Oyster Restoration in Maryland



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DEPARTMENT OF LEGISLATIVE SERVICES
OFFICE OF POLICY ANALYSIS
MARYLAND GENERAL ASSEMBLY

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Executive Director

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December 18, 2019

The Honorable Thomas V. Mike Miller, Jr., President of the Senate
The Honorable Adrienne A. Jones, Speaker of the House of Delegates
Members of the General Assembly

Ladies and Gentlemen:

Oysters are a keystone species in the Chesapeake Bay because of the environmental benefits they provide to the bay as well as the cultural and economic benefits they provide in the State. Despite the fact that Maryland has taken steps to manage and restore the oysters in the bay for over two centuries, current oyster populations are languishing at historic lows due to a combination of harvest pressures, habitat loss and degradation, and disease. Restoring the oyster population in the bay will require coordination and cooperation across diverse interest groups, with management and restoration efforts continuing into the foreseeable future.

The Office of Policy Analysis prepared this report to promote an understanding of oyster management and restoration in Maryland. The report provides an overview of how oysters are managed in the State as well as some of the issues and challenges the State faces in making decisions about how best to manage and restore oyster populations going forward. It begins with background information on oysters in Maryland, including information on oyster biology; the economic and environmental significance of oysters; and the history of oyster decline. Next, the report provides an overview of how oysters are managed in the State. The report concludes with a discussion of recent developments and ongoing challenges in oyster management and restoration. A timeline of major developments in oyster management from the late 1800s through 2019 may be found in **Appendix A**.

We trust this report will prove useful to the General Assembly in gaining a better understanding of oyster management and restoration in Maryland. The report was researched and written by David Morgan, April Morton, T. Patrick Tracy, and Emily Wezik. Ria Hartlein prepared the manuscript.

If you would like additional information regarding this report, please contact Ryane Necessary or Crystal Lemieux at (410) 946-5350.

Sincerely,

Victoria L. Gruber
Executive Director

Ryan Bishop
Director

VLG:RB/RN:CL/mlm
Enclosure

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Chapter 1. Oyster Basics

Introduction

"*The Chesapeake has the largest and the finest oyster ground in the world, but it is not standing the constant depletion, and exhaustion will be the sure result, unless there shall be a systematic effort for reproducing the supply*."

– "Fine Prospect for Oystermen," *New York Times*, Oct. 2, 1893

Due to a combination of harvest pressures, habitat loss and degradation, and disease, oysters in the Chesapeake Bay are in peril. And while more than two centuries have passed since Maryland passed its first oyster law in 1811, the State continues to grapple with how to manage and restore oysters in the bay. Central to debates surrounding oyster management and restoration in Maryland is the dual role the species plays. On one hand, healthy oyster reefs are vital to bay restoration efforts; on the other, oyster harvesting remains an economically and culturally important industry for the State, particularly in tidewater communities. Thus, the central question surrounding oysters becomes how to balance the need to grow and protect oyster populations in the water for their environmental benefits with the need to sustain the oyster fishery and the communities that depend on it.

To help answer that question, this report provides a general overview of how oysters are managed in the State as well as some of the issues and challenges that the State faces in making decisions about how best to manage and restore oyster populations going forward. To this end, the report is divided into three chapters. This chapter (Chapter 1) provides background information on oysters in Maryland, including information on oyster biology, the economic and environmental significance of oysters, and the history of oyster decline in the State. Chapter 2 provides a broad overview of how oysters are managed in the State, including the various groups involved in management decisions, tools and strategies for the management of the public oyster fishery, descriptions of the State's sanctuary and aquaculture programs, and enforcement mechanisms. Finally, Chapter 3 discusses recent developments and ongoing challenges in oyster management and restoration, as well as some of the options that have been proposed to address those challenges going forward.

Biology

The Eastern oyster (*Crassostrea virginica)*, also known as the American oyster, is the only oyster species native to the Chesapeake Bay. However, the bay is not the only habitat for the Eastern oyster, which can also be found all along the east coast of North America from the Gulf of St. Lawrence in Canada, along portions of the Florida Keys, down to Mexico's Yucatan Peninsula and Venezuela.

Like other bivalves, such as clams and mussels, the Eastern oyster's soft body is protected from the environment and predators by two tightly fit shells. In the bay, adult oysters generally reach a length of three to five inches, but they can grow to roughly eight inches. Anything greater than three inches is considered market-sized in the Chesapeake region.

The lifecycle of Eastern oysters is notable in that all oysters begin their lives as males. However, by around their second year, most oysters will become female and remain as such for the remainder of their lives. Reproduction occurs via spawning. Oysters release sperm and eggs into the surrounding water where the eggs are fertilized and then continue to float in the water column as larvae for two to three weeks. Because the larvae are nonswimming organisms, oyster migration is largely a function of currents. In general, oyster larvae become trapped in circulation patterns and settle close to the reef from which they were spawned. However, if larvae enter the right current, it is possible for them to travel great distances before attaching to a surface. A healthy breeding population in one location (known as a "source" population) may therefore affect abundance some distance away (known as a "sink" population).

Regardless of the distance that they travel, all oyster larvae require a hard surface, or substrate, on which to grow. This substrate often takes the form of older oyster shells, although oyster larvae can successfully attach to a variety of surfaces, including rock, concrete, and the shells of other mollusks. On finding a suitable location, the larvae secrete a cement-like substance that adheres them to the surface. Once the larvae have settled onto a substrate, they are known as "spat." Many variables affect the health and longevity of Eastern oysters, but they generally prefer waters with a salinity range of 10 parts per thousand (ppt.) to 28 ppt. Of note, all oyster bars in Maryland are located in waters with a salinity range of between 5 ppt. and 18 ppt. Additionally, because of freezing temperatures during portions of the year, Maryland oyster bars are found only in subtidal waters, where the bars are submerged at all times.

Significance

Benefits to the Chesapeake Bay

Oysters are considered a keystone species in the Chesapeake Bay because of their importance to the ecosystem. Large connected oyster populations provide a number of environmental benefits. These benefits include the establishment of reef habitat for finfish, shellfish, blue crabs, and other marine life as generations of oysters settle on top of one another. Significant biodiversity can exist in and around these reefs as surface irregularities create multiple smaller habitats.

Oysters also contribute to the improvement of water quality through filter feeding. Oysters feed by pumping water through their gills, trapping food, sediment, nutrients, and other contaminants. A single adult oyster is able to filter up to 50 gallons of water each day. Additionally, as oysters feed, they assimilate nitrogen and phosphorus – two nutrients that, in large quantities,

negatively impact the bay ecosystem – into their tissues and shells. In fact, oysters are so effective at removing nutrient pollution from the bay, that the State has identified oyster aquaculture as a strategy for meeting federally mandated pollution reduction goals. The State's Phase III Watershed Implementation Plan calls for growing and harvesting 350,000 bushels of farm-raised oysters by 2025, with an expected result of removing 10,000 pounds of nitrogen and 1,000 pounds of phosphorus from the bay.

A cleaner, healthier bay, achieved through the various environmental and ecological benefits of large connected oyster populations, is also a more efficient and productive bay. These benefits can be measured in terms of ecosystem services. An ecosystem service is any benefit that people receive from the environment, often something with a quantifiable monetary value. With respect to oyster reefs, these services include not only water quality improvement, but also shoreline stabilization and habitat diversification.

Depending on the location of a healthy oyster reef and the type of ecosystem services that it provides, the estimated value per year of a healthy reef can be anywhere from $10,000 to $99,000 per hectare (2.471 acres). As such, the potential economic return on the restoration of the bay's oyster reefs may offset the cost of oyster restoration. According to the 2019 *Maryland Chesapeake Bay Oyster Management Plan* (which is discussed in greater detail in Chapter 3 of this report), oyster restoration could potentially lead to economic output of more than $20 million per year in Dorchester and Talbot counties alone. The Department of Natural Resources (DNR) additionally estimates that, in the Harris Creek Sanctuary, the removal of nitrogen and phosphorus could result in economic values exceeding $1 million for each nutrient.

Benefits to Maryland's Oyster Fishery

In addition to the environmental and ecological benefits described above, oysters offer an economic benefit and employment for watermen, shellfish farmers, and other participants in the seafood industry. Maryland's commercial oyster fishery remains an important cultural and economic driver within bayside communities. According to DNR, since the 1999 to 2000 harvest season, the average annual dockside value of Maryland's oyster fishery is estimated to be roughly $6.9 million. DNR states that the commercial oyster fishery in Maryland's portion of the Chesapeake Bay saw a dockside value of $8.6 million in the 2017 to 2018 season.

Maryland's aquaculture industry has grown dramatically over the last several years as well, producing roughly 3,300 bushels of oysters in 2012, 22,000 bushes in 2013, and reaching 74,000 bushels in 2017. Aquaculture is a roughly $5 million industry in the State, and the number of farmed oysters currently equals about one-third of the number of wild oysters caught each year.

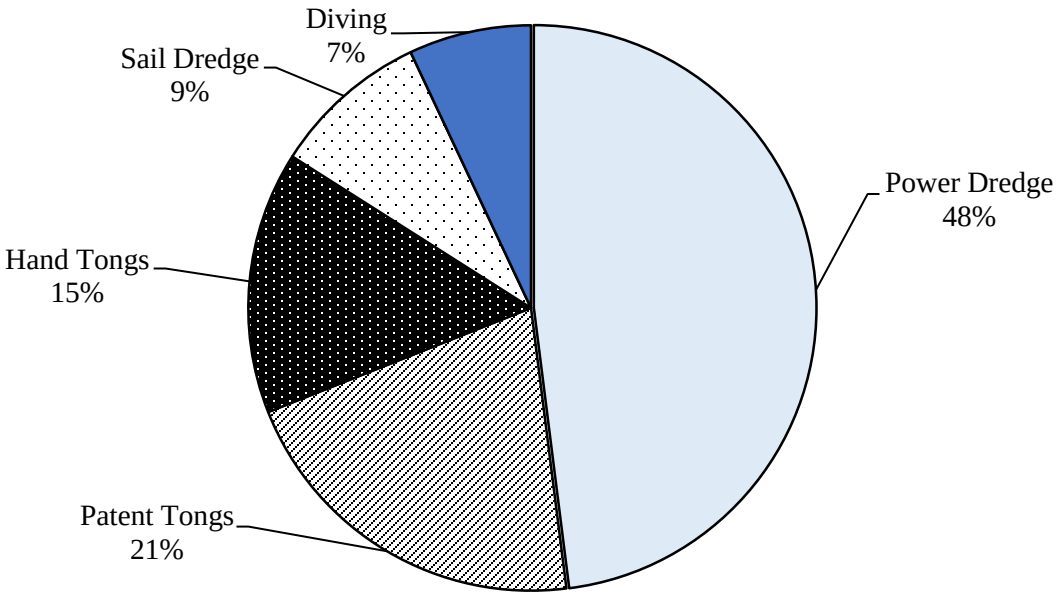
A vibrant oyster fishery is also central to the culture and heritage of Maryland's watermen. The traditional working boat of the bay's oystermen, the skipjack, has been the State boat since 1985. Having contributed significantly to the country's seafood supply since the

nineteenth century, Maryland's watermen continue to shape the identity of the region through the use and passing on of skills, customs, and lore.

