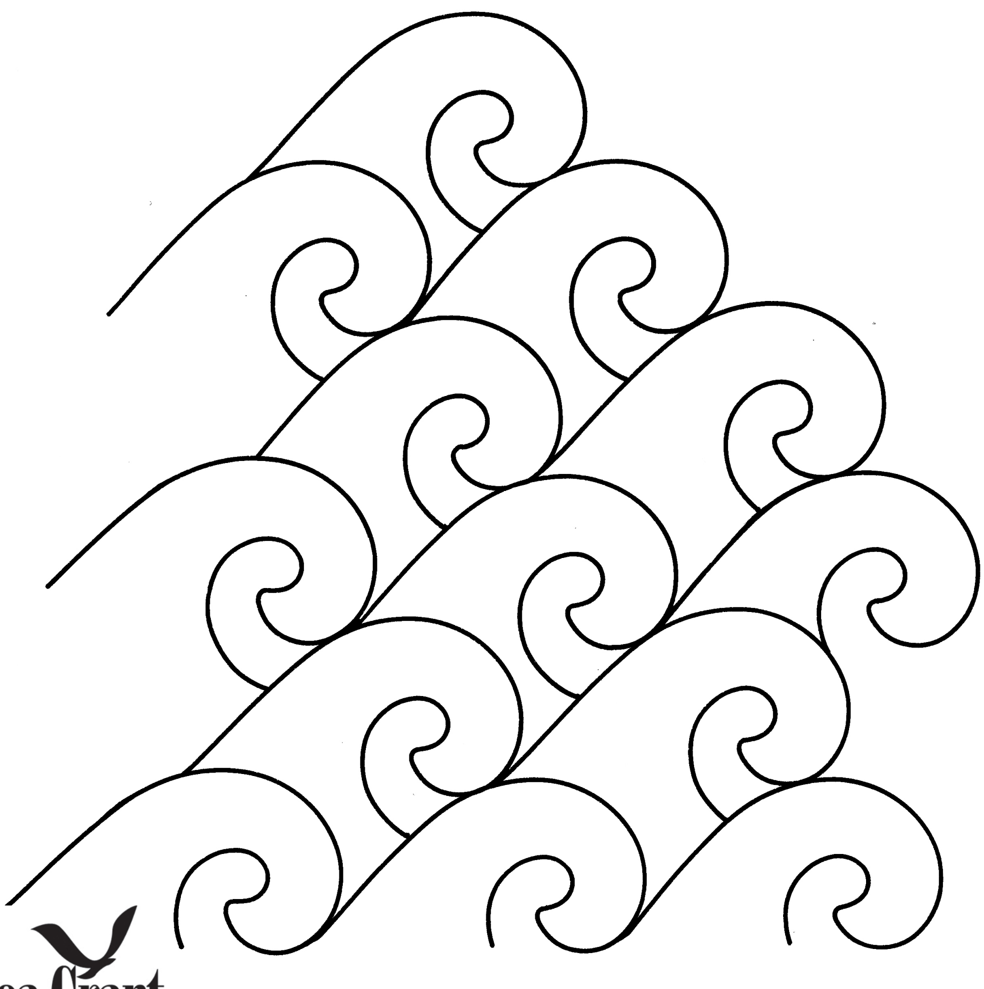
DEL-SG-28-14

SHELLFISH AQUACULTURE IN DELAWARE'S INLAND BAYS: STATUS OPPORTUNITIES, AND CONSTRAINTS

by John W. Ewart



Sea Grant Delaware

Delaware Sea Grant College Program
Newark, Delaware 19716

Shellfish Aquaculture in Delaware's Inland Bays

Status, Opportunities, and Constraints

Compiled and edited by

John W. Ewart
Delaware Sea Grant Program
College of Earth, Ocean and Environment (CEOE)
University of Delaware
700 Pilottown Road
Lewes, DE 19958

In cooperation with

Delaware Center for the Inland Bays (CIB)
Delaware Department of Natural Resources and Environmental Control (DNREC)

July 2013

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Acknowledgements

The purpose of this report is to provide Delaware coastal residents, businesses, and state policy makers with a review of the science-based technical information used to support Inland Bays shellfish resource management decision-making, and development the shellfish aquaculture legislative initiative HB 160 *An Act to Amend Title 3 and Title 7 of The Delaware Code Relating to Aquaculture*.

This review and discussion of the status, opportunities and constraints with regard to shellfish aquaculture in Delaware's Inland Bays would not be possible without the contributions and assistance of the following individuals (in alphabetical order), institutions, organizations, and state agencies:

Chris Bason, Sally Boswell, EJ Chalabala, Roy Miller, Zac Moffitt, and Bart Wilson, Delaware Center for the Inland Bays (CIB)

John Ewart, Jim Falk, and Ed Lewandowski, Delaware Sea Grant College Program, and Sea Grant Marine Advisory Service (DSGMAS)

Bryan Bloch, Mike Bott, John Clark, Rick Cole, Nick Couch, Scott Figurski, Debbie Rouse, Dave Saveikis, Gene Shaner, Jeff Tinsman, and Richard Wong, Delaware Department of Natural Resources and Environmental Control (DNREC)

Mark Davis, and Ed Kee, Delaware Department of Agriculture (DDA)

Steve Copp, Delaware Shellfish Advisory Council

Patrick Erbland, Johnna Fay, Frank Marenghi, Dr. Gulnihal Ozbay, and Brian Reckenbeil, Delaware State University (DSU)

Julie Wheatley, Sussex County Economic Development

Dr. Robert Rheault, East Coast Shellfish Grower's Association (ECSGA) (Rhode Island)

Don Webster, University of Maryland Extension

Tommy Leggett, Chessie Seafood and Aquafarms, and the Chesapeake Bay Foundation (Virginia)

Gef Flimlin, Rutgers Cooperative Extension (New Jersey)

Captain Bill Baker, Bill's Sport Shop Lewes, Delaware

Michael Morgan, Delaware Coast Press

Bob Dorman and Steve Friend, commercial clammers

Rob Robinson, and Josh Thompson, prospective shellfish aquaculturists

John W. Ewart, Editor
Delaware Sea Grant Program
Lewes, Delaware

Dedication

This report is dedicated to:

Dave "The Clam Man" Monte (1930-1996). Dave's foresight about the potential for shellfish aquaculture in the Inland Bays, and his hard work over many years to successfully cultivate hard clams with his family business "Mercenaria Manufacturing" serves as a model and an inspiration to others with similar interests.

The following individuals also warrant special recognition for their important contributions to Inland Bays shellfish aquaculture and the research and demonstration work summarized in this report:

John D. "Jack" Pingree (1958-2008). Jack was the Manager of the Shellfish and Recreational Water Branch for the State of Delaware-Department of Natural Resources and Environmental Control. Jack was a constant advocate for the shellfish industry and served on the Interstate Shellfish Sanitation Conference (ISSC) Executive Board representing the State of Delaware. His key support at the beginning of the field research work in 1998 to evaluate and improve the shellfish resources of the Inland Bays will always be remembered and appreciated.

Jim Alderman (retired). Jim served as the Center for the Inland Bays Restoration Coordinator and Manager of the James Farm Ecological Preserve on Indian River Bay from 1998 to 2008. Jim's commitment to improve the bay's shellfish resources and his great relationships with coastal community residents and local businesses providing their support, materials and supplies, and other in-kind services was instrumental to the progress of the shellfish field research and demonstration work at the James Farm and other field sites around the estuary.

Finally, many thanks and much appreciation to all of the Sussex County waterfront residents on Rehoboth, Indian River, and Little Assawoman Bays past and present who have volunteered their valuable time to participate in the Center for the Inland Bays Oyster Gardening Program.

Executive Summary

World population growth and economic development trends are principal drivers of a steadily increasing demand for high quality, nutritional seafood products. With wild capture fisheries at their maximum sustainable harvest capacity of 100 million metric tons, aquaculture, the husbandry or controlled cultivation of aquatic plants and animals, has been bridging the expanding gap between rising demand and static traditional seafood sources. Farmed seafood currently accounts for approximately 50 percent of overall production in the global marketplace. The U.S. aquaculture industry, valued at over $1.1 billion, produces a diversity of fish and shellfish species for food, recreation, and industrial applications. Bivalve shellfish such as oysters, clams and mussels represent 20 percent of domestic production value. This percentage continues to grow along with increasing recognition of the nutritional, environmental, and economic benefits associated with shellfish aquaculture.

Historical accounts of oysters and clams as a food staple and a product of commerce in Delaware date back to pre-colonial times. The commercial oyster fishery in Delaware Bay originated in the early 1800s and reached its production peak following World War II from 1947 until 1957, when a devastating disease caused by the protozoan parasite MSX or Multi-Nucleated Sphere Unknown (*Haplosporidium nelsoni*) destroyed 95 percent of the oyster resource. Chronic losses from MSX were compounded by the arrival in 1990 of a second deadly parasite, *Perkinsus marinus*, causing “Dermo” disease. In 2001, the State of Delaware authorized a “direct harvest” fishery from the natural seed beds as a countermeasure to maintain the remaining oyster resource and industry. During the post-war period in the Delaware Inland Bays more than 4,000 acres of bottom in Rehoboth Bay and Indian River Bay were also being leased for oyster production. Utilization of bottom lease acreage declined during the 1950s and 1960s due to disease related losses, and reduced availability of seed oysters. By 1978 there was no remaining oyster production or available seed oyster supply. Based on this and the ongoing conflict with the public hard clam fishery, the *DNREC Shellfisheries Management Plan for Indian River, Indian River Bay and Rehoboth Bay* (March 15, 1979) recommended that the Delaware General Assembly return all remaining bottom leases back to state/public ownership. That revision from private commercial leases to “public” bottom remains unchanged to the present time.

Delaware's three “Inland” bays (Indian River, Rehoboth and Little Assawoman) comprise 32 square miles (20,480 acres) of surface waters within a 320 square mile watershed. The cumulative impact of sustained agricultural and suburban development and associated nutrient input has degraded estuarine water quality and habitat, and has reduced diversity and abundance of various species of fishes, invertebrates and submerged aquatic vegetation. In 1994 the Delaware General Assembly established the Delaware Center for the Inland Bays (CIB), a non-profit participant in the National Estuary Program (NEP), to develop a management plan for stewardship of the estuary and its indigenous flora and fauna. Maintaining healthy populations of bivalve shellfish for their ecological, recreational and commercial value to Delaware’s Inland Bays is one of the Center’s top priorities.

The timeline for Inland Bays applied shellfish research, demonstration and field work to evaluate the performance and potential of shellfish aquaculture methods for stock enhancement and

seafood production encompasses a 15 year period from 1998 to the present (2013). The goal of this work has been to assess the value and effectiveness of using aquaculture technologies as part of a shellfish management strategy for the Delaware Inland Bays.

Research and demonstration activities summarized in this report include characterization of seasonal hard clam and oyster growth and survival (1998-2001); establishment and monitoring of a pilot-scale 1/4 acre oyster reef at the James Farm on Indian River Bay (2001-2006); bivalve shellfish stock assessment in Little Assawoman Bay (2002-2003); development of a citizen volunteer oyster gardening program (2003-2013); oyster habitat related research in association with Delaware State University (2005-2013); and a field survey of hard clam population density and distribution in Rehoboth Bay and Indian River Bay (2010-2011).

Oysters and other bivalves are highly efficient at filtering algae, suspended sediments and other particles from the water column and there is growing recognition of the important beneficial ecosystem services and environmental impacts of shellfish aquaculture. These ecosystem services include turbidity reduction, water quality improvement, nutrient cycling and sequestration, nursery habitat for other juvenile invertebrate and fish species, and high (larval/spat) reproductive rates and natural recruitment that serves as a food source for predators. Oysters and other filter feeding bivalves facilitate the transfer of nutrient energy (nitrogen and phosphorous) from the water column (pelagic) to bottom (benthic) communities and reduce nutrient bio-availability. Researchers have estimated that "net nitrogen removal from a 1.5 acre oyster farm would correspond to the amount of nitrogen from the untreated wastewater discharge for more than 3,000 people or treated sewage of about 18,000 people." Shellfish aquaculture is also responsible for converting thousands of acres of barren bottom into productive fish habitat with research documenting that aquaculture cages and floats commonly used for shellfish growout support a higher abundance of fish and crustaceans than natural eel grass beds.

Shellfish aquaculture also contributes both directly and indirectly to local economic development. The current value of the U.S. shellfish aquaculture industry is estimated at over $200 million. According to the East Coast Shellfish Growers Association (ECSGA), shellfish aquaculture production on 1,000 farms from Maine to Florida is valued at approximately $119 million with Virginia, Florida, and Massachusetts as the top three producing states. Besides the market value of the product, the industry supports full-time and seasonal employment and a variety of business related goods and services that collectively have a multiplier effect on the wholesale or farm gate value by a factor of 2.5 times or higher – 5 times as estimated in New Jersey. In addition there are other indirect economic benefits that are not as well understood or are difficult to quantify. Examples include cultural and quality of life aspects such as increasing the local seafood supply, preservation of working waterfront and coastal community heritage, enhanced recreational fishing, and eco-tourism. Nutrient removal (sequestration) and other shellfish related ecosystem services are also increasingly viewed as having a significant economic value.

With the exception of Delaware, all other coastal states on the eastern seaboard currently have commercial shellfish aquaculture activity. Reviews of the status of shellfish aquaculture for four states in particular Virginia, Maryland New Jersey and Rhode Island provide valuable insight and examples for evaluating the economic development potential for commercial shellfish production in Delaware's Inland Bays. Neighboring Virginia is a major seafood producer from capture fisheries and aquaculture and has a well-developed shellfish aquaculture industry that leads the nation in hard clam production. Maryland, with a much smaller industry but similar development potential, has recently enacted major legislative and policy changes designed to support industry growth. Commercial clam aquaculture in New Jersey dates back to the 1970s, but conflicting state policies and other regulatory hurdles, lack of additional bottom leases, and out-of-state competition have limited industry expansion. Rhode Island and Delaware, as the two smallest states in the nation, have much in common with regard to their respective maritime heritage, marine resources, and constraints to shellfish aquaculture development. Renewed interest for leasing bottom for shellfish aquaculture in the late 1980s and policy changes enacted during the 1990s are responsible for the steady development of the Rhode Island shellfish industry, especially during the last decade.

