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# HARD CLAM
# FISHERY MANAGEMENT PLAN
# AMENDMENT 3

**NC Division of Marine fisheries**
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**Disclaimer**: Data in this Fishery Management Plan may have changed since publication based on updates to source documents.

## ACKNOWLEDGMENTS

Keep to a single page by using columns (table format) for PDT members. Shrimp FMP Amendment 2 as an example:

Amendment 3 to the North Carolina (NC) Hard Clam Fishery Management Plan (FMP) was developed by the NC Department of Environmental Quality (NCDEQ), Division of Marine Fisheries (NCDMF) under the auspices of the NC Marine Fisheries Commission (NCMFC) with the advice of the Shellfish Advisory Committee (AC). Deserving special recognition are the members of the Shellfish AC and the NCDMF Plan Development Team (PDT) who contributed their time and knowledge to this effort.

Shellfish Advisory Committee

Oyster/Clam Plan Development Team

The following Division staff were also invaluable in assisting with the development of this document: Kathy Rawls, Mike Loeffler, Catherine Blum, Lee Paramore, Casey Knight, Laura Lee, Alan Bianchi, and the many reviewers of the multiple drafts of this plan. Also grateful for the administrative support from Deborah Manley, Michelle Brodeur, and Patricia Smith.

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## EXECUTIVE SUMMARY

*** added before secretarial review***

## INTRODUCTION

This is Amendment 3 to the Hard Clam Fishery Management Plan (FMP). By law, each FMP must be reviewed at least once every five years (G.S. 113-182.1). The N.C. Division of Marine Fisheries (NCDMF) reviews each FMP annually and a comprehensive review is undertaken about every five years. The last comprehensive review of the plan (Amendment 2) was approved by the N.C. Marine Fisheries Commission (NCMFC) in 2017. FMPs are the ultimate product that brings all information and management considerations into one document. The NCDMF prepares FMPs for adoption by the NCMFC for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries. All management authority for the North Carolina hard clam fishery is vested in the State of North Carolina. The NCMFC adopts rules and policies and implements management measures for the hard clam fishery in Coastal and Joint Fishing Waters in accordance with 113-182.1. Until Amendment 3 is approved for management, hard clams are managed under Amendment 2 (NCDMF 2017).

The status of the hard clam stock in North Carolina is unknown due to data limitations preventing the NCDMF from conducting a hard clam stock assessment and calculating sustainable harvest metrics. Data available for the stock are commercial landings and associated effort. Data is obtained from the North Carolina Trip Ticket Program, where catch rates are estimated for both hand and mechanical harvest. Landing trends will reflect population abundance to an extent, but other factors like market demand, regulations, changes in effort and gear technology will also play a role in those trends (NCDMF 2017).

### Fishery Management Plan History

| | |
|---|---|
| Original FMP Adoption: | 2001 |
| Amendments: | Amendment 1 (2008) |
| | Amendment 2 (2017) |
| Revisions: | None |
| Supplements: | None |
| Information Updates: | None |
| Schedule Changes: | None |
| Comprehensive Review: | 2022 |

The 2001 N.C. Hard Clam FMP recommendations included adding a new mechanical clam harvest area in Pamlico Sound and rotating openings in this area with northern Core Sound, decreasing the daily harvest limit for mechanical harvest in Core Sound, changing some of the lease requirements, increasing relay of clams, and increasing funding for Shellfish Sanitation (NCDMF 2001).

The N.C. Hard Clam FMP Amendment 1, adopted in 2008, recommended the hard clam fishery from public bottom continue harvesting at current daily limits, eliminating the mechanical clam harvest rotation in Pamlico Sound, instituting a resting period in the northern Core Sound mechanical clam harvest area, and developing sampling programs to collect information necessary for the completion of a hard clam stock assessment (NCDMF 2008). Amendment 1 also endorsed several changes to the shellfish lease program to increase the accountability of the leaseholders and to improve public acceptance of the program.

The N.C. Hard Clam FMP Amendment 2, adopted by the NCMFC in February 2017, recommended maintaining status quo on recreational harvest limits, eliminating mechanical harvest in Pamlico Sound by rule, instituting shading requirements for harvesters from April 1 to September 30, implementing 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.

Review of the FMP was initiated in 2022, following the FMP review schedule.

**Management Unit**
Includes the hard clam (*Mercenaria mercenaria*) and its fisheries in all Coastal and Joint Fishing Waters of coastal North Carolina.

**Goal and Objectives**
The goal of N.C. Hard Clam FMP is to manage the hard clam resource to provide long-term harvest and continue to offer protection and ecological benefits to North Carolina's estuaries. To achieve this goal, it is recommended that the following objectives be met:

- Use the best available biological, environmental, habitat, fishery, social, and economic data to effectively monitor and manage the hard clam fishery and its environmental role.
- Manage hard clam harvesting gear use to minimize damage to the habitat.
- Coordinate with DEQ and stakeholders to implement actions that protect habitat and environmental quality consistent with the Coastal Habitat Protection Plan (CHPP) recommendations.
- Promote stewardship of the resource through public outreach to increase public awareness regarding the ecological value of hard clams and encourage stakeholder involvement in fishery management and habitat enhancement activities.