Harvest Methods

Because wild oysters form three-dimensional reefs, oyster harvesting requires specialized equipment capable of scraping oysters from the substrate on which they grow. The most common commercial gear types are tongs (hand tongs and patent tongs) and dredges (sail dredges and power dredges). **Exhibit 1.1** provides a breakdown of the percentage of the total commercial harvest attributable to each gear type since the 2009 to 2010 harvest season. Additionally, some commercial and recreational fishers use diving equipment, such as a surface-supply air hose or SCUBA gear, to collect oysters by hand.

Exhibit 1.1
Oyster Harvest by Gear Type
2009-2018 Harvest Season



Note: The Department of Natural Resources reports that approximately 33% of watermen use multiple gear types throughout the harvest season.

Source: Department of Natural Resources; Department of Legislative Services

Hand tongs, also known as shaft tongs, are typically constructed of two wooden shafts ranging from 16 feet to 30 feet with rakes at each end to harvest oysters. The rakes, at each end, are held together with a pin so that the whole apparatus mimics scissors. An oysterman will stand on the side of the boat and lower the tongs into the water until the tongs hit a mound of oysters. By opening and closing the tongs, known as "making a lick," the oysters are gathered into the rakes where they can be hoisted onto the boat. Patent tongs are similar to hand tongs in basic design and function. However, patent tongs are suspended by a cable, are larger and heavier, and the mechanism to open and close them is operated through hydraulic power instead of by hand. Because the use of hydraulics and a larger rake make the use of patent tongs more efficient, an oysterman can expect to harvest about 50% more oysters from a given oyster bar than their counterparts using hand tongs.

A dredge is a chain-mesh bag attached to a frame that is lowered to the bottom using a winch. The dredge may be pulled along the bottom using a motorized vessel (power dredging) or a sailing vessel (sail dredging). While dredges are the most efficient means of harvesting oysters, their use is strictly limited due to the damage they may cause to oyster beds. Skipjacks are the traditional vessels used for sail dredging in the Chesapeake Bay. Today, most skipjacks are used for education and tourist trips, but some watermen still use skipjacks (often powered by small auxiliary yawl boats carrying diesel engines) to harvest oysters.

Regardless of how oysters are collected from the bottom, oysters must be sorted (or "culled") once they are deposited on the boat. During this process, the waterman separates out the market-sized oysters and returns undersized oysters and empty shells to the area from which they were taken.

Oyster aquaculture has become more common in recent years. There are two types of oyster aquaculture leases: bottom leases; and water column leases. Oysters grown on bottom leases are harvested using the same gear that is used in the public oyster fishery. Oysters grown in water column leases, however, are not set on traditional substrate; instead, they are grown in cages placed on the bottom or suspended at or near the surface. These cages protect the oysters from predators as they mature and allow the oysters to be harvested without the use of additional gear.

Harvest and Abundance History

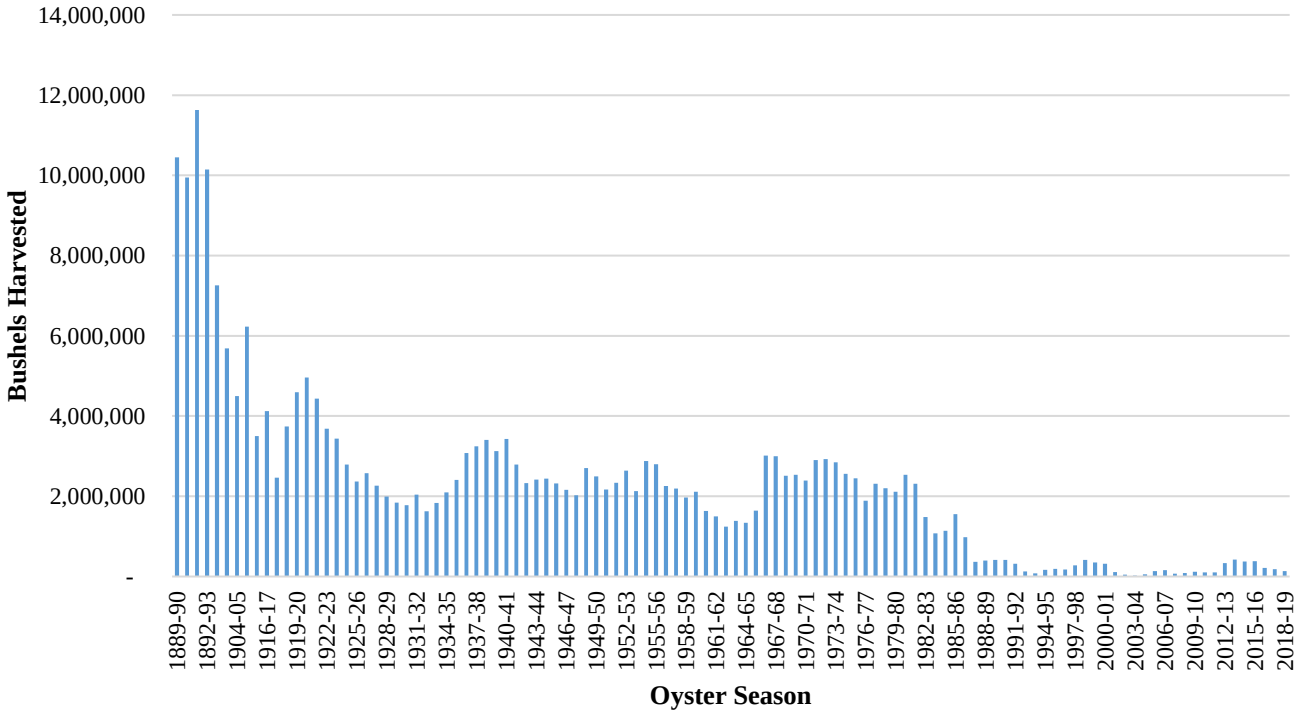
Historical Abundance

According to the 2019 *Maryland Chesapeake Bay Oyster Management Plan*, Maryland's oyster population is currently estimated to be at an historically low abundance. Information gaps and changes in the way oyster abundance has been calculated over time make it difficult to determine exactly how much of the State's oyster population has been lost. However, according to a frequently cited study published by the University of Maryland Center for Environmental

Science (UMCES) in 2011, the current population is likely less than 1% of historic (early 1800s) levels.[1]

As shown in **Exhibit 1.2**, the dramatic decline in the State's oyster population is reflected in historic harvest trends. At the fishery's peak in the late 1800s, the Chesapeake Bay was the greatest oyster-producing region in the world, with commercial landings in Maryland ranging from 7 million to 11 million bushels each year. Harvests rapidly declined in the first half of the twentieth century, however, before experiencing a roughly 50-year period of relative stability with annual harvests remaining around 2 million bushels until the mid-1980s. At that point, harvests experienced another rapid decline as the bay's oyster population was ravaged by the diseases MSX and Dermo. Since that time, commercial harvests have ranged from a high of approximately 416,000 bushels in the 1990 to 1991 oyster harvest season to a low of approximately 19,000 bushels in the 2003 to 2004 season (less than 0.01% of the highest recorded harvest, which occurred in the 1891 to 1892 season).

Exhibit 1.2
Oyster Harvests from the Maryland Portion of the Chesapeake Bay



Source: Department of Natural Resources

[1] Michael J. Wilberg *et al*., "Overfishing, disease, habitat loss, and potential extirpation of oysters in upper Chesapeake Bay" *Marine Ecology Progress Series* 436 (August 2011).

Depletion

The depletion of Maryland's oyster stock can be attributed to a number of factors, including harvest pressures, habitat loss, and disease. The degradation of the bay's water quality is another important factor. As land throughout the Chesapeake Bay watershed has been developed from rural, forested landscapes that act as natural filters for stormwater entering the bay to urban and suburban areas, an excess of nutrients and sediment has flowed freely. The influx of nutrients can cause "dead zones," or areas of low oxygen, which make it hard for oyster larvae to develop. Moreover, increased sediment in the bay may suffocate otherwise healthy oysters, and those that are weakened may become more susceptible to disease, as discussed below.

Disease

Compounding the effects of harvesting, environmental degradation, and habitat loss, Maryland's oyster population has been decimated by the infectious diseases Dermo and MSX. These diseases affect both wild and cultivated oysters. While there is some evidence that oysters are developing resistances to Dermo and MSX, many scientists believe that stressors like pollution and harvesting limit the ability of the oyster population to fully combat the diseases.

Dermo disease (*Perkinsus marinus*) is a parasite that thrives in a broad range of temperatures and salinities that are common throughout the Chesapeake Bay. The main method of transmission occurs when infective stages of the parasite are ingested by young, uninfected oysters. The parasites, which are released into the water column from the decay of dead oysters, can infect young oysters within 3 days and can prove fatal in as little as 18 days. While salinity is a contributing factor to Dermo infections, temperature is the primary regulator of Dermo activity and distribution. Prevalence of the disease peaks in the summer months with the greatest mortalities occurring in early fall when water temperatures are at their warmest.

Unlike Dermo, which generally infects younger oysters, MSX disease (*Haplosporidium nelson*) affects all ages of oysters, from spat to adult. Infections of MSX are acquired through the gills and then spread rapidly. While both temperature and salinity affect the activity and distribution of MSX, it proliferates mostly in high salinity waters that are between 41 and 68 degrees Fahrenheit. Accordingly, when greater levels of freshwater enter the bay, reducing overall salinity, the range of MSX is limited. By the same token, MSX can expand further into upstream waters during drought years when salinity increases.

Chapter 2. Oyster Management Overview

Introduction

The oyster fishery plays an important role in Maryland's economy, ecosystem, and culture. Because of the decline in oyster populations and habitat, the State manages the oyster fishery in a variety of ways.

Partners and Stakeholders

The Department of Natural Resources (DNR) has primary responsibility for managing the State's oyster resources. However, other State and federal agencies, regional bodies, and stakeholder groups also play an important role in the State's management and restoration efforts.

State Agencies and Advisory Groups

DNR is the primary regulator of the oyster fishery and oyster habitat. DNR is responsible for developing and implementing oyster management plans, establishing and enforcing regulations for the oyster fishery, and issuing oyster harvest licenses and aquaculture leases and permits. DNR also engages in oyster restoration activities and monitors and assesses the State's shellfish resources through the Shellfish Monitoring and Assessment Program. The Maryland Department of the Environment (MDE) is primarily responsible for the State's water quality management, which can have an impact on oysters and their ability to thrive. MDE monitors how pollutants are affecting shellfish and fish throughout the State and may close an area to fishing if it believes the area is contaminated.