The absence of commercial shellfish aquaculture in the Inland Bays is due to the lack of sub-aqueous (bottom) leases which were discontinued in 1979, and provisions in the Delaware Statutory Code that in effect prohibit shellfish aquaculture. The potential value of the ecological and economic benefits from shellfish aquaculture for the Inland Bays underscores the importance of determining how best to integrate management of shellfish aquaculture with other existing uses of the estuary. Two key tasks that have been identified to accomplish this are 1) a review of existing regulations to develop the necessary management policies appropriate for the three coastal bays and 2) the development of spatial planning information for siting bottom leases and related management decision-making designed to minimize or eliminate conflicts with other users of Inland Bay resources.

Regulatory authority for management of commercial aquaculture and shellfish resources is shared among state and federal agencies. The Delaware Aquaculture Act enacted by the General Assembly in 1990 designated the Delaware Department of Agriculture as the lead agency to coordinate state aquaculture development. Shellfish or finfish aquaculture in tidal waters is regulated on a case-by-case basis by the Delaware Department of Natural Resources and Environmental Control (DNREC) under existing fishery statutes and regulations detailed in Title 7 and relevant chapters of state Statutory Code. Several DNREC Divisions have shellfish related responsibilities. The Division of Fish and Wildlife issues licenses for shellfish harvesting, enforces laws and regulations governing shellfish harvesting, conducts scientific surveys of shellfish resources, and collects harvest statistics. The Wetlands and Subaqueous Lands Branch of the Division of Water Resources issues leases for sub-aqueous bottom and permits for discharges from land-based aquaculture facilities to the waters of the Inland Bays. The Division of Watershed Stewardship contains the Shellfish Sanitation program that classifies shellfish growing areas, adopts laws and regulations for control of the shellfish industry, conducts sanitary surveys of harvesting areas, inspects shellfish facilities, issues certifications to shellfish dealers, and issues tags and permits to ensure that any shellfish legally harvested in Delaware are fit for human consumption. It also participates in the National Shellfish Sanitation Program (NSSP) in cooperation with the U.S. Food and Drug Administration (FDA) to promote and improve sanitation of shellfish in interstate commerce. The Division of Fish and Wildlife Enforcement Section oversees compliance with shellfish sanitation requirements among shellfish harvesters. Also, the U.S. Army Corps of Engineers has jurisdiction for issuing federal aquaculture permits under the Rivers and Harbors Act and under Nationwide Permit 48 (NWP48) to ensure that shellfish farms do not interfere with navigational channels, migratory species, and submerged aquatic vegetation (SAV) beds greater than 0.5 acres.

The cumulative results of more than a decade of Inland Bays applied shellfish research, demonstration, and field work and examples of related activities in neighboring states have increased public interest in the importance of Inland Bay shellfish resources for both restoration and potential commercial production. The Center for the Inland Bays, Delaware Sea Grant, DNREC, and University of Delaware's Sustainable Coastal Communities Program developed an educational workshop titled *"Shellfish Aquaculture in Delaware's Inland Bays: Status, Opportunities, and Constraints"* held on June 18, 2011 in Lewes, Del. to summarize and discuss the history, applied research, ecological and economic benefits, regulatory and socio-economic constraints and policy issues related to shellfish aquaculture.

In March 2012 the Center for the Inland Bays convened a shellfish aquaculture stakeholder work group, or "Tiger Team," to evaluate scientific and educational accomplishments, and policy changes needed to reinstate commercial shellfish aquaculture in Delaware's Inland Bays. The group included representation from the Center for the Inland Bays, the Delaware Sea Grant Marine Advisory Service, DNREC, Delaware Department of Agriculture, Delaware Shellfish Advisory Council, commercial shellfish industry, recreational fishing, Sussex County Economic Development Office, and prospective shellfish farmers. A Policy, Permitting, and Funding Subcommittee reviewed current rules and regulations in the Delaware Code, and proposed draft revisions and legislation to permit commercial aquaculture on the Inland Bays for consideration by the Delaware General Assembly. The Spatial Planning Subcommittee used Geographic Information System (GIS) technology and consultation with stakeholder groups to identify and map existing uses and activities on the bays to determine the areas that shellfish aquaculture could occur in balance with other bay users. The Education and Outreach Committee worked to inform the public about the economic opportunities for coastal communities, and ecological benefits related to commercial shellfish aquaculture. By March 2013 the Tiger Team released a *Final Report of the Shellfish Aquaculture Tiger Team to the Board of Directors of the Delaware Center for the Inland Bays* with recommended policy revisions for a legislative initiative.

On June 4, 2013 during the 147th session of the Delaware General Assembly, House Bill 160 "AN ACT TO AMEND TITLE 3 AND TITLE 7 OF THE DELAWARE CODE RELATING TO AQUACULTURE" was introduced by Representative (and House Speaker) Peter C. Schwartzkopf, with Additional Sponsors Senators Patricia Blevins, Gerald Hocker, and 14 CoSponsors. The Bill authorized the Department of Natural Resources and Environmental Control "to direct and control the shellfish aquaculture activities within the Inland Bays and to set criteria for the approval of lease sites and applications for leasing". The legislation was passed by unanimous vote in both the House (June 11, 2013) and the Senate (June 26, 2013) and is scheduled to be signed into law by Governor Jack Markell on August 28, 2013. Efforts are currently underway by the DNREC Division of Fish and Wildlife to organize and develop a shellfish aquaculture leasing program and regulatory framework for the Inland Bays.

1. **Introduction and Overview of Aquaculture**

Seafood is a popular protein source worldwide with ample nutritional research documenting that fish and shellfish are a healthy, low-fat alternative to beef, poultry, and pork. World population growth and economic development trends are the principal drivers of a steadily increasing demand for high quality seafood products. With wild capture fisheries at their maximum sustainable harvest capacity of 100 million metric tons, aquaculture production has been bridging the expanding gap between rising demand and static traditional seafood sources and currently accounts for approximately 50 percent of overall production in the global marketplace.

Aquaculture, defined as the husbandry or controlled cultivation of aquatic plants and animals, has a long history dating back several thousands of years to China and Egypt. According to the United Nations Food and Agriculture Organization (FAO), aquaculture is a diverse and global industry valued at more than $100 billion with Chinese production eclipsing all other international output combined. The history of aquaculture in the United States dates back to the late 1800s with the development of hatchery technology to produce fish for restoration of depleted inland freshwater fisheries. Aquaculture in the U.S. has a relatively short commercial history (50 years) and the industry has a current annual farm gate* value of $1.9 billion. Domestic aquaculture production includes a diversity of fish and shellfish species for food, recreation (fishery stock enhancement and restoration, ornamental fish, aquatic plants, live bait), and industrial applications (food additives).

Annual domestic seafood consumption averaging approximately 16 pounds per capita is relatively low in comparison to global demand (37 pounds) and in Asia (>90 pounds). However, because current U.S. demand exceeds the available domestic supply from both capture fisheries and aquaculture sources, more than 90 percent of the seafood consumed in the United States is imported resulting in annual trade deficits of $9-10 billion. Marine aquaculture is a relatively newer and rapidly growing segment of a U.S. industry that is predominantly (70 percent) freshwater based with catfish, crawfish, trout, and tilapia as leading species. Bivalve shellfish such as oysters, clams and mussels currently account for approximately 20 percent of domestic production value. This percentage continues to grow along with increasing recognition of the nutritional, environmental, and economic benefits derived from shellfish aquaculture. Oysters and other bivalves are growing in popularity as a healthy food choice and are delicious and nutritious, high in protein, minerals, and heart healthy omega-3 fatty acids. Filter feeding bivalves can be cultured sustainably because they feed low on the food chain on naturally available food. They provide important ecological services to maintain water quality and the overall health of the estuary. Shellfish farms also generate jobs and other business related economic benefits for coastal communities.

* Editor's Note: The farm gate value of a cultivated product in agriculture or aquaculture is considered to be the wholesale or net value of the product sold by the farm. It excludes shipping, processing, marketing, and other costs related to bringing a product to the retail market.

2. Historical Background on Shellfish and the Oyster and Clam Industries in Delaware

A June 2001 DNREC/EPA publication on Living Resources in the Inland Bays/Atlantic Ocean Basin describes historical changes to the flora and fauna of Delaware's coastal bays noting that 17th century European settlers found that "the Inland Bays and the waters of Lewes Creek teemed with fish, oysters and other shellfish" (page 85). Local historian Michael Morgan offers a historical perspective on shellfish in Delaware's Inland Bays dating back to pre-colonial times with this excerpt from a recent article "*Pickled Oysters and Chocolate*":

Long before Rehoboth Beach, Bethany Beach and Fenwick Island were established as seaside resorts, Native Americans from the Nanticoke tribe camped on the shores of Rehoboth and Indian River Bays. During the hot summer months, Nanticokes built seasonal houses on the banks of the coastal bays, where they caught fish, crabs and oysters. Camping on a level area that began near the north shore of Rehoboth Bay and extending northward for three quarters of a mile, the Native Americans left several hundred small mounds that contained clam, oysters and mussel shells, together with pieces of charcoal, as evidence of their summer stay. In 1879, these mounds were investigated .by Francis Jordan, who commented: "So far as I have been able to ascertain, no similar example of an encampment possessing the same archaeological value exits on the Atlantic seaboard."[1]

In the 17th century, European colonists, who recognized the natural advantages of Rehoboth Bay and Indian River Bay, joined the Nanticokes on the banks of the coastal bays. Many of the newly arrived colonists viewed the coastal bays as a convenient highway that enabled them to ship tobacco and other crops through the Indian River Inlet to distant markets. In addition, the European settlers shared the Native American view of the coastal bays as a repository of wildfowl, fish, and, especially oysters, which were a common dish on many colonists' tables. The tasty bivalve was fried, stewed, and served in other inventive ways. In 1709, William Byrd of Virginia noted in his diary that he had a breakfast of "pickled oysters and chocolate."[2]

Although the idea of having oysters with chocolate may not be universally well liked, throughout the colonial period into the 19th century, oysters were intensely popular. In 1790, an advertisement announced a new establishment in the village of Frederica proclaiming: "NOTICE: The subscriber respectfully informs the public that he has opened an OYSTER HOUSE in the village of Frederica… where gentlemen and ladies will meet with good entertainment. He has engaged Oysters from Rehoboth Bay once a month, until they are out of season."[3]

Following the War of 1812, improved packing techniques, and the development of the railroad allowed oysters, which, in the past, had been harvested mainly for living relatively close to the coastal bays, to be shipped farther inland. With this wider market came a greater demand for oysters; and the oystermen of southern Delaware did all that they could to satisfy that demand. During the 19th century, the intense harvesting of the oysters in Delaware and the coastal bays was depleting the oyster beds; and in 1852, the state legislature prohibited oystering from May 1 through August 10. During the first year that the law was in effect, August 10 fell on the second Thursday of the month; and on that day, a crowd gathered

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[1] ***Ibid***. p. 1

[2] Audrey Noel Hume, ***Food***, Colonial Williamsburg Archaeological Series No. 9, Williamsburg, Va.: The Colonial Williamsburg Foundation, 1978, p. 30.

[3] Harold B. Hancock, ***Delaware Two Hundred Years ago, 1780-1800***, Wilmington: The Middle Atlantic Press, 1987, p. 36.

at landings on the coastal bays to celebrate the opening of the oyster season. The celebration became known as "Big Thursday," which developed into an annual event.

In addition to excessive harvesting, the oyster population in the bays was threatened by the closing of the coastal inlets. By the early 20th century, the Indian River Inlet, the last and most important waterway that led from the bay to the ocean, had silted shut. For several decades, the coastal bays were denied the normal flow of water to and from the ocean which resulted in a significant change in the bays' ecosystem. It was not until the 1930's that the inlet was permanently reopened.

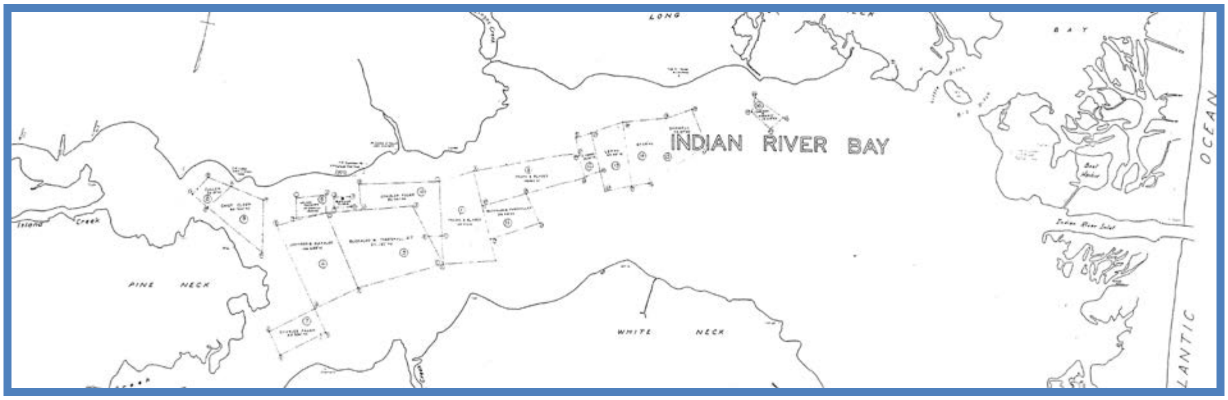
Editor's Note: While Big Thursday is still held as an annual event in Millsboro, Delaware, the original purpose and theme - the opening of oyster harvest season - has been largely forgotten by the public.

