FISHERY MANAGEMENT PLAN UPDATE
EASTERN OYSTER
AUGUST 2018

STATUS OF THE FISHERY MANAGEMENT PLAN

Fishery Management Plan History

Original FMP Adoption:	August 2001
Amendments:	Amendment 1 – January 2003 Amendment 2 – June 2008 Amendment 3 – April 2014 Amendment 4 – February 2017
Revisions:	None
Supplements:	Supplement A to Amendment 2 – November 2010
Information Updates:	None
Schedule Changes:	None
Next Benchmark Review:	July 2022

The original N.C. Oyster Fishery Management Plan (FMP) was adopted by the North Carolina Marine Fisheries Commission (NCMFC) in 2001. This FMP set up a process for designation of additional areas limited to hand harvest methods around Pamlico Sound and recommended several statutory changes to the shellfish lease program including higher fees, training requirements, and modified lease production requirements (NCDMF 2001). The N.C. Oyster FMP Amendment 1 simply changed one of the criteria for designation of hand harvest areas from waters generally less than 10 feet deep to waters less than six feet deep (NCDMF 2003). Highlights of the management measures developed in the N.C. Oyster FMP Amendment 2 included adopting a 15-bushel harvest limit in Pamlico Sound and a 10-bushel harvest limit for all gears (hand and mechanical) in designated areas around the sound, reducing the available harvest season, changing the way lease production averages were calculated, limited lease applications to five acres and had a recommendation to expand oyster sanctuary construction efforts (NCDMF 2008). Supplement A raised the potential harvest limit in Pamlico Sound to 20 bushels and created a monitoring system for determining when to close mechanical harvest in that area (NCDMF 2010). The N.C. Oyster FMP Amendment 3 created two seed oyster management areas in Onslow County. Amendment 4 was adopted in February 2017 with selected management measures including: the continuation of the monitoring system for when to close mechanical harvest off public bottom in an area, a reduction of the culling tolerance from 10 to five percent in the commercial fisheries off public bottom, a reduction of the daily harvest limit for holders of the Shellfish License off public bottom to two bushels per person per day

maximums four bushels per vessel, the continuation of the six-week open season to mechanical harvest off public bottom in the bays with changes in the timing of the six-week opening, modifications to shellfish lease provisions, and adding convictions of theft on shellfish leases and franchises to the types of violations that could result in license suspension or revocation.

Management Unit

The management unit includes the eastern oyster (*Crassostrea virginica*) and its fisheries in all waters of coastal North Carolina.

Goal and Objectives

The goal of the N.C. Oyster FMP is to manage the state's oyster population so that it achieves sustainable harvest and maximizes its role in providing ecological benefits to North Carolina's estuaries. To achieve this goal, it is recommended that the following objectives be met:

1. Identify, restore, and protect oyster populations as important estuarine habitat.
2. Manage and restore oyster populations to levels capable of maintaining sustained production through judicious use of natural oyster resources, enhancement of oyster habitats, and development and improvement of oyster production on shellfish leases and franchises.
3. Minimize the impacts of oyster parasites and other biological stressors through better understanding of oyster disease, better utilization of affected stocks, and use of disease resistant and biological stress resistant oysters.
4. Consider the socioeconomic concerns of all oyster resource user groups, including market factors.
5. Recommend improvements to coastal water quality to reduce bacteriological-based harvest closures and to limit other pollutants to provide a suitable environment for healthy oyster populations.
6. Identify and encourage research to improve understanding of oyster population ecology and dynamics, habitat restoration needs, and oyster aquaculture practices.
7. Identify, develop, and promote efficient oyster harvesting practices that minimize damage to the habitat.
8. Initiate, enhance, and continue studies to collect and analyze economic, social, and fisheries data needed to effectively monitor and manage the oyster resource.
9. Promote public awareness regarding the ecological value of oysters and encourage public involvement in management and enhancement activities.

STATUS OF THE STOCK

Life History

The eastern oyster (*Crassostrea virginica*) is a non-moving, filter feeding shellfish occurring naturally along the western Atlantic Ocean from the Gulf of St. Lawrence off Quebec, Canada to the Gulf of Mexico and the Caribbean Islands. The eastern oyster has been called the ultimate estuarine animal. It can tolerate a wide range of salinity, temperature, turbidity and dissolved oxygen levels, making it well adapted to the ever-changing conditions of the estuary. The

distribution and survival of eastern oysters within habitat types is influenced by abiotic factors such as salinity, tide, oxygen levels and flow, as well as biotic factors such as disease, shell erosion caused by other species and predation. North Carolina's oyster stocks are composed of both intertidal (oysters growing between the mean high and low tide levels) and subtidal (oysters growing below the mean low water level) populations.

Oysters are typically dioecious but can change their sex (hermaphroditic) once each year. Researchers have found that natural oyster populations maintain relatively balanced sex ratios, but exposure to stress, such as food limitation and pollution, results in a higher ratio of males. Gonads may develop in oysters two to three months old. Fully developed oysters entering their first summer season may spawn, but large portions of these young oysters are not sexually mature. Age or size selective mortality from disease and harvest pressure can alter oyster population demographics and result in a shift from male to female. The rate of oyster growth is highest during the first six months after the spat (juvenile oyster) sets and gradually declines throughout the life of the oyster. Seasonally, adult oysters grow most rapidly during spring and fall in North Carolina, reaching market size (3 inches) in about three years. Growth rates in other East Coast and Gulf Coast regions produce market size oysters in time periods ranging from 18 to 24 months in the Gulf of Mexico to four to five years in Long Island Sound.

Stock Status

There are insufficient data to conduct a traditional stock assessment for the eastern oyster in North Carolina, therefore population size and the rate that oysters are removed from the population could not be determined. North Carolina commercial oyster landings have been in decline for most of the past century. This decline was likely initiated by overharvest and compounded by habitat disturbance, pollution, and biological and environmental stressors. Oysters are believed to be more vulnerable to overharvest because these other factors negatively impact their survival.

Stock Assessment

An oyster stock assessment was attempted in 1999, but the necessary data were lacking to determine levels of sustainable harvest (NCDMF 2001). Since there were no significant changes in the types and quantity of data collected, an oyster stock assessment could not be achieved in 2006 and again in 2014 (NCDMF 2008; NCDMF 2017). Collection of appropriate data is needed in order to conduct a stock assessment and determine levels of sustainable harvest (NCDMF 2008).

Data are not available to perform a traditional assessment so it was not possible to estimate population size, demographic rates, or removals from the population in the latest FMP adopted in 2017. The only data representative of the stock were the commercial landings and associated effort. For this reason, the most recent analysis focused on trends in catch rates in the commercial oyster fishery. These catch rates could not be considered an unbiased representation of trends in population size; fisheries-dependent data are often not proportional to population size due to a number of caveats and should be interpreted with caution if the interest is relative to changes in the population. In order for a fisheries-dependent index to be proportional to

abundance, fishing effort must be random with respect to the distribution of the population and catchability must be constant over space and time (NCDMF 2017). Other factors affecting the proportionality of fishery-dependent indices to stock size include changes in fishing power, gear selectivity, gear saturation and handling time, fishery regulations, gear configuration, fishermen skill, market prices, discarding, vulnerability and availability to the gear, distribution of fishing activity, seasonal and spatial patterns of stock distribution, changes in stock abundance, and environmental variables. Many agencies, such as the NCDMF, do not require fishermen to report records of positive effort with zero catch; lack of these "zero catch" records in the calculation of indices can introduce further bias.

The North Carolina commercial oyster fishery is subject to trip limits, which could bias catch rates (Mike Wilberg, University of Maryland Center for Environmental Science, personal communication; John Walter, National Oceanic and Atmospheric Administration Fisheries, personal communication). The trip limits affect the amount of catch that is observed per unit effort, preventing the true value of this variable from being observed. A censored regression approach was attempted to calculate an index of relative abundance (numbers harvested per transaction) using data collected from a fishery with trip limits.

Data were obtained from the North Carolina Trip Ticket Program for 1994 through 2013. The censored response variable (catch per unit effort) was fit within a Generalized Additive Models for Location Scale and Shape framework using the 'gamlss.cens' (Stasinopoulos et al. 2014) and 'survival' (Therneau 2014) packages in R (R Core Team 2014). Catch rates were estimated for both hand harvest and mechanical harvest in each of the major water bodies from which eastern oysters are harvested where sufficient data were available. Data were summarized by fishing year (October through March for hand harvest and November through March for mechanical harvest). Only landings from public bottom were examined.

Catch rates were expressed as bushels harvested per transaction. The censored regression approach failed for both hand and mechanical harvest data despite trying three different distributional assumptions (lognormal, gamma, t). This failure was believed to be due to the large number of trips (transactions) that meet or exceed the trip limit in both fisheries. Similar work found that when about 50 percent or more of the trips equaled or exceeded the trip limits, there was not enough information from the uncensored trips to produce a reliable model. Here, 51.4 percent of trips by hand gears equaled (39.3 percent) or exceeded (12.1 percent) the trip limits over all water bodies and fishing years combined; the number of trips equaling or exceeding the trip limits for mechanical gears was 43.5 percent (42.9 percent equaled and < one percent exceeded).

Available data were considered insufficient for estimating reliable fishing mortality rates.

A pilot project is underway over the next three years by The Nature Conservancy and North Carolina State University, with guidance from NCDMF, to develop a subtidal oyster population survey with the potential to become a long-term biological sampling program in NCDMF. Concurrent with these efforts and outside the scope of this pilot project, The Nature Conservancy is collaborating with the NCDMF and commercial oystermen to refine the collection of harvest data to gather more accurate information on harvest levels and effort, as well as discard mortality

from dredges. For the southern portion of the state, The Nature Conservancy will also map and illustrate changes from the NCDMF bottom mapping sampling program to delineate oyster reefs and evaluate changes over time as a precursor to a biological sampling program in intertidal oysters in the southern region of the state.