The Oyster Advisory Commission (OAC), established in statute in 2007, advises DNR on matters related to oysters, oyster harvesting, oyster population rehabilitation, and the science related to oyster restoration and alternatives. The Secretary of Natural Resources is required to appoint members to OAC. Currently, there are 24 members, including scientists, regulators, environmental advocates, academics, legislators, and individuals who represent the seafood, real estate, and oyster fishing industries. OAC meets several times a year and intermittently produces reports on oyster-related issues. The Tidal Fisheries Advisory Commission, which is mostly comprised of commercial fishermen, and the Sport Fisheries Advisory Commission, which is mostly comprised of recreational fisherman, also advise DNR on matters related to the tidal and sport fisheries, including oysters. The University of Maryland System, including the Center for Environmental Science (UMCES), also supports the management of the oyster fishery by conducting research on oysters.

Federal Agencies

Several federal agencies are involved in managing the oyster fishery. The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers are involved in restoration planning and implementation in oyster sanctuaries in the Chesapeake Bay. NOAA provides both financial and technical support to these projects. The Army Corps of Engineers assists with the construction of restoration projects and uses its permitting authority under the Clean Water Act to evaluate the impacts of restoration projects.

Regional Partnerships

Because the Chesapeake Bay spans multiple states, several regional partnerships have been established to address issues in the bay in a comprehensive way. The Chesapeake Bay Commission (Bay Commission) was established in 1980 to advise state legislatures in Maryland, Pennsylvania, and Virginia on bay matters. To accomplish its goal, the Bay Commission studies issues that are critical to the bay, including comparing policies in each of the states, and periodically reports its findings and recommendations on those issues. Over the last several years, the Bay Commission has worked to secure funding for oyster restoration projects both federally and in its members' respective state budgets. The Bay Commission specifically requested funding for oyster restoration projects in its 2018, 2019, and 2020 federal budget requests. The Bay Commission has 21 members including 5 members from each of the Maryland, Virginia, and Pennsylvania legislatures; the secretaries of the state agencies responsible for the regulation of natural resources in each of the three states; and 1 citizen representative from each state.

The Chesapeake Bay Program (Bay Program) was founded in 1983 after the signing of the first Chesapeake Bay Agreement and is a partnership between states, academic institutions, and experts dedicated to restoring the Chesapeake Bay. The Bay Program is directed by the Chesapeake Bay Executive Council, which is made up of the governors of Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia; the chair of the commission; and the Administrator of the U.S. Environmental Protection Agency. The Bay Program provides support on baywide issues through projects such as environmental modeling, water quality monitoring, and providing quality assurance on environmental data. The Bay Program is also responsible for a series of regional agreements establishing restoration goals for the bay, including the 1987 Chesapeake Bay Agreement, Chesapeake 2000, and the 2014 Chesapeake Bay Watershed Agreement. Notably, the 2014 Chesapeake Bay Watershed Agreement includes a goal of restoring oyster reefs and populations in 10 tributaries of the bay by 2025; the Bay Program's Sustainable Fisheries Goal Implementation Team coordinates efforts to meet this goal.

The Potomac River Fisheries Commission (PRFC) was established by the Maryland and Virginia Potomac River Compact of 1958 for the purpose of regulating recreational and commercial fishing (including oyster harvesting) in the tidal stem of the Potomac River. PRFC includes four members from Maryland and four members from Virginia appointed by each state's respective governor. Like DNR, PRFC has an advisory committee made up of four members from

each state who are involved in the oyster industry to advise PRFC on matters related to oysters and clams.

Industry and Environmental Stakeholders

Watermen who harvest oysters in the Chesapeake Bay have a significant interest in the management of the oyster fishery. The Maryland Watermen's Association represents the watermen and seafood industry in supporting or opposing State and local policies. Other trade associations that represent the interests of Chesapeake Bay watermen include the Delmarva Fishermen's Association, the Maryland Oystermen Association, and the Chesapeake Bay Commercial Fishermen's Association. In addition, each tidewater county of the State has a committee of licensed oystermen that advises DNR on the management of the oyster fishery, including whether certain bars should be opened or closed to oyster harvesting and whether certain bars could benefit from oyster seed planting. These committees were created in 1947 and are referred to as county oyster committees.

Finally, because oysters play such an important role in the health of the bay, many environmental advocacy groups are interested in the management of the oyster fishery. For example, the Chesapeake Bay Foundation maintains several projects related to oyster restoration, including a shell recycling program, an oyster gardening program, and oyster restoration programs. The Nature Conservancy is also involved in oyster restoration efforts and provides funding for research and restoration activities.

History of Oyster Management in Maryland

Maryland began passing laws on oyster harvesting in the early 1800s. In 1830, the General Assembly passed a law banning the use of oyster dredges (then considered a new technology) and prohibiting nonresidents from harvesting oysters in Maryland waters. Later, in 1865, the State passed a law requiring a person to have a license before harvesting oysters – one of the first commercial fishing license requirements in the country. As oyster harvesting in the bay increased during the late 1800s, the State passed additional laws limiting when and where a person could harvest oysters. However, oysters were extremely popular at that time, and watermen began harvesting them in unprecedented amounts, sometimes illegally. The period from the mid-1860s through the mid-1900s is sometimes referred to as the "Oyster Wars," as fights (some of them violent) broke out on the bay between legal harvesters and so-called "oyster pirates" who were harvesting oysters illegally. To aide with the enforcement of oyster laws, Maryland established the State Oyster Police Force (colloquially referred to as the "Oyster Navy") in 1868; this was the first iteration of the Natural Resources Police (NRP).

Since that time, Maryland has continued to enact statutes and adopt policies and regulations for the management of the oyster fishery. **Appendix A** highlights some of the major developments in oyster management from the late 1800s through 2019. The following sections describe the

current framework for managing the State's oyster fishery and restoring the State's oyster population.

Current Management Strategies

DNR uses several tools and strategies to manage oyster harvesting, including license requirements, harvest limits, time and season restrictions, and restrictions on the areas in which a person may harvest oysters. In addition, DNR conducts repletion activities, aimed at maintaining the productivity of publicly fished oyster bars, and restoration activities, aimed at achieving environmental and ecosystem goals within oyster sanctuaries.

Licenses and Fees

In order to harvest oysters commercially in Maryland's public oyster fishery, an individual must possess either an (1) an unlimited tidal fish license or (2) a tidal fish license with an oyster harvester or oyster dredge boat authorization. Additionally, the individual must pay a $300 surcharge before the start of the oyster harvest season in order to activate the license. A license is not required for recreational harvesters.

As shown in **Exhibit 2.1**, DNR regulations cap the number of unlimited tidal fish licenses and oyster authorizations that may be issued each year. While the total cap is quite high, only a small fraction of license holders (less than 30%, on average) actually pay the oyster surcharge and participate in the fishery during a given year.

Exhibit 2.1
Oyster Licenses
2019

Abbreviation	Authorization	Number
OYH	Oyster Harvester	40
ODB	Oyster Dredge Boat	32
TFL	Unlimited Tidal Fish	2,091
	Total	**2,163**

Source: Department of Natural Resources; Department of Legislative Services

Commercial Harvest Restrictions

In addition to regulating who may harvest oysters, DNR also regulates which oysters may be harvested, as well as the times and manners in which they may be harvested. Management tools include (1) minimum size limits; (2) gear-dependent bushel or catch limits; (3) season limits; (4) day and time limits; and (5) gear restrictions. Historically, many of these limits were established in regulation or (more rarely) in statute. More recently, however, DNR has begun establishing and adjusting some harvest restrictions, including seasons, days, and catch limits, by public notice, in accordance with the *2019 Maryland Chesapeake Bay Oyster Management Plan* (the 2019 OMP, discussed further in Chapter 3 of this report).

Spatial Management

The State also uses certain geographic designations to manage oysters. Broadly speaking, oysters are managed differently according to whether they grow in sanctuaries, aquaculture leases, or in areas open to public harvesting (the public fishery). The fishery may be broken down further into the following overlapping categories: Yates Oyster Bars; Non-Yates Oyster Bars; Historic Oyster Bottom; Natural Oyster Bars; Public Shellfish Fishery Areas; Harvest Reserve Areas; and Rotational Harvest Areas. **Exhibit 2.2** provides an overview of the State's oyster management areas.

Exhibit 2.2
Oyster Management Areas

Management Area	**Description**	**Total Surface Area (Acres)**
General Designations		
Yates Oyster Bars	Natural oyster bars delineated by Yates survey, conducted from 1906 to 1912	215,448
Non-Yates Oyster Bars	Natural oyster bars delineated after the Yates survey	115,205
Historic Oyster Bottom	Combination of Yates and Non-Yates Bars	330,653
Natural Oyster Bars	Bottom identified as actual or potential oyster habitat in the Maryland Bay Bottom Survey conducted from 1975 to 1983; 69.8% overlap with Historic Oyster Bottom	294,536

Management Area	Description	Total Surface Area (Acres)
Public Fishery		
Public Shellfish Fishery Areas	Areas delineated in 2010 based on recent use by the public fishery; off limits to clamming and aquaculture; 78.9% overlap with Historic Oyster Bottom	179,943
Harvest Reserve Areas	Individual oyster bars that are closed to harvest for a period of time and then opened after certain biological criteria are met	376
Rotational Harvest Areas[1]	Areas closed to harvest for a set time period, during which stock enhancement and/or habitat modification activities are completed, then opened to harvest for another set time period	0
Sanctuaries		
Sanctuaries	Areas set aside for ecological purposes and closed to public oyster harvesting; aquaculture allowed in some areas; 31.1% overlap with Historic Oyster Bottom	252,285
Aquaculture		
Aquaculture Enterprise Zones[2]	Areas of the Chesapeake Bay pre-approved for aquaculture leasing	0
Water Column Leases and Submerged Land Leases	Areas currently leased for oyster aquaculture	7,238

[1] Rotational Harvest Areas are a new category created by the 2019 Oyster Management Plan. DNR has not yet designated any Rotational Harvest Areas.
[2] Although Aquaculture Enterprise Zones (AEZ) are still defined in statute, regulations adopted by DNR in 2018 eliminated the State's only designated AEZs.

Source: Department of Legislative Services

In summer 2019, DNR adopted regulations defining the new term "oyster harvest area" to mean "submerged ground where an individual may catch oysters." Oyster harvest areas do not include areas (1) leased for aquaculture; (2) restricted by MDE; or (3) designated as a submerged aquatic vegetation protection zone, harvest reserve area, or sanctuary. The new regulations authorize DNR to open or close an oyster harvest area for the harvesting or conservation of oysters by public notice. The public notice must be posted on DNR's website at least 48 hours before the change takes effect, and must state (1) the specific area; (2) the specific period of time that the area is opened or closed; (3) daily bushel limits; and (4) the days of the week that a person may catch

oysters in the area. These regulations may signal an intent by DNR to adopt a more geographically targeted approach to oyster management in the future.