# DESCRIPTION OF THE STOCK

## Biological profile

### General life history

#### DISTRIBUTION

The hard clam, *Mercenaria mercenaria*, is a large bivalve distributed along the east coast of North America from the Gulf of St. Lawrence, Canada to the central coast of eastern Florida (Harte 2001, Abbott 1986, Mackenzie et al. 2002). This species has been transplanted in the northwest Pacific (Crane et al. 1975, Carlton 1992, Chew 2001), Puerto Rico, Europe (Heppell 1961, Chew 2001), China (Chavanich et al. 2010), and Japan (Hiwatari et al. 2006). Another species, *M. campechiensis*, also known as the southern quahog, inhabits ocean waters off North Carolina and occurs mainly from North Carolina to Florida (Hadley and Coen 2006). The hard clam is not native to the Gulf of Mexico (Abbott 1986); however, a subspecies, *M. mercenaria texana*, and *M. campechiensis* inhabit the Gulf Coast and have been mistaken for *M. mercenaria* (Dillon and Manzi 1989a,b).

Common names for *M. mercenaria* include quahog, quahaug, northern quahog, littleneck clam, and cherrystone clam. Hard clams occur throughout the south Atlantic region in estuaries from the intertidal zone to depths exceeding 18 m (Abbott 1974; Eversole et al. 1987). In North Carolina, hard clams are most abundant in higher salinity waters inside the barrier islands from Ocracoke southward to the South Carolina border (NCDMF shellfish bottom mapping data, unpublished). Hard clams are found near Oregon and Hatteras inlets and the western side of Pamlico Sound, but are much less abundant compared to those that inhabit waters inside and south of Ocracoke Island.

#### HABITAT PREFERENCES AND TOLERANCES

Hard clams occupy mostly shallow, estuarine environments and can inhabit a variety of sediment types, including sand or muddy sediments, bare, course substrates, as well as among seagrass and near oyster beds (Wells 1957, Roegner and Mann 1991, Harte 2001). Localized adult population densities can vary considerably, ranging from small patches to extensive beds, and density is dependent on many environmental factors, including organic content and composition of sediment and localized flow (Fegley 2001). Experimental and field studies have shown that areas with heterogeneous substrate mixtures of sand or mud with shell or gravel often support more clams than homogeneous substrates as the larger substrate can act as a spatial predator refuge (Anderson et al. 1978, Arnold et al. 1984). Increased densities and survivorship have also been observed for hard clams that inhabit seagrass beds (Peterson et al. 1984; Peterson 1986b).

Hard clams have a wide temperature and salinity tolerance which likely contributes to their extensive species range and successful transplantations worldwide. Adult hard clams can tolerate temperatures between -6 and 35°C (21.2 and 95°F) (Stanley and Dewitt 1983); below freezing temperatures, subtidal clams have a higher survival rate than those exposed in the intertidal areas (Eversole et al. 1987). Growth rates of hard clams are most favorable at water temperatures around 20°C (68°F) and ceases at 9°C (48.2°F) and 31°C (87.8°F) (Ansell 1968; Eversole et al. 1986). Hard clams have been found in waters with salinity ranges from 4 to over 35 parts per thousand (ppt) but cannot survive extended periods in salinities less than about 12 ppt. Growth is optimal at salinities from 24 to 28 ppt for adults (Chestnut 1951a) and 26 to 27 ppt for larval growth and survival to settlement (Davis 1958, Davis and Calabrese 1964). Hard clams cease siphoning water below 15 and above 40 ppt (Hamwi 1968), or below about 4°C (39.2°F) (Loosanoff 1937) and above 34°C (93.2°F) (Roegner and Mann 1991), and will close their valves tightly during periods of stress and respire anaerobically to reduce mortality (Eversole et al. 1987).

Adequate water circulation is essential for successful growth and recruitment of hard clams. Water currents move food, maintain water quality, remove waste, and transport eggs and larvae in the water column (Eversole et al. 1986). Hard clams obtain food by filtering suspended particulate matter and absorbing dissolved organics directly from the water. Larvae and adult hard clams are able to select their food and regulate the quality and quantity of food they consume. Hard clams adapt well to a changing food supply, but they are sensitive to the presence or absence of particular algal species that can affect growth (Eversole et al. 1986; Eversole et al. 1987). More detailed habitat and water quality information is available in the Environmental Factors section.