STATUS OF THE FISHERY

Current Regulations

Oysters cannot be taken from any public or private bottom in areas designated as prohibited (polluted) by proclamation except for special instances for: Shellfish Management Areas (NCMFC Rule 15A NCAC 03K .0103), with a permit for planting shellfish from prohibited areas (NCMFC Rule 15A NCAC 03K .0104), and for the depuration of shellfish (NCMFC Rule 15A NCAC 03K .0107). Beginning in April 2014, time and temperature control measures were initiated for oysters to prevent post-harvest growth of naturally-occurring *Vibrio* sp. bacteria that can cause serious illness in humans between April 1 and September 30 of each year. Oysters cannot be taken between the hours of sunset and sunrise of any day. Beginning in the 2017-2018 season the culling tolerance was reduced from 10 percent to five percent off public bottom based on management measures adopted in Amendment 4 of the N.C. Oyster Fishery Management Plan.

Public Bottom

The minimum size limit for oysters from public bottom is three-inch shell length. Both the hand and mechanical oyster harvest season from public bottom are opened annually by proclamation. It is unlawful to sell oysters taken on Saturday and Sunday from public bottom. The hand-harvest season for commercial and recreational harvest begins on October 15 each year with commercial harvest limited to Monday through Friday each week and recreational harvest allowed seven days a week. Hand-harvest methods to take oysters are allowed in all areas found suitable for shellfish harvest by the Shellfish Sanitation and Recreational Water Quality Section of the NCDMF during the open season. Beginning in 2013 through statutory changes, the Shellfish License was restricted to hand harvest only, and harvest by mechanical methods was prohibited. Recreational harvest is only allowed by hand methods. The season typically continues until closed by rule on March 31 although some locations close earlier due to perceived excessive harvest. Brunswick County is the only area frequently closed early due to this concern and it closed prior to March 31 fifteen times between the1996-1997 and 2017-2018 seasons. The daily hand harvest limit for oysters in Pamlico Sound outside the bays is 15-bushel per day per commercial fishing operation and 10-bushels per day per commercial fishing operation in the bays and in the Mechanical Methods Prohibited area along the Outer Banks of Pamlico Sound. Areas from Core Sound south have a daily hand harvest limit of five-bushels per person not to exceed 10-bushels in any combined fishing operation regardless of the number of persons, license holders, or boats involved. Recreational daily harvest limits in 2017-2018 were one bushel per person per day not to exceed two bushels per vessel per day.

Beginning in October of the 2017-2018 season, hand harvest for Shellfish License holders was limited to two bushels per person per day not to exceed four bushels per vessel per day if two or

more Shellfish License holders are onboard the vessel (NCDMF 2017). Hand harvesters with the Standard Commercial Fishing License were allowed to continue landing the higher daily harvest limits in all areas.

The mechanical harvest season for oysters in 2017-2018 was opened November 13, 2017, and areas where mechanical harvest gear was allowed were restricted to deeper portions of the sounds, rivers and bays north of Pamlico Sound. These areas are designated by rule (NCMFC Rule 15A NCAC 03R .0108). Mechanical methods for oysters were only allowed to operate from sunrise to 2:00 p.m. during the 2017-2018 season (November 13 – March 31). Beginning in the 2017-2018 harvest season the six-week open period in the bays was split into two. The first opening in the deep bays began on the Monday of the week prior to Thanksgiving (November 13, 2017) through the Friday after Thanksgiving (November 24, 2017). The second opening of the bays began two weeks before Christmas (December 11, 2017) and ended on January 8, 2018.

Areas outside the bays open to mechanical harvest were limited to a daily harvest limit of 15-bushels of oysters per operation.

The mechanical harvest season can close sooner for areas in Pamlico Sound if sampling by NCDMF indicates that oysters of legal size have been reduced to below 26 percent of the live oysters sampled for two consecutive sampling trips, as directed by Amendment 4 of the Oyster FMP. Mechanical harvest was closed on December 7, 2017 in the Neuse River area, Pamlico River and Northern Dare County areas on December 25, 2017, and Northern Hyde County area on January 29, 2018 (Table 1; Figure 1). All mechanical harvest areas remained closed until the season ended on March 31, 2018.

There are also further restrictions noted in the proclamation for mechanical oyster harvesters to make sure that cultch material and culled oysters are either put back into the water where they were taken or remain on the existing rocks. North Carolina has a rule in place (NCMFC Rule 15A NCAC 03K .0202) requiring culling on site. The following restrictions were put in place beginning with the 2012-2013 oyster season to discourage harvesters from not culling and removing extra cultch material.

> It is unlawful to possess more than **five** bushels of unculled catch onboard a vessel. Only material on the culling tray is exempt from culling restrictions.
>
> It is unlawful to possess unculled catch or culled cultch material while underway and not engaged in mechanical harvesting.

Also, some harvesters did not have vessels or dredges rigged for circular dredging patterns which work best with towing points over the side of the vessel or for short tows to allow for culling between pickups. The following restrictions were put in place to encourage circular dredging patterns and shorter tows to keep the cultch and culled oysters on the existing rocks.

> It is unlawful for the catch container (bag, cage) attached to a dredge to extend more than **two** feet in any direction from the tooth bar.

It is unlawful to tow a dredge unless the point where the tow line or cable exits the vessel and goes directly into the water is on the port or starboard side of the vessel forward of the transom.

Private Bottom

The minimum size limit for oysters from private bottom is a three-inch shell length and culling requirements only occur during the open public harvest season, the rest of the year there is no minimum size requirement for oysters taken from private bottom. There is no daily maximum harvest limit applied to the taking of oysters from private bottom in internal waters. Permits are required to use mechanical methods for oysters on a lease or franchise. Public bottom must meet certain criteria in order to be deemed suitable for leasing for shellfish cultivation and there are specific planting, production, and marketing standards for compliance to maintain a shellfish lease or franchise. There are also management practices that must be adhered to while the lease is in operation, such as: marking poles and signs, spacing or markers, and removal of markers when the lease is discontinued.

Possession and sale of oysters by a hatchery or aquaculture operation and purchase and possession of oysters from a hatchery or aquaculture operation are exempt from the daily harvest limit and minimum size restrictions. The possession, sale, purchase and transport of such oysters must be in compliance with the Aquaculture Operation Permit. Leases that use the water column must also meet certain standards as outlined in G.S. 113-202.1 in order to be deemed suitable for leasing and aquaculture purposes.

There is a specific application process to obtain a lease and a public comment process that is required before a shellfish lease is granted if anyone wishes to protest the issuance of a lease. Owners of shellfish leases and franchises must provide annual production reports to the Division. Failure to furnish production reports can constitute grounds for termination. Cancellation proceedings will begin for failure to meet production requirements and interfering with public trust rights. Corrective action and appeal information is given. And there are also requirements for the transfer of a lease before the contract term ends.

Commercial Landings

Data on landings from public bottom by gear indicate that, prior to 1960, most of the oysters were taken by dredge when compared to all hand methods. Chestnut (1955) reported that 90 percent of the oysters landed in North Carolina came from Pamlico Sound. The Pamlico Sound area is largely dependent on dredging. The resurgence of the dredge landings in 1987 was due, in part, to increased oyster populations and in part to increased effort, as displaced mechanical clam harvesters turned to oyster dredging due to closure of southern clam areas by a red tide. The red tide was a dinoflagellate bloom that caused closure of over 361,000 acres of public bottoms to shellfish harvest from November 1987 to May 1988. The dinoflagellate (*Karenia brevis*) produced a neurotoxin, which was concentrated in shellfish, making them unfit for consumption. These closures affected 98 percent of the clam harvesting areas and had its greatest impact on the clam fishermen. Hand harvest landings of oysters failed to reach their potential that same year due to the fact that the majority of the hand-harvest-only areas were also closed because of the

red tide. Hand harvest landings are the most consistent contributor to the state's oyster fishery. Hand harvest landings exceeded the dredge landings for significant periods between 1961 and 1970 and between 1989 and 2008 (NCDMF 2017).

The oyster parasite *Perkinsus marinus*, also known as Dermo disease, has been responsible for major oyster mortalities in North Carolina during the late 1980s to mid-1990s. Dermo, a protist, similar to dinoflagellates, causes degradation of oyster tissue. Once infected, oysters suffer reduced growth, poor condition, diminished reproductive capacity and ultimately mortality resulting from tissue lysis and occlusion of hemolymph vessels (Ford and Figueras 1988; Ford and Tripp 1996; Haskin et al. 1966; Ray and Chandler 1955). Chestnut (1955) may have been the first to report its occurrence in North Carolina. However, no extensive assessments were attempted until large-scale oyster mortalities prompted investigations during the fall of 1988. Oyster samples from 11 sites were sent to the Virginia Institute of Marine Science (VIMS) and the Cooperative Oxford Laboratory. Results showed that Dermo infection was the major cause of mortalities (NCDMF 2008).

Staff observed in the southern estuaries, while the Dermo infections were on the rise, that during late summer, moderate and high Dermo infection levels did not reduce oyster populations. Hand harvest landings in the south from 1991 through 2002 did not decline in the same manner as landings from Pamlico Sound during the same time. It is suspected that the small, high salinity estuaries may inhibit mortality by flushing out parasites at a higher rate or by exceeding the salinity tolerance of the Dermo parasite, allowing for a higher survival rate compared to Pamlico Sound. The link between low dissolved oxygen, increased availability of iron and increased parasite activity may also be a factor in the different mortality rates as the smaller, high salinity estuaries are less prone to low dissolved oxygen events than the Pamlico Sound (Leffler et al. 1998). Dermo infection intensity levels since 2005 have remained low; however, prevalence appears to be increasing (NCDMF unpublished data; Colosimo 2007). Dermo infection intensity has remained low and mechanical harvest landings in Pamlico Sound continued to recover from the extremely high Dermo mortality levels and hurricane impacts of the mid-1990s until additional environmental impacts (i.e., low dissolved oxygen) began affecting the fishery in 2011 (Figure 2).