Replenishment Efforts

Maryland has a long and robust history of conducting replenishment activities aimed at enhancing natural oyster bars through the addition of shell and, in some cases, seed (shell on which oyster spat has already settled). In fact, according to a formal stock assessment conducted in 2018, almost every oyster bar in Maryland has been modified over time through replenishment efforts. The most significant of these efforts was the DNR Repletion Program. Operated from 1960 through 2006, the program consisted of two main components: (1) natural bar plantings, in which shell was placed directly on oyster bars to enhance oyster habitat and encourage natural spat set; and (2) seed area plantings, in which shell was initially placed in areas with high natural spat set, then moved to areas with low natural spat set for growth and harvesting.

Dredged shell, obtained from deposits in the northern part of the bay, comprised the majority of the shell used in the Repletion Program. Between 2 million and 5 million bushels of dredged shell were planted each year under the program, at an annual cost of between $1 million and $2 million. This cost was partially covered by taxes and fees paid by commercial harvesters, but the program was also heavily subsidized by the State. Nevertheless, the program was considered to be a success for many years. Under the program, shell plantings exceeded the amount of oysters removed through harvesting, resulting in a positive shell budget. These plantings enhanced habitat and natural spat set and, in the case of the seed plantings, augmented areas with low natural spat set. Moreover, for most of the program's existence, the dockside value of oysters harvested from Maryland waters exceeded the cost of the Repletion Program. However, the program was discontinued in 2006 in the face of rising costs, dwindling shell supplies, and concerns about the spread of disease.

In recent years, DNR has continued to conduct shell plantings in the public fishery but on a smaller scale. The State does not currently have the necessary federal permits to dredge buried shell deposits, so current replenishment efforts rely on fresh shell, much of it purchased at a high cost from out-of-state suppliers. DNR also continues to conduct seed plantings in areas with low natural spat set, using wild seed from Virginia and hatchery-raised seed sourced primarily from UMCES' Horn Point Oyster Hatchery. **Exhibit 2.3** shows the amount of replenishment plantings for the public fishery and the associated costs from 2013 through 2018. Each year, a portion of the plantings are conducted by the various county oyster commissions, who decide which oyster bars within their respective counties will be targeted for replenishment.

Exhibit 2.3
Public Fishery Replenishment Plantings and Associated Costs
2013-2018

Planting Year	Virginia Wild Seed (Bushels)	Amount Planted Hatchery Seed (Millions)	Fresh Shell (Bushels)	Cost ($)
2013	11,117	106.60	119,800	1,064,206
2014	0	211.94	84,936	1,033,061
2015	0	198.45	200,812	1,727,753
2016	5,099	254.67	269,920	2,384,881
2017	51,362	163.32	100,608	1,792,936
2018	33,141	71.49	113,332	1,254,748

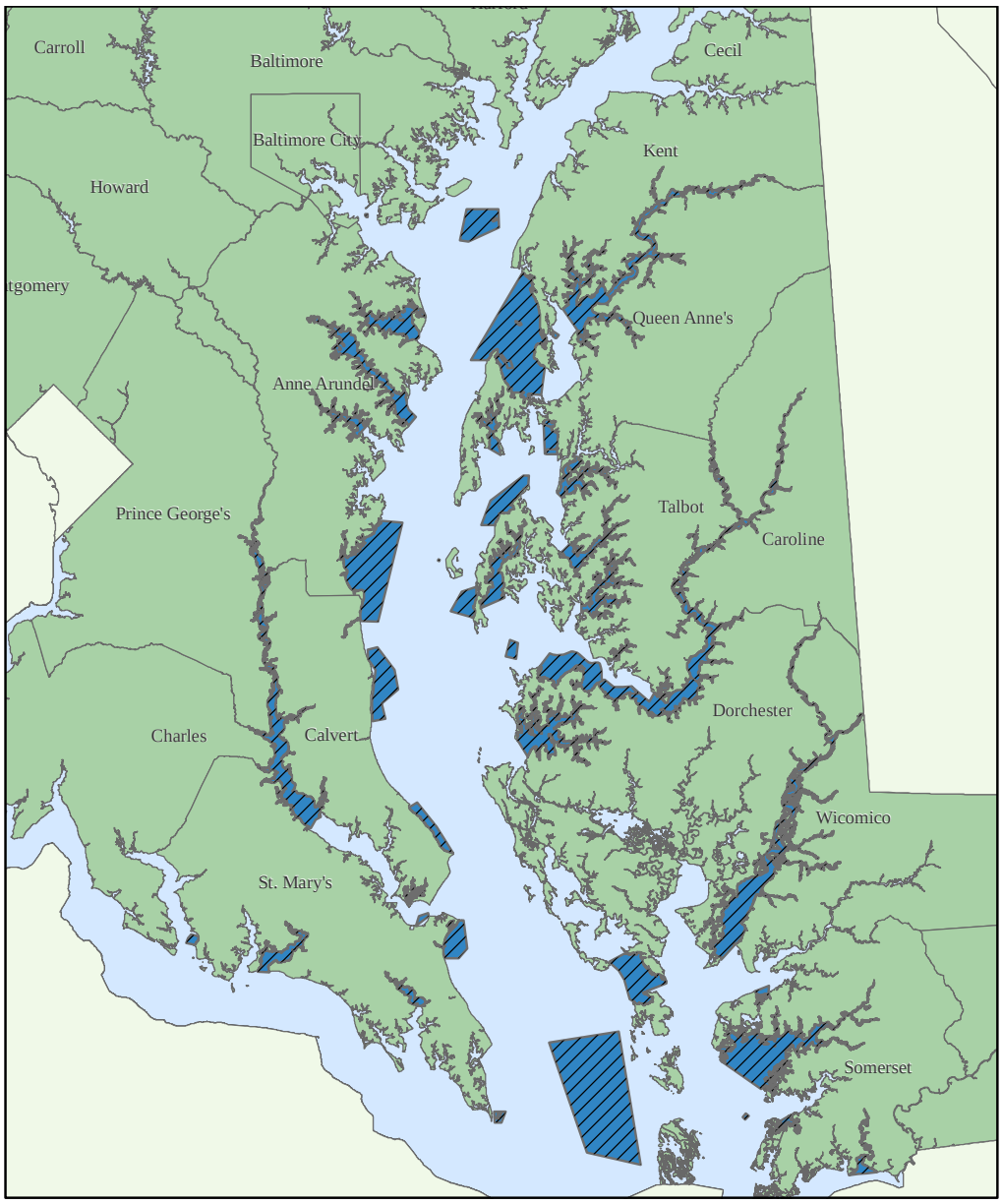
Source: Department of Natural Resources; Department of Legislative Services

Replenishment plantings are funded in part by revenue from an oyster bushel tax and the oyster surcharge, both paid by commercial harvesters. However, DNR indicates that since 1991, the average annual revenue from these combined sources has been about $450,000, far less than the cost of the plantings. Currently, plantings are also funded by an annual grant from the Maryland Department of Transportation.

Oyster Sanctuaries and Restoration

An oyster sanctuary is an area that is permanently closed to oyster harvesting. Maryland established its first oyster sanctuary in the Tred Avon River in 1961. Between that time and 2010, additional sanctuaries were established throughout the bay, some for research and educational purposes and some for restoration purposes. In 2008, OAC recommended expanding sanctuaries in the bay. In response, DNR established new oyster sanctuaries, increasing the percentage of quality oyster bars designated as sanctuaries from 9% to 24%. Currently, sanctuaries cover 252,285 acres, including 78,520 acres (or about 24%) of the State's Historic Oyster Bottom, and are located throughout the bay and its tributaries. **Exhibit 2.4** shows the locations of Maryland's oyster sanctuaries. Expected benefits of oyster sanctuaries include developing oysters resistant to disease, protecting some of the bay's productive oyster grounds from harvest pressures, and increasing oyster populations on publicly fished oyster bars located near the sanctuaries.

Exhibit 2.4
Maryland Oyster Sanctuaries



Source: Department of Natural Resources (geographic data); MD iMAP (geographic data); State Highway Administration (geographic data); U.S. Census Bureau (geographic data); Department of Legislative Services

While oyster populations within some sanctuaries are simply allowed to regrow naturally, the State actively restores habitat and populations within others. DNR chooses which sanctuaries to restore based on a number of factors affecting the ability of oysters to grow and thrive, including salinity and water quality. DNR's restoration activities include rebuilding oyster bar habitat through the addition of substrate and enhancing oyster populations through seed plantings.

In 2014, Maryland signed the Chesapeake Bay Watershed Agreement, which establishes goals and outcomes for the restoration of the entire Chesapeake Bay, its tributaries, and the lands that surround them. The agreement includes a goal of restoring large connected native oyster habitat and populations in sanctuaries in 10 bay tributaries (5 sanctuaries each in Maryland and Virginia) by 2025. Harris Creek, the Tred Avon River, the Little Choptank River, the Upper St. Mary's River, and the Manokin River have been selected as the locations for Maryland's 5 tributary-scale sanctuaries. Chapter 17 of 2019 codified the boundaries of these sanctuaries and required DNR, in coordination with OAC, the Oyster Interagency Workgroup, and interested stakeholders, to develop and implement restoration plans for each sanctuary.

Reef construction and oyster seeding for the 351 acre Harris Creek Sanctuary was completed in 2015, and that sanctuary is currently undergoing monitoring and evaluation. As of 2019, reef construction and oyster seeding was completed on 84 of 130 planned acres in the Tred Avon River Sanctuary and 351 of 357 planned acres in the Little Choptank River Sanctuary. Restoration of the Upper St. Mary's River Sanctuary is expected to begin in 2020, while tributary restoration plans are being prepared for the Manokin River Sanctuary. In addition to its restoration work within the tributary-scale sanctuaries, DNR has started to consider possible small scale restoration projects in the Nanticoke River Sanctuary in Wicomico County and in sanctuaries located in the Magothy, Severn, and South rivers in Anne Arundel County.

Aquaculture

In the early 2000s, facing steep declines in wild oyster harvests, the State began to explore oyster aquaculture as a possible way of rejuvenating the shellfish industry, creating jobs and economic opportunity, improving water quality, replenishing depleted wild oyster stocks, and providing seafood for the marketplace.

In 2005, the State enacted legislation to establish the Aquaculture Coordinating Council for the purpose of guiding aquaculture policy. Among other things, the council is required to formulate and make proposals for advancing Maryland aquaculture; conduct applied studies of projects and products that will expand Maryland's aquaculture industry; and, on a regular basis, review State regulations impacting aquaculture and make appropriate recommendations.