Delaware Oyster Industry

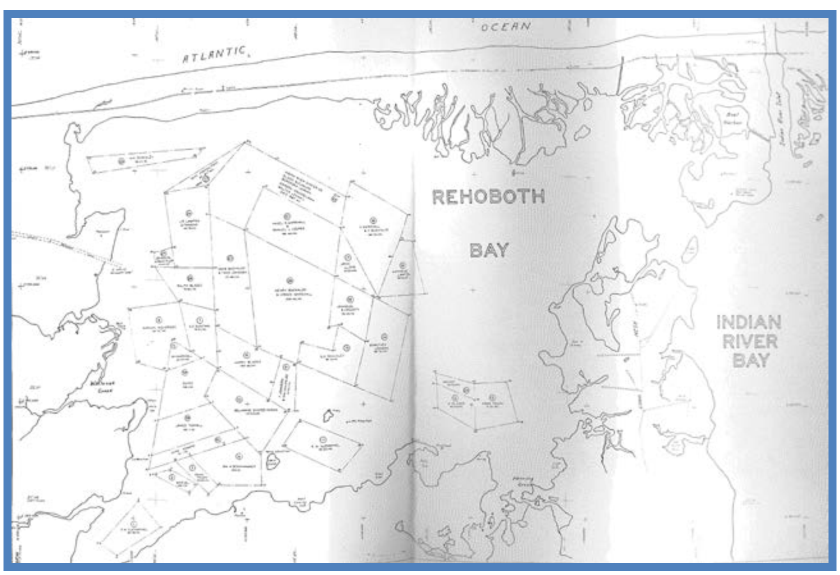
The Delaware oyster industry has a long history dating back to the early 1800s. Data on commercial landings of oysters in Delaware Bay extend back to 1880. Landings have varied over time with peaks averaging approximately a half million bushels per year occurring from 1947 through 1958. One factor that contributed to this peak harvest period was the conversion of harvesting vessels from sail power to motor power, which made dredging for oysters a much more efficient process. However, indiscriminate dredging of the natural seed oyster beds during this period resulted in a depletion of the resource to the point that by 1952 the availability of oysters on the natural beds was nonexistent. As such, the industry had to rely on a program of large importations of seed oysters from Virginia in order to provide oysters for Delaware's industry. By the fall of 1958 significant oyster mortalities were occurring and at least 95 percent of the oysters on the leased grounds had died. In 1959 the Delaware Commission of Shell Fisheries placed an embargo on importation of seed oysters into Delaware in an effort to control the spread of MSX aka "Multi-Nucleated sphere Unknown" (*Haplosporidium nelsoni*) which was destroying the oyster resource.

Oyster harvest landings throughout the 1960s averaged 6,750 bushels per year (Lesser and Ritchie, 1979), and much of the industry infrastructure (shucking houses, docks, dredge boats and markets) was lost due to the extremely low level of landings. Starting in the mid-1960s and continuing until the present time the State of Delaware has been actively planting shell cultch (dead, weathered oyster and clam shell) on the natural oyster beds when funds are available to support this important management process. Millions of bushels of oyster and surf clam shell have been planted on the state-owned natural oyster beds in an effort to maximize spat setting on these areas and revitalize the resource. Since 1990, a second deadly parasite *Perkinsus marinus* causing "Dermo" disease has also significantly impacted oyster stocks. In June 2001 the Delaware General Assembly promulgated an amendment to Delaware Code, Title 7, Chapter 21 that changed the way that the oyster resource was to be managed. The major focus of the amended legislation dealt with changes in the long-standing requirements that oysters harvested from the state-owned natural oyster beds must be transplanted to privately leased beds in Delaware Bay. The new amended legislation now permits the "direct harvest" of oysters from the natural seed beds for commercial purposes. The harvest is limited by an annual quota that is based on resource abundance levels as determined by annual surveys conducted by the State. To date, under this new program, more than 10 consecutive years of commercial harvesting have occurred and it appears that long term sustainability of the oyster resource may be achievable under the current management regime.

Historical landings information for commercial oyster harvesting in the Inland Bays is not available. Subsequent to the commercial activity previously described by Michael Morgan during the 18th and 19th centuries (pages 10-11), oyster production was re-established after stabilization of the Indian River inlet in 1938 with large areas of bay bottom being leased. By 1948, more than 3,164 acres (34 percent) of Rehoboth Bay and 1,143 acres of Indian River Bay (13 percent) were being utilized for oyster production grounds. According to anecdotal information from individuals leasing shellfish bottom in Indian River during the 1950s and



1960s, seed oysters were harvested from Delaware Bay natural beds, when available, and transplanted to leased bottoms in Indian River Bay. As many as 16 parcels comprising 1,073 acres of shellfish bottom were leased by private companies or individuals in Indian River Bay during the peak of these operations. Utilization of bottom lease acreage declined during the 1950s and 1960s due to disease related losses, and reduced availability of seed oysters. The last oyster transplanting effort in Indian River Bay occurred in 1978 when just over 2,000 bushels of



oysters were harvested from the Broadkill River and temporarily transferred for 30 days to a private lease in the Indian River Bay for depuration purposes.

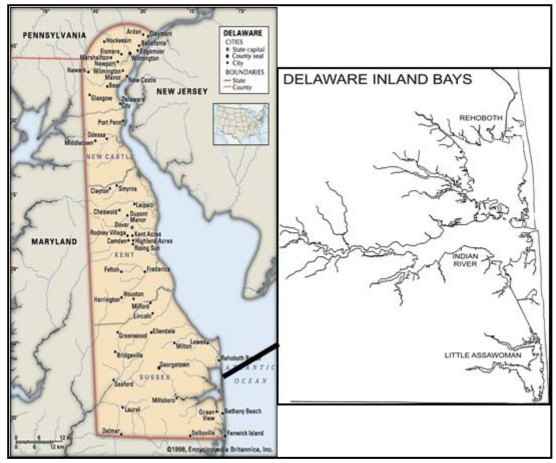
The large amount of acreage leased for oyster cultivation reduced access to the bay bottom and was a highly controversial issue with the hard clam industry. By 1978 oyster productivity on the leases was nonexistent, and no natural supply of seed oysters was available. The Delaware General Assembly directed DNREC to reassess the status of Inland Bay shellfish resources and to review and update the shellfisheries management plan to conserve and sustain the remaining wild hard clam resource. The resultant *DNREC Shellfisheries Management Plan for Indian River, Indian River Bay and Rehoboth Bay* (March 15, 1979) recommended that the General Assembly return all remaining sub-aqueous (bottom) leases back to state/public ownership. This revised status from private commercial leases back to "public" bottom remains unchanged to the present time.

Until recently, wild or natural set oysters, while relatively scarce, were found in the Inland Bays as evidenced by the occasional observation of oyster spat found below the mean low water line on dock pilings, bulkheads, riprap, ribbed mussel shells, and other hard surfaces. A general consensus among state resource managers has been that since the demise of the Inland Bay oyster industry in the 1970s, high salinities, predation, and the potential for disease outbreaks made the bays an unsuitable environment for oysters. It is undetermined at this point if increased natural oyster recruitment observed in Indian River Bay can be attributed to increased spawning stock from oyster stock enhancement activities during the last decade.

In Delaware's Inland Bays, commercial hard clam landings data are available dating back to 1943. These data indicate that in the 1950s landings for the decade averaged approximately 270,000 pounds per year, while an annual yearly landing in the 1960s averaged 184,000 pounds. Subsequent annual harvests were lower and ranged from a yearly average high of 65,000 pounds in the 1970s to a yearly average low of 32,000 pounds in the 1980s. Most recent landings data during the present decade indicate average yearly landings for hard clams of approximately 62,000 pounds. Hard clams are quite long-lived and the standing stock at any time is typically high compared with the number harvested. Landings are tied closely to effort, which is affected by many variables including: availability of small (high value) clams, availability of other fishery resources (finfish, crabs, etc.) and general economic considerations such as other available local jobs. Today, the hard clam remains as the predominant and most commercially and recreationally important bivalve filter feeder in Delaware's Inland Bays.

It is also important to note that for more than a decade from the 1980s until his passing in 1996, Dave Monte operated a successful commercial clam farm with his family "Mercenaria Manufacturing" on a small 1.5-2 acre area of sub-tidal bottom in Roman T Pond adjacent to the entrance to Rehoboth Bay and the navigational channel at Massey's Ditch. Monte, who was a well-known and respected local waterman, also built and operated a clam hatchery and raceway nursery system to produce and supply seed clams for his grow out operation. Known locally as "the Clam Man", Monte developed a popular live market for his cultured clams at his farm stand located at the intersection of Route 24 and Long Neck Road (Route 5) in Sussex County, Del.

3. **Delaware's Inland Bays and the National Estuary Program**



Delaware's 3 Inland Bays comprise 32 square miles (20,480 acres) of surface waters within a 320 mile watershed. The estuary exhibits the effects of chronic eutrophication from several decades of sustained agricultural and suburban development and associated nutrient input.

The cumulative impact has degraded water quality and habitat and has reduced diversity and abundance of various species of fishes, invertebrates and submerged aquatic vegetation. (CCMP 1995, 2012; DNREC/USEPA 2001). Despite these ongoing environmental quality issues the estuary remains as a popular location for boating, sport fishing, commercial and recreational shellfisheries for the hard clam (*Mercenaria mercenaria*), and is a major asset to the tourism-based economy in lower Delaware.

In 1994 the Delaware Assembly established the Delaware Center for the Inland Bays (CIB) as a participating institution in the National Estuary Program (NEP). The NEP, established under the Clean Water Act and administered by the U.S. Environmental Protection Agency, provided approximately $2 million to study the Inland Bays to characterize and set priorities for addressing the environmental problems in the watershed, and to develop a *Comprehensive Conservation and Management Plan for Delaware's Inland Bays (CCMP)* to protect and restore the bays. The underlying theme of the program is that a collaborative, consensus-building effort involving citizens, private interests, organized groups, and federal, state, and local governments is essential to the successful development and implementation of the CCMP. Adopted in 1995, and recently updated in 2012, the CCMP addresses action plans in five targeted areas:

- Education and Outreach
- Agricultural Sources
- Industrial, Municipal, and Septic System Sources
- Land Use
- Habitat Protection

The Center promotes the wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing restoration projects, encouraging scientific inquiry and sponsoring needed research, and establishing a long-term process for the protection and preservation of the Inland Bays watershed.

The goals of the Center for the Inland Bays are:

- To sponsor and support educational activities, restoration efforts, and land acquisition programs that lead to the present and future preservation and enhancement of the Inland Bays watershed;

- To build, maintain, and foster the partnership among the general public, the private sector, and local, state, and federal governments, which is essential for establishing and sustaining policy, programs, and the political will to preserve and restore the resources of the Inland Bays watershed; and
- To serve as a neutral forum where Inland Bays watershed issues may be analyzed and considered for the purposes of providing responsible officials and the public with a basis for making informed decisions concerning the management of the resources of the Inland Bays watershed.

4. Inland Bays Shellfish Aquaculture Research and Demonstration

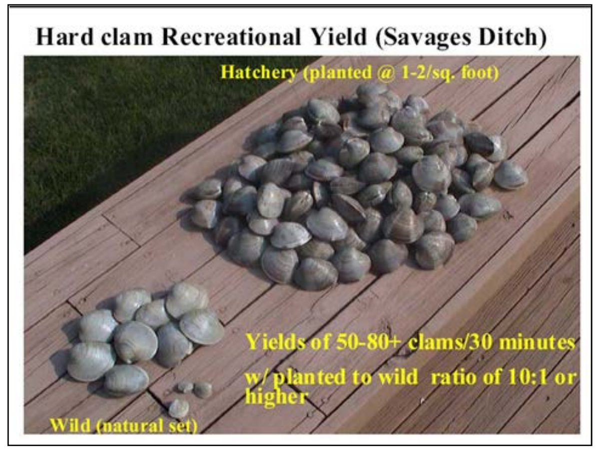
Research Timeline

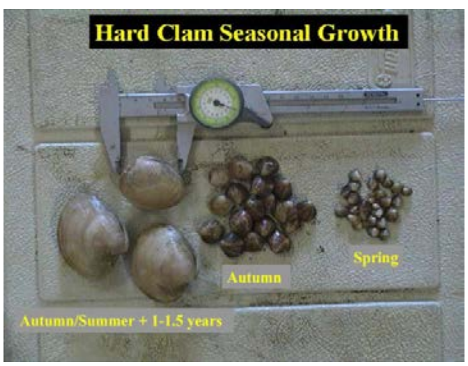
Maintaining healthy populations of bivalve shellfish for their ecological, recreational and commercial value to Delaware's coastal bays is an important priority of the Center for the Inland Bays Comprehensive Management Plan. As part of the Center's mission for public education and to facilitate a long-term approach for the wise use and enhancement of the estuary, the James Farm Ecological Preserve, a 150-acre property with frontage on Indian River Bay, was established in 1998. In addition to seasonal environmental education programs for students and other groups and a network of trails, observation platforms, and supporting facilities, the James Farm also serves as a demonstration site for beneficial land use practices and similar watershed-based conservation activities. The adjacent sub-tidal waters of Indian River Bay at the James Farm is one of several locations around the three bay estuary where aquatic research and field demonstration activities have been undertaken to evaluate the performance and potential of shellfish aquaculture methods for enhancement of natural oyster and hard clam stocks and for seafood production. The goal of this work has been to assess the value and effectiveness of using aquaculture technologies as part of a shellfish management strategy for the Delaware Inland Bays.

The timeline for applied shellfish research, demonstration and stock enhancement field work encompasses a 15 year period from 1998 to 2013. Examples include characterization of seasonal hard clam and oyster growth and survival (1998-2001); establishment and monitoring of a pilot-scale 1/4 acre oyster reef at the James Farm (2001-2006); bivalve shellfish stock assessment in Little Assawoman Bay (2002-2003); development of an oyster gardening program (2003-2013); a hard clam survey of Rehoboth and Indian River Bays (2010-2011) and additional oyster habitat related research in cooperation with Delaware State University (2005-2013).