## REPRODUCTIVE BIOLOGY

The gametogenic and spawning cycle of the hard clam varies with latitude (Eversole et al. 1984; Eversole et al. 1987). Spawning occurs in North Carolina from spring through fall, when water temperatures reach 20°C (68°F) (Loosanoff and Davis 1950; Porter 1964). Spawning clams release eggs and sperm through the exhalent siphon into the water where fertilization occurs and rapid development begins. The first larval stage is the trochophore stage that lasts about a day, followed by several veliger/pediveliger stages that last approximately 20 days. Juvenile clams (spat) settle along edges of sandbars and channels where varying water currents occur (Carriker 1959). Hard clams will also settle in substrates with shell and subtidal vegetation. These substrates appear to have better conditions for spat survival than unstructured substrates because they offer protection from predators (Kerswill 1941; Wells 1957; MacKenzie 1977; Peterson 1982).

Precursors to both male and female sex cells are found in the gonads of juveniles (Eversole 2001). During the juvenile stage, gonadal cells differentiate and clams develop predominately as males. As adults, many clams transform into females. The sex ratio of adult clams is approximately 1:1 across its geographical range (Eversole 2001).

Sexual maturity in hard clams tends to be a function of size not age, therefore maturity is dependent on growth. Sexual maturity is usually reached during the second to third year at a shell length of 1.3 inches (33 mm), but faster growing clams may mature at an earlier age (Eversole et al. 1987). The legally harvestable size of one-inch thick (25.4 mm) is typically reached by age two to five with three as a reasonable average expectation in North Carolina (C. Peterson, UNC Institute of Marine Science, personal communication).

Although estimates vary, fecundity depends on size and condition (Ansell and Loosmore 1963). Several studies have found that fecundity increased with shell length (Bricelj and Malouf 1980; Peterson 1983; Eversole et al. 1984; Peterson 1986a). Reproductive senescence is often common in long-lived species but there is no evidence that reproductive production declines with age in hard clams (Peterson 1983; Peterson 1986a). Hard clams occur in aggregations over a wide area, and close proximity of adults is important for successful reproduction to occur in organisms that spawn in the water column (Peterson 2002). Because hard clams have limited mobility, spawning efficiency could be reduced in areas where harvest has caused a significant decrease in number and size of hard clams within these aggregations. Reduced spawning efficiency could affect future recruitment in hard clam populations (Fegley 2001; Peterson 2002).

### SIZE STRUCTURE, AGE, AND GROWTH

Hard clam populations exhibit a wide size range of individuals (Fegley 2001). Growth rates of hard clams are highly variable and depend on water temperature, habitat, food availability, and genetics (Ansell 1968; Pratt and Campbell 1956; Chanley 1958; Peterson et al. 1983; Peterson et al. 1985; Arnold et al. 1991). Shell growth is greatest during the first year after which growth decreases as age increases (Eversole et al. 1986; Eversole et al. 1987). Shell growth is fastest in the spring and fall, slower in the winter, and the slowest in the summer months when water temperatures exceed 30°C (86°F) (Eversole et al. 1987).

The age of clams can be determined by direct examination of annual growth lines within the shell. Age frequency distributions differ widely among sites within and between regions (Fegley 2001). There is also a lot of variation in the age of similar-sized clams even within the same habitat (Peterson et al. 1984; Rice et al. 1989; Fegley 2001). The maximum age seen in North Carolina is 46 years old (Peterson 1986a); however, the maximum life span of this species can exceed 100 years (Ridgway et al. 2011).

Shell growth patterns vary by latitude. North Carolina shell growth follows a southern growth pattern where light bands form during the winter months when animals are growing the fastest and dark band form during the late summer to fall months when growth is slowest, resulting in annual banding patterns (Peterson et al. 1983; Jones et al., 1990; Arnold et al. 1991, Goodwin et al. 2021). The opposite shell pattern growth is observed in northern latitudes (i.e., Connecticut to Massachusetts and England) where a dark band forms during the colder winter months, and a light band forms during the warmer months. At the middle part of the geographical range (i.e., New Jersey) shell pattern banding follows the “northern” banding pattern during the first several years of growth and then takes on a more “southern” banding pattern as they age (Fritz 2001). Unlike in other areas of their geographic range where growth ceases during certain times of the year, mature hard clams in North Carolina are capable of depositing shell material throughout the entire year, suggesting the species may serve as an important sclerochronological archive, documenting some of the most complete records of intra-annual environment conditions in their shells (Goodwin et al. 2021).

### BIOLOGICAL STRESSORS

Little data is available on the direct predation rates on larval hard clams (Kraeuter 2001). High natural mortality in the larval stages suggest predation is probably high during this life stage of the hard clam. Newly set or juvenile hard clams (<1 mm shell length) are vulnerable to a large number of predators. Primary predators of juvenile hard clams are the snapping shrimp (*Alpheus heterochaelis*), mud crab (*Dyspanopeus sayi*), and blue crab (*Callinectes sapidus*; Beal 1983; Kraeuter 2001). Stone crabs (*Menippe mercenaria*) are effective predators of both juvenile and adult hard clams, efficiently consuming large hard clams (30-60 mm shell length) that are typically free from blue crab predation, and the abundance of stone crabs in North Carolina has been increasing in recent years (Wong et al. 2010). Several types of snails (*Urosalpinx* sp*., Polinices* sp.), whelks, (*Busycon* sp.), cownose rays (*Rhinoptera bonasus*), and various birds feed on adult hard clams (Kraeuter and Castagna 1980; Kraeuter 2001). As hard clams grow the number of potential predators is reduced (Kraeuter 2001). Hard clam survival from predation is affected by sediment characteristics such as presence of shell fragments and seagrasses, and presence of other prey species (Peterson 1982; Peterson 1986b; Kraeuter 2001).

