable interchanging between sub-tidal and inter-tidal methods using riser posts with clips to suspend the longline at various heights.

Figure 6.5c The longline is anchored on both ends to pilings and can contour the shape of shorelines in shallow water areas.
Stocking, Harvesting, and Processing

The bags will be stocked with 75 to 100 triploid oysters produced at a hatchery, with a shell height of approximately 25 mm, for attachment to the longlines. The longlines will be adjusted approximately twice per month to allow for diurnal exposure, raising or lowering according to tide tables. The system operator, who has the appropriate harvest and dealer licenses, will handle the harvest and maintenance of the system. The oysters will remain on the longline system for 10 months or longer depending on when they reach market-size. Nursery products or shellstock seed must be subjected to a minimum of six-month growing time prior to harvest for human consumption. Records of deployment and harvest dates will be kept. At harvest, the bags will be removed from the longlines and taken to shore where the oysters will be cleaned, culled, graded, placed in 100-count boxes, and put into cold storage before sale. The oysters harvested from the longlines will be handled the same as oysters harvested from wild stocks.

Records

The system operator will be required to maintain records of the system location and operation including the species culture, the source of seed, the production levels and the water quality data.

Summary

Off-bottom oyster culture is commonly practice on the West Coast of the U.S. (Anon. 1990). The ALS is not intended to replace the existing oysters industry, but to develop new technologies to increase production and provide a premium oyster. With an oyster hatchery providing triploid seed and proper maintenance of the ALS, high meat yield oysters will reach market-size in ten to twelve months. This is half the time to it normally takes for oysters to reach market-size when cultured on-bottom. Other advantages of off-bottom culture is that survivals
range from 80% to 96%, and because the bags are held off-bottom they are less likely to be buried in sediment by storm surges. Another advantage is that there is less movement of seed; once the system is deployed it does not need to be moved from one location to another. However, it does have different maintenance requirements (e.g., routine aerial exposure and replacement of duck and riser clips. With experience, this system will be able to produce high meat yield oysters during months when traditionally meat yields are poor.

References


Chapter 7

Summary and Conclusions

The overall goal of this dissertation was to develop a framework for permitting and operating the Adjustable Longline System (ALS) for triploid oyster culture. Specifically, this dissertation has: 1) provided the first documented review of mariculture policy for aquaculture parks an off-bottom oyster culture in the Gulf of Mexico States; 2) provided data on growth, survival, and fouling control on using the ALS; 3) developed an enterprise budget for commercial production of triploid oyster culture using the ALS; and, 4) developed an operational plan for culturing triploid oysters using the ALS based on the guidelines of the National Shellfish Sanitation Program.

Review of existing aquaculture parks show that they play an important role in economic development, but that no public aquaculture parks exist solely in the water. The high-density clam leases in Florida are the closest example of how a nearshore aquaculture park could be established and managed. These leases are part of a retraining program that successfully trained displaced gill-net fishermen to be clam farmers when gill nets were banned in 1995 (Adams et al. 2003). The result of this dissertation shows that there are many differences in the policies among the Gulf of Mexico States; each state manages aquaculture differently. Some states, such as Florida and Mississippi, manage mariculture as agriculture. Other states, such as Louisiana, Texas, and Alabama, manage mariculture as part of the fisheries. The states that manage mariculture as a fishery have less developed programs. There are no clearly defined permitting processes that are consistent through out the U.S. (Marine Aquaculture Taskforce 2007). This leads to confusion among Federal and state agencies as to how to proceed when developing programs or addressing permits applications (Chapter 3). In countries such as Japan and Australia, off-bottom culture is common practice (Murai 1992, O'Sullivan 1993). They manage
aquaculture differently in permitting and liability issues. Aquaculture is a planned use of public 
waters and user conflicts with navigation and recreation are managed to allow for commercial 
scale aquaculture. A public aquaculture park is a step in creating a format for the development 
of aquaculture in the coastal zone as well as a means of developing a mariculture permitting 
program.