4.1 Seasonal Hard Clam and Oyster Growth and Survival (1998-2001)

Applied research to evaluate the use of off-bottom and in-bottom and shellfish aquaculture methods was initiated at the James Farm and locations in Rehoboth Bay during spring and summer 1998. To minimize the potential for oyster losses from exposure to MSX and Dermo pathogens, growth trials used a dual disease resistant line of seed oysters developed by Rutgers University and the Virginia Institute of Marine Sciences (VIMS) CROSBreed program. Hard clam seed were produced by a New Jersey hatchery using (*M. mercenaria notada*) broodstock, a sub-species of *M. mercenaria* commonly used for aquaculture because of its distinct shell coloration pattern. Small-scale field demonstration trials to characterize and evaluate growth and survival of individual or “culchless” oysters (not attached to other shell) using off-bottom aquaculture gear at the James Farm consistently yielded market-sized oysters. From June to November, it typically took between one and two growing seasons to produce a 3-inch (75 millimeter) oyster from 1-inch (25 millimeter) hatchery seed.





Vexar bags with harvested oysters and ratio of live (left) vs dead oysters (right)

Oysters held in the off-bottom cages were protected from crabs and other predators by ½ inch mesh plastic (Vexar) bags. Monthly growth was greatest between June and September and average mortality ranged between 5-10 percent. The aquaculture gear (racks, cages, nets, ropes, trays, and lines) also served as nursery habitat by providing refuge and food for a variety of fish, crabs, grass shrimp and other small invertebrate species.

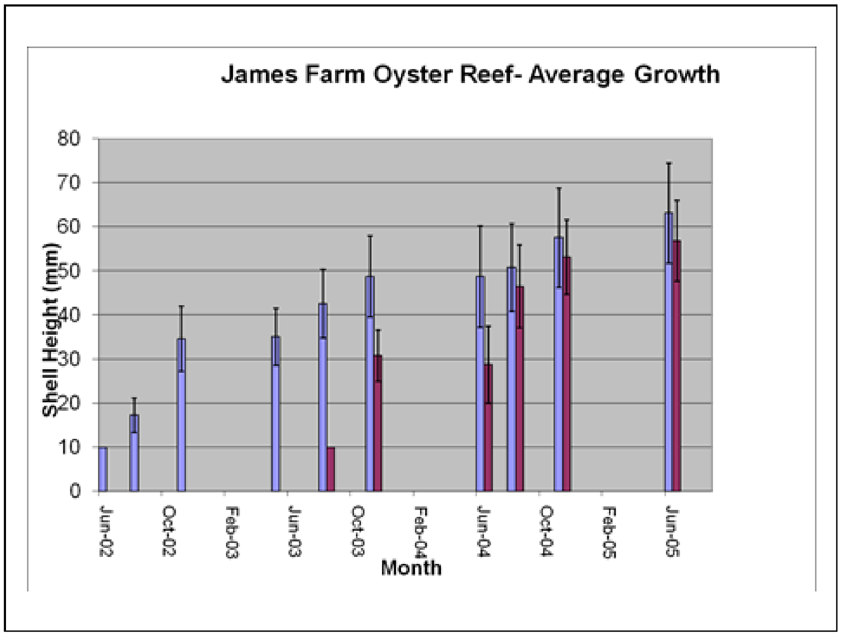
Hard clam growth to minimum market size 1.5 inch (38.1 millimeters) also generally required up to 18 months or longer (two field growing seasons) using 0.4-0.6 inch (10-15 millimeter) seed. Best results were obtained by planting seed from nursery upwellers in field plots during cooler fall months when crab predation is reduced (October and November). Additional work to evaluate low density (1-2 clams/square foot; 11-22 clams/square meter) plantings for stock enhancement and recreational fishery potential without the use of predator netting generally yielded similar growth and harvest rates. However, depending on predation activity by the cow nose ray (*Rhinoptera bonasus*) mortality rates were highly variable ranging between 40 percent and in some cases 100 percent.

4.2 Establishment and Evaluation of a Pilot-scale 1/4 acre Oyster Reef at the James Farm (2001-2006)

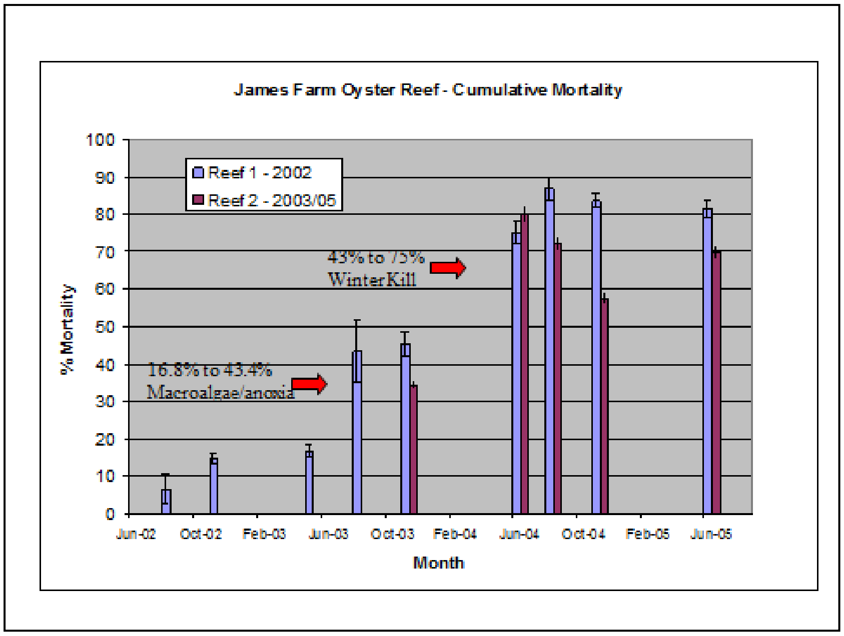
Using similar state-of-the art methods being employed in Virginia and Maryland, an experimental, pilot-scale oyster reef on Indian River Bay was established at the CIBs James Farm on Indian River Bay during summer 2001. Approximately 250 cubic yards of surf clam

shell was deposited on a 10,000 square foot (0.23 acre) area of bottom to harden it and form a base for stocking a 4-inch layer of hatchery produced oyster spat on shell. The first stocking (Reef 1) of approximately 150 bushels of shell with oyster spat averaging 10 millimeters (0.4 inch) shell height occurred during summer 2002. The advent of the oyster gardening program in spring/summer 2003 presented an opportunity to evaluate the effectiveness of using hatchery produced oyster spat to replenish the reef since natural recruitment was negligible and insufficient to supply the reef with additional year classes. A comparison of oyster growth and mortality between Reef 1 and a second section of the shell base (Reef 2) was done using 0.4 inch (10 millimeter) spat on shell supplemented in the fall and subsequent spring with larger 1.2-2 inch (30-50 millimeter) juvenile oysters produced by the oyster gardening program during the 2003-2005 growing seasons. Clusters of oysters on shell were collected from both plantings during spring, summer and fall to measure comparative growth and cumulative mortality. A volumetric method (4 liters shell displacement) was used to equalize samples. Both Reef 1 (blue bars) and 2 (red bars) produced reproductively viable (spawning) oysters.

Natural oyster recruitment, although very low, was observed on both sections of the reef. Wild oyster set observed on Reef 1 (blue bars) was similar to the random low level natural recruitment observed in other parts of Indian River Bay where riprap or other hard structure for shoreline protection is commonly present.



Annual supplements of juvenile oysters on Reef 2 (red bars) from two seasons of the gardening program produced oysters with an average size similar to Reef 1 oysters. In addition to anticipated losses from crabs, oyster drills and other predators, two mortality events that had the most significant impact were due to adverse natural environmental conditions. During summer 2003 a widespread and massive algal bloom dominated by *Ulva lactuca* the green macro-algae commonly known as sea lettuce occurred throughout the Inland Bays. The bloom covered large tracts of bottom, including the James Farm reef, which remained covered by the macro-algae through the summer. The accumulated algal mat significantly reduced water circulation, increased sedimentation on the reef and created hypoxic (low oxygen) conditions that were highly stressful for oysters and other benthic invertebrate populations. Cumulative mortality of 17 percent after the first season (2002) increased by fall 2003 to 43 percent.



The second significant mortality event occurred during what was subsequently rated as the 11^{th} coldest winter on record. In January 2004 the normally sub-tidal reef was exposed by large (-0.7 to -0.9) low tides coinciding with single digit air temperatures (4 degrees F) for an extended period resulting in a freezing “winter kill” and an additional 30-40 percent loss. Cumulative mortality on Reef 1 during the 2004 growth season was estimated at 80-90 percent while mortality on Reef 2 was approximately 70 percent. The lower mortality observed on Reef 2 was attributed to seasonal oyster gardening supplements of additional juveniles. Between 2003 and 2005 an increase in Dermo pathogen activity was most likely a by-product of the stress placed on the oyster population by the combination of exceedingly hot weather conditions and summer long macro-algal accumulations. Dermo prevalence on Reef 1 increased from 20 percent to 93 percent and average infection intensity [based on the Cooperative Oxford Laboratory (Maryland) Infection Intensity Scale: 1 (very very light) to 7 (very very heavy)] rose from 1.7 to 3.2.

Subsequent long-term research to develop artificial oyster reefs in Virginia and Maryland has demonstrated that larger, multi-acre areas with hard bottom conditions, a three-dimensional bottom topography effect created by the uneven peaks and valleys of the reef base, moderate or higher current/tidal flow, and consistent natural oyster recruitment are highly important characteristics of sustainable reefs. Our research modeled after earlier work in Virginia and Maryland confirmed that one-dimensional, flat platform type reefs especially those with sporadic or low levels of natural recruitment, such as the case at the experimental reef at the James Farm on Indian River Bay, generally tend to not perform as well and are not naturally sustainable. Besides losses from predation and disease, flat reefs often experience additional cumulative mortalities from external factors such as sedimentation, macro-algal fouling, hypoxia, and increased environmental stress.

While seasonal replenishment of juvenile oysters produced by the volunteer gardening program did help to mitigate losses and maintain reef oyster populations, it was determined to not be a viable and best use of limited shell-stock resources. As an alternative strategy, oysters were maintained at gardening sites for an additional growth season to reduce their vulnerability to predation and to increase the potential for natural spawning and recruitment in the more restricted waters of the residential canal systems. During the second season larger, reproductively viable clusters of oysters were redeployed to sub-tidal off-bottom locations utilizing shoreline stabilizing riprap as a substrate.

4.3 **Bivalve Shellfish Stock Assessment in Little Assawoman Bay (2002-2003)**

The Little Assawoman Bay (LAB), located on Delaware’s southern border with the state of Maryland, is the least studied and understood portion of the Inland Bays estuary. Other than a comprehensive field study conducted in 1991, little additional information is available. See Ullman et al. “*A Day in the Life of Delaware’s Forgotten Bay: A Scientific Survey of Little Assawoman Bay* (12 June, 1991). Anecdotal reports suggest that hard clams at one time occurred naturally in some areas of the bay where suitable bottom habitat exists but not in sufficient quantities to support a commercial fishery. During fall 2002 and summer and fall 2003, a bivalve shellfish survey was conducted in the LAB by revisiting the same 13 field stations originally established in the 1991 study by DNREC. The DNREC survey of hard clams in Little Assawoman Bay yielded no live animals but did yield dead shells of hard clams, soft shell clams, and oysters (Tinsman, 1991). The 2002-2003 survey produced similar evidence for clams and oysters but also noted the presence of the Atlantic Ribbed Mussel (*Geukensia demissa*). While not considered to have commercial importance, the mussel was the only naturally occurring living bivalve observed in Little Assawoman Bay. The mussels were commonly found in the high intertidal zone along banks of marsh grass, especially in the southern portion of the bay. The adequacy of local water quality and environmental conditions in Little Assawoman Bay to support introduced plantings of hard clams and oysters had not been previously evaluated, and a general consensus among resource managers was that their absence was evidence of local water quality conditions being unsuitable for either species. The advent of the Inland Bays Oyster Gardeners program, organized and managed during summer and fall 2003 by the Center for the Inland Bays and Delaware Sea Grant Marine Advisory Service, provided an opportunity to deploy seed oysters and hard clams at various locations around the bay to assess shellfish growth performance.

4.4 **Little Assawoman Bay Hard Clam and Oyster Growth**

During October 2003 small-scale test plantings of 250 0.5 inch (10-15 millimeter) seed clams at 1-2 per square foot without predator netting were made at two locations along the eastern bayside part of the bay where firmer bottom characteristics (sandy-mud sediments) are more common. In addition to sampling the general area around the sites, shallow sub-tidal areas closer to shore were examined using hand rakes, but no evidence of hard clams or other bivalve species were found at either location. During October 2005, 50 percent of the clams from both sites were recovered and all were greater than the market size minimum of 1.5 inches. Other clams from the original plantings were unaccounted for, and very few dead shells or other evidence of predation related mortality were recovered. Oyster spat (on shell) with an initial average shell height of 10 millimeters (0.4 inches) were deployed in off-bottom Taylor Floats (page 21) during the first two

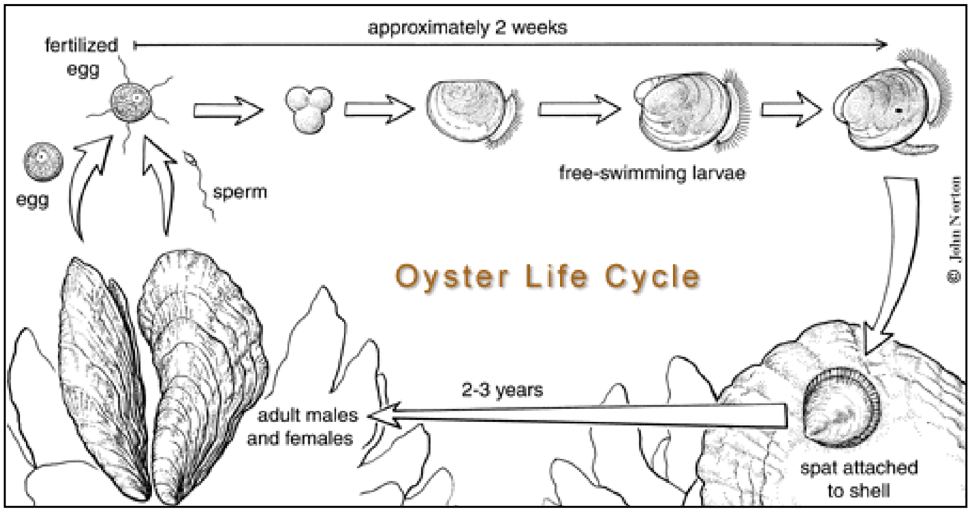
weeks of August 2003 at nine residential canal locations in the Little Assawoman Bay. After eleven weeks, good growth was observed at all gardening sites, especially in the southern portion of the bay. The average increase in shell height ranged from 23 to 34 millimeters (0.9 to 1.4 inches) and oyster mortality was negligible at all locations. Subsequent observations at volunteer oyster gardening sites in Fenwick Island and South Bethany have demonstrated that local water quality conditions will support oyster growth to market size. In addition, observation of new recruitment (spatfall) in Fenwick Island canals in the vicinity of gardening sites and adult (spawning) oysters indicates that the relatively poor water circulation and quality in the canals is adequate to support larval development and natural spatfall.