Bioeroders (other species that tunnel into the oyster's shell), in particular boring sponge (*Cliona* sp.), are also of concern to researchers for their impacts to oyster reefs in North Carolina. These sponges can chemically etch out canal systems within oyster reefs, as well as encrust and smother them. Boring sponges range in color from yellow to dark brown or black and can cause mortality by weakening the shell. As the shell becomes weak, the oyster is unable to protect itself from predators. Once the oyster reef has been compromised, there is a loss of material for spat attachment and eventually a reduction in the vertical height of the reef. Boring sponges are linked to salinity gradients with some species found in high salinity waters while other species are found in the low to mid-range salinities but typically are not found in waters with less than 10 parts per thousand. Intertidal oysters have some refuge from boring sponge. Dunn et al. (2014) examined the distribution and abundance of oyster reef bioerosion by *Cliona* sp. in North Carolina. The study examined levels of boring sponge infestations across salinity gradients in multiple oyster habitats from New River through the southern portions of Pamlico Sound. The study found boring sponge infestations in all oyster communities sampled, with the exception of

those found in the upper reaches of some tidal creeks in the Newport and North rivers in Carteret County. Low salinity areas had mean salinity levels of 15 parts per thousand while the higher salinity areas had a mean salinity of 20 parts per thousand or greater. High salinity areas were infested by the high salinity tolerant boring sponge *Cliona celata*. The study found that as salinities increased, infestations increased.

Overall commercial oyster landings from private bottom have been increasing while landings off public bottom have been much more variable in the last 10 years (Figure 2). Hand harvest landings exceeded the mechanical landings from public bottom in 2007 to 2008, 2012 to 2013, and 2015 to 2017 (Figure 3). The most significant increase in oyster landings from public bottom in the past ten years occurred in the mechanical harvest fishery in Pamlico Sound during the 2009-2010 and 2010-2011 seasons (Figures 2 and 3). There was a high abundance of oysters in some areas in Pamlico Sound that had not been seen in over 20 years, high market demand, and an increase in new participants in the fishery likely influenced these higher landings. In 2013 General Statute 113-169.2 limited the use of the Shellfish License to hand harvest methods only, this license is available to all residents of North Carolina for a lower fee than the Standard Commercial Fishing License. Hand harvest has shown a slight increasing trend in landings for the past 10 years. In 2017, hand harvest commercial landings off public bottom were five times higher than mechanical harvest landings off public bottom (Figure 3).

Mechanical Harvest Fishery Off Public Bottom

During the early 2009-2010 mechanical harvest oyster season, the Narrows area between Great Island and the mainland in Hyde County in Pamlico Sound experienced intensive oyster harvest (Figures 1, 2 and 3). Some of the operations were harvesting the 15-bushel limit, offloading, returning to the area with a new crew and harvesting another limit the same day. The 2010-2011 season began with a 2:00 pm time limit on dredging to stop the two-trips-per-day loophole but it probably had little impact on mechanical harvest since experienced dredgers could take their limit in a few hours and there appeared to be many new entrants into the fishery. The traditionally harvested oyster rocks in the deeper waters of western Pamlico Sound contributed greatly to the increased landings in the 2009-2010 and 2010-2011 seasons but the Middle Ground area in 2010-2011 provided another unexpected source of significant oyster production similar to the Great Island Narrows in 2009 (Figures 2 and 3). Also, interest in taking advantage of expected high market demand caused by closure of oyster harvest areas in the Gulf of Mexico due to the Deepwater Horizon oil spill lengthened the season slightly with a November 1 mechanical harvest season opening in the fall of 2010.

Hurricane Irene hit the North Carolina coast on August 27, 2011 and had major impacts on the mechanical harvest area for oysters. The oyster resources on the Middle Ground could not be located after the storm probably due to sedimentation or physical relocation caused by waves or currents. Many of the deeper water oyster resources located near Brant Island Shoal were also significantly damaged (Figure 4). Oyster resources in the Neuse and Pamlico rivers did not appear to suffer much damage but also did not show any of the typical growth characteristics during the following fall and winter months. These factors had a pronounced effect on the mechanical harvest oyster season in 2011-2012 and the mechanical harvest area in western Pamlico Sound was closed in January. Mechanical harvest landings declined to near 2008-2009

levels during the 2011-2012 season (Figure 3). Regular sampling of oyster sizes to fulfill the requirements of Amendment 4 to the N.C. Oyster FMP has made it clear that oyster growth during the harvest season is essential to sustain acceptable harvest levels.

In the summer prior to the 2012-2013 mechanical harvest season, an apparent, severe low dissolved oxygen event occurred in the Neuse River that caused virtually a 100 percent mortality of the oyster resources at 18 feet or greater depths. The Pamlico River area also had not recovered from the effects of Hurricane Irene at this time. There still was little evidence of any recovery of the Neuse River oyster resources prior to the 2013-2014 season but the Pamlico River area appeared to be recovering and growth indicators were good during the season. The Northern Dare area in Pamlico Sound also supported some significant mechanical harvest activity throughout the 2013-2014 season.

During the 2014-2015 mechanical harvest season effort was still consistently low in the Neuse River, with effort peaking in all areas in mid-December. Closures of the Northern Hyde and Dare areas resulted in declines in harvest in January and foul weather increased these declines in February. Staff continued to sample and Northern Dare was re-opened in early March and closed by rule on March 31, 2015. The fleet encountered what was described as a “crust” covering much of the oyster rocks fished on re-opening day and took several days to break up this “crust”. Effort was high for the re-opening with approximately 50 boats fishing on the first day and dropping off to around 20 boats after a few days.

Water temperatures were quite warm throughout the 2015-2016 season and not a lot of new growth was observed until January on the oysters. Some areas in Northern Hyde were covered in tunicates the previous year and little spat was seen in these locations during this season. Planting sites in the Northern Dare area samples showed a lot of dredge damage from the previous year and effort was low the entire season because the warm water temperatures kept most fishermen potting for crabs up until the pot closure period in January. The Neuse River area was limited in locations to harvest oysters and closed early this season. Effort was highest in the Pamlico River at the beginning of the season and then after Christmas effort shifted to areas off Northern Hyde. The area that was dredged by most of the fleet in January 2016 was an old clam bed with little bottom relief. The oysters were large and showed good growth. By late January the new area was depleted and fishermen were seen working offshore Juniper Bay Point near the sanctuary, off Great Island, and Royal Shoal in the deeper areas of Pamlico Sound. By mid-February many oyster fishermen working in Northern Hyde and the Pamlico River quit harvesting oysters because they could not reach their daily harvest limit and were gearing up for other fisheries (i.e. crab pots and shad fishing). The Northern Dare area closed in late February.

Like the previous season, water temperatures were quite warm and little growth was observed in the oysters until January in the 2016-2017 season. In the Neuse River live oysters were present in only a few locations. A confirmed low dissolved oxygen event occurred earlier that summer over a prolonged period near the mouth of the Neuse River which may have had an impact on oysters in this area. Within a few weeks of the season opening, only a few oyster harvesters were working in the Neuse River area, and most live oysters were found in shallow water (less than 20 feet deep). At the beginning of the season most of the effort was concentrated in an old clam bed west of Bluff Shoal in the Northern Hyde area, which showed good numbers of legal-sized

oysters with hardly any spat. Oyster harvesters continued to work in this area all season without much movement. In mid-November, reports from Northern Hyde and the Pamlico River areas indicated only a few fishermen were harvesting oysters. By late December the few oyster harvesters seen on the water were having to move around a lot to find oysters. In January, dealers indicated fishermen had moved on to other fisheries (shrimping in the ocean or small mesh gill netting in estuarine waters). January 2017 samples showed better growth on the oysters and spat on the cultch. Mechanical harvest was closed within a few weeks apart starting in mid-January in the Neuse River and Northern Dare areas for the remainder of the season. The Pamlico River and Northern Hyde areas remained open for the entire 2016-2017 season, but only a few fishermen remained harvesting oysters in early February and by mid-February no effort was seen in the open areas while sampling.

Pre-season sampling in October-November 2017 showed a lot of spat and small oysters in all areas, and two areas (Neuse River and Northern Dare) came in below the threshold (<26 percent) of legal-sized oysters in the samples. The 2017-2018 mechanical harvest season began Monday, November 13, 2017, and the six-week open period in the bays was split into two. The culling tolerance was also reduced from 10 to 5 percent following the latest management strategies. Oysters were small according to the dealers at the beginning of the season and showed little growth. The Neuse River only had a few areas with live oysters available and closed on December 7, 2017 after reaching the legal-sized threshold for closure. Small oysters that would not grow into legal-size this season were also pre-dominant in the Pamlico River and Northern Dare areas sampled early in the season. By early December both areas had one sampling event that came in below the legal-size threshold. As legal-sized oysters became harder to find in the Northern Hyde and Pamlico River areas, effort started to move to the Northern Dare area and by mid-December the majority of the fishermen were working in the main oystering areas in Northern Dare. Both Pamlico River and Northern Dare areas were closed to mechanical oyster harvest on December 25, 2017. Only Northern Hyde County remained open into 2018, but eventually met the threshold as the other areas and closed to mechanical harvest by late January. All mechanical harvest areas for oysters remained closed for the rest of the season. In addition, starting the first week of January 2018 and for the next two weeks, coastal North Carolina experienced record low temperatures, with at least one consecutive 72-hour period where air temperatures were below freezing. Most inshore areas and some of the deeper water areas had ice. Some areas maintained ice for two weeks. In mid-January reports were coming in that some of the subtidal oysters in Pamlico Sound had been impacted by the freezing. Particularly in shallow water areas where oysters are exposed to the air for a period of time caused by wind-driven tides.

Hand Harvest Fishery Off Public Bottom

Hand harvest gear accounts for the majority of the landings and has been the dominant harvest gear for oysters in North Carolina since the 1960s. Hand harvest oyster landings are also less variable than landings from mechanical gears (Figure 3). These higher, more consistent landings come from Core Sound south to the state line. The hand harvest areas in the northern region of the state are exclusively subtidal reefs with depths of 2 to 6 feet in which hand tongs are used. Hand harvest gear has not been extensively used in the northern area since oyster dredging was allowed in 1887. In Amendment 2 to the N.C. Oyster FMP in 2008, the MFC adopted the

strategy to promote a more habitat friendly fishery by increasing the hand harvest limits to match dredging limits in the Pamlico Sound bay areas. Amendment 2 put in place a 15 bushel per day hand/mechanical harvest limit per commercial fishing operation in Pamlico Sound mechanical harvest areas outside the bays, a 10 bushel per day hand/mechanical harvest limit per commercial fishing operation in the bays and in the Mechanical Methods Prohibited area along the Outer Banks of Pamlico Sound. This management option raised the limits of hand harvest to encourage less destructive harvest methods in those particular bays and open waters.