Infectious diseases can result in devastating losses of wild populations of some mollusks. For the most part hard clams appear to be relatively disease free and a number of studies of captive populations show that non-predation losses are typically only 5 % to 10% per year (Eldridge and Eversole 1982; Eversole et al. 1987; Bower et al. 1994). QPX (Quahog Parasite X = Unknown) is a parasite found in hard clams along the eastern coast of North American from Atlantic Canada to Virginia (Smolowitz et al. 1998; Dahl et al. 2011). Susceptibility to QPX is variable but with higher outbreaks in southern broodstocks compared to northern broodstocks within its range, yet QPX disease has not been identified in hard clams south of Virginia (Dahl et al. 2011). A study in 2011 confirmed that QPX disease is a cold-water infection and not likely to occur in North Carolina because of warmer waters which impedes development of this disease in hard clams (Dahl et al. 2011).

Many of the large-scale hard clam mortalities along the northeastern United States and Canada are related to air exposure during extreme cold events and negative impacts from stress associated with parasites (Smolowitz et al. 1998). Diseases in larval and juvenile hard clams held in culture conditions are often caused by bacteria, fungi, and viruses that are common in the cultured bivalves and are associated with opportunistic invaders of animals under stress in high-density culture situations (Ford 2001).

Anthropogenic activities can also affect hard clam populations. Physical disturbances including bulkhead and dock construction, boat scarring, and dredging, can disrupt the sediment and increase turbidity (Bricelj et al. 2017) which can negatively impact hard clam feeding and growth. Additionally, extensive dredging can change bottom topography and flow patterns (Bricelj et al. 2017) which can alter food availability and larval distribution. Propeller wash from boat traffic may also lead to the displacement of sediment which can expose clams and increase their vulnerability to predators, and clam larvae that go through the propeller and engine cooling system are at risk of damage from the shear forces of the propeller and engine. Furthermore, toxic compounds from pressure-treated wood used to construct new docks, piers, and bulkheads leach into the water and accumulate in the sediment (Weis and Weis 1996). New construction often occurs in the spring, coinciding with hard clam spawning which can expose hard clam larvae to toxic leachates (Bricelj et al. 2017).

**Stock Unit**
For the purposes of stock assessment, the unit stock is considered all hard clams occurring within North Carolina coastal waters.

**Assessment Methodology**
Data are not available to perform a traditional assessment, so it was not possible to estimate population size or fishing mortality rates.

**Stock Status**
Data limitations prevent the NCDMF from conducting a hard clam stock assessment and calculating sustainable harvest metrics. Currently, the only data available for the stock in most areas are the commercial landings and associated effort. Amendment 2 of the FMP recommends the status continue to be defined as unknown due to the continued lack of data needed to conduct a reliable assessment of the stock. The statutory obligation to manage hard clams according to sustainable harvest cannot be met until the appropriate data are collected.

## DESCRIPTION OF THE FISHERY

Additional in-depth analyses and discussion of North Carolina's commercial and recreational hard clam fisheries can be found in earlier versions of the Hard Clam FMP, (NCDMF 2001, 2008, and 2017); all FMP documents are available on the NCDMF Fishery Management Plans website. Commercial and recreational landings can be found in the License and Statistics Annual Report (NCDMF 2022) on the NCDMF Fisheries Statistics website.

Discussion of socio-economic information (NCDMF 2022) describes the fishery as of 2021 and is not intended to be used to predict potential impacts from management changes. This and other information pertaining to the FMPs are included to help inform decision-making regarding the long-term viability of the state's commercially and recreationally significant species and fisheries. For a detailed explanation of the methodology used to estimate economic impacts, please refer to the NCDMF License and Statistics Section Annual Report (NCDMF 2022).

## STATUS OF THE FISHERIES

### Commercial Fishery

Since the inception of the Trip Ticket Program (TTP) in 1994, data collection of hard clam information has improved through time. One consideration with hard clam landings is they come from both public harvest and private production, which are under different regulations, therefore trip numbers, landings, and effort cannot be compared between public harvest and private production. Since 2003, approximately 1% of the annual landings cannot be identified as either public harvest or private production. Much of the improvement has been from better recording and editing requirements, and from the new licensing system. In the following sections the different gear types in the fishery are separated into either public harvest or private production. Since there are some trips that could not be differentiated in the database, they were excluded in the analyses.