The Little Assawoman Bay is unique in comparison to the other Inland Bays because its relatively closed nature offers good potential for larval retention and gradual establishment of natural recruitment as a result of shellfish farming or establishment of shellfish spawning sanctuaries. Bottom (sediment) conditions in the center and western portions of Little Assawoman Bay where potential shellfish growing waters are located, are predominantly a silt-clay mixture and are typically too soft to support natural aggregates of benthic oyster populations. However, there is good potential for oyster aquaculture in the LAB using off-bottom culture gear (floats, trays, or rack and bag systems). Clam aquaculture would be more feasible in shallow waters on the eastern shore of the bay, but the area that would be available for commercial scale production using standard methods has not been determined or field tested.

4.5 Center for the Inland Bays Oyster Gardening Program (2003-2013)

Oyster gardening is a community-based shellfish aquaculture program that originated in the Chesapeake Bay (Virginia and Maryland) and has been emulated in most states along the east coast from Alabama to Maine as it has grown in popularity. The program enlists the participation of coastal waterfront resident volunteers to nursery culture small hatchery-produced oyster "spat" to a larger juvenile or adult size less vulnerable to predation and more suitable for use in stock enhancement fieldwork. The Delaware Center for the Inland Bays Oyster Gardening Program, initiated during summer 2003, is a cooperative effort among the Center, the Delaware Sea Grant Marine Advisory program, Delaware State University, and volunteers from waterfront residential canal communities along Rehoboth, Indian River, and Little Assawoman Bays.

During the 2013 season, approximately 200 volunteer oyster gardeners are participating by growing oysters at their docks in floating baskets (Taylor Floats) at over 120 locations around the three bays. The largest concentration of gardening sites is located in the residential canal systems of Fenwick Island and South Bethany. Since 2007, oyster spat used to stock the gardening sites are being produced using a “remote setting” method. Remote setting utilizes mature oyster larvae that are ready to “set” or attach themselves to oyster shell or other hard substrate. The larvae, which are 250 microns (0.25 millimeter) in size, are concentrated on a fine mesh screen, and kept moist and cool in an insulated container. The larvae are then sent by the hatchery using surface or air transport to a distant or otherwise “remote “location to complete the setting process in an aerated seawater tank filled with oyster shell or another hard substrate material (cultch). Using this method mature oyster larvae can remain viable for 72 hours, thus significantly extending the distribution range for selectively bred oyster stocks and eliminating the need for a local or on site hatchery facility.



Maryland Sea Grant

A 1,500 gallon seawater tank located at the University of Delaware College of Earth, Ocean, and Environment (CEOE) Hugh R. Sharp campus in Lewes is used for producing oyster spat for the gardening program. Oyster larvae are cultured at the Rutgers University shellfish hatchery in

Cape May, New Jersey using Rutgers NorthEastern High Survival Resistant Line (Haskin NEH) broodstock selected for their resistance to MSX and Dermo disease. Upon receipt the larvae are slowly acclimated to ambient water temperature and salinity conditions before being added to the setting tank with aerated seawater and aged oyster shell. Settlement occurs between 24-48 hours, and duplicates the natural “setting” or attachment process that occurs annually in coastal estuaries.

The remote setting process typically yields several hundred thousand 10-15 mm (0.4- 0.6 inch) oyster spat, which are subsequently distributed throughout the Inland Bays to volunteer gardeners for nursery culture at their residential canal dock locations through the remainder of the growth season (October/November). Oysters are cultivated for up to two seasons until sexually mature to promote natural oyster spawning activity and recruitment, and for the shell to provide important refuge and recruitment habitat for juvenile fish and macro-invertebrates (grass shrimp, marine worms, and other small marine organisms). Clusters of mature oysters, which due to their larger size are substantially less vulnerable to predation, are then transferred to the crevices and interstitial spaces found in riprap, the stone embankments commonly located around the estuary for shoreline erosion protection. Transplanting oysters to the sub-tidal, three-dimensional off-bottom structure of the riprap provides exposure to higher water quality and flow, and increased protection from larger predators like cow nose rays.

4.6 Oyster Habitat and Environmental Research (2005-2013)

In 2005, faculty and students from Delaware State University began an ongoing collaboration with the Center for the Inland Bays and the University of Delaware (Delaware Sea Grant) to conduct field research to document the habitat value of oyster aquaculture, local environmental conditions, and oyster field methods. Between 2005 and 2013, 4 master’s thesis projects related to the Inland Bays shellfish research and demonstration and oyster gardening program were completed and are summarized below (with published journal citations where applicable):

A Comparison of the Macro-faunal Communities Inhabiting a Crassostrea virginica Oyster Reef and Oyster Aquaculture Gear in Indian River Bay, Delaware. Patrick J. Erbland, and Gulnihal Ozbay. Journal of Shellfish Research. Aug 2008: Volume 27 Issue 4. 757–768.

A quantitative comparison of the macro-faunal communities (fish and invertebrates) in the James Farm oyster reef and off-bottom oyster aquaculture gear found similar species diversity between the reef and gear habitats, and that the aquaculture gear supported significantly higher species abundance and richness (number of different species present). The study demonstrated that off-bottom oyster aquaculture gear provided additional three-dimensional volume of beneficial habitat and refuge for populations of ecologically and economically important finfish and invertebrate species vs. the one-dimensional reef base.

Floating Oyster, (*Crassostrea virginica*) Aquaculture as Habitat for Fishes and Macroinvertebrates in Delaware Inland Bays: The Comparative Value of Oyster Clusters and Loose Shell. Frank P. Marenghi, and Gulnihal Ozbay. Journal of Shellfish Research. December 2010: Volume 29 Issue 4: 889–904.

This project to evaluate the habitat value of Taylor Floats used in the CIB Oyster Gardening program found that the aquaculture gear attracted 49 species of fishes and invertebrates, including 9 commercial or recreational fishery species, and 8 species of macro-algae, and provided important recruitment and nursery habitat in the otherwise barren residential canals. Also, the first evidence of natural oyster recruitment was found at Fenwick Island gardening sites demonstrating that water quality at the study sites was adequate to support oyster larval development and recruitment ("setting" or the transition from free-swimming to newly formed oyster spat).

Water-Quality Parameters and Total Aerobic Bacterial and Vibrionaceae Loads in Eastern Oysters (*Crassostrea virginica*) From Oyster-Gardening Sites. Fay, J., Richards, G.P., Ozbay, G. 2012. Archives of Environmental Contamination and Toxicology. 64:628-637.

With the Inland Bays at risk for algal and possible blooms of *Vibrio* a natural and commonly occurring bacterium with potential human health implications, a third study compared water quality, total bacteria, and *Vibrio* concentrations in oysters located at two oyster gardening sites in Little Assawoman Bay with poor (dead end canal) and good (open bay) water flow. Both sites were found to be degraded in regard to high phosphorous, nitrogen, and total suspended solids and low dissolved oxygen levels. *Vibrios* were present at both locations but were significantly greater during the duration of the study at the canal site. The project provided the first baseline levels for total *Vibrionaceae* at an Inland Bays location, and has contributed to the development of a predictive index for when conditions are favorable for *Vibrio* outgrowth.

Assessment of Oyster (Crassostrea virginica) Restoration within Human Altered Shoreline in the Delaware Inland Bays: An examination of Riprap stocked with The Eastern Oyster (*Crassostrea virginica*). Brian A. Reckenbeil. Master's Thesis, Delaware State University.

A fourth project completed during summer 2013 in part evaluated the effectiveness of using existing riprap (rocks and larger stones used for shoreline erosion protection) as a substrate for oyster stock enhancement at several different Inland Bays locations. The study found that overall survival of recovered oysters averaged 50 percent with a 29 percent loss rate attributed to wave action especially at the higher energy sites. Survival among planting sites was not significantly different, but riprap constructed with medium sized rocks 16-24 inches in diameter (0.4-0.6 meters) proved to be the most ideal for both oyster stock enhancement and survival.

4.7 Inland Bays Hard Clam Survey (2010-2011)

A quantitative hard clam population density and distribution survey was conducted by DNREC and the CIB during the 2010 and 2011 field seasons in Rehoboth and Indian River Bays. The purpose of the survey was to compare and update previous survey information collected during 1976, with current distribution and density changes for possible reclassification of shellfish growing areas, and for spatial planning purposes related to potential siting of shellfish aquaculture bottom leases. The survey duplicated the sampling methods used by Cole and Spence (1976) by deploying a hand operated Venturi Suction Dredge. The device utilizes water pressure to "vacuum" all clams, other benthic shellfish species and sediment from a series of 1 square meter (10.8 square foot) sampling plots following a bay-wide grid pattern at 1,500 foot

(457 meters) intervals. A total of 194 sites were sampled in Rehoboth Bay and 83 sites were sampled in Indian River Bay. There were no significant differences in clam densities in Rehoboth Bay and Indian River Bay respectively between the 1976 and 2011 surveys, but significant density differences were found between the 2 bays in both the 1976 and 2011 surveys. Clam density distribution results were significantly different between bays in 1976, but not in the 2010 survey. Higher density and distribution values in Rehoboth Bay were attributed to more uniform environmental conditions and sediment characteristics conducive to higher clam recruitment and survival. Overall, clam densities in both bays were considered to be historically stable based on 2011 survey results. For additional survey results and analysis, see *Hard Clam (Mercenaria mercenaria) Population Density and Distribution in Rehoboth Bay and Indian River Bay, Delaware* <http://www.inlandbays.org/wpcontent/documents/hard_clam_final_copy.pdf>.

The Little Assawoman Bay (LAB) is currently classified as a nonproductive resource area by the State Shellfish and Recreational Water Programs due to negligible standing stocks of bivalve shellfish. As an addition to the work in Rehoboth and Indian River Bays, a bull rake survey conducted at 10 locations in LAB during summer 2012, recovered a total of 9 hard clams.

4.8 Inland Bays Shellfish Aquaculture Research and Demonstration Summary

Inland Bays shellfish aquaculture research and demonstration work conducted from 1998 to 2013 has produced valuable information on hard clam abundance and distribution, and the performance and environmental benefits of different shellfish technologies used for stock enhancement, restoration, and seafood production. The main or open areas (approved shellfish harvest waters) of all three bays with good water quality and current flow conditions support the best hard clam and oyster growth. Oyster growth and survival in the lower quality closed waters of the residential canal systems used for the oyster gardening program is highly variable in proximity to water quality and flow, ranging from poor (≤ 25 percent survival) in terminal, and dead end canals furthest from the open bay to very good-excellent (≥ 80-95 percent survival) at gardening sites closer or adjacent to open water.

Off-bottom and floating oyster aquaculture gear supports significantly higher growth and survival, and provides greater habitat value (species abundance and richness – the number of different species present) in comparison to on-bottom oyster planting (artificial reef) which may be subject to higher cumulative mortality due to exposure to harsher environmental conditions such as sedimentation, hypoxia (low oxygen), predation, algal mat (Sea Lettuce, *Ulva lactuca*) accumulations, and stress related increases in pathogen prevalence. Larger scale, multi-acre reefs like those developed in Virginia and Maryland on historic oyster grounds with hard bottom, three-dimensional topographic relief, and exposure to greater current flow have demonstrated restoration value. Spat on shell bottom planting is also a production method in both states for the shucked oyster market. In Delaware’s significantly smaller Inland Bays, the use of riprap as an alternative substrate vs. artificial reef development has proven to be a more effective method for oyster stock enhancement. Planting several thousand acres of bottom leases with wild seed oysters (temporary artificial reefs for commercial production) was the basis for the Inland Bays oyster industry from the 1940s up to its final demise during the 1960s and 1970s.