These management measures for hand harvest in Pamlico Sound area will continue through Amendment 4 of the N.C. Oyster FMP adopted in February 2017, but only to holders of the Standard Commercial Fishing License after October 2017. Beginning in the 2017-2018 season, hand harvest limits will remain five bushels per person, not exceeding 10 bushels per commercial fishing operation from Core Sound south to the North Carolina-South Carolina border for holders of the Standard Commercial Fishing License. Harvesters holding a Shellfish License statewide will be limited to two bushels of oysters per person per day no more than four bushels per vessel beginning in October 2017 to maintain the selected management strategy adopted by the NCMFC in Amendment 4 of the N.C. Oyster FMP. Areas in the southern region from Core Sound south are closed to mechanical harvest of oysters.

Other factors affecting the hand harvest fishery are the loss of harvest area due to pollution closures. Many shellfish waters in North Carolina are permanently or conditionally closed due to bacterial contamination associated with urban development (Table 2). The greatest proportion of closed shellfish waters occur in the southern district (Onslow, Pender, New Hanover, and Brunswick counties) where over half of the waters are closed and can be attributed to small, narrow waterbodies and more developed watersheds. The area north of Core Sound with the higher hand harvest limits does not have the same problem with large percentages of the available harvest area closed by pollution so oyster harvest is not impacted.

Hand-harvest oyster landings have generally increased in recent years (Figure 3). Oyster harvest south of the Highway 58 Bridge generates significant landings even though the area only encompasses five percent of the total area open to shellfishing in the state.

The 2017-2018 open oyster harvest season off public bottom from Core Sound and areas south started slow because of rain and temporary closures, and high tides during the middle of the day making it difficult to access the oysters. Staff did look at oysters in Pender and Onslow counties, and the oysters showed good growth. No complaints were received from the public or dealers from the southern region on oyster harvest until January. As in the Pamlico Sound, the intertidal oysters in the southern region of the state were impacted by record low temperatures that lasted over two weeks in early January. Reports were received that the cold temperatures and low tides during this period caused the oysters to die. Staff also saw directly dead spat and legal-sized oysters with meat still intact. The oyster season was closed 15 days early in Brunswick County due to public comment and management’s concerns of excess harvest pressure on an ever-decreasing area open to shellfishing. Brunswick County continues to be closed more often during the season because of temporary shellfish closures after rainfall events, compressing harvest into small areas and decreasing the amount of legal-sized oysters available to harvesters much quicker than in most other areas.

Permanent and Temporary Shellfish Closures

Microbial contamination from fecal matter is important to NCDMF because it affects the opening and closing of waters to shellfish harvest. Fecal coliform bacteria occur in the digestive tract of, and are excreted in the solid waste from, warm-blooded animals including humans, wildlife and domesticated livestock (Mallin 2009). Because consumption of shellfish containing high levels of fecal coliform bacteria and associated pathogens can cause serious illness in humans, shellfish growing waters must be closed to shellfish harvest when fecal coliform counts increase above the geometric mean standard of 14 MPN/100mL [NCMFC Rules 15A NCAC 18A Section .0900 Classification of Shellfish Waters], where MPN denotes "most probable number." The NCDMF closes waters where a high potential for bacterial contamination exists, such as around marinas and point source discharges. Shellfish harvest closures have continued to occur over time, which has led to a reduction in available shellfish harvest areas. Long term shellfish closures due to bacterial contamination remove available harvest area for shellfish and concentrate those activities on remaining resources compounding harvest related impacts on the oyster habitat in those areas.

Between 2007 and 2014, there were 1,427 additional acres of water permanently closed to shellfish harvesting in North Carolina, while between 2015 and early 2018, 3,729 additional acres were closed (Table 2). In March 2017, about 180 acres of additional shellfishing waters were permanently closed in the Lockwoods Folly River and Spring Creek, which made almost the entire river unavailable to shellfish harvest. About 90 acres of this closure was reopened in late 2017 after improvements in bacteriological water quality were seen. Throughout 2017 and early 2018, an additional 1,882 acres were closed to shellfishing activities in Pamlico County and areas north. On February 4, 2015, approximately 314,710 acres were closed administratively in lower resource areas as a result of the inability to sample due to budget constraints. The areas closed to shellfish harvest because of the inability to meet federal sampling requirements caused by funding cuts were approximately 11,834 acres in the Neuse River, approximately 3,042 acres in the Pungo River, and approximately 299,107 acres in Albemarle Sound.

In addition to the areas that are permanently closed to shellfishing, other areas are temporarily closed during periods of high rainfall due to runoff. The rainfall closure threshold varies by growing area as detailed in each management plan, and can vary from 1 inch to 2.5 inches of rain in a 24-hour period. Closures last from several days to more than a month, and reopen when bacteriological water sample results show the area has returned to normal conditions. Large storms, such as hurricanes, result in harvest closures covering much larger areas, sometimes including all of North Carolina's estuarine waters. The conditionally approved areas are concentrated in the Core-Bogue, New-White Oak, and Southern Estuaries management units. Within these watersheds, permanent closures are most common in the upper reaches of tidal creeks and rivers, with conditionally approved areas occurring downstream of those areas or in the upper portions of less degraded creeks. As temporary closures have increased in frequency and duration, they have become an issue of great concern to the public, particularly in the southern area of the coast.

2017 was an average year for rainfall amounts throughout the North Carolina coast, and temporary closures during oyster season were not as significant as those seen in 2015 or 2016.

Portions of the Newport River area were closed to harvest for 20 percent of the harvest season (compared to 63 percent in 2016), while portions of the Lockwoods Folly River area were closed for 31 percent of the season (compared to 51 percent in 2016), and portions of Stump Sound for 13 percent of the season (compared to 43 percent in 2016).

Private Culture

Statutory authority to lease bottomlands for shellfish cultivation can be traced back to a statute adopted in 1909. Today some shellfish leases are held by commercial fishermen to supplement their income from public harvest areas. Other shellfish leases are held by individuals and corporations looking to augment other sources of income; to be engaged in a sustainable business opportunity; or to maintain an attachment to cultural maritime heritage and way of life. Since 2012 administrative and process changes have been made to allow for better customer service, communication and ongoing support of the North Carolina Shellfish Lease and Franchise Program. Process operations and customer support were reviewed; actions were undertaken and implementation steps were completed to improve process operations and to provide a higher level of customer service.

The NCDMF administers the shellfish lease program whereby state residents may apply to lease estuarine bottom and water columns for the commercial production of shellfish. The NCDMF does not differentiate between clam, oyster, bay scallop, and mussel leases; therefore, allowing shellfish growers to grow out multiple species simultaneously or as their efforts and individual management strategy allows. For the period of 2003-2013, roughly 40 percent of all private culture operations harvested only oysters (NCDMF 2017).

Since 1994 there has been an overall increase in oyster harvest from private culture operations. Oyster harvest from private culture operations in the period from 1994 to 2013 account for 12 percent of all oyster landings (NCDMF 2017). Due to increase interest in private culture of oysters and lower landings off public bottom, private culture harvest accounted for 53 percent of the total oyster landings in 2017 (Figure 2). As of 2017, the lease program had 325 leases, and 50 bottom lease and 46 water columns amendment applications during the year. Currently shellfish leases take up about 1,960.7 acres of bottom (M. Graven; Lease Program Coordinator, NCDMF; May 2018).

Recreational Landings

Recreational landings for oysters in North Carolina are unavailable because there are no license requirements to take shellfish for personal consumption and therefore no way to fully determine the user group to collect their harvest information. Since 2011, the division has collected effort and catch data from the recreational oyster harvesters by surveying those individuals that indicate participation when purchasing a recreational fishing license. This survey does not include recreational oyster harvesters that do not purchase a recreational fishing license. Effort continues to produce state wide estimates of recreational oyster harvest.

MONITORING PROGRAM DATA

Fishery-Dependent Monitoring

Currently, the only data available for the stock in all areas are the commercial landings and associated effort from the Trip Ticket Program. No fishery dependent monitoring programs occur for oysters.

Fishery-Independent Monitoring

There are two independent programs for oysters. One is an indicator for habitat disturbance and damage of the commercial dredge fishery on public bottom to determine closure of the season for habitat protection of oyster rocks (Program 627). The second program. is a long-term spatfall sampling program conducted by the Habitat and Enhancement section to estimate recruitment of spat (Program 610).

Public Bottom Mechanical Harvest Area Oyster Sampling

Supplement A to Amendment 2 established the trigger for closing areas to mechanical harvest to protect the resource and habitat, which was approved to continue under Amendment 4 of the Oyster FMP. The management trigger was established and defined as when the sampling indicates the number of legal-sized (three-inch) oysters in the area has declined to 26 percent of the live oysters sampled. The management areas are divided geographically into four areas; the Neuse River Area, Pamlico River Area, Northern Hyde Area, and Northern Dare Area (Figure 1). Sampling targets areas and oyster rocks being worked by commercial oystermen, directly before the opening of and throughout the mechanical harvest oyster season. The sampling sites are selected based on the presence/absence of commercial oystermen working in the area. Only areas where commercial oystermen are working are sampled to determine localized depletion and address habitat protection. From each sample, the first 100 live oysters, including spat and any boxes, are collected for workup. Each oyster, up to a maximum of 100, is measured to the nearest mm and inspected for any damage. Shell damage is denoted as none, minor, or substantial for further evaluation.