The hard clam industry has provided a way to make a living and food for coastal communities along the entire Atlantic East Coast from the Canadian maritime region to Florida. Fluctuations in commercial landings are common along the Atlantic East Coast with a general trend of decline through time (Figure 1). A large part of the decline in Atlantic Coast landings occurred after the 1970's as a result of overfishing in New York and closure of shellfish beds due to bacterial pollution (MacKenzie et al. 2002). For more on environmental pathogens, see Environmental Factors, Threats, and Alterations section.

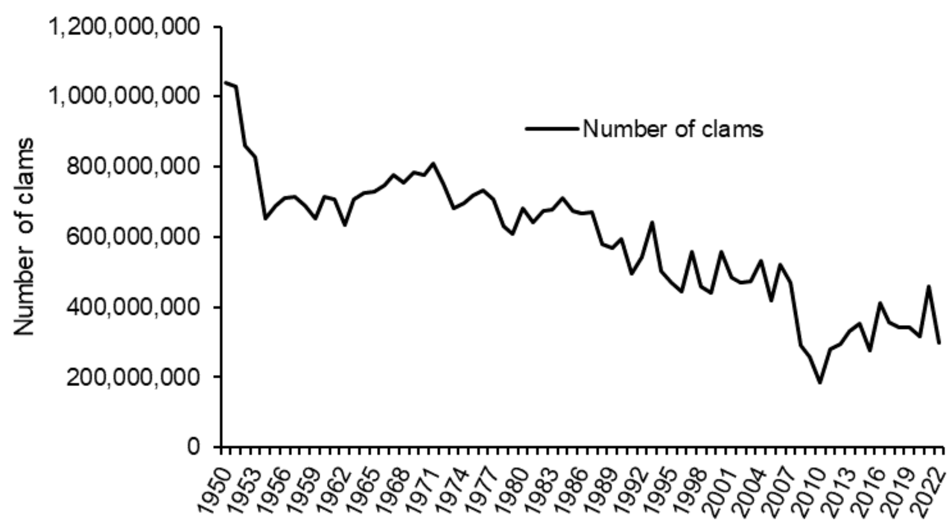



Figure 1. Commercial hard clam landings (number of clams, using a conversion factor of 0.32 oz per individual; ASFMC 1992) along the Atlantic East Coast (Maine south to Florida east coast), 1950-2022. Source: NMFS commercial fisheries landings database, except for NC landings from 1994 to 2022 using TTP.

## Gear Types

### Hand Harvest

The hand harvest fishery for hard clams is year-round in North Carolina. Hand harvesting methods include signing (spotting siphon holes), treading, hand raking, hand tonging, and bull raking. Clams are taken by hand and rake in shallow water, up to 4 feet deep, (≤1.2 meters) while hand tongs and bull rakes are used in deeper water up to 20 feet deep (1.2 to 12.2 meters) (Cunningham et al. 1992). Bull rakes have been used to exploit clam populations in New River, White Oak River, Bogue Sound, and the Intracoastal Waterway channel of Brunswick, New Hanover, Pender, and Onslow counties. A large number of subsistence fishermen use bull rakes in the southern area of the state.

### Mechanical Harvest

The two types of mechanical harvest gear currently used in North Carolina are the hydraulic escalator dredge and the clam trawl or “clam kicking” vessel. The hydraulic escalator dredge has an escalator or conveyor located on the side of the vessel. A sled is connected to the front end of the escalator. When the front end of the escalator is lowered to the bottom, the sled glides over the bottom. A blade on the sled penetrates the bottom to a depth of about four inches (10 cm) and collects the clams as they are forced from the bottom by water pressure (Cunningham et al. 1992). In clam trawling or “kicking”, clams are dislodged from the bottom with propeller backwash and a heavily chained trawl with a cage attached at the cod end towed behind the boat gathers the clams. Kick boats are generally 20 to 30 ft long and can operate in depths from 3 to 10 feet (1.0m to 3.05 m). The propeller is usually positioned 12 to 15 inches above the bottom and extra weight can be added to the stern to improve the angle and height above the bottom. For better efficiency in varying water depths, boats include a winged rudder, which has two iron plates welded on either side of the rudder to deflect water downward (Cunningham et al. 1992). One person operates smaller kick boats, while larger boats may have a crew of two or three (Guthrie and Lewis 1982).

## Historical Public Harvest Fishery

Clam harvest has fluctuated historically, often in response to changes in demand, improved harvesting techniques, and increases in polluted shellfish area closures. Hand harvest accounted for all recorded landings prior to the mid-1940s, when early forms of mechanical harvest were developed. Hand harvest is currently allowed year-round with daily harvest limits. A daily harvest limit was established in 1986 by proclamation to 6,250 clams per fishing operation from public waters and has remained in effect since.