In September 2008, the Maryland Department of Agriculture (which oversaw the State's aquaculture program at the time), in consultation with other State agencies and the Aquaculture Coordinating Council, issued recommendations aimed at creating opportunities for aquaculture businesses in Maryland waters while maintaining the public oyster fishery. Legislation enacted in 2009 implemented several of the recommendations. The legislation and subsequent amendments

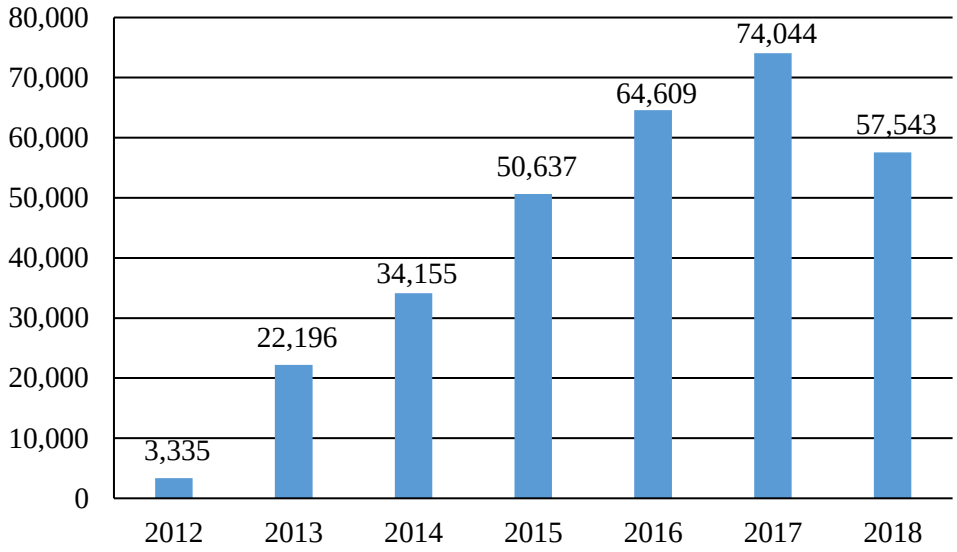
required DNR to identify and establish (1) a public commercial shellfish fishery area in productive wild areas traditionally harvested by watermen on which leasing is prohibited; (2) Aquaculture Enterprise Zones (under a federal general approval permit similar to one in effect in Virginia) in the Chesapeake Bay for streamlined aquaculture leasing; and (3) aquaculture demonstration leases for educational, conservation, or ecological purposes.

The 2009 legislation implemented numerous policies to incentivize aquaculture operations. Elimination of the location, ownership, and size barriers for aquaculture leasing increased the areas available for leasing and made the aquaculture program more attractive for and available to outside investment (authorization for corporate ownership was somewhat tempered under subsequent 2011 legislation that limited corporate ownership to a corporation chartered in Maryland and for which more than 50% of the stock is owned by Maryland residents, a requirement substantially similar to Virginia's). Additional legislation enacted in 2011 streamlined the aquaculture permitting process by consolidating all of the State's aquaculture activities under DNR. Other legislation enacted in 2011 eliminated the daily harvest limit for aquaculture operations. Subsequent legislation in 2012 authorized DNR to eliminate the size limit for oysters harvested from oyster aquaculture operations, helping to alleviate disease pressure on these oysters as MSX and Dermo tend to infect oysters when they are close to harvest size.

Under current law, a person interested in aquaculture may seek either a submerged land lease or a water column lease. A person with a water column lease may cultivate shellfish, including oysters, in structures such as floats, cages, or racks. A person with a submerged land lease, or "bottom lease," may only cultivate shellfish directly on the bottom, without the use of structures. To obtain either lease, a person must submit an application to DNR along with a fee of $300. The individual must also obtain a shellfish aquaculture harvester permit, which is valid for one year, and harvest oysters in accordance with the restrictions in DNR regulations. Rent on submerged land is $3.50 an acre per year. Leases are prohibited in certain areas, and certain activities are also prohibited on leased land or water column space.

As of December 2019, there were 455 shellfish aquaculture leases on 7,238 acres in active use in Maryland waters. These leases were held by 283 distinct individuals or entities, of whom 45% were also commercial watermen (tidal fish license holders). In 2017, Maryland shellfish farmers produced 74,044 bushels of oysters, a nearly 15% increase over the previous year. In 2018, production dropped to 57,543 bushels, due largely to low salinity caused by heavy rainfalls. **Exhibit 2.5** shows the increase in farm-raised oyster harvests from 2012 through 2018.

Exhibit 2.5
Total Annual Farm-raised Oyster Harvests (Bushels)
2012-2018



Source: Department of Natural Resources; Department of Legislative Services

Enforcement

Illegal oyster harvesting has been a problem in the Chesapeake Bay since the time of the Oyster Wars. Illegal harvesting can affect the bay by reducing oyster populations and counteracting restoration efforts, which are often expensive and time consuming. It is estimated that almost all of the 34 existing sanctuaries have been subject to oyster poaching. It is also estimated that 33% of oysters placed in State oyster sanctuaries between 2008 and 2010 were removed by illegal harvests. The State uses a variety of penalties and other tools to curtail illegal oyster harvesting. Additionally, as aquaculture has become more prevalent, the theft of oysters from private aquaculture leases has also become a concern.

Available Penalties

In general, there are several penalties that may apply if an individual violates fisheries laws. A person who violates any State law related to fish or fisheries may be charged with a misdemeanor and, if convicted, be subject to (1) a fine of up to $1,000 for a first offense and (2) a fine of $2,000 and imprisonment of up to one year for a second or subsequent offense occurring within two years.

DNR also has the general authority to suspend or revoke a person's entitlement to engage in a particular commercial activity, such as oyster harvesting, if the person violates State or federal commercial fisheries law. A court may suspend or revoke the license of a person convicted of violating fish and fishery provisions of the Natural Resources Article and associated regulations. Finally, an NRP officer or other law enforcement officer may arrest a person found violating fisheries laws or regulations and may seize any unlawfully used equipment, which may later be forfeited if the individual is convicted of the violation.

There are also penalties specifically for harvesting oysters illegally. DNR may revoke an authorization to catch oysters if a person is found to have taken oysters (1) within 200 feet of a closed area; (2) with gear prohibited in that area; (3) over an hour outside of a time restriction on oyster harvesting; (4) during a closed season; or (5) from a leased area if the person is not the leaseholder or a leaseholder's designee. In addition to any other applicable penalty, a person who unlawfully takes oysters from a leased oyster bottom, an oyster sanctuary, an oyster reserve, or an area closed to shell fish harvest by MDE, when the area is designated and marked by buoys or other signage or the person knew or should have known that taking the oysters from the area was unlawful, is subject to a fine of up to $3,000. A person who willfully harvests, destroys, or transfers oysters on an aquaculture or leased submerged land area may be subject to criminal penalties for theft of property and may have their tidal fish license revoked. A person who destroys or damages oyster reefs, bars, rocks, or other areas located on a natural oyster bar in the Chesapeake Bay that is not a leased oyster bottom may be liable to the State for the cost of repairing the structure or the resources on the natural oyster bar. Furthermore, a person who "willfully, negligently, recklessly, wrongfully, or maliciously" harvests oysters or damages equipment on leased land is liable for damages to the leaseholder, except under certain circumstances.

Natural Resources Police

The Natural Resources Police (NRP) began in 1868 as the State Oyster Police Force, a body that was established specifically to enforce oyster laws during a period of intense oyster harvesting. Since that time, the name and responsibilities of NRP has evolved as it merged with other natural resources law enforcement agencies over the years. NRP also saw several changes to the requirements for officers and the availability of technology to support the NRP's mission. For example, in 1941, officers were required to undergo law enforcement training, and radiotelephones were installed on patrol boats. In 1963, the Maryland State Marine Police Academy opened for the purpose of training the officers responsible for enforcing the State's fisheries and boating laws. Today, in addition to enforcing the State's natural resource and conservation laws, NRP is responsible for maritime and rural search and rescue operations; public education in hunting, boating, and water safety; law enforcement in State parks and on other public lands; and maritime homeland security on State waterways.

NRP enforces fish and fisheries laws by patrolling State waters by boat and by air. Additionally, a person may file a complaint for a violation with NRP, including online or by phone. In 2013, NRP began using a system called the Maritime Law Enforcement Information Network

(MLEIN). MLEIN allows NRP to set up invisible boundaries around areas in which shellfish harvesting is prohibited and alerts officers if the boundary is crossed. The system uses radar, cameras, and other equipment to monitor and detect oyster poaching activities in sanctuaries. This new system has led to NRP catching several individuals illegally harvesting oysters from prohibited areas.

Enforcement Data

In 2018, NRP issued 148 citations and 182 warnings for oyster related offenses. The majority of violations related to the failure to mark private bottom (128 warnings issued); the failure to mark coupled with harvesting from unmarked leased bottom (27 warnings and 2 citations issued); the possession of undersized oysters (24 citations issued); the possession of unculled oysters (20 citations issued); and oystering during the closed season (14 citations issued). **Exhibit 2.6** provides a summary of violations noted in 2017 and 2018.

Exhibit 2.6
NRP Oyster Enforcement Data – Select Offenses
2017 and 2018

	2017			2018		
Offense	**Citations**	**Warnings**	**2017 Total**	**Citations**	**Warnings**	**2018 Total**
Oystering without license	9	-	9	7	-	7
Possession of undersized oysters	17	1	18	24	-	24
Possession of unculled oysters	12	-	12	20	-	20
Oystering during closed season	3	-	3	14	-	14
Dredging in prohibited area	15	-	15	2	-	2
Over commercial limit	1	-	1	2	-	2
Failure to mark private bottom with stake	-	14	14	–	128	128
Tonging on leased bottom without written permission	4	-	4	-	-	0
Failure to mark/harvesting from unmarked leased bottom	-	2	2	2	27	29
Oystering in sanctuary	14	-	14	2	-	2

Offense	2017 Citations	2017 Warnings	2017 Total	2018 Citations	2018 Warnings	2018 Total
Theft of oysters from aquaculture lease-bottom	-	-	-	1	-	1
Other	42	3	45	74	27	101
Total	**117**	**20**	**137**	**148**	**182**	**330**

NRP: Natural Resources Police

Source: Department of Natural Resources; Department of Legislative Services

Chapter 3. Recent Developments and Ongoing Challenges

Introduction

The management and restoration of the State's oyster population remains a major challenge. This chapter highlights recent legislative and policy initiatives related to oysters and examines some of the ongoing issues facing this important environmental and economic resource.

Recent Legislative and Policy Developments

2009 Oyster Restoration Plan and *Five-Year Evaluation Report*

In December 2009, the Department of Natural Resources (DNR) proposed a new management and restoration plan for oysters and the State's oyster industry. The plan and its implementing regulations were, in part, based on the recommendations of the State's Oyster Advisory Commission (OAC). The plan called for increasing the State's network of oyster sanctuaries (areas where the wild harvest of oysters is prohibited) from 9% to 24% of the bay's remaining quality oyster bars and established enhanced oyster aquaculture leasing opportunities (as well as related financial assistance programs). The plan also called for maintaining 76% of the bay's remaining quality oyster habitat as areas open to commercial harvest, known as public shellfish fishery areas (PSFA).