Sampling began on September 23, 2009 with preseason oyster sampling, in four management areas, using mechanical harvesting methods. Sampling has consistently continued with a target of 10 sites per management area, throughout the four management areas. All sampling is conducted using NCDMF vessels and standard oyster dredges with comparable construction to those used by commercial oystermen. Samples are collected at least bi-monthly in each management area (weather permitting) before, during, and after the open mechanical oyster harvest season. More intensive sampling is conducted if samples are near the trigger percentage. Sampling continues after an area is closed to assess the possibility of reopening. Sampling is discontinued when it is apparent that reopening is not likely to occur. Mean oyster shell height (commonly referred to as length) is calculated for each 100-oyster sample. The number of legal-sized ($\geq$76 mm; $\geq$ 3 inches) and undersized (<76 mm; < 3 inches) oysters is determined for each sample. The total legal-sized oysters for all the samples taken in a management area on a sampling trip is divided by the total of all oysters sampled on that trip to calculate the percentage

used to assess compliance with the harvest closure trigger. Oyster sizes are also sorted into five-mm size bins and the size distribution for the area is presented as a bar graph. Sampling results are reported to interested dealers/fishermen and staff after each sampling event.

This sampling is not intended for use as a species abundance index, but instead to reflect the conditions of the habitat during the open oyster mechanical harvest season to determine closure of an area as a protection measure. For this update, only the 2017-2018 open mechanical harvest season data will be provided with a brief overview of the season.

Pre-season samples from the Pamlico River and Northern Hyde areas exceeded, while the Neuse River and Northern Dare areas fell below the 26 percent legal-sized threshold, before the 2017-2018 mechanical harvest season opened. Table 1 shows the percentages of legal-sized oysters taken by area throughout the 2017-2018 mechanical harvest season and the number of commercial oyster vessels operating in the area while sampling occurred in parentheses. Effort was down this harvest season in all areas. By January the long duration of low temperatures had frozen some of the oysters and dealers did not want to buy them in case the oysters would die while on the shelf. Like the 2016-2017 season little growth was observed in the oysters until January. A lot of spat and small oysters were present in the Pamlico Sound harvest areas that would not grow into legal size that season. Mechanical harvest was closed on December 7, 2017 in the Neuse River area and in the Northern Dare and Pamlico River areas on December 25, 2017 (Table 1; Figure 4). Northern Hyde closed on January 29, 2018 and all mechanical harvest areas remained closed until the season ended on March 31, 2018.

Spatfall Evaluation

Division staff conduct spatfall sampling annually (Program 610), on cultch planting sites from the previous three years during January, but samples may be collected through April if required. Subtidal sites are sampled by towing a standard oyster dredge over the planting site until, at a minimum, 30 pieces of cultch are collected. Normally a 75-pound, 36-inch toothed bar dredge is used; however, various other dredges may be used. On rare occasions, patent tongs and hand tongs may be used to obtain planting samples. Intertidal sites are sampled by hand at low tide in all applicable intertidal areas of the Southern District and hand tongs are used in the more northerly subtidal areas of Stump Sound and New River. Three tong grabs per location are usually taken to obtain the minimum amounts of cultch required. Gear type and any other valuable gear parameters are recorded. Prior to 2005, data was not collected south of New River.

Thirty pieces of cultch are randomly selected from each sample and the type of cultch (oyster, calico scallop, surf clam, marl, or sea scallop) is noted. The total number of spat on each piece of cultch is enumerated, with each spat being measured to nearest millimeter shell length. The average number of spat per piece of cultch is calculated by summing the number of spat per cultch piece, divided by the total number of cultch pieces sampled. Annual Juvenile Abundance Index (JAI) is calculated as the average number of spat per site and then averaged across all sites within that year. The 10-year average is calculated by averaging the annual JAI over the last 10 years.

The Juvenile Abundance Index has been somewhat variable from year to year in the early years in the time series, but overall showing a declining trend for the past 10 years (Table 3; Figure 5). The 2017 and 2018 indices were the lowest and below the average (Annual average number of spat across all sampling sites) in the 10-year time series (Table 3).

MANAGEMENT STRATEGY

There are no management triggers or methods to track stock abundance, fishing mortality, or recruitment between benchmark reviews in the current FMP.

Amendment 4 was adopted in February 2017 and implementing rule changes became effective May 1, 2017. The selected management strategies of the NCMFC in Amendment 4 for oysters taken from public bottom include:

- the continuation of the monitoring system to determine when to close mechanical oyster harvest in an area;
- aligning the maximum daily harvest limit for oysters with current management;
- continuing the six-week open mechanical harvest in the bays, but close the bays to mechanical harvest for two weeks after Thanksgiving and then re-open two weeks before Christmas for the remainder of the six-week open mechanical harvest in the bays;
- a reduction of the culling tolerance from 10 percent to five percent for the possession of sublegal oysters; and
- a reduction of the daily harvest limit for Shellfish License holders to two bushels per person not to exceed four bushels per vessel.

For private culture of oysters, the selected management strategies in Amendment 4 include:

- adding convictions for theft of shellfish from leases or franchises to the list of convictions that may result in revocation of fishing licenses to implement stronger deterrents to shellfish theft and intentional aquaculture gear damage;
- clarifying how production and marketing rates are calculated for shellfish leases and franchises to meet minimum production requirements;
- expanding the maximum proposed lease size to 10 acres in all areas; and
- specifying criteria that allow a single extension period for shellfish leases of no more than two years per contract period to meet production and marketing requirements in the case of unforeseen circumstances, and reorganize the rules for improved clarity.

Amendment 4 also included the expansion of oyster enhancement activities.

The selected management recommendations and implementation status can be found in Table 4 in Amendment 4 of the FMP adopted by the NCMFC in February 2017.

2017 Legislative Long Session

Session Law (S.L.) 2017-57, the Appropriations Act of 2017, allocated both non-recurring and recurring funds in the budget to support oyster sanctuaries, oyster rehabilitation or cultch planting, and positions within NCDMF to provide services to accelerate shellfish industry

growth. Section 13.12 required that the NCDMF and the University of North Carolina at Wilmington report annually to the chairs of the Senate and the House of Representatives appropriations committees with jurisdiction over natural and economic resources and the Fiscal Research Division regarding the funding for oyster research and restoration activities provided by this act. The report shall include details regarding the use of the funds, including activities completed and additional personnel supported by the funds.

Session Law 2017-57 also amended S.L 2016-94, which had already made several changes to General Statutes 113-202, 113-202.1, and 113-202.2 that are part of the shellfish lease and franchise program. Section 13.13(a) identified the North Carolina Policy Collaboratory (known as the Collaboratory) as the lead to convene a stakeholder group to study and advance efforts to ecologically restore and achieve economic stability of the shellfish industry. This clarified the focus on both native oyster populations and aquaculture-grown oysters in North Carolina and identified how to populate the stakeholder group.

In S.L. 2017-57, Section 13.13(b) the Collaboratory was also tasked to prepare and deliver a Shellfish Mariculture Plan by Dec. 31, 2018 to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources, the chairs of the House of Representatives Appropriations Committee on Agriculture and Natural and Economic Resources, the chairs of the Senate Appropriations Committee on Agriculture, Natural, and Economic Resources, and the Fiscal Research Division with specific details on what information the Plan shall consider. These considerations include an examination of existing shellfish mariculture operations within the State and from other states and countries, siting strategies, enforcement needs, opportunities for local traditional fishermen, environmental policies that protect or enhance operations, appropriate substrate for cultch planting, strategies to mitigate or eliminate shellfish pests, and any other issues deemed relevant by the Collaboratory. Section 13.13(d) requires the Collaboratory to consult with several stakeholder groups and develop conceptual plans and recommendations for economic development related to promotion of the State's shellfish harvesting heritage, including recommendations of locations, oversight, governmental support, cost, and timing of initiatives. The Collaboratory’s recommendations shall be provided no later than March 1, 2018 to the same groups as required for the Shellfish Mariculture Plan. These economic development plans and recommendations shall be included as an appendix to the Shellfish Mariculture Plan.

2016 Legislative Short Session

During the 2016 legislative short session, both non-recurring and recurring funds were part of the budget to support oyster sanctuaries (non-recurring), oyster rehabilitation or cultch planting (non-recurring), and positions within NCDMF to provide services to accelerate shellfish industry growth (recurring funds).

Session Law 2016-94, Section 14.11: Promote the Shellfish Industry

Session Law 2016-94, Section 14.11 made several changes to General Statutes 113-202, 113-202.1, and 113-202.2 that are part of the shellfish lease and franchise program. The lease rental due date was modified [G.S. 113-202 (j)], clarifications were made for water column and bottom

lease transfers [G.S. 113-202.1(a)], the time frame for water column leases to perpetual franchises was changed from five to 10 years [G.S. 113-202.2(d)], and there were changes to the terms for transfers of water column leases to perpetual franchises [G.S. 113-202.2(f)]. Changes were also made to the time frame for demonstration or research aquaculture development projects from two to five years [G.S. 113-202.2(i)]. And a study on shellfish aquaculture is to be conducted by the University of North Carolina's Chief Sustainability office. The study is to include a stakeholder group with representatives from the commercial and recreational oyster harvesting industries as well as staff from the NCDMF and members of the NCMFC, nature conservation groups, and experts in the fields of marine biology and marine ecology. A report is expected from this study with recommendations and suggested legislation needed to implement the recommendations to the Fiscal Research Division, Environmental Review Commission, and the Joint Legislative Oversight Committee on Agriculture and Natural Resources by Dec. 31, 2018.

2015 Legislative Long Session

Session Law 2015-241, Section 14.9: Senator Jean Preston Oyster Sanctuary Network

Session Law 2015-241, Section 14.9 required the NCDMF to develop a 10-year plan to enhance shellfish habitat within the Albemarle and Pamlico sounds and their tributaries to benefit fisheries, water quality, and the economy. In this 10-year plan, the Oyster Sanctuary Program and the Cultch Planting Program will continue the development of a network of oyster sanctuaries and cultch planting sites within the Pamlico Sound and its tributaries. The 10-year plan calls for NCDMF to design two new sampling programs which will help guide the future oyster rehabilitation projects. These future sites will also be constructed in a way that will provide complex fish habitat to promote hook and line fishing while minimizing the impact to commercial trawling. Through the use of sampling programs and alternative materials, the NCDMF aims to construct oyster sanctuaries and cultch planting sites in a manner so the highest benefit-cost ratio is achieved.