The first mechanical method for harvesting hard clams was known as dredging. This gear allowed fishermen to remain on board and enabled them to work in poor weather (Guthrie and Lewis 1982). Trawls were first used to harvest clams in 1968 and remain in use today in a technique known as “kicking” (Guthrie and Lewis 1982). Increase in market demand along with more efficient gear soon led to increased landings. Another major development in the fishery also occurred in 1968 with the advent of hydraulic dredges. This gear used jets of water from a high-pressure pump to displace bottom sediments covering the clams and a conveyor carried the catch up to the vessel. Hard clam landings remained stable through the 1960s and 1970s. Since the late 1980s, hard clam landings have declined. This decline may be the result of a decrease in abundance, increase closures of shellfish waters from pollution, changing market demand, and several storms in Core Sound.

Allocation conflicts did not occur in the hard clam fishery until the late 1980’s as more management measures were put in place to reduce impacts to habitat and harvesters had to compete more for the limited resource. It is accepted that mechanical harvest methods can negatively impact submerged aquatic vegetation (SAV) and oyster rocks (Peterson et al. 1987). Regulations to protect habitats from mechanical harvest methods have been in place since 1977 and mechanical harvest was largely confined to the deeper waters of the sounds and rivers. A rotation scheme was put in place in the early 1980s for White Oak River and New River including a portion of the Intracoastal Waterway (IWW). The intent was to prevent overharvesting of the clam stocks, discourage violations by mechanical harvesters who cross the lines in search of more lucrative clam quantities, and the taking of undersized clams, or “buttons”. These measures continue to be in place each year by proclamation. The NCDMF also allows the harvest of clams by mechanical means before maintenance dredging occurs in some navigational channels. Dredging activity is performed by the U.S. Army Corps of Engineers (USACE). For a thorough history of the hard clam fishery including overall history, historic landings and trends, management changes for mechanical commercial gear, length of seasons, and openings and closures of bays, please refer to Amendment 2 of the Clam FMP.

**Present Public Harvest Fisheries**

The current minimum size limit for clams is 1-inch thickness (width). The current daily hand harvest limit is 6,250 clams and the fishery is open year-round. Current public mechanical harvest limits vary by waterbody. In some instances, mechanical harvest areas are rotated (alternately open and close) with other areas (Table 1). Since 2008, upon adoption of Amendment 2 to the Hard Clam FMP, Core Sound has been divided into two areas and the northern area is open every other year while the southern portion is opened annually. In 2017 there were modifications to the areas in Core Sound and North River, along with discontinued use in Bogue Sound due to SAV encroachment.

Table 1. Current daily mechanical hard clam harvest limits by waterbody.

| Waterbody | Daily harvest limit (Number of clams) | Additional information |
|---|---|---|
| Northern Core Sound | 5,000 | Rotates one year open and one year closed opposite the open/close rotation of the New River |
| Southern Core Sound | 5,000 | Open annually |
| North River | 3,750 | Open annually |
| Newport River | 3,750 | Open annually |
| White Oak River | 6,250 | Rotates one year open and one year closed opposite the open/close rotation of the New River |
| New River | 6,250 | Rotates one year open and one year closed opposite the open/close rotation of Northern Core Sound, the White Oak River, and the IWW in the Onslow/Pender counties area |
| New River Inlet | 6,250 | Open annually from Marker 72A to the New River Inlet |
| IWW Onslow/Pender counties area | 6,250 | Intracoastal Waterway (maintained marked channel only) from Marker #65, south of Sallier's Bay, to Marker #49 at Morris Landing. All public bottoms within and 100 feet on either side of the Intracoastal Waterway from Marker #49 at Morris Landing to the "BC" Marker at Banks Channel. Open every other year when the New River is closed. |

## Annual Landings, Trips, And Market Grades

Separating the hard clam landings data into public harvest and private production is inexact prior to 1994 because landings information was collected only on a voluntary basis. Since 1994, about 88% (1994-2013 combined estimates) of the total commercial hard clam harvest came from public harvest areas in North Carolina. The annual number of hard clams from public bottoms averaged 19.6 million from 1994-2022, but landings have steadily declined through time. Landings form 2012-2022 averaged 11.7 million (Figure 2).

There are year-to-year fluctuations in the number of trips harvesting hard clams. The annual number of trips has declined during the time series (1994-2022) with the highest number of trips in 2001 (Figure 3). Adverse weather conditions (i.e., hurricanes, heavy rain events) can impact the annual landings. Freshwater runoff after storm events often increase shellfish harvest area closures and therefore reduce effort in hard clam harvest for short term periods.