When DNR adopted the plan and implementing regulations in 2010, it committed to evaluating after five years, and every five years thereafter, the State's oyster sanctuary network, the PSFAs, and areas open to oyster aquaculture. In July 2016, DNR completed *Oyster Management Review: 2010-2015* (*Five-Year Evaluation Report*), its first five-year oyster management evaluation. At that time, DNR determined that 253,411 acres of the bay were held in sanctuaries (with 31% being historic oyster bottom) while 179,942 acres were designated as PSFAs (with 79% being historic oyster bottom). The evaluation found that many sanctuaries showed progress in oyster restoration, including increased biomass and reproductive capacity, while other sanctuaries showed little or no progress. As part of the evaluation, DNR placed the sanctuaries and PSFAs into "tiers" based on oyster productivity. The report recommended adjustments to the boundaries of the sanctuaries and PSFAs by allowing for trading of areas within equivalent tiers to facilitate a fair distribution of the most productive oyster areas.

These recommendations were not implemented, however, due to subsequent legislative action. Chapter 703 of 2016 required DNR, as part of its fishery management plan for oysters, to conduct a study, in consultation with the University of Maryland Center for Environmental Science (UMCES), on the oyster stock (including a stock assessment and development of biological reference points) and management strategies to address the maintenance of a sustainable oyster

population and fishery. The following year, Chapter 27 of 2017 prohibited DNR from reducing or altering the boundaries of oyster sanctuaries until it had developed a fisheries management plan for the scientific management of oysters that was based on the stock assessment report required under Chapter 703.

2018 Stock Assessment Report

In accordance with Chapter 703, DNR issued the final report, *A Stock Assessment of the Eastern Oyster, Crassostrea virginica, in the Maryland Waters of the Chesapeake Bay* (2018 Stock Assessment Report), in December 2018. As the first formal assessment of the State's oyster population, the 2018 Stock Assessment Report outlined current stock size, rates of exploitation, and target biological reference points.

The reference points were based on data collected between the 1999 to 2000 season and the preliminary data from the 2017 to 2018 season. The analysis in the 2018 Stock Assessment Report was performed based on a scale of 36 National Oceanic and Atmospheric Administration (NOAA) codes, which are regional units of the Maryland portion of the Chesapeake Bay. In addition to the stock assessment information, the report also listed various tools that DNR could use to manage the oyster fishery. However, because multiple management tools are likely to be needed in conjunction with one another, and different management tools are likely needed within different NOAA codes, the report did not make any specific recommendations on implementing the management tools.

2019 Oyster Management Plan

In summer 2019, DNR released a final draft of the *2019 Maryland Chesapeake Bay Oyster Management Plan* (2019 OMP). At the same time, DNR introduced two sets of regulations: one incorporating the plan by reference; and the other making regulatory changes necessary to implement certain aspects of the plan. The 2019 OMP replaces the previous plan released in 2004 and amended in 2010. It describes the history and current status of the State's oyster fishery, and provides a broad framework for managing oyster harvesting, restoration, and aquaculture going forward.

The stated goal of the 2019 OMP is to "conserve, protect, and where possible, rebuild oyster populations to fulfill their important ecological role and to support the culturally significant oyster fishery and industry throughout the Maryland portion of the Chesapeake Bay." To this end, the 2019 OMP establishes objectives for the management of the State's oyster resource, general strategies for achieving those objectives, and specific actions for carrying out those strategies. New topics addressed by the 2019 OMP, which were not included in the State's previous oyster management plan, include:

- the results of the 2018 Stock Assessment Report and biological reference points developed in accordance with Chapter 703;

- large-scale restoration in sanctuaries;
- community-based oyster gardening programs;
- the establishment of rotational harvest areas;
- the National Shellfish Sanitation Program;
- recreational oyster harvesting;
- socioeconomic considerations; and
- ecosystem considerations.

Additionally, the 2019 OMP contains updated approaches to the adaptive management of the oyster fishery, the impact of salinity on oyster reproduction and growth, substrate, sanctuaries, fishery management techniques, aquaculture, monitoring and enforcement, and research needs.

The concept of "adaptive management" is central to the 2019 OMP. As explained in section 2.3 of the plan:

> Adaptive management is a structured, iterative process of decision-making. It generally involves a variety of techniques that can be refined or modified based on input from monitoring results, new scientific research and data and/or improved understanding from empirical observations. […] Adaptive management requires feedback, flexibility and the ability to adapt and make necessary changes. Implementation of adaptive management could include establishing or modifying certain parameters of the oyster fishery by public notice to allow flexibility in developing a sustainable fishery.

Accordingly, Action 2.3.3 of the plan calls for the use of public notices "to modify oyster fishery parameters as an adaptive management measure." DNR has adopted regulations to facilitate implementation of this approach by allowing certain management actions to be taken through public notice. The regulations repeal language establishing commercial seasons and the days of the week for catching oysters with specified gears. The regulations instead require DNR, on or before July 1 of each year, to issue a public notice on the department's website establishing, for each gear type (1) the season for catching oysters commercially; (2) the days of the week that an individual may catch oysters for commercial purposes; and (3) daily commercial catch limits. DNR may alter any of these parameters by issuing a public notice on its website at least 48 hours in advance. The regulations make similar changes to sections governing recreational oyster harvests.

DNR intends to use its public notice authority to adaptively manage the oyster fishery in the following manner. DNR will first work with OAC and other stakeholder groups to select a suite of management measures for the upcoming harvest season. At the end of the season, DNR will then run a stock assessment to review the outcomes of those management measures and evaluate its progress toward ending overfishing. The information learned from this process will inform the selection of management measures for the following season, and the cycle will begin

again. DNR projects that this process should result in sustainable levels of fishing within 8 to 10 years.

Ongoing Issues

Rotational Harvests and the Future of Maryland's Oyster Sanctuaries

In February 2017, following the completion of the Five-Year Evaluation Report, DNR issued a draft *Consolidated Strawman Management Plan Proposal* proposing changes to the boundaries of oyster management areas that had been established under the State's 2009 management and restoration plan. One of the significant changes included in the draft proposal was to declassify certain sanctuary areas that performed poorly or were difficult to enforce and make them available to the public fishery. In the draft proposal, DNR committed to (1) maintaining 20% to 30% of estimated productive oyster bottom baywide within sanctuaries; (2) adding new sanctuary areas as needed; and (3) making no changes to the three tributary-scale sanctuaries that existed at that time (Harris Creek, the Little Choptank River, and the Tred Avon River).

The draft proposal also laid out a plan to establish between four and six rotational harvest and planting areas, including in declassified sanctuary areas. Under the draft proposal, rotational harvest areas would be open to harvest for a limited period of time and on a staggered basis, and then closed for a minimum of three years for additional shell or seed planting.

The rotational harvest measures were based on a similar program in Virginia, where most of the public oyster grounds are managed on a rotating basis. Public oyster fishery areas in Virginia are only open once every two or three years, and then only for a portion of the season. Openings are staggered, however, so that at least some public oyster fishery areas are open at a given time during the oyster harvest season. According to the Virginia Marine Resources Commission, while the three-year rotational harvest areas have generally shown improvement over time, the areas subject to two-year or no rotational harvest have shown signs of deterioration.

The changes outlined in the draft proposal were temporarily halted by Chapter 27, which prohibited DNR from reducing or altering the boundaries of existing oyster sanctuaries pending the completion of the stock assessment required under Chapter 703 and the adoption of an updated fishery management plan for oysters. Now that the 2018 stock assessment report and the 2019 OMP have both been completed, DNR has the ability to move forward with changes to sanctuary boundaries and the establishment of a rotational harvest program.[2] In fact, Strategy 6.3 of the 2019 OMP explicitly calls for the creation and use of Rotational Harvest Areas, although it does not specify their location.

[2] Note, however, that Chapter 17 of 2019 prohibits DNR from altering the boundaries of the five tributary-scale sanctuaries located in Harris Creek, the Little Choptank River, the Tred Avon River, the St. Mary's River, and the Manokin River.

Shell and Seed Shortages

Shell Shortages

In Maryland's Chesapeake Bay, the loss of oyster shell from sedimentation and harvesting exceeds the natural replacement of shell through reproduction. Historically, DNR obtained shell for use in commercial replenishment and sanctuary restoration projects from two primary sources: fresh shell from shucking houses and dredged shell from old shell deposits buried in the bay bottom. However, both of these sources have become severely limited in recent years. Few shucking houses remain in Maryland, forcing DNR to purchase most of its fresh shell from out-of-state vendors. The 2019 OMP notes that the cost of fresh shell increased from $0.50 per bushel in 2006 to $2.75 per bushel in 2017, making the acquisition of fresh shell much more costly. In terms of dredged shell, few deposits of buried shell remain in Maryland waters, and DNR does not currently have the permits necessary to dredge these deposits.

DNR has proposed to dredge buried oyster shell at Man-O-War shoal in the upper Chesapeake Bay. The U.S. Army Corps of Engineers approved a provisional permit for the project in May 2018, but the provisional permit cannot become a valid permit (under which work may be performed) until certain State certifications, which are contingent on Board of Public Works approval of the project, are made. The project is controversial with environmentalists and some commercial and recreational fishers, who fear that it will disrupt habitat for crabs and striped bass. Despite concerns about the environmental impact of dredging buried shell deposits, OAC voted in August 2019 to request that DNR "apply for individual permits to dredge for buried shell on areas not limited to but including Shad Battery Shoal, Worton Point, and Plum Point."[3]

DNR is also continuing to explore the use of alternative substrates, including (1) biogenic substrates, like clam shell and fossilized shell; (2) geologic substrates, like sandstone, granite, and limestone marl; and (3) anthropogenic substrates like "oyster castles" and "oyster reef balls" manufactured from concrete. The 2019 OMP notes that geologic and anthropogenic substrates may be particularly useful as a foundation for restoration projects within sanctuaries because they provide more three-dimensional structure, creating habitat for other species and increasing the surface area for spat settlement. However, these substrates must be located with care to avoid potential conflicts with other activities. Although oyster harvesting is prohibited within sanctuaries, geologic and anthropogenic substrates have the potential to interfere with fishing gear used to target other species like crabs and finfish. Moreover, depending on their depth and location, these substrates can pose navigational hazards to boaters.

[3] Meeting Summary, OAC (August 12, 2019).

Seed Shortages

Oyster seed (spat attached either to whole shells or to pieces of pulverized shell known as "cultch") is used for restoration and replenishment activities as well as for oyster aquaculture. Seed can be obtained from wild sources or from oyster hatcheries. Currently, however, almost all of the seed used in Maryland comes from a single source – the UMCES Horn Point Oyster Hatchery, located near Cambridge, Maryland.