A joint Public Private Partnership was initiated in late 2016 between the NCDMF and the North Carolina Coastal Federation to develop a 40-acre oyster sanctuary near Swan Island near West Bay in eastern Carteret County. The NCDMF purchased and stockpiled materials and obtained necessary permits for the project. The Coastal Federation contracted the deployment of the material. Deployment started in May 2017 and will continue into the summer. This project leveraged approximately one million dollars in state funding and will result in a doubling of funding for this sanctuary over a two-year period.

A comprehensive sampling program has been developed to assess and sample oyster sanctuary sites. A Subtidal Estuarine Reef Sampling Program (Program 941) was developed for estuarine artificial reef and oyster sanctuary sampling. This program looks at different material types in three salinity regimes. Additionally, meter square oyster sampling is conducted on these sites. The existing spatfall monitoring program (Program 610) will be modified to include more quantitative data on spatfall in the future as time and staffing permits.

Session Law 2015-241, sections 14.10D and 14.8: Shellfish Aquaculture and Core Sound Shellfish Aquaculture Leasing

Session Law 2015-241, Section 14.10D, requires the NCDMF to develop recommendations covering nine topics for shellfish aquaculture. Section 14.8 requires the NCDMF to create a proposal to open shellfish cultivation leasing certain areas of Core Sound that are currently subject to a moratorium

The NCDMF provided a report which addresses these topics ranging from shellfish aquaculture to oyster restoration. It identifies existing bottlenecks, deficiencies and inefficiencies, and recommends ways to improve existing programs. The recommendations on new ways to develop the shellfish industry will benefit the state shellfish aquaculture industry and the overall shellfish resource. Some of the recommendations in this study are also included in the Senator Jean Preston Marine Oyster Sanctuary Program Plan, which was mandated by S.L. 2015-241, Section 14.9. That law required the NCDMF to develop a 10-year plan that includes recommendations for oyster sanctuary construction, cultch planting, funding and any other resources needed.

To develop this plan, NCDMF staff, including its own shellfish experts, met with shellfish and aquaculture experts from North Carolina and Virginia, shellfish growers, and non-governmental organizations. This included meeting with the existing steering committee of stakeholders that oversees the implementation of the N.C. Oyster Restoration and Protection Plan: Blueprint for Action that covers 2015 to 2020 (N.C. Coastal Federation 2015 https://ncoysters.org/). Cumulatively, the recommendations listed in this report create a holistic approach to shellfish aquaculture and resource enhancement by linking research, permitting, outreach and extension and support services of several state agencies with private shellfish aquaculture organizations and interests as well as to non-governmental organizations.

The success of aquaculture operations goes beyond permitting and site selection functions that have traditionally been the role of the NCDMF. Achieving and sustaining a successful shellfish aquaculture industry will depend on use of sound scientific principles, solid business planning, marketing, training and assistance from other groups.

Section 14.8 of S.L. 2015-241 requires the NCDMF to create a proposal to open shellfish cultivation leasing to certain areas of Core Sound that are currently subject to a moratorium. NCDMF staff met with the Carteret County Fisheries Association, which represents commercial fishing interests, the president of the N.C. Shellfish Growers Association, and aquaculture experts from the National Oceanic and Atmospheric Administration. The report provides a conservative, methodical approach to re-opening limited areas of Core Sound to shellfish leasing (N.C. Coastal Federation 2015). A proposal was developed to open portions of western Core Sound to shellfish leasing in a controlled manner with oversight from the NCMFC through the Shellfish and Crustacean Advisory Committee. The eastern side of Core Sound was not considered in the proposal because of high densities of submerged aquatic vegetation, it is part of the Cape Lookout National Seashore, has an existing pound net fishery, and other commercial and recreational uses that make this area unsuitable for considering shellfish cultivation. An action plan is also provided in the report to allow limited shellfish leases in Core Sound.

The Shellfish Aquaculture Recommendations report along with other interests and support resulted in the North Carolina General Assembly providing dedicated funding of $149,000 (re-occurring) including permanent Biologist I and Technician II positions. No changes were made in the Core Sound moratorium statute. NCDMF is currently participating with the University of North Carolina Collaboratory to identify requirements to develop a statewide shellfish aquaculture plan.

RESEARCH NEEDS

Table 4 provides the NCMFC selected management strategies from Amendment 4 adopted in February 2017. The specific research recommendations from Amendment 4, with its priority ranking are provided below. The prioritization of each research recommendation is designated either a HIGH, MEDIUM, or LOW standing. A low ranking does not infer a lack of importance but is either already being addressed by others or provides limited information for aiding in management decisions. A high ranking indicates there is a substantial need, which may be time sensitive in nature, to provide information to help with management decisions.

Amendment 4

Many environmental considerations are applied throughout the Coastal Habitat Protection Plan (CHPP) and are not part of this list but are still considered very important to oysters. Specifically, the proposed implementation actions on sedimentation within the CHPP are considered a high priority.

Proper management of the oyster resource cannot occur until some of these research needs are met, the research recommendations include:

- Support all proposed implementation actions under the priority habitat issue on sedimentation in the CHPP – HIGH (Ongoing through the CHPP)
- Improve the reliability for estimating recreational shellfish harvest – HIGH (Ongoing)
- Survey commercial shellfish license holders without a record of landings to estimate oyster harvest from this group – HIGH (Needed)
- Develop regional juvenile and adult abundance indices (fisheries-independent) – HIGH (Pilot study in progress with the Nature Conservancy and NC State University)
- Complete socioeconomic surveys of recreational oyster harvesters – MEDIUM (Needed)
- Continue to complete socioeconomic surveys of commercial oyster fishermen – LOW (Needed)
- Determine alternative substrates for reef development and monitoring of intertidal and subtidal reefs (cost-benefit analysis for reefs and cultch planting) – HIGH (Ongoing)
- Identify number and size of sanctuaries needed – LOW (Ongoing)
- Identification of larval settlement cues which influence recruitment to restored reefs (i.e. sound, light, current, etc.) – LOW (Ongoing)
- Support collaborative research to more efficiently track bacterial sources for land-based protection and restoration efforts - MEDIUM (Ongoing)
- Quantify the impact of current fishing practices on oyster habitat suitability in North Carolina – HIGH (Needed)

- Quantify the relationship between water quality parameters and the cumulative effect of shoreline development units (e.g., docks, bulkhead sections) - MEDIUM (Needed)
- Develop peer reviewed, standardized monitoring metrics and methodologies for oyster restoration and stock status assessments – MEDIUM (Needed)
- Further studies on the effects of dredge weight and size on habitat disturbance and oyster catches – LOW (Needed)
- Develop a program to monitor oyster reef height, area and condition – HIGH (Ongoing)
- Estimate oyster mortality associated with relay - LOW (Needed)
- Estimate longevity and yield of oysters on cultch planting sites - HIGH (Needed)
- Develop methods to monitor abundance of the oyster population – HIGH (Pilot study in progress with the Nature Conservancy and NC State University)

FISHERY MANAGEMENT PLAN RECOMMENDATION

Recommend maintain the current timing of the Benchmark Review. Amendment 4 of the N.C. Oyster FMP was adopted by the NCMFC in February 2017 with rule changes in effect May 1, 2017.

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TABLES

Table 1. Percentage of legal-sized oysters by area for the 2017 portion of the 2016-2017 season and the 2017-2018 season in the mechanical fishery. Number of boats seen while out sampling is in parentheses.
2016-2017 season:
*Neuse River closed on Jan. 16, 2017 (Proclamation SF-1-2017)
+Northern Dare County closed on Feb. 6, 2017 (Proclamation SF-2-2017)
2017-2018 season:
*Neuse River closed on Dec. 7, 2017 (Proclamation SF-8-2017)
+Pamlico River and Northern Dare County closed on Dec. 25, 2017 (Proclamation SF-10-2017)
**Northern Hyde County closed on Jan. 29, 2018 (Proclamation SF-2-2018)

Neuse River*		Pamlico River+		Northern Hyde County**		Northern Dare County+	
Date	Percent	Date	Percent	Date	Percent	Date	Percent
1/10/2017	23.5 (0)	2/15/2017	29.5 (2)	1/17/2017	47.6 (5)	1/10/2017	26.1 (4)
1/25/2017*	Closed 17.0	2/28/2017	29.1 (0)	2/6/2017	36.5 (0)	1/25/2017	21.8 (4)
2/14/2017*	Closed 22.8			2/22/2017	43.1 (0)	2/1/2017	15.3 (4)
2/27/2017*	Closed 19.7			3/9/2017	35.1 (0)	2/21/2017+	Closed 11.1
	Pre-season		Pre-season		Pre-season		Pre-season
10/27/2017	16.4	10/25/2017	26.2	11/2/2017	46.3	10/25/2017	25.6
11/28/2017	9.5 (5)	12/7/2017	18.3 (3)	11/29/2017	34.6 (9)	11/27/2017	30.4 (11)
1/10/2018*	Closed 9.5	12/19/2017	11.2 (1)	12/15/2017	27.5 (11)	12/11/2017	17.1 (12)
2/1/2018*	Closed 4.1	1/22/2018+	Closed 12.8	1/11/2018	16.5 (5)	12/18/2017	15.7 (21)
3/19/2018*	Closed 10.6	2/23/2018+	Closed 17.3	1/22/2018	16.8 (2)	1/25/2018+	Closed 13.0
				2/20/2018**	Closed 19.0		

Table 2. Status of shellfish waters in acreage from 2007-2018 From NCDMF Shellfish Sanitation & Recreational Water Quality Section.