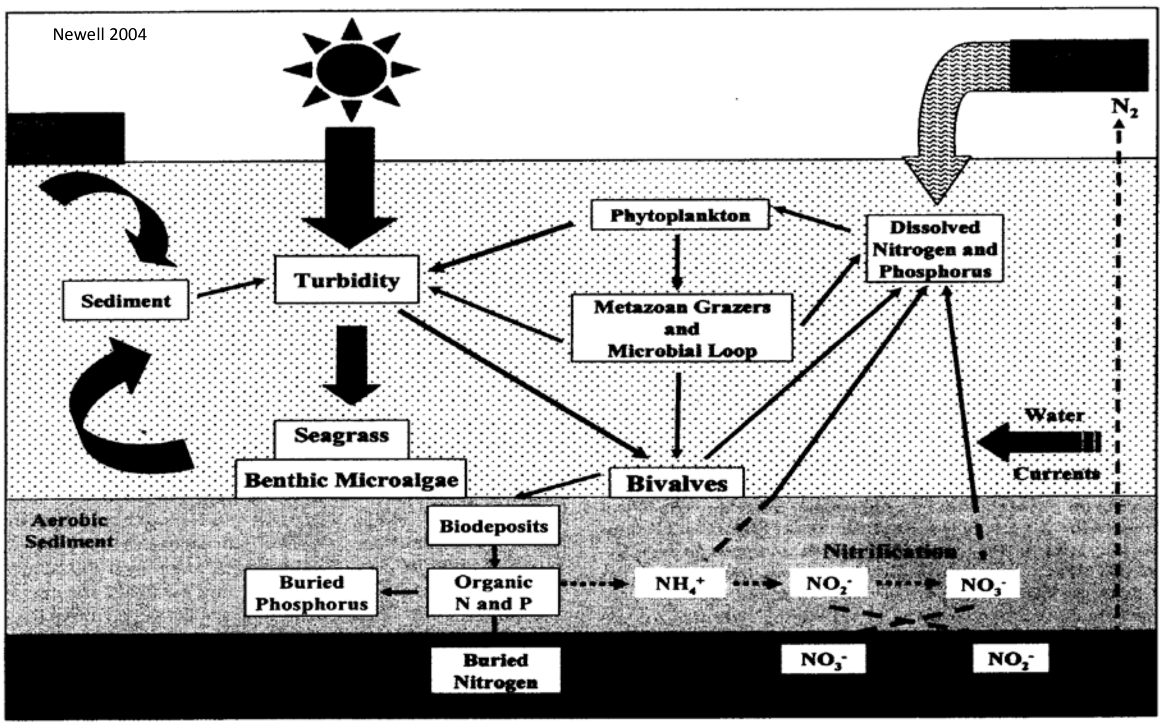
This production method is no longer economically viable or logistically feasible, and renewing large acreage leases is not an option given historical and anticipated present day conflicts with other commercial and recreational stakeholders. Aquaculture technologies such as off-bottom cages, racks, and floating oyster growout gear stocked with hatchery produced disease resistant seed oysters on smaller 1-5 acre leases in underutilized or non-navigable areas of the Inland Bays represent a proven and much more efficient and highly productive approach for commercial scale production.

Research to characterize Inland Bays hard clam growth demonstrated that approved waters in all three bays supported growth to market size in 2 growing seasons. Predation by crabs, moon snails, whelks, drills, and especially by the cow nosed ray (*Rhinoptera bonasus*) in Rehoboth and Indian River Bays is a significant concern for stock enhancement and commercial production requiring the use of predator exclusion netting to minimize losses that can reach 100 percent without protection. Recent (2011) clam density and distribution surveys in Indian River and Rehoboth Bays provided important information for resource management and marine spatial planning decision making. Clam densities in both bays are considered to be historically stable based on comparison of the current survey results with survey data collected in 1976.

The Little Assawoman Bay is unique in comparison to the other Inland Bays. It is considered to be a nonproductive resource area due to negligible standing stocks of commercially important bivalve species. Also, the bay's geographical location, and its relatively closed nature offers good potential for larval retention and natural recruitment facilitated by shellfish culture, and/or establishment of shellfish spawning sanctuaries. Water quality and environmental conditions support good growth of hatchery produced oyster and clam seed to market size. The bay scallop (*Argopecten irradians*), widely recognized for its rapid growth, and high reproductive and colonization rate, is a potential candidate species of interest that thus far has not been evaluated. Water quality conditions at some Fenwick Island residential canal oyster gardening sites supported larval development and natural recruitment. Oysters and shell in the Taylor Floats used for oyster gardening were found to provide valuable habitat and refuge for 49 commercial and recreational fishery and forage species of juvenile fishes and invertebrates. Overall, there is good potential for commercial oyster aquaculture in the Little Assawoman Bay using off-bottom culture gear (floats, cages, trays, or rack and bag systems). Clam aquaculture is more feasible in the shallow waters and firmer sediments found on the eastern side of the bay. The total area of bay bottom suitable for clam culture has not been determined. Commercial scale production methods (predator nets, soft bags) and optimum stocking densities have not been evaluated.

5. **Environmental and Ecological Benefits of Shellfish Aquaculture**

There is growing recognition of the important beneficial impacts of shellfish aquaculture on improving estuarine health. Bivalve shellfish feed by filtering bay water to remove phytoplankton and other suspended particles. By serving as natural biological filters, they perform an important ecological function to maintain water clarity and quality and to re-cycle nitrogen and phosphorous, two nutrients responsible for over-enrichment of the Inland Bays and other estuaries. This "keystone species" role of oysters and other filter feeding bivalves, such as hard clams and mussels, and the associated ecosystem services they provide, is a key rationale for shellfish stock enhancement/restoration programs and commercial aquaculture development around the coastal United States and internationally. Ecosystem services are natural biological, chemical, and physical processes that yield important environmental benefits that are often poorly understood or are taken for granted. For example, salt marshes and other wetlands serve as a filter to clean water resources while also providing a food source and habitat for juvenile fish and birds. Marsh grasses capture sediment and improve water quality, and bacteria decompose organic waste. Marsh and other wetland plants produce oxygen via photosynthesis and stabilize sediments providing protection to upland communities from storm surges. Ecosystem services associated with bivalve filter feeding shellfish include turbidity reduction, water quality improvement, nutrient cycling and removal, nutrient sequestration, nursery habitat for other juvenile invertebrate and fish species, and high (larval/spat) reproductive rates that serve as a food source for other predators and support natural recruitment.



Nutrient pollution from excessive levels of nitrogen and phosphorous is the primary cause of reduced water quality and species diversity in Delaware's Inland Bays and other estuarine systems. Coastal waters in moderate to highly populated areas are often classified as "degraded" due to excessive nutrient inputs from difficult to control non-point sources such as land run-off from fertilizer, sewage, suburban development, and fossil fuel combustion. In marine systems, excessive nitrogen levels increase turbidity by promoting blooms of phytoplankton and macro-algae (seaweeds). Reduced light penetration shades out eelgrass and other submerged aquatic plants that provide both nursery refuge habitat and oxygen for juvenile fish and invertebrates. When the algae eventually completes its life cycle and dies, the resultant organic decomposition and oxygen demand by bacteria further reduces oxygen levels leading to hypoxia, habitat loss and lower species diversity.

Oysters and other bivalves are highly efficient at filtering algae, sediments, and other suspended particles from the water column. A single adult oyster can filter approximately 30 or more gallons of seawater per day. This filtration process is the mechanism by which the oyster captures and consumes particulate food necessary for maintenance and growth. An equally important but lesser known benefit of oyster and other bivalve shellfish filtration is that the solid waste products or bio-deposits produced from feeding effectively capture and remove nitrogen taken up by the phytoplankton. These nutrient rich bio-deposits reduce the environmental availability of nitrogen in the water column, and also serve as a food source for small bottom dwelling (benthic) worms and crustaceans which in turn represent the food source for a diverse community of fish, crabs, and other larger invertebrates. An aerobic (using oxygen) bacterial process called nitrification stabilizes and reduces the bio-availability of nitrogen, and another bacterial driven geochemical process known as denitrification occurs in anaerobic (no oxygen) bottom sediments, and removes nitrogen from the aquatic environment in gaseous form. Increased filtration of plankton by healthy shellfish populations can also help to minimize or prevent harmful algal blooms (HABs) from occurring. In addition to facilitating the transfer nutrient energy (nitrogen and phosphorous) from the water column to bottom (benthic) communities, the oysters themselves assimilate or sequester nitrogen and phosphorous in their body tissues and carbon in their shells.

Ferreira et al. (2011), discussing the role of shellfish farms in provision of ecosystem goods and services in the Wiley-Blackwell book *Shellfish Aquaculture and the Environment*, estimates that "net nitrogen removal from a 1.5 acre oyster farm would correspond to the amount of nitrogen from untreated wastewater discharge for more than 3,000 people, or treated sewage of about 18,000 people." Robert Rheault, executive director of the East Coast Shellfish Grower's Association (ECSGA), has calculated that a market-size oyster contains 0.2-0.5 grams of nitrogen and 0.16 grams of phosphorous. Although nutrient and carbon sequestration by individual oysters may appear to be inconsequential, Rheault estimates that the harvest of 3,750 oysters (equivalent to 15 bushels at 250 oysters per bushel) compensates for the annual nitrogenous waste production of one person living in the watershed. The combined effect of just the U.S. eastern oyster commercial aquaculture harvest alone (800 million oysters) from the east and Gulf coasts excluding other commercially produced species (500 million hard clams) and wild populations, is estimated to filter 94 million cubic meters (2.48 trillion gallons) of water daily and annually remove 357 metric tons of nitrogen, 110 metric tons of phosphate, hundreds of tons of other nutrients removed by burial or denitrification, 51,559 tons of sequestered carbon and approximately 1.7×10^{15} (1.7 quadrillion or 1,700 billion) larvae released to the environment.

Shellfish aquaculture is also responsible for converting thousands of acres of barren bottom into productive fish habitat. The interstitial spaces created by the three-dimensional profile of the living and dead oyster shells on natural or restored reefs and the structure provided by aquaculture cages, floats, and other growout systems are protective refuge and nursery habitat for juvenile fish and shellfish. This structure also creates a settlement substrate for a variety of seaweeds, barnacles, sponges, mussels and other food and forage species including the recruitment of the next generation of oysters. There is a growing body of research documenting that aquaculture cages and floats commonly used for shellfish growout (typically because of their larger three-dimensional volume) support a higher abundance of fish and crustaceans than eel grass beds. The diversity of species found is comparable to an eelgrass environment and is far superior to species diversity on non-vegetated bottom. Tallman and Forrester (2007) determined that aquaculture cages mimic essential fish habitat because of its structural similarity to natural and constructed rocky reefs with similar patterns of biodiversity, species assemblages, and growth and survival rates. As an added benefit, increasing the volume and productivity of fish habitat can in turn enhance the viability of fisheries for recreationally and commercially important species.

Despite these numerous environmental and ecological benefits, it is important to emphasize that shellfish aquaculture is not a panacea for estuarine nutrient pollution. While unlikely to exclusively counter excessive nutrient problems, it is however, an affordable mechanism to address non-point source nutrient issues and can be a viable component of a multi-faceted management strategy. Shellfish farmers are by definition stewards of the environment and advocates for clean water because their businesses and livelihoods depend on it. Members of the shellfish industry are often likened to "canaries in the coal mine" when it comes to detecting (and opposing) watershed management policies and activities contributing to water quality degradation. Shellfish producers lead the seafood industry in sustainability by often adopting "Codes of Practice" or Best Management Practices (BMPs) with methods designed optimize environmental benefits and to educate consumers about the origin, quality, and safety of their products.

6. **Shellfish Aquaculture and Economic Development**

Shellfish aquaculture contributes both directly and indirectly to local economic development. Besides the farm gate or market value of the product, the industry supports full-time and part-time seasonal employment and a variety of business related goods (boats, equipment, supplies) and services (processing, marketing, distribution, retail sales), which collectively are estimated to have a multiplier effect on farm gate value by a factor of 2.5 times and higher. The current farm gate value of the U.S. shellfish aquaculture industry is estimated at $200 million. According to the East Coast Shellfish Growers Association (ECSGA), shellfish aquaculture production on 1000 farms from Maine to Florida is valued at approximately $119 million with Virginia, Florida, and Massachusetts as the top three producing states. Full (1,162) and part-time/seasonal (1,297) employment equals 2,459.

In addition to business development and employment, shellfish aquaculture for seafood production, stock enhancement, and restoration also offers indirect economic benefits that are not as well understood or are difficult to quantify. Examples include cultural and quality of life aspects such as increasing the local seafood supply, preservation of working waterfront and coastal community heritage, enhanced recreational fishing, and eco-tourism. Various ecosystem services associated with shellfish aquaculture are also increasingly viewed as having significant economic value. Valuation of ecosystem services (water filtration, nutrient cycling, habitat creation/preservation, shoreline stabilization, and other benefits) on estuarine water quality and environmental health is currently an active and growing area of research among marine resource economists. Some estimates suggest that the value of ecosystem services associated with shellfish aquaculture may equal or exceed the crop's harvest value.

With the exception of Delaware, all other east coast states currently have commercial shellfish aquaculture activity. Updates on the status of shellfish aquaculture for four states in particular Virginia, Maryland, New Jersey, and Rhode Island provide useful insight and examples for evaluating the economic development potential for commercial shellfish production in Delaware's Inland Bays. All four states have similar barrier island coastal bay systems, and all share a common maritime heritage with respect to shellfish and commercial fisheries. Neighboring Virginia, a major seafood producer from capture fisheries and aquaculture, has one of the best developed shellfish aquaculture industries in the country and leads the nation in hard clam production. Maryland with a much smaller industry but similar development potential has recently enacted significant legislative and policy changes designed to support and facilitate expansion of shellfish aquaculture. New Jersey commercial clam aquaculture dates back to the 1970s. There is very good potential for additional shellfish aquaculture but conflicting state policies and regulatory hurdles have limited any significant industry expansion. Rhode Island and Delaware, as the two smallest states in the nation, have much in common with regard to marine resources and constraints to shellfish aquaculture development. A Rhode Island Sea Grant publication *A History of Oyster Aquaculture in Rhode Island*, provides a historical context and describes the renewed interest for leasing bottom for shellfish aquaculture in the late 1980s and the related issues and policy changes enacted during the 1990s that set the stage for the steady and significant growth the Rhode Island shellfish industry has experienced especially during the last decade.

Virginia

The Commonwealth of Virginia is a leading national producer of seafood from both capture fisheries and aquaculture. Virginia is the largest producer of cultured hard clams in the U.S. with the industry centered on the bayside and seaside of the Eastern Shore. The annual status of shellfish aquaculture is estimated by the Virginia Sea Grant program using a producer crop reporting survey. Results from 2012 are summarized in a situation and outlook report that is available online (see http://www.vims.edu/research/units/centerspartners/map/aquaculture/docs/MRR2013_02.pdf).