All of the Gulf of Mexico states have oyster production, although Louisiana is the leading 
producer of oysters in the nation (Gulf Marine Fisheries Commission 1991). Therefore, off-
bottom oyster culture is a logical step in developing mariculture permits because the 
infrastructure for the industry already exists. This reduces some confusion by having a 
supporting industry looking for development. Off-bottom oyster culture has already been 
developed on the East and West coasts of the U.S. Therefore, a logical step is for it to develop in 
the Gulf of Mexico. However, there are different issues in the Gulf of Mexico that are not issues 
on the other coasts. On the East and West coasts, lack of production due to disease and predation 
are reasons that the industries developed hatcheries and new technologies. In the Gulf of 
Mexico, especially Louisiana, the natural production of oysters is abundant during most years for 
there to be a need for hatcheries to produce oyster seed unless that oyster seed is genetically 
improved, such as being disease resistant or polyploid.

One common issue with all mariculture systems is fouling control; this dissertation shows 
that fouling can be reduced by routine aerial exposure (Chapter 4). The ALS is specifically 
designed to allow for aerial exposure, and has shown that oysters can grow to market size in ten 
to twelve months with survivals between 80% and 96%, for diploid oysters. This an 
improvement over the traditional on-bottom leases which take 18 to 24 months to reach market 
size with survivals of 50% of less (Gulf States Marine Fisheries Commission 1991). The 
traditional method of oyster culture is also labor-intensive involving movement of oysters from
seed grounds to private leases and then from one private lease to another to improve growth (Korringa 1976). Because of this movement of the oysters, it is difficult to quantify production in terms of yield per acres of leases. These on-bottom leases are also susceptible to predation and damage from storms or mineral lease activities. The ALS survived Hurricane Katrina and, if properly sited, can be placed in areas that will not be impacted by oil & gas activities.

Improved growth and survival during off-bottom culture can be used to increase oyster productions, but there are the added costs of the system and the seed. Because wild seed is readily available on public seeding grounds for extensive culture, paying for hatchery-base seed is a premium. This increased cost can be offset by producing a higher quality organism or having a product in demand when the supply is low. Producing triploid oysters in the months from June to October would provide an oyster with a high-quality meat yield when common oyster meat yield is poor. This dissertation shows that depending on fouling control maintenance, stocking densities, survivals and loan interest rates that the ALS can produce 100-count boxes for $22.76 to $57.00 before freight costs are added. This can be altered by reducing the initial investments costs. Shipping the equipment from Canada and Australia cost $5,600 and could be reduced by finding domestic products to replace some of the imported products. Costs can also be reduced by using less expensive materials, such as replacing the recycled plastic riser posts with pine that is treated for salt water. While it may not be as environmental friendly, it will help to reduce the initial investment costs (Chapter 5). The enterprise budget developed in this dissertation can be used for those entering the aquaculture park to use the ALS. This dissertation has developed an Excel program that can be used for entering costs, stocking densities, survival rate, and loan interest rates to determine the break-even price that farmers could expect for selling their product.
While the enterprise budget allows the operator to determine the break-even prices, the operational plan will inform the operator what is required to actually install and operate the system (Chapter 6). This dissertation has produced an operation plan designed for someone in the industry to use the ALS to produce triploid oysters to market size from seed purchased from a hatchery. Due to MSX found on the East and West coasts of the U.S., seed cannot be imported. Therefore, it is necessary for there to be a hatchery in the Gulf of Mexico if triploid oyster seed are desired.

This dissertation was an effort to compile all the information necessary to permit, install, operate, and market triploid oysters cultured off-bottom using a nearshore aquaculture park. However, there are still several aspects that need further investigation. This information has been based on preliminary data, due to permitting delays and the destruction caused by Hurricane Katrina. There is still data to be collected when the aquaculture park is permitted and the 0.40 hectares of the ALS is installed. This includes a market survey, research on the effects of stocking density on the growth and survival rates of the oysters, insurance for the system and the crop, and any aspects that become issues once there is equipment in the water. There is still much to be learned as the aquaculture park is established and progress allows research into areas such as baitfish warehousing or other organisms that can be cultured while staying within the approved stipulations of the aquaculture park.

References


## Appendix A
### Presentations and Abstracts

Conference presentations and abstracts based on the research presented in this dissertation.