Year	Open	Closed	Approved	Conditionally Approved Open	Conditionally Approved Closed	Prohibited
2007*	1,777,523	441,448	1,734,339	43,184	12,512	428,936
2008	1,777,473	441,527	1,734,192	43,281	12,788	428,739
2009	1,777,777	441,276	1,734,246	43,531	12,552	428,724
2010	1,777,992	440,966	1,734,938	43,054	12,552	428,414
2011	1,777,992	440,966	1,734,938	43,054	12,552	428,414
2012	1,777,534	441,498	1,732,902	44,632	11,834	429,664
2013	1,777,349	441,684	1,733,067	44,282	11,832	429,852
2014	1,776,967	442,102	1,733,118	43,849	11,739	430,363
2015**	1,462,222	756,908	1,418,373	43,849	11,739	745,169
2016	1,461,745	757,605	1,416,960	44,784	12,008	745,597
2017	1,459,134	759,968	1,414,709	44,425	12,209	747,759
2018	1,458,552	760,637	1,414,626	43,926	12,031	748,606

*In 2007 the NC Division of Environmental Health – Shellfish Sanitation Section started calculating acreage from GIS, whereas prior figures were hand-tallied by planimeter on NOAA Charts. Data will be slightly higher than previous data calculated by hand beginning in 2007.
**314,710 acres administratively closed on 2/4/15 due to budget cuts and office closures

Table 3. The annual average number of oyster spat across all sampling sites, 2008-2018 (NCDMF Habitat and Enhancement Section).

Year	Number of sites sampled	Annual average number of spat across all sampling sites	Standard error
2008	107	2.38	0.16
2009	111	3.15	0.19
2010	112	2.77	0.20
2011	99	2.10	0.22
2012	89	3.04	0.31
2013	82	1.90	0.19
2014	76	2.92	0.25
2015	92	1.75	0.15
2016	92	1.86	0.17
2017	93	1.79	0.27
2018	69	1.45	0.16

Table 4. Summary of the NCMFC management strategies and their implementation status for Amendment 4 of the N.C. Oyster FMP adopted February 2017.

Management Strategy	Implementation Status
OYSTER MANAGEMENT	
Maintain the cost of the Shellfish License, establish a daily limit of two bushels of oysters per person with a maximum of four bushels of oysters per vessel off public bottom with the Shellfish License.	Existing proclamation authority
Increase efforts to plant and monitor cultch material.	Ongoing
Implement a five percent cull tolerance for oysters	Rule change to 15A NCAC 03K .0202 in effect on May 1, 2017
Pursue elimination of the Shellfish License for oysters only and require all oyster harvesters to have a Standard or Retired Commercial Fishing License with a shellfish endorsement to harvest commercially.	Amend G. S. 113-169.2
Allow Shellfish License holders to be eligible to acquire a Standard Commercial Fishing License after they show a history of sale of shellfish. Continue to allow commercial harvest of all other shellfish as currently allowed.	No action required; Process already in place
Status quo (Maintain the shallow bays (less than 6 feet) as defined in 15A NCAC 03R .0108)	No action required
Recommend a six-week opening timeframe for deep bays to begin on the Monday of the week prior to Thanksgiving week through the Friday after Thanksgiving. Reopen two weeks before Christmas for the remainder of the six-week season.	Existing proclamation authority; Completed in 2017-2018 season
Status quo (Maintain the 15-bushel hand/mechanical harvest limit in Pamlico Sound mechanical harvest areas outside the bays, 10-bushel hand/mechanical harvest limit in the bays and in the Mechanical Methods Prohibited area along the Outer Banks of Pamlico Sound)	Existing proclamation authority
Adopt the provisions of Supplement A – a flexible harvest limit up to 20 bushels, a trigger of 26 percent legal-sized oysters for closing an area to mechanical harvest and set the upper harvest limit of 20 bushels in rule (rule change required).	Existing proclamation authority and rule change to 15A NCAC 03K .0201 on May 1, 2017
Attempt to develop and ground-truth a fishery dependent metric of effort to better inform management decisions in the future	Additive to NCDMF monitoring; Working with the Nature Conservancy
PRIVATE CULTURE	

Management Strategy	Implementation Status
Support modification of G.S. 113-208 and G.S. 113-269 to add minimum fines for violations on shellfish leases and franchises. With minimum fines set at $500 for the first violation and $1,000 for the second violation	Amend G.S. 113-208 and G.S. 113-269
Support modification of G.S. 113-269 to include protection to all shellfish leases and franchises, not just those with water column amendments	Amend G.S. 113-269
Modify Rule 15A NCAC 03O .0114, regardless whether statute changes occur, so that a first conviction under G.S. 113-208 or G.S. 113-269 the Fisheries Director shall revoke all licenses issued to the licensee	Rule change to 15A NCAC 03O .0114 in effect on May 1, 2017
Status quo (Adhere to Regional Conditions of U.S. Army Corps of Engineers Nationwide Permit 48 with no adverse effect to submerged aquatic vegetation from shellfish leases and following measure identified in the interim)	No action required
Continue the moratorium of shellfish leases in Brunswick County	No action required
Establish a rule to support extensions for where “Acts of God” prevent lease holder from making production, with a two-year extension and only one extension allowed per term	Rule change to 15A NCAC 03O .0201 in effect on May 1, 2017
Allow leases returned to the state to remain delineated for a period of one year to allow the pre-existing leased bottom to be re-issued to other shellfish growers	Amend G.S. 113-202
Improve public notice of proposed lease applications on the physical lease, at fish houses, and/or through electronic notices	Ongoing
Allow a maximum of 10 acres in both mechanical methods prohibited areas and mechanical methods allowed areas	Rule change 15A NCAC 03O .0201(a)(3) in effect on May 1, 2017

FIGURES

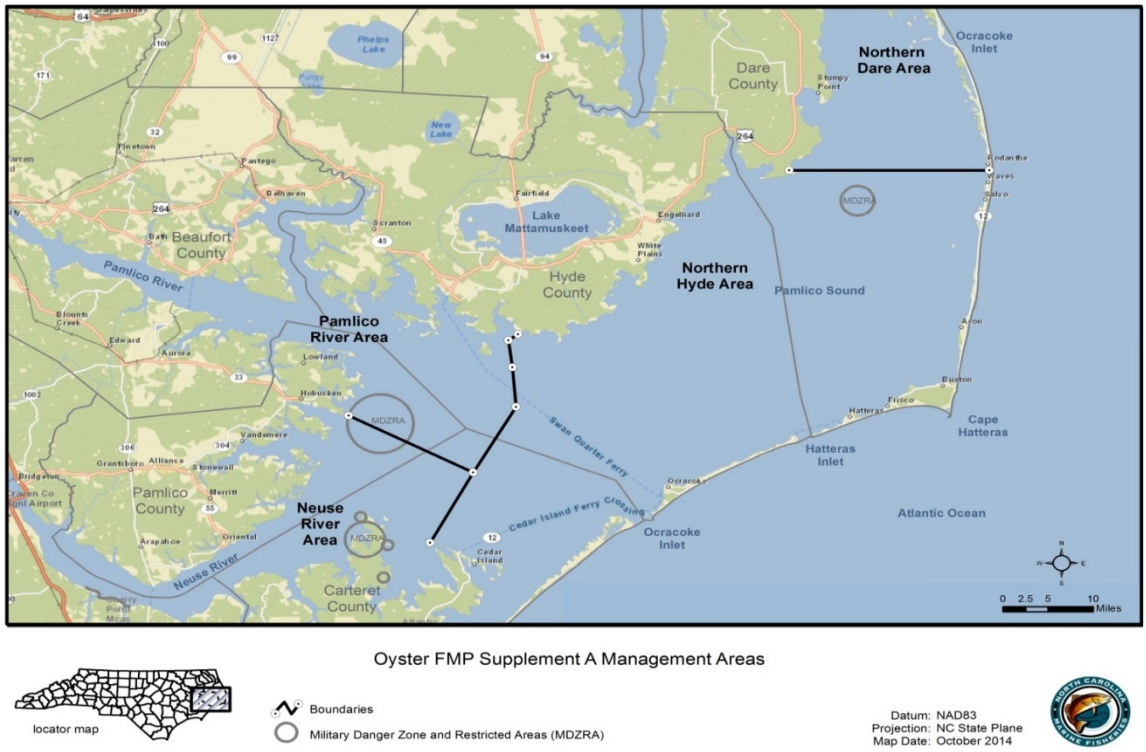

Figure 1. Mechanical harvest management areas from Amendment 4 of the Oyster Fishery Management Plan.

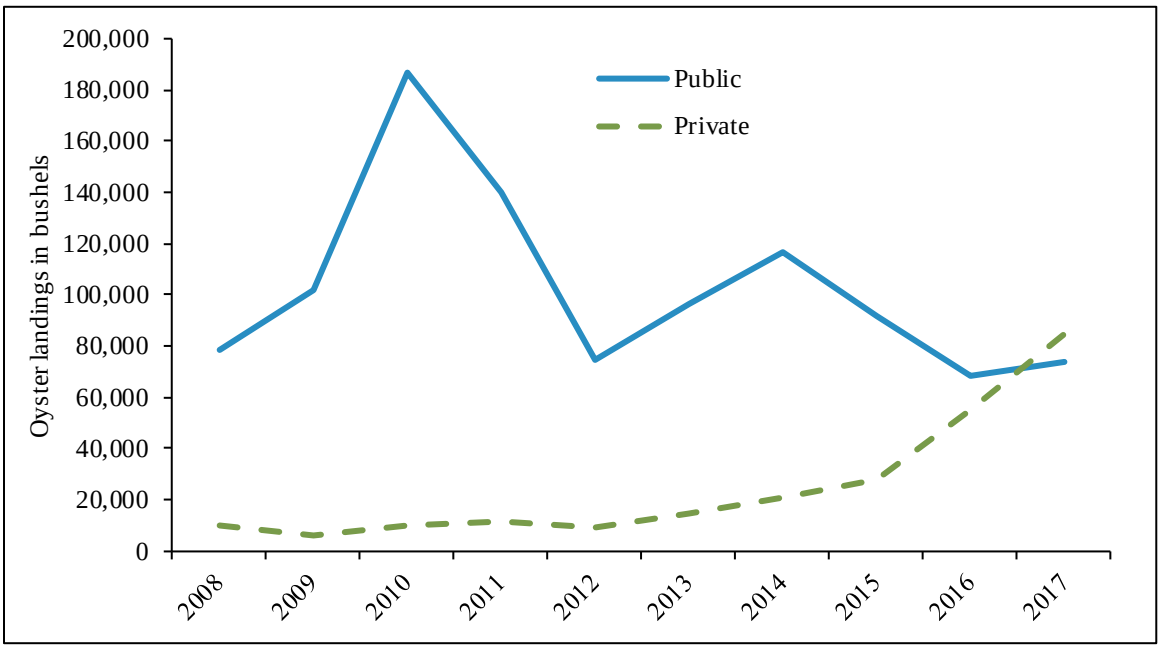

Figure 2. Annual commercial oyster landings (bushels) from private and public bottom in North Carolina, 2008-2017 (NCDMF Trip Ticket Program).