The 2019 OMP notes that the demand for hatchery-produced seed currently exceeds production in Maryland. This problem is exacerbated in years when, because of environmental factors, hatchery production is low. For example, in summer 2019, the Horn Point hatchery experienced a near total failure owing in part to low salinity caused by unusually high rainfall the previous year. The failure delayed restoration projects in oyster sanctuaries and sent oyster farmers scrambling to find alternative sources of seed for their aquaculture operations.

To address seed shortages, the 2019 OMP calls for encouraging the development of private oyster hatcheries and spat-setting facilities within the State. The 2019 OMP also calls for a return to the practice of producing wild oyster seed in areas with high natural spat set, or Seed Areas. Seed Areas were used extensively under the now-defunct Repletion Program (discussed in Chapter 2 of this report). However, Seed Area production has been limited in recent years by poor natural recruitment (spat settlement), reduced shell availability, and high costs. Nevertheless, the 2019 OMP includes the following three actions related to Seed Areas: (1) "identify oyster habitat in various regions of the bay that may be able to function as Seed Areas then delineate and manage those areas"; (2) "develop and utilize the seed transplanting guidelines to control the movement of disease"; and (3) "develop minimum seed counts that maximize the cost efficiency of moving/transporting seed to other areas within the Maryland portion of the Chesapeake Bay."

Overfishing

A key finding of the 2018 Stock Assessment Report was that overfishing had occurred during the immediately preceding 2017-2018 oyster harvest season in a majority of the NOAA codes surveyed for the report. In other words, the level of harvesting exceeded sustainable levels throughout much of the bay.

DNR indicates that, through the use of the adaptive management techniques outlined in the 2019 OMP, it expects to end overfishing and achieve sustainable oyster harvest levels within 8 to 10 years. However, many environmental stakeholders, including the Chesapeake Bay Foundation and the Chesapeake Bay Commission, have advocated for a more aggressive approach. These groups would like DNR to act immediately to end overfishing in areas where it is occurring. Additionally, these groups would like DNR to use science-based predictive modeling of the sort used in the OysterFutures process (discussed later in this chapter) to forecast the likely outcomes of different management actions before they are implemented.

Finally, environmental groups have called on DNR to establish abundance targets for the bay's oyster populations. The 2018 Stock Assessment Report established abundance *thresholds* (minimum levels, below which oyster populations should not be allowed to fall) for oyster populations in different parts of the bay. However, the report did not establish abundance *targets* (goals for what a restored oyster population would look like). The authors of the report explained, "Given the current low abundance of oysters relative to historic periods and significant changes in the ecosystem (*e.g.*, habitat loss, and disease), the stock assessment team was unable to generate a suitable method for calculating an abundance target."[4] Likewise, the 2019 OMP contains abundance thresholds for oyster populations throughout the bay but no abundance targets. Instead, Action 4.3 of the plan calls for evaluating and developing target levels of abundance at a later date. However, many environmental stakeholders believe that abundance targets should be established now in order to guide future management actions.

Latent Effort

Latent Effort in the Oyster Fishery

As noted in Chapter 2 of this report, an individual who wishes to harvest oysters commercially must (1) possess either a tidal fish license with an oyster harvester or oyster dredge boat authorization or an unlimited tidal fish license and (2) pay a surcharge of $300. DNR regulations cap the number of oyster harvester authorizations and oyster dredge boat authorizations that may be issued each year at 705 and 32, respectively. The number of unlimited tidal fish licenses that may be issued each year is similarly capped at 2,091. That means that a total of 2,828 individuals have the potential to harvest oysters in any given year (provided that they pay the necessary surcharge). Typically, however, only a small fraction of the individuals who could participate in the fishery actually do so. DNR reports that, from the 1994 to 1995 through the 2016 to 2017 oyster harvest season, an average of 804 eligible individuals paid the annual oyster surcharge. This number varied dramatically from year-to-year, however, going from a low of 599 individuals in the 2011 to 2012 season to a high of 1,134 individuals in the 2014 to 2015 season. Even among the individuals who pay the oyster surcharge, an average of only 80% report actually harvesting any oysters. DNR attributes these variations to fluctuations in the oyster population. When oysters are more abundant, more individuals enter the fishery; when oysters are less abundant, more people stay home.

"Latent effort" refers to the number of people who possess the necessary licenses and authorizations to participate in a particular fishery but who do not regularly participate in that fishery. Some of these people may never participate in the fishery, while others may participate when conditions are favorable – for example, when the target species is particularly abundant, or when prices for the species are high. Latent effort complicates fisheries management by introducing uncertainty into the decision making process. Fisheries managers make decisions about harvest restrictions (seasons, catch limits, etc.) based on assumptions about how many

[4] Maryland Department of Natural Resources, *A Stock Assessment of the Eastern Oyster, Crassostrea virginica, in the Maryland waters of Chesapeake Bay* (November 2018), p.11.

individuals will actually be harvesting that resource. If those assumptions turn out to be wrong, harvest restrictions may not work as intended.

Management Options

The 2019 OMP acknowledges the need to address latent effort in Maryland's public oyster fishery. Action 6.0.6 of the 2019 OMP calls for monitoring latent effort and working with the commercial industry and other stakeholders to identify potential strategies to control or decrease effort if necessary. The OysterFutures Workgroup (discussed in greater detail later in this chapter) went even further, calling for DNR to consider limiting entry to the oyster fishery in order to maintain a level of fishing effort that will ensure the long-term viability of the fishery and improve the health of the oyster resource. Specifically, the workgroup recommended the following:

> Working together with oyster resource stakeholders, DNR should evaluate a limited entry oyster fishery that can provide access to watermen making the majority of their living from commercial fishing, enables generational succession in the fishery, and should have a way for new participants to gain entry that does not solely rely on having a large amount of capital.[5]

DNR indicates that it received similar recommendations during the public comment period for the 2019 OMP. Maryland's blue crab fishery offers one possible model for limiting entry to the oyster fishery. In 2009, facing dramatic declines in the bay's blue crab population, DNR launched a voluntary commercial license buy-back program using federal Blue Crab Disaster Funds. Under the program, DNR bought and permanently retired limited crab catcher authorizations, crab harvester authorizations, and unlimited tidal fish licenses from commercial watermen – many of whom no longer actively participated in the crab fishery. According to Maryland Sea Grant, which helped to design the buy-back program, the program resulted in the permanent retirement of 683 crabbing authorizations and 100 unlimited tidal fish licenses.[6] These reductions have allowed DNR to more accurately predict crabbing activity on an annual basis.

DNR has indicated that imposing any additional limits on entry to the oyster fishery (beyond the current caps on issuing unlimited tidal fish licenses and oyster harvester permits) would require legislative changes. Moreover, DNR has stated that it does not believe such measures to be necessary at this time. According to DNR, the new 2019 regulations, which authorize DNR to adjust harvest restrictions by public notice with only 48 hours lead time, will allow DNR to respond to unexpected changes in the number of people participating in the oyster fishery. While DNR continues to monitor the impact of latent effort on the oyster fishery, it is likely that discussions about controlling latent effort will continue among stakeholder groups.

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[5] OysterFutures Stakeholder Workgroup, *Recommendations for Oyster Management and Restoration in the Choptank and Little Choptank Rivers. Report to Maryland Department of Natural Resources* (May 14, 2018), p.5.

[6] Maryland Sea Grant College, *Performance Review Panel Report for 2010–2013*, p.2.

Consensus Model for Oyster Management

Current Oyster Advisory Commission

Under current law, OAC is charged with (1) reviewing the best possible science and recommending strategies for rebuilding and managing the bay's oyster population; (2) reviewing the latest findings relevant to evaluating oyster restoration alternatives; and (3) reviewing any other scientific, economic, or cultural information relevant to oysters in the bay. OAC is also specifically charged with reviewing and reporting on strategies related to (1) oyster disease; (2) the effectiveness of sanctuaries, harvest reserve areas, and repletion programs; (3) management of, and maximization of ecological benefits for, natural oyster bars; and (4) enforcement.

Since its creation in 2007, OAC has provided valuable input related to oyster restoration and management in the bay, including providing recommendations that formed the basis for the 2010 oyster management and restoration plan, and reviewing and commenting on the *Five-Year Evaluation Report*. State law, however, does not establish the size or composition of OAC (which are determined by the Secretary of DNR), require OAC to meet at any specific times or on any schedule, or provide any standards or requirements for OAC procedures. As a result, at times OAC as a group has been dysfunctional or dormant.

Proposed Changes under Senate Bill 830 and House Bill 720 of 2019

During the 2019 session, the General Assembly passed SB 830/HB 720 to address these issues concerning OAC; the legislation was subsequently vetoed by the Governor, and its final status at the time of this report remains unknown. The legislation would have reconstituted OAC to include specified representatives of the oyster industry, conservation organizations, and research institutions. The legislation also would have required the reconstituted OAC, with the assistance of external conflict resolution and facilitation experts, to (1) develop a package of consensus recommendations addressing oyster management and the oyster industry through a facilitated consensus solutions process; (2) recommend management actions to achieve the targets identified in the oyster stock assessment, with the goal of increasing oyster abundance; and (3) use collaboratively developed, science-based modeling tools to determine which management actions to recommend. The modeling tools would have been required to quantify the long-term impacts of identified management actions on (1) oyster abundance; (2) oyster habitat; (3) the oyster harvest; (4) oyster harvest revenue; and (5) nitrogen removal. In developing the consensus recommendations, a vote of a 75% supermajority of OAC would be required for each recommendation. DNR, in coordination with UMCES and OAC, would have been required to use the consensus recommendations to implement an enhanced fishery management plan for oysters.

The process that the reconstituted OAC would have been required to follow was patterned after the process implemented by the OysterFutures research pilot program, an oyster management stakeholder group supported by the National Science Foundation and UMCES. In particular, the OysterFutures program (1) used a facilitated consensus solutions process with the assistance of

external conflict resolution experts to develop recommendations addressing oyster management and the oyster industry and (2) required a 75% supermajority vote for approval of each recommendation. In May 2018, the OysterFutures program issued a report to DNR that included recommendations on oyster management and restoration in the Choptank and Little Choptank rivers. The program evaluated opening portions of sanctuaries for which no restoration activities had occurred or were planned, combined with oyster planting during closed seasons. The program also specifically recommended establishing a rotational harvest in the Middle Choptank Sanctuary. The recommendations further addressed enforcement, the establishment of a limited entry oyster fishery, oyster shell resources, areas for planting junior oysters, and oyster related fees and taxes.

Looking Forward

The question of how to best manage and restore the State's oyster population is complex, involving diverse interests and complicated environmental end economic factors. While Maryland has been facing these issues for more than two centuries, the State has made major strides over the past two decades in fostering oyster aquaculture and restoring oyster populations within sanctuaries. The public oyster fishery continues to struggle, however, and the State's overall oyster population remains just a fraction of historic levels.