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Conference</th>
<th>Location</th>
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<tbody>
<tr>
<td>2005</td>
<td>Sustainable Community Development Through an Inshore Aquaculture Park: A Viable and Responsible Use of the Public Trust.</td>
<td>Louisiana Chapter of the American Fisheries Society</td>
<td>Baton Rouge, Louisiana</td>
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<td>Permitting and Policy of an Aquaculture Park in the Coastal Louisiana.</td>
<td>Coastal Zone '05: Balancing on the Edge</td>
<td>New Orleans, Louisiana</td>
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<td>2005</td>
<td>Aquaculture Parks in the Coastal Zone: A Review of Legal and Policy Issues in the Gulf of Mexico State Waters</td>
<td>Louisiana Chapter of the American Fisheries Society</td>
<td>Natchez, Mississippi</td>
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<tr>
<td>2007</td>
<td>Louisiana State University Oyster Research</td>
<td>Grand Isle High School Oyster Week</td>
<td>Grand Isle, Louisiana</td>
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¹Award received for Best Student Presentation from the United States Chapter of the World Aquaculture Society.
# Appendix B
## Published Papers
Published papers and manuscripts in preparation based on the research presented in this dissertation.

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<th>Journal</th>
<th>Status</th>
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<td>1</td>
<td>Aquaculture Parks in the Coastal Zone: A Review of Legal and Policy Issues in the Gulf of Mexico State Waters</td>
<td><em>Coastal Management Journal</em></td>
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<tr>
<td>2</td>
<td>Biofouling Control in Off-bottom Longline Culture of the Eastern Oyster, (Crassostrea virginica)</td>
<td><em>Journal of World Aquaculture Society</em></td>
<td>In review</td>
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# Appendix C  
Scientific Nomenclature

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<th>Scientific name</th>
<th>Kingdom</th>
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<th>Class</th>
<th>Order</th>
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<th>Common name</th>
<th>Other names</th>
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<td>Bivalvia</td>
<td>Ostreida</td>
<td>Ostereida</td>
<td>Eastern oyster</td>
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<td>Ulotrichales</td>
<td>Ulvaceae</td>
<td>Green algae</td>
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Appendix D
List of Acronyms

ADEM – Alabama Department of Environmental Management
CUP – Coastal Use Permit
DOA – (Florida Agriculture and Consumer Services) Division of Aquaculture
FAO – Food and Agriculture Organization of the United Nations
EPA – Environmental Protection Agency
FAPA – Florida Aquaculture Policy Act
FDACS – Florida Department of Agriculture and Consumer Services
FDEP – Florida Department of Environmental Protection
LDWF – Louisiana Department of Wildlife and Fisheries
MDAC – Mississippi Department of Agriculture and Commerce
MDEQ – Mississippi Department of Environmental Quality
MDMR – Mississippi Department of Marine Resources
NADA – National Aquaculture Act
TCEQ – Texas Council on Environmental Quality
TDA – Texas Department of Agriculture
TDHSH – Texas Department of State Health Services
TGLO – Texas General Land Office
TPWD – Texas Parks and Wildlife Department
USACE – United States Army Corps of Engineers
Vita

Vanessa Jane Maxwell was born in July 1979, in Elyria, Ohio. She was adopted by Virgil and Sandra Maxwell at six months old, to make her the only daughter of a family that had already adopted a son four years earlier. She moved from Ohio to Tennessee in 1991 where she attended Franklin High School and marched in the 1996 Rose Bowl Parade with the Franklin High School Marching Rebels. After high school she attended Florida Institute of Technology where she majored in Marine Biology and Aquaculture and graduated with honors in 2001. She then attended Auburn University where she received the degree of Masters of Science in 2003 in Fisheries and Allied Aquaculture for her work with red snapper larviculture and probiotics. After graduating from Auburn she spent a year working as a Port Sampler for the Florida Fish and Wildlife Commission in the Florida Keys. In July of 2004 she moved to Louisiana and is currently a candidate for the degree of Doctor of Philosophy from the School of Renewable Natural Resources with the major in wildlife and fisheries science, which will be awarded on August 10, 2007. She also will be one of 52 recipients of the Knauss Fellowship in 2008.