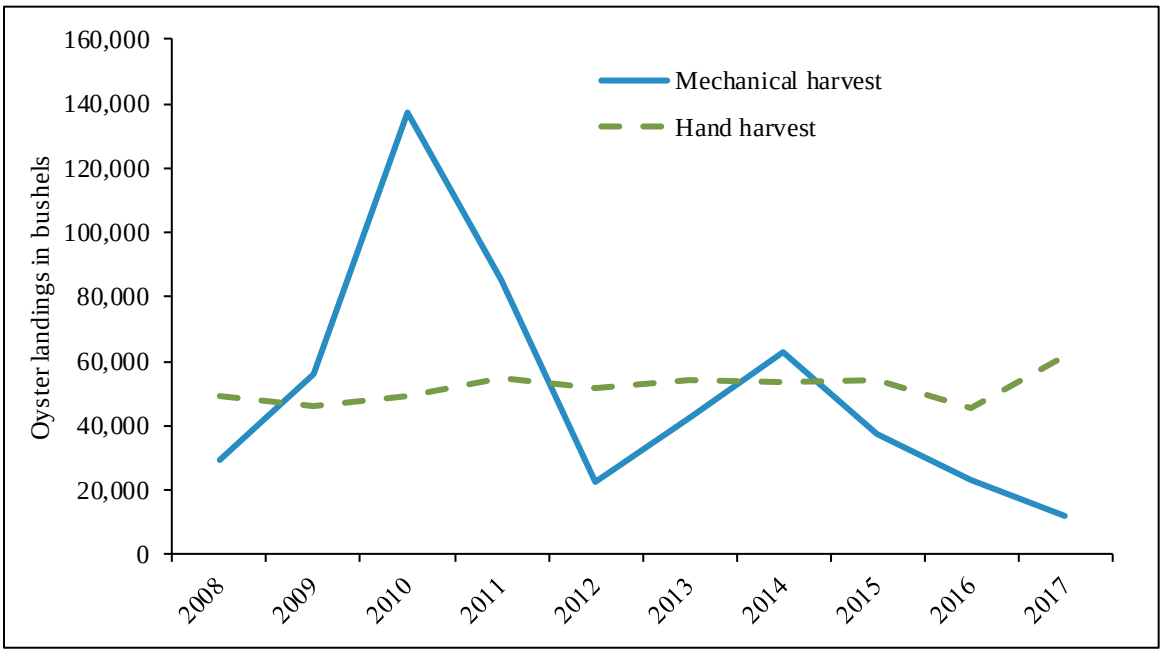

Figure 3. Annual commercial oyster landings (bushels) from public bottom in the mechanical and hand harvest oyster fisheries, 2008-2017 (NCDMF Trip Ticket Program).

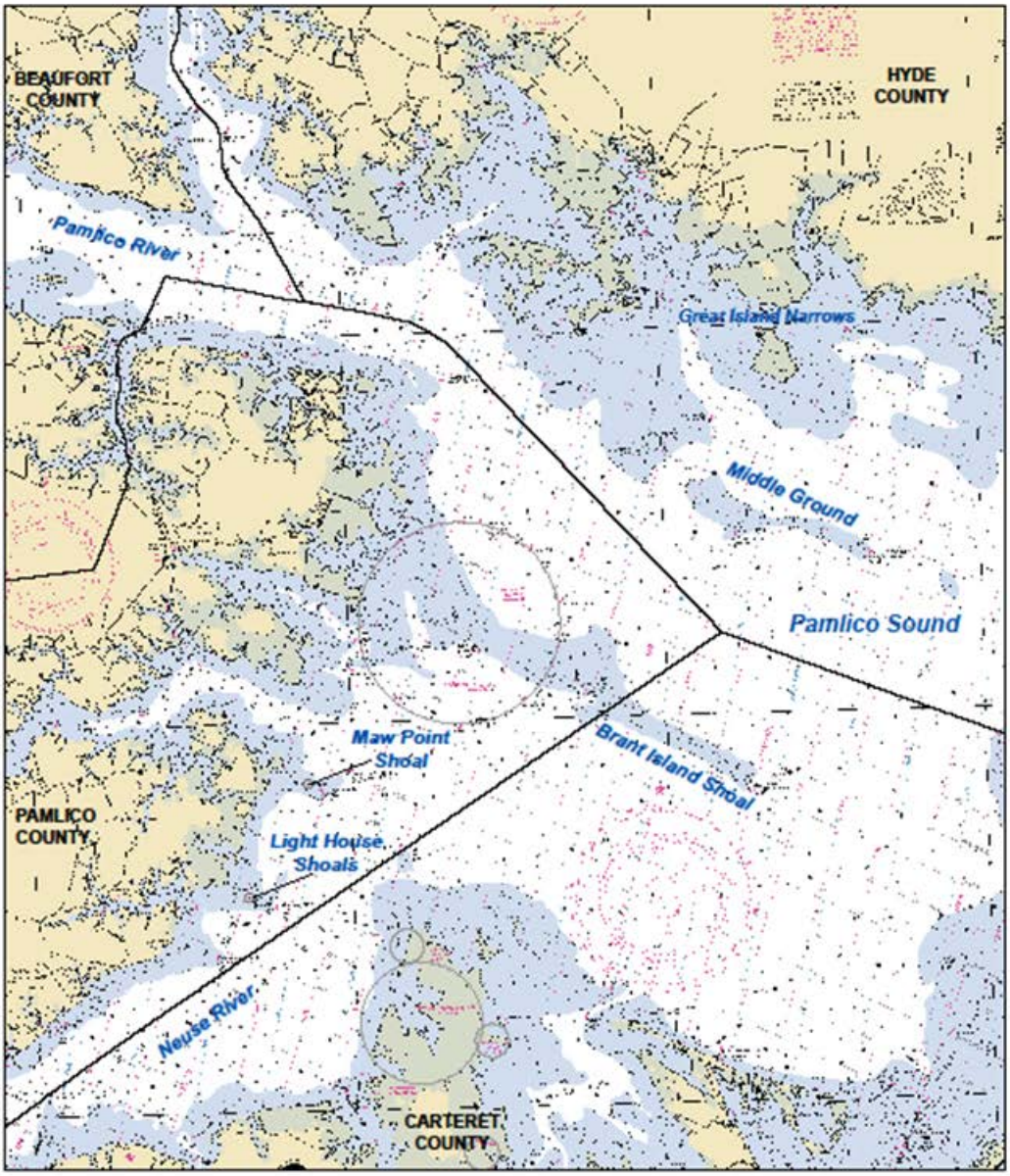

Figure 4. Map of areas referenced in the commercial landings section NCDMF Geographical Information System database).

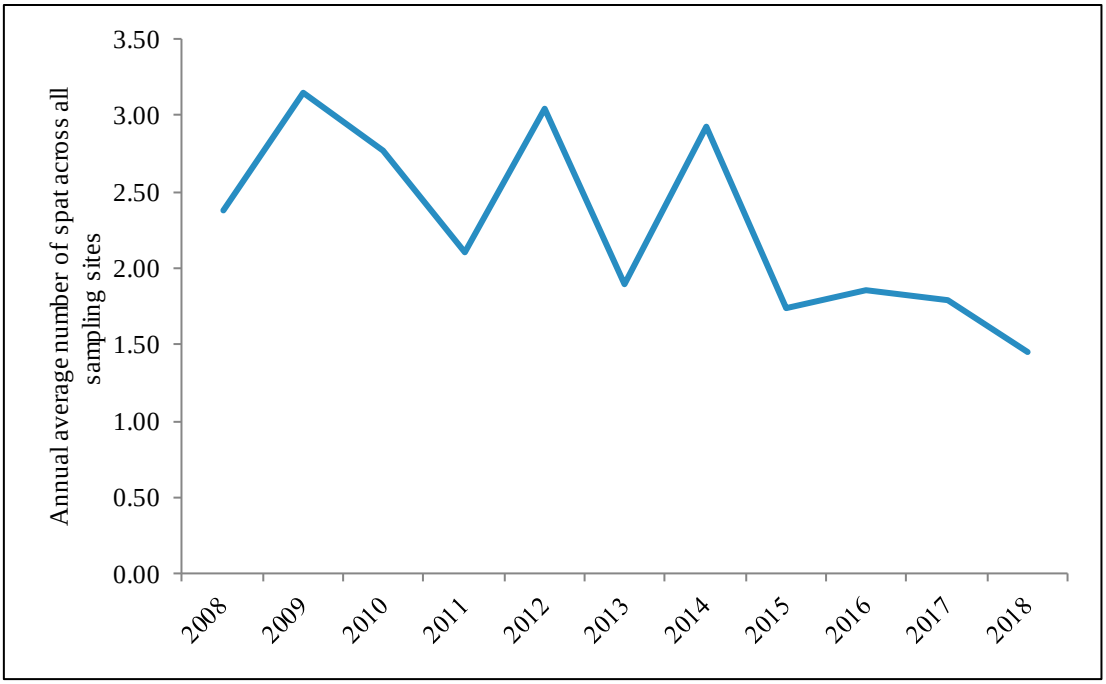

Figure 5. The annual average number of oyster spat across all sampling sites, 2008-2018 (NCDMF Habitat and Enhancement Section).