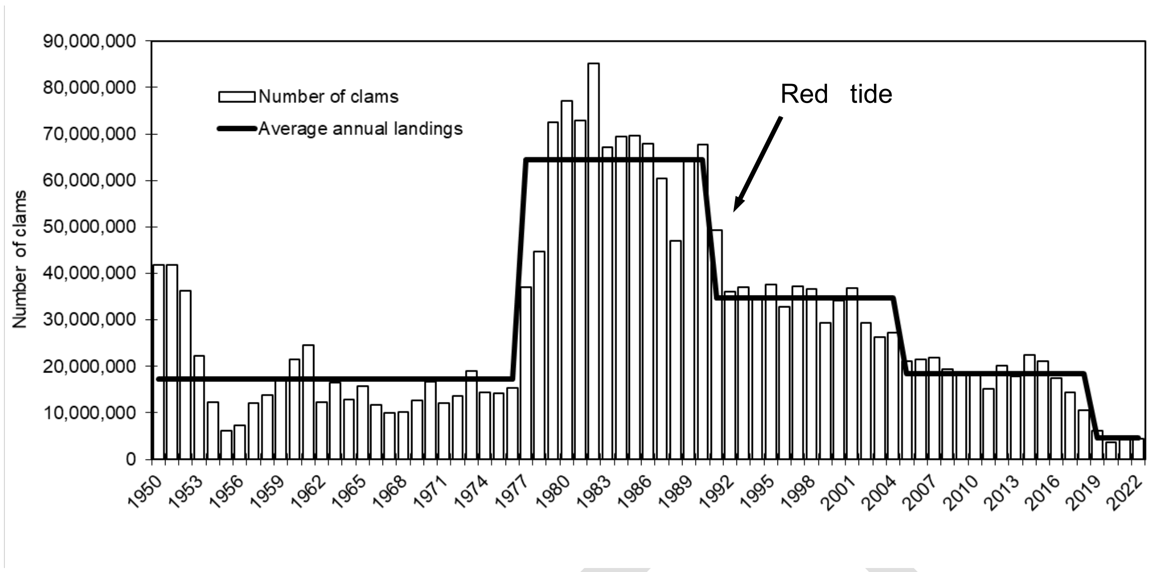



Figure 2. Hard clam landings (number of clams) from public harvest and private production showing the average annual landing trends (solid line) for specific time periods, 1950-2022. TTP.

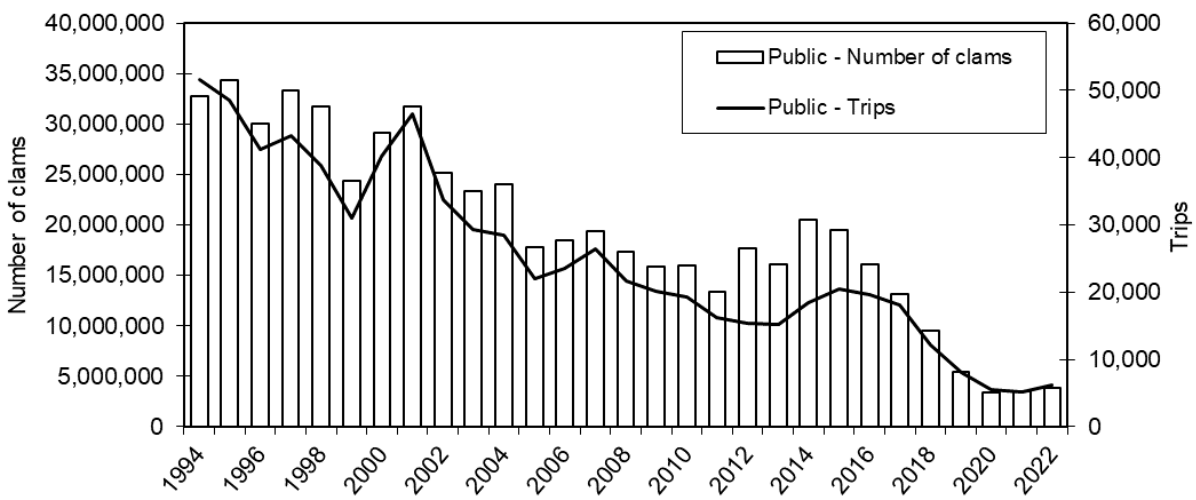



Figure 3. North Carolina annual commercial hard clam landings (number of clams) and trips from public harvest, 1994-2022. TTP.

New River and Core Sound are the top two waterbodies where hard clams are harvested from public harvest areas and accounted for 50% of the landings from 1994 to 2022 (Figure 4). Landings in the southern part of the state, including the areas of Stump Sound, Lockwood Folly, Topsail Sound, Masonboro Sound, Cape Fear River, Shallotte River and the Inland Waterway accounted for an additional 25% of the hard clam landings from public harvest from 1994 to 2022.