Hard clams and oysters are the two main species produced. After more than a decade of steady expansion, clam production, valued at $26.8 million during 2012, has not had a positive growth trend since 2005. During that same six year period, the number of market oysters sold has undergone an unprecedented, rapid expansion from 800,000 in 2005 to 28.1 million in 2012 valued at $9.5 million. While there has been a long tradition of extensive (low intensity) oyster planting on privately leased bottom for more than a century, the impact of predation and MSX and Dermo diseases has prompted a transition by the industry to more intensive off-bottom cage culture. Use of protective gear and disease resistant triploid (a genetic modification that reduces reproductive capacity and increases growth rate) hatchery stocks have offset previous losses from predation and disease. The Virginia shellfish industry and bottom leasing system is managed by the Virginia Marine Resources Commission (VMRC)

<http://www.mrc.state.va.us/Shellfish_Aquaculture.shtm>. The industry is currently comprised of 73 farms with employment at 117 full-time and 211 part-time or seasonal jobs.

Maryland

Maryland's aquaculture industry has an annual farm gate production of approximately $5 million. Growers produce a wide range of aquatic species with ornamental fish and aquatic (ornamental) plants as the oldest and largest contributing sectors. The shellfish industry, valued at $500,000, produces oysters and hard clams. Expansion of the industry has been significantly limited by outdated leasing and management regulations. Governor Martin O'Malley's interest in the economic and environmental benefits associated with shellfish aquaculture and the success of the Virginia shellfish industry prompted a state initiative to remove policy constraints to shellfish aquaculture in Maryland. Legislation enacted in 2009 by the State Assembly streamlined the regulatory process and leasing management system, created pre-permitted Aquaculture Enterprise Zones (AEZ), significantly increased penalties for poaching and theft from shellfish farms, and opened up additional areas of unproductive bottom for private sector leasing. The shellfish aquaculture program and bottom leasing system is managed by the Maryland Department of Natural Resources (DNR) <http://www.dnr.state.md.us/fisheries/oysters/industry/aquaculture/>.

New Jersey

The earliest examples in New Jersey of local baymen using aquaculture methods with wild oyster seed) date back over 100 years. Initial industry oriented research on shellfish biology and ecology is attributed to Julius Nelson at Rutgers University in the late 1800s. Further work by his son Thurlow Nelson and later by Harold Haskin formed the basis for industry related shellfish aquaculture research and development that continues to the present day. The Haskin Shellfish Research Laboratory (HSRL) located in Bivalve, N.J. is a world leader in shellfish genetics and breeding programs for aquaculture and for research on shellfish pathology.

The current status of the shellfish aquaculture industry in New Jersey is summarized in a 2011 report *Opportunities and Potential for Aquaculture in New Jersey*. According to the Rutgers Cooperative Extension report, the current farm gate value of the shellfish aquaculture industry is estimated at $4 million with an estimated 5 time seafood multiplier effect for a total of $20 million. Clams are the principal species with 30-40 growers and oyster production with 11 growers is ranked second. There are also 5 commercial hatcheries in the state. Despite ranking as the 5th top clam producing state nationally, New Jersey remains a net importer of shellfish because domestic production is insufficient to satisfy local market demand. The New Jersey Department of Agriculture (NJDA) serves as the lead agency for aquaculture development. Shellfish lease administration is managed by the Bureau of Shellfisheries in the New Jersey Department of Environmental Protection (NJDEP). An Aquatic Farmer License (AFL) program and creation of Delaware Bay Aquaculture Development Zones (ADZ) for shellfish aquaculture are examples of efforts targeted to regulate shellfish aquaculture as an agricultural vs. a natural resource activity and to streamline and improve integration of state agency and coastal zone management policies.

Rhode Island

Since 1995, the Rhode Island farm-raised shellfish industry had experienced steady growth to its current valued of $2.82 million in 2012. Combined value of aquaculture products for consumption and restoration was $3.01 million. During 2012, the average production per acre of leased bottom was $17,439. Species of interest include eastern oysters, northern quahogs (*Mercenaria mercenaria*), and blue mussels (*Mytilus edulis*). Oysters are the number one product in terms of production and value, representing 99 percent of the total farm gate. There are 50 farms with 105 employees (32 full-time and 73 part-time or seasonal jobs) and 172.6 acres under lease. The General Assembly created the Coastal Resources Management Council (CRMC), which has responsibility for aquaculture regulatory oversight. The CRMC staff includes an Aquaculture Coordinator position to administer bottom leases and associated management policies. The Aquaculture Coordinator produces an annual review, *Aquaculture in Rhode Island 2012 Annual Status Report*, containing detailed information about Rhode Island's aquaculture production based on survey results from leaseholders.

7. Issues and Constraints Affecting Inland Bays Shellfish Aquaculture

In response to increased public interest and inquiries regarding the potential for commercial aquaculture in Delaware's Inland Bays (IBs), the Center and partners organized an educational workshop, "*Shellfish Aquaculture in Delaware's Inland Bays: Status, Opportunities, and Constraints*," which was held on June 18, 2011. The program included representatives from the shellfish aquaculture industry, researchers, state legislators, resource managers, prospective shellfish farmers, and other stakeholders. Speakers reviewed the early history of the estuary and the former Inland Bays oyster industry (1940s-1970s); summarized Inland Bays research and demonstration results; discussed the industry status and issues affecting commercial shellfish aquaculture in other regional and leading east coast states; and reviewed current regulatory and policy constraints affecting Delaware shellfish aquaculture. Two important findings from the workshop were that 1) Inland Bays field research and demonstration work, commercial activity in neighboring states and the continued development of the industry on a regional and national scale validate the environmental and economic benefits of shellfish aquaculture for seafood production and coastal community economic development; and 2) Delaware is the <u>only</u> coastal state on the eastern seaboard with <u>no</u> commercial shellfish aquaculture due primarily to the absence of an Inland Bays sub-aqueous leasing system (rescinded in 1979) and other state regulatory policies that, in effect, prohibit shellfish aquaculture in the Inland Bays. Spatial planning information for resource management decision-making and for regulatory policy review/reform to determine how best to integrate management of commercial shellfish aquaculture with other compatible uses of the estuary was clearly identified as a future need. In response to these workshop issues, the Center for the Inland Bays organized and convened a public and private sector stakeholder work group ("Tiger Team") in March 2012 which met monthly to March 2013 with the targeted goal of producing a legislative policy initiative and management framework for commercial shellfish aquaculture in the Inland Bays (See Section 8., page 36) .

7.1 State and Federal Aquaculture Regulatory Authority

The Delaware Aquaculture Act enacted by the General Assembly in 1990 designated the Delaware Department of Agriculture as the lead agency to coordinate aquaculture development in the State. The Department has proposed draft regulations pertaining to aquaculture in non-tidal waters and no specific regulations exist for aquaculture in tidal waters. Shellfish or finfish aquaculture in tidal waters is presently subject to governance on a case-by-case basis by DNREC under existing fishery statutes and regulations detailed in Title 7 and relevant chapters.

The Delaware Aquaculture Act also created a 12-member Advisory Council to promulgate regulations governing aquaculture in the State of Delaware; to provide technical assistance and marketing; and to ensure that aquaculture activities do not promote introduction of potentially competing exotic species. To date the Department of Agriculture in consultation with DNREC has not been called upon to issue any shellfish aquaculture permits in the Inland Bays or elsewhere in Delaware. Additional rule making and/or legislative authority will be necessary in order to effectively do so.

Statutes embodied in 7 DE Code, Titles 19, 21, 23 (Shellfish) define shellfish as any mollusca, crustacea, or chelicerata (horseshoe crabs). These statutes give DNREC control and direction of the shellfish industry and protection of shellfish resources, authority to promulgate regulations to preserve and improve the shellfish industry and shellfish resources, to issue licenses, to establish leases of shellfish grounds, issue scientific collecting permits, and enforce marine fishing laws and regulations. Some other specific regulatory authorities granted to DNREC include prevention and control of shellfish-borne diseases and to regulate and inspect vessels or equipment used in the shellfish industry.

The DNREC Division of Fish and Wildlife issues shellfish harvest licenses, enforces laws and regulations governing shellfish harvesting, conducts scientific surveys of shellfish resources, and collects harvest statistics. By regulation, no one may bring oysters from outside the State to be placed in waters of the State without prior written approval of the Division. With regard to the Division's oversight of leasing of shellfish bottom on public sub-aqueous lands, there can be no reinstatement of shellfish bottom leases in the Inland Bays until 1) completion of a shellfish survey (first done in late 1970s and updated in 2011and 2012); 2) two public hearings are held (one hearing was held in February 1979); and there is a concurrent resolution passed by the Delaware General Assembly to approve a shellfish management plan for the Inland Bays. The management plan which in part recommended rescinding bottom leases until such time when shellfish mariculture was determined to be again 'feasible" was submitted to the General Assembly in 1979, but never received formal approval leaving the issue technically unresolved. Mass oyster mortalities caused by the MSX epidemic, however, precipitated the same result. With the abandonment of the last four remaining and unproductive Inland Bays oyster bottom leases in 1979, all Inland Bays sub-aqueous lands returned to "public bottom" status. That is the recognized situation today and there is general agreement that reinstatement of an Inland Bays bottom-leasing program for shellfish aquaculture will require the approval of the Delaware General Assembly. If by legislative action leases are to be issued for the Inland Bays, then there are fees and minimum size requirements that must be changed (presently leases must be 50-100 acres in size) and advertising and monthly reporting requirements and other shellfishing prohibitions on leased shellfish grounds must be re-considered. Attempts to rear shellfish (and finfish for that matter) for aquaculture purposes in the waters of the Inland Bays would be ground breaking and would require new regulations from DNREC and better defined statutory authority among permitting and regulatory state agencies.

DNREC Division of Water

The Wetlands and Subaqueous Lands Branch of the issues permits for the placement of any structure on or over public and private sub-aqueous lands or for the dredging, filling, extraction of materials or mooring of platforms over sub-aqueous lands. This branch also issues leases of sub-aqueous bottom. Docks and floating platforms require a sub-aqueous lease (presently leases are for 20 years and there is a fee of $225 required at application). Since heretofore no leases for aquaculture purposes have been applied for, permit requirements on any such application are likely to be ground-breaking. Any discharges from a land-based aquaculture facility to the waters of the Inland Bays would require a permit.

DNREC Division of Watershed Stewardship

The Division of Watershed Stewardship contains the Shellfish Sanitation program, whose task it is to ensure that any shellfish legally harvested in Delaware are fit for human consumption. The Shellfish Sanitation program classifies shellfish growing areas, adopts laws and regulations for control of the shellfish industry, conducts sanitary surveys of harvesting areas, inspects shellfish facilities, issues certifications to shellfish dealers, and issues tags and permits. It also participates in the National Shellfish Sanitation program, which is recognized by the U.S. Food and Drug Administration (FDA) to promote and improve sanitation of shellfish in interstate commerce with annual oversight by the FDA. Enforcement of the shellfish sanitation requirements among shellfish harvesters is enforced by the Division of Fish and Wildlife Enforcement Section. Shellfish growing areas are classified by the Shellfish Sanitation program using three general classifications: those waters from which shellfish harvest is approved year round, those from whose waters shellfish harvesting is seasonally approved, and those areas closed to shellfish harvesting year round. The Shellfish Sanitation program specifies regulations for relays of shellfish from seasonally approved areas and depuration requirements for these shellfish before they may be marketed. The classification areas in the Inland Bays are delineated on maps provided by DNREC, are available on DNREC websites, and apply to the harvest of any bivalve shellfish. Delaware uses counts of total coliform bacteria to classify approved waters for shellfish harvesting. Permits are issued for certified shellfish dealer and/or processors in compliance with state and federal HACCP (Hazard Analysis Critical Control Points) specifications. The Shellfish Sanitation program can specify that shellfish harvesting areas are to be closed for emergency purposes.

U.S. Army Corps of Engineers Federal Permits

U.S. Army Corps of Engineers has jurisdiction for issuing federal aquaculture permits under the Rivers and Harbors Act. Federal Modifications to pre-existing commercial shellfish aquaculture projects (of which there are none presently in the Inland Bays) would be covered under

Nationwide Permit 48 (NWP48). The permit includes provisions to protect navigation, spawning areas and migratory patterns of aquatic species, migratory bird breeding areas, and concentrated shellfish populations. Recently the Corps has modified NWP48 to authorize commercial shellfish aquaculture activities in new project areas, provided the project proponent obtains a valid authorization (e.g., a lease or permit from the appropriate state or local government agency responsible for granting such leases or permits) and the activity will not directly affect more than 1/2-acre of submerged aquatic vegetation beds.

7.2 Socio-Economic Issues

In addition to state, federal, and often local regulatory requirements, there are other public resource equity considerations associated with the siting and operation of shellfish aquaculture farms. The most significant of what are collectively known as "socio-economic issues" are the inherent conflicts that occur among local stakeholders with regards to accessing coastal waters for different recreational and commercial uses. The Delaware Bay, the Inland Bays, their tributaries, and other tidal and non-tidal water bodies are all considered to be public resources that are classified as "waters of the State" for regulatory and management purposes in accordance with maintaining the "public trust". According to the National Sea Grant Law Center, the Public Trust Doctrine is a historic element of common law that "provides that public trust lands, waters, and living resources in a state are held by the state in trust for the benefit of all the people"... It establishes the right of the public to enjoy fully public trust lands, waters, and living resources for a wide variety of public uses." The most commonly cited uses include navigation, recreational boating and sailing, recreational and commercial fishing, and other forms of commerce which would include temporary leasing of the water column or bay bottom for shellfish aquaculture. State resource agencies have the responsibility to identify and manage the proper balance among these "conflicting uses" in a manner that best benefits the overall public interest.