Going forward, the State faces difficult decisions on a broad range of topics, from how to achieve sustainability within the public fishery to whether to alter sanctuary boundaries. These decisions must be made with care if the State is to achieve the goal articulated in the 2019 OMP of conserving, protecting, and – where possible – rebuilding oyster populations "to fulfill their important ecological role and to support the culturally significant oyster fishery and industry throughout the Maryland portion of the Chesapeake Bay."

Appendix A
Maryland Oyster Management Timeline

Year	Summary
1811	Maryland's first oyster law prohibits dredging in State waters and imposes residency requirements for oyster harvesters
1830	Maryland's first aquaculture law allows Maryland residents to use up to one acre of submerged land for planting and growing oysters
1865	The first major legislative overhaul of State oyster laws; statewide license requirements established, use of sail dredges authorized, closed season for dredging established, and authorization for oyster plantings expanded
1868	Establishment of State Oyster Police Force (colloquially referred to as the "Oyster Navy") to enforce oyster laws
1882	Three-person Oyster Commission appointed to "examine the oyster beds and advise as to their protection and improvement"
1890	Passage of "cull law" based on recommendations of the 1882 Oyster Commission; law sets minimum size requirements for oysters and requires undersized oysters and shells with spat to be thrown back on the bars from which they were taken
1906	Haman Act authorizes individuals to lease up to 30 acres of "barren" bottom in county waters and up to 100 acres of barren bottom in the Chesapeake Bay beyond county limits; provides for the establishment of a Shell Fish Commission to survey natural oyster bars of the State
1912	Price-Campbell Bill codifies boundaries of natural oyster bars, as determined by the Shell Fish Commission in its Maryland Oyster Survey, and prohibits leasing of natural oyster bars; bars come to be known as "Yates Bars" after survey leader C.C. Yates
1922	Shell-planting legislation initiates annual placement of shell on depleted oyster bars
1943	Development of State's first Oyster Management Plan by the Maryland Board of Natural Resources (predecessor to Department of Natural Resources (DNR)); the plan calls for shell and seed plantings on natural oyster bars financed by $0.20 per bushel tax on oyster harvests
1948	Report by the Commission on Conservation of Natural Resources recommends adopting a 15-year plan for the rehabilitation of the oyster industry; recommendations include establishing county oyster committees, requiring in-State shucking houses to sell a certain percentage of shell to the State for replenishment projects and establishing an oyster inspection tax to fund shell purchases

Year	Summary
1960	Repletion Program begins; dredged and fresh shell is planted on public oyster bars to improve habitat and enhance natural spat set; seed is planted to augment natural production
1967	New law creates the Fishery Research and Development Fund and provides for specified fishing fees (license fees, fines, taxes, and penalties) to be paid into the fund; much of the fund is earmarked for the Repletion Program
1987	The Chesapeake Bay Program (Bay Program) adopts the first Chesapeake Bay Agreement, which includes a commitment to develop, adopt, and begin implementing a baywide management plan for oysters
1989	The Bay Program adopts the first *Chesapeake Bay Oyster Management Plan*; the plan includes management actions addressing (1) harvest decline and overharvesting; (2) recruitment; (3) disease mortality; (4) low production from leased grounds; (5) habitat degradation; (6) shellfish sanitation problems; (7) market stability; and (8) repletion efforts
1993	State convenes the Oyster Roundtable to develop "sound, broadly supported recommendations on how to revive oyster populations in the Chesapeake Bay"; among other recommendations, the *Maryland Oyster Roundtable Action Plan* calls for addressing institutional barriers to oyster aquaculture, using Oyster Recovery Areas for the implementation and evaluation of experimental rehabilitation activities, and conducting an environmental impact assessment of the potential introduction of non-native species into Maryland's portion of the Chesapeake Bay
1994	The Bay Program adopts the *Chesapeake Bay 1994 Oyster Fishery Management Plan* and adopts the *Chesapeake Bay Aquatic Reef Habitat Plan* to guide the development and implementation of a regional program to rebuild and restore reefs as habitat for oysters and other ecologically valuable aquatic species; the habitat plan calls for designating about 5,000 acres each in Maryland and Virginia for oyster reef construction over 5 years
2000	The Bay Program adopts the Chesapeake 2000 Agreement, which includes a goal of achieving a tenfold increase in native oysters in the Chesapeake Bay by 2010 compared with a 1994 baseline
2005	The Bay Program adopts the *2004 Chesapeake Bay Oyster Management Plan*; the plan calls for (1) increasing oyster populations to levels that restore important ecological functions; (2) achieving a sustainable oyster fishery through a combination of harvest from public oyster grounds and private aquaculture; (3) reducing the impacts of disease on oyster populations; and (4) increasing hatchery production and developing disease-resistant strains
2005	Chapter 405 of 2005 establishes the Aquaculture Coordinating Council to formulate and make proposals for advancing Maryland aquaculture

Year	Summary
2007	Chapters 113 and 114 of 2007 establish the Oyster Advisory Commission (OAC) to review science and management issues relevant to oysters in the Bay
2008	The Maryland Department of Agriculture, in consultation with the Aquaculture Coordinating Council and other State agencies, publishes the *Maryland Shellfish Aquaculture Plan: Enhancing the Environment through Private Sector Investment*; the plan includes recommendations for developing a sustainable fishing industry while creating opportunities for prospective shellfish growers to establish aquaculture businesses in Maryland waters
2009	OAC issues its 2008 report, *Concerning Maryland's Chesapeake Bay Oyster Management Program*; major recommendations include: • focusing ecological restoration in a large-scale and interconnected approach; • implementing a new fisheries management plan for oysters; • addressing the illegal harvesting of oysters, particularly in "protected, prohibited and leased areas"; • revising laws and regulations that impede private cultivation; • transitioning the State's oyster industry to be based primarily on aquaculture; • reversing the degradation and loss of vital oyster habitat; • identifying new substrate sources; and • increasing and diversifying sources of disease–free oyster seed
2009	The U.S. Army Corps of Engineers issues the *Final Programmatic Environmental Impact Statement for Oyster Restoration Including Use of Native and/or Non-Native Oysters* (Programmatic EIS), which lays out the first comprehensive baywide strategy for large-scale oyster restoration; the Programmatic EIS determines that the introduction of nonnative oysters to the bay poses "unacceptable ecological risks" and instead calls for (1) enhancing native oyster restoration; (2) restricting oyster harvests; and (3) expanding native oyster aquaculture

Year	Summary
2009	Chapters 173 and 174 of 2009 implement several recommendations of the *Maryland Shellfish Aquaculture Plan*; the bills require DNR to adopt regulations establishing (1) public shellfish fishery areas in which leasing is prohibited; (2) Aquaculture Enterprise Zones for aquaculture leasing; and (3) aquaculture demonstration leases for educational, conservation, or ecological purposes
2009	Governor Martin J. O'Malley releases the *10-Point Oyster Restoration and Industry Revitalization Plan for Oysters*; among other things, the plan calls for increasing the State's network of oyster sanctuaries from 9% to 24% of the bay's remaining quality oyster habitat, establishing oyster aquaculture leasing opportunities and related financial assistance programs, and maintaining 76% of the bay's remaining quality oyster habitat for commercial harvest
2010	Maryland adopts Amendment I to the 2004 OMP; the amendment explicitly authorizes oyster aquaculture and clamming to occur in certain oyster sanctuaries
2014	The Bay Program adopts the *2014 Chesapeake Bay Watershed Agreement*; the agreement calls for restoring large connected native oyster habitat and populations in sanctuaries in 10 bay tributaries (5 sanctuaries each in Maryland and Virginia) by 2025
2016	The Sustainable Oyster Population and Fishery Act of 2016 (Chapter 703) requires DNR, as part of its fishery management plan for oysters, to conduct a study, in coordination with the University of Maryland Center for Environmental Science, on the oyster stock and management strategies to address the maintenance of a sustainable oyster population and fishery
2016	DNR completes *Oyster Management Review: 2010-2015*, evaluating the State's oyster sanctuary network; the review recommends adjusting the boundaries of sanctuaries and public shellfish fishery areas to facilitate a fair distribution of the most productive oyster areas
2017	Chapter 27 of 2017 prohibits DNR from reducing or altering the boundaries of oyster sanctuaries until it has developed a fisheries management plan for the scientific management of the oyster stock after the completion of the report required under Chapter 703 of 2016
2018	DNR releases *A Stock Assessment of the Eastern Oyster, Crassostrea virginica, in the Maryland Waters of the Chesapeake Bay*, the report required under Chapter 703 of 2016; the report establishes biological reference points for the oyster stock and lists oyster management tools for consideration by DNR
2019	Chapter 17 of 2019 codifies the boundaries of the five tributary-scale oyster sanctuaries identified for restoration under the 2014 Chesapeake Bay Watershed Agreement

Year	Summary
2019	DNR adopts the *2019 Maryland Chesapeake Bay Oyster Management Plan*, replacing the 2004 OMP; the plan describes the history and current status of the State's oyster fishery and provides a broad framework for managing oyster harvesting, restoration, and aquaculture going forward

Appendix B

Information Resources

Publications

Maryland Department of Legislative Services, *Fostering Shellfish Aquaculture Production in Maryland and Other States* (2013), *see* http://dls.maryland.gov/pubs/prod/NatRes/Fostering-Shellfish-Aquaculture-Production-in-Maryland-and-Other-States.pdf

Maryland Department of Natural Resources, *Oyster Management Review: 2010-2015* (July 2016), *see* https://dnr.maryland.gov/fisheries/Pages/oysters/5-Year-Oyster-Review-Report.aspx

OysterFutures Stakeholder Workgroup, *Recommendations for Oyster Management and Restoration in the Choptank and Little Choptank Rivers* (May 2018), *see* https://oysterfutures.files.wordpress.com/2018/05/oysterfutures_stakeholder_recommendations_report_14may2018.pdf

Maryland Department of Natural Resources, *A Stock Assessment of the Eastern Oyster, Crassostrea virginica, in the Maryland waters of Chesapeake Bay* (November 2018), *see* https://dnr.maryland.gov/fisheries/Pages/oysters/Oyster_Stock_Assess.aspx

Maryland Department of Natural Resources, *Maryland Chesapeake Bay Oyster Management Plan* (May 2019), *see* https://dnr.maryland.gov/fisheries/Documents/MD_Oyster_FMP-2019.pdf

Websites

U.S. Army Corps of Engineers, Maryland Oyster Restoration webpage:
https://www.nab.usace.army.mil/Missions/Environmental/Oyster-Restoration/

Chesapeake Bay Program, Oysters webpage:
https://www.chesapeakebay.net/issues/oysters

Maryland Department of Natural Resources, Shellfish Aquaculture webpage:
https://dnr.maryland.gov/fisheries/Pages/aquaculture/shellfish.aspx

National Oceanic and Atmospheric Administration, Chesapeake Bay Office, Oyster Restoration webpage: https://chesapeakebay.noaa.gov/oysters/oyster-restoration

Oyster Advisory Commission webpage:
https://dnr.maryland.gov/fisheries/Pages/mgmt-committees/oac-index.aspx