When bottom leases are allocated for commercial shellfish aquaculture, other coastal stakeholder groups may be potentially affected. The primary concerns of local watermen are that aquaculture leases and future industry growth will jeopardize their livelihood by excluding them from prime fishing areas, interfering with navigation, and undermining market prices for wild harvested products. Recreational and commercial boaters also have similar concerns about reduced access, navigation, and safety. Another reaction that has become widely known as NIMBY (Not In My Back Yard), waterfront property owners may view shellfish farms as potentially restricting their riparian rights to utilize adjacent waters or they may object to the negative aesthetic of having a shellfish farm and the sights and sounds of daily operations interfering with waterfront views and the enjoyment of their property. However, with thorough planning, public input, and an efficient regulatory framework, there are numerous and widespread examples of the successful integration of shellfish farms with commercial and recreational fishing and other coastal activities.
Most of the U.S. coastal states have determined that the sum total of environmental and economic contributions made by shellfish farms substantially benefit the greater public interest and include aquaculture as an additional compatible use of tidal waters. Individual state agencies develop and implement siting and management programs designed to minimize conflicts with other user groups, and to assure orderly industry operation and development. In addition to

federal Army Corps of Engineer navigation and environmental provisions, other state regulatory approaches to reduce conflicts include the use of minimum buffer zones for shorelines and navigable channels; limiting assignment of bottom leases to naturally unproductive or underutilized areas; “use it or lose it” lease provisions; farm bonding requirements to insure active participation and proper removal of storm damaged or abandoned gear; limitations to industry development in a waterway based on a maximum acreage allowance and/or ecological carrying capacity limit; and a public hearing and review process for lease applications and new regulations. To streamline and simplify the siting and regulatory process some states like New Jersey and Maryland have pre-designated tracts of bottom as Aquaculture Enterprise Zones (AEZs) allowing shellfish farms to operate under a comprehensive general permit.

8. Developing a for Plan for Inland Bays Shellfish Aquaculture: Regulatory/Policy Review, Marine Spatial Planning, and Public Stakeholder Forum (CIB Tiger Team)

The cumulative results of more than a decade of Inland Bays applied shellfish research, demonstration and field work and related activities in neighboring states increased public interest in Inland Bay shellfish resources and aquaculture as a management tool for stock enhancement and possible commercial production. Subsequent to the public forum “Shellfish Aquaculture in Delaware’s Inland Bays: Status, Opportunities, and Constraints” held on June 18, 2011 in Lewes, Del., the Center for the Inland Bays convened a shellfish aquaculture task force or “Tiger Team” in March 2012 to evaluate scientific and educational accomplishments, and policy changes needed to re-establish commercial shellfish aquaculture in Delaware’s Inland Bays. The Team included representation from the Center for the Inland Bays, the Delaware Sea Grant Marine Advisory Service, DNREC, Delaware Department of Agriculture, Delaware Shellfish Advisory Council, commercial shellfish industry, recreational fishing, Sussex County Economic Development Office, and other stakeholder groups. The Policy, Permitting and Funding Subcommittee reviewed current rules and regulations in the Delaware Code and proposed draft revisions and legislation to permit commercial aquaculture on the Inland Bays. The Spatial Planning Subcommittee used Geographic Information System (GIS) technology and stakeholder consultation to identify and map existing uses and activities on the bays to determine the areas that shellfish aquaculture can occur in balance with other bay users. The Education and Outreach Committee worked to inform the public about the economic opportunities for coastal communities, and ecological benefits related to commercial shellfish aquaculture. During 2012 the Team and its three subcommittees held 22 meetings and consulted with regional shellfish aquaculture experts on economic, management, and policy issues. In March 2013, the Tiger Team released a final report with recommended policy revisions for an aquaculture legislative initiative for consideration by the Delaware General Assembly <http://www.inlandbays.org/wp content/documents/Tiger_Team_Report_Full.pdf >.

By unanimous vote of the Shellfish Aquaculture Tiger Team, the final report recommended consideration of the following points in any proposed revisions to the Delaware Code:

1. **Who administers:** DNREC’s Division of Fish and Wildlife shall administer the leasing of shellfish aquaculture sites in Delaware waters. Division of Fish and Wildlife’s approval does not remove the applicant from complying with any and all other state and federal requirements for

site approval and marking. DNREC's Division of Watershed Stewardship Shellfish and Recreational Waters Program will ensure that all shellfish aquaculture in Delaware waters complies with the National Shellfish Sanitation Program.

2. **Assigning leases:** After due public notification, shellfish aquaculture lease sites shall be assigned initially by a lottery. Participants in the shellfish aquaculture sites lottery shall include all persons, partnerships, or corporations who register in advance their desire to participate in the lottery. The first applicant (name/partnership/corporation) drawn shall have first choice among available aquaculture lease sites up to the maximum acreage available to any one applicant. The second applicant drawn by lottery shall have second choice as to lease sites, and so on, until all applicants have selected lease sites, or the pre-approved lease acreage is exhausted. After the initial lottery is held, any new applicants may select sites from among available lease sites on a first-come, first-served basis.

3. **Size of leases:** Leases shall be issued on a per acre basis. The minimum lease acreage shall be 1 acre and the maximum to be issued to any one applicant shall be 5 acres within Rehoboth Bay and Indian River Bay combined. An applicant who leases up to 5 acres in Rehoboth Bay and/or Indian River Bay may also lease an additional 1-5 acres in Little Assawoman Bay. Lease sites issued to an applicant may be separate or contiguous up to the maximum of 5 acres. Leases that shall be issued in Rehoboth and Indian River Bays shall not exceed 5 percent of the total subaqueous lands within each of these Bays. In Little Assawoman Bay, the maximum allowable acreage for leasing shall not exceed 10 percent of the subaqueous lands within Little Assawoman Bay. After 3 years from the date of issuance of the first lease, DNREC shall decide by regulation if the size of leases issued to any one applicant may be increased beyond 5 acres. Those already holding leases shall have first right of refusal concerning adding to their acreage beyond 5 acres up to the maximum acreage allowed.

4. **Duplication of lease sites:** There shall be no overlap of lease sites, nor duplication in lease holders for any particular lease site. Holding of a valid lease site may be transferred at any time from one applicant to another applicant by written transfer on an application to be issued and administered by DNREC.

5. **Lease terms:** Leases are annually renewable for 15 years. At the end of a 15-year lease period, the holder of the previous lease shall have first right of refusal for a further 15-year renewal of the original lease.

6. **Abandonment of lease sites:** Abandoned leases go back into the pool of available lease sites. Lease holders may designate any 1-acre or larger portion of their lease site to go back into the inventory of available lease sites at any time during the calendar year. There shall be no refund of lease fees for acreage that is placed back into the inventory of leasable acreage.

7. **Lease fees:** The application fee for an aquaculture lease shall be $300. The annual fee for a lease shall be $100/acre for a resident and $1,000/acre for a non-resident. All lease application and annual fees shall be received by DNREC Division of Fish and Wildlife and used to partially

offset aquaculture program administrative and operating costs. There shall be reciprocity for nonresident applicants in that if other states charge their nonresidents more for a shellfish aquaculture lease than Delaware does, then whatever fee is greater, to include the non-availability of leasing for nonresidents, then these fees and restrictions shall be imposed upon the residents of any other state that applies for a shellfish aquaculture lease in Delaware.

8. **Harvester license:** DNREC may issue, for $25 per annum a shellfish aquaculture harvest license to qualifying individuals desiring to work only on leased shellfish aquaculture grounds who are not the lease holder for these grounds. Among any crew working on leased shellfish aquaculture grounds, there shall be present at all times at least one person having in his or her possession a valid shellfish aquaculture harvest license or the lease holder possessing proof of a shellfish aquaculture lease to these grounds.

9. **Illegal gear:** It shall be unlawful to use mechanized harvesting gear on leased shellfish grounds other than power winches to raise aquaculture gear.

10. **Poaching:** No person shall take and/or remove any shellfish from an approved shellfish aquaculture lease site without having received written authority by the lessee to take and/or remove said shellfish. Such a violation could be considered petty or grand theft, depending on the value of the shellfish removed. The fine for a first offense shall be $250 to $1,000, plus the dockside value of all such shellfish removed. Subsequent offenses shall be $1000 plus the dockside value of all such shellfish removed. If anyone convicted of a subsequent offense of illegally removing shellfish from leased aquaculture sites has an aquaculture lease site of their own, this lease may be vacated by DNREC; or if the person or persons have an aquaculture harvest license, then his or her license shall be suspended for a period to be determined by DNREC. Any equipment used in the illegal removal of shellfish aquaculture products may be seized by DNREC and made available to the rightful owner. Any shellfish aquaculture products seized will be destroyed and the party guilty of the theft will be assessed the market value of the seized shellfish Assessed penalty funds will be deposited into an account created by DNREC for the purpose of reimbursing the lease holders for their losses of shellfish that occur from the theft in question.

11. **Intentional damage:** The fine for the intentionally removing or intentionally damaging equipment on a leased aquaculture site shall be $500, plus the replacement value of the equipment damaged or removed. DNREC shall determine by investigation whether the damage of said aquaculture equipment was intentional or accidental, and if deemed intentional, the person or persons shall be charged according to this statute. Subsequent offenses shall result in a $1,000 fine per offense, plus license suspension and/or vacating of any leases held by the convicted party.

12. **Regulatory authority:** DNREC is authorized to adopt, promulgate, amend, and repeal regulations consistent with the law, including but not limited to:

> a. Issue and administer leases, licenses and permits to engage in shellfish aquaculture and to revoke said licenses or permits for due cause.

b. To add acreage for shellfish aquaculture from areas not previously identified by DNREC as suitable for shellfish aquaculture, as long as all state and federal criteria are met, and the percentages in #3 above are not exceeded.
c. To inspect and approve vessels and equipment intended to be used in Inland Bays waterways in support of the shellfish aquaculture industry.
d. To prevent and control the spread of shellfish-borne diseases among both shellfish aquaculture products and wild shellfish and to provide for the sanitary harvest, handling, transportation, processing, production, and sale of shellfish aquaculture products and wild shellfish.
e. To inspect and approve the importation of any live or dead shellfish and/or seed-on-cultch material to be used for shellfish aquaculture purposes.
f. To identify areas where shellfish aquaculture leases may be established and to set criteria for the approval of shellfish aquaculture leases that are compatible with and do not adversely impact existing uses like commercial and recreational fishing and boating.
g. To establish criteria for the approval or denial of any requests to conduct shellfish aquaculture outside of identified shellfish aquaculture lease sites.
h. To establish criteria for what constitutes active use of a shellfish aquaculture lease site and the criteria that define the abandonment of a shellfish lease site, and for the release of this acreage into the inventory of leasable shellfish aquaculture sites.
i. To set marking requirements for shellfish aquaculture leases and any equipment moored on, suspended above, or placed on sub-aqueous bottom in Delaware's Inland Bays.
j. To establish reporting requirements for shellfish planted or harvested from aquaculture lease sites.
k. To approve which species of shellfish may be used for aquaculture purposes in the Inland Bays.
l. To establish seasonal restrictions on when leased shellfish aquaculture sites may be actively worked.
m. To establish density methodologies that will allow shellfish aquaculture lease sites to be identified.

9.0 Legislation (House Bill 160) and Future Development

On June 4, 2013 during the 147th session of the Delaware General Assembly, House Bill 160 "AN ACT TO AMEND TITLE 3 AND TITLE 7 OF THE DELAWARE CODE RELATING TO AQUACULTURE" was introduced by Representative (and House Speaker) Peter C. Schwartzkopf, with Additional Sponsors Senators Patricia Blevins, Gerald Hocker, and 14 CoSponsors. The Bill authorized the Department of Natural Resources and Environmental Control "to direct and control the shellfish aquaculture activities within the Inland Bays and to set criteria for the approval of lease sites and applications for leasing".

HB160 Synopsis: "Delaware is the only state on the East Coast of the United States that does not have a shellfish aquaculture industry. Shellfish aquaculture can provide significant economic benefits to coastal communities while improving the water quality and enhancing the habitat value of Delaware's most imperiled estuaries, the Inland Bays. This bill is designed to minimize conflicts with existing uses of the Inland Bays. It authorizes the Department of Natural Resources and Environmental Control to direct and control the shellfish aquaculture activities within the Inland Bays and to set criteria for the approval of lease sites and applications for leasing. The legislation also gives the Department the authority to collect fees for lease applications and to administer a harvester license. The bill sets lease fees and harvester license fees, establishes term limits on leases, sets penalties for non-compliance with the provisions of the bill, defines illegal gear, stipulates what is to be the disposition of abandoned lease sites, and defines what would constitute theft or tampering with gear legally set on leased sites. The legislation also authorizes the Department to promulgate regulations on issuing and administering leases, including the revocation of leases for cause. It further gives the Department regulatory authority over determining: what species may be cultured and where, adding acreage to approved lease sites, the required marking and inspection of lease sites, limits on the type and nature of gear that may be used on lease sites, what would constitute abandonment of lease sites and disposition of gear left on abandoned sites, seasonal restrictions on working on lease sites, prevention and control of shellfish-borne diseases, and criteria for importation of shellfish to be used for aquaculture purposes in order to protect wild shellfish. The legislation also clarifies the authority of the Department of Agriculture to coordinate activities in closed-system aquaculture only and deletes reference to the Department's Delaware Aquaculture Council, which is not active and is no longer needed given the clarification of authority".

HB160 was passed by unanimous vote in both the House (June 11, 2013) and the Senate (June 26, 2013). Delaware Governor Jack Markell is scheduled to sign the aquaculture Statutory Code changes into law on August 28, 2013. The full text and additional details about the legislation are available online at <http://legis.delaware.gov/LIS/LIS147.nsf/vwlegislation/5FA45ACF1EDC76AB85257B79004E49CF>. In accordance with the new legislation, the DNREC Division of Fish and Wildlife is adding a new staff position Environmental Scientist III to be responsible for oversight of shellfish aquaculture in Rehoboth, Indian River and Little Assawoman Bays. Position duties will include development of regulations, field validation of proposed subaqueous lease sites, organization and moderation of public hearings, serving as the departmental contact for industry enquiries, and administration of the shellfish leasing program. The Delaware Sea Grant program and other representatives of the Tiger Team stakeholder group will remain as active participants, and will continue to support and work with DNREC during the regulatory development process and beyond. It is estimated that the Inland Bays shellfish leasing program will require 1 year to fully implement.

The Delaware Sea Grant Marine Advisory Service (DSGMAS) has developed an educational resource page *Delaware Inland Bays Shellfish Aquaculture* <http://darc.cms.udel.edu/ibsa> with updates on the DNREC regulatory development process; technical, economic, and environmental information; links to other state shellfish aquaculture programs; and links to information of interest for prospective shellfish growers, and local coastal community businesses and residents.

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