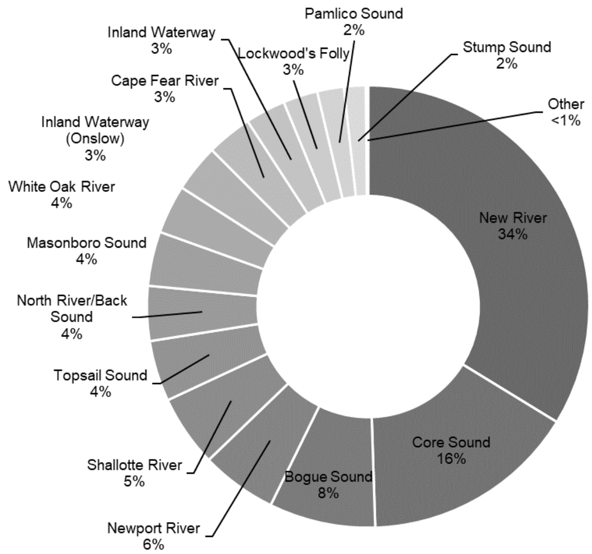
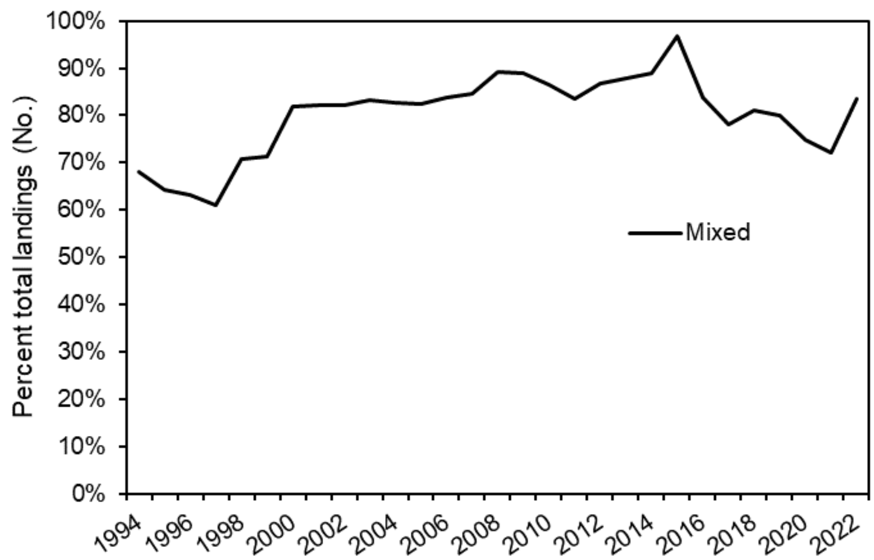
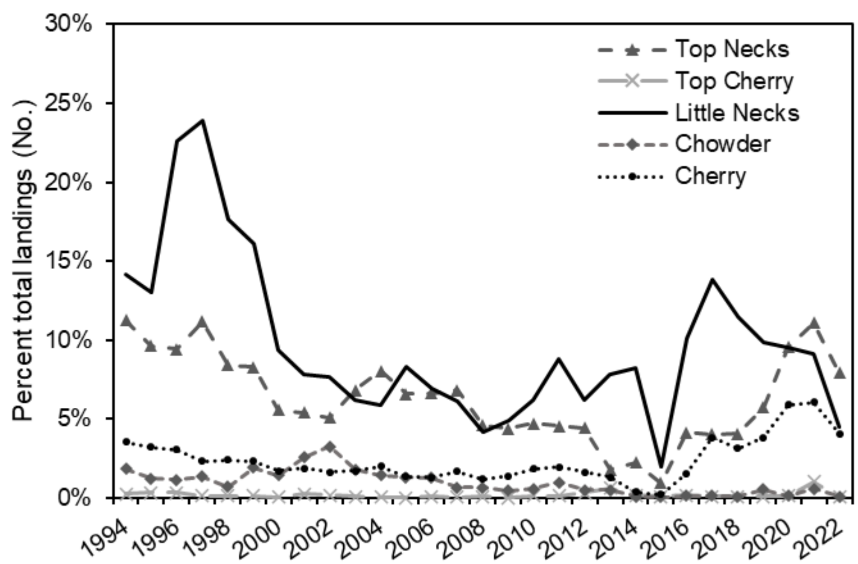



Figure 4. Commercial hard clam landings (percent of total landings) by waterbody from public harvest 1994 to 2022 combined. TTP.

Hard clam harvest is sorted by thickness (shell width) into various market grades when purchased by the seafood dealer from the fisherman. A mixed or unclassified market grade is the most common hard clam size category from public harvest and comprised 79% of the total landings from 1994 to 2022 (Figure 5a). Little neck is the second dominant market category in the hard clam landings from public harvest (Figure 5b). This market grade consists of the smallest sized hard clams measuring between 1-inch (25 mm) to 1 ¼-inch (32 mm) in thickness. Top neck is the next market category in size and ranges from 1 ¼-inch (32 mm) to 1 5/8-inch in thickness (41 mm). The proportion of hard clams as top necks to the total hard clam landings from public harvest has remained about the same throughout the time series (6% on average) (Figure 5b). Hard clams in the cherry and top cherry market grades are selected by a shell thickness that ranges between 1 5/8-inch (41 mm) to 2 ¼-inches (57 mm). These two market categories have not shown much change in proportion to the total hard clam harvest from public harvest from 1994 to 2022, although the cherry market grade began to see a slight increase in 2017 (Figure 5b). Chowder hard clams are the largest market category by size and are any hard clams greater than 2 ¼-inch shell thickness (Figure 5b).




A.




B.

Figure 5. Annual landings (percent to total annual landings) from public harvest by market grade, 1994-2022 combined. A. Mixed grade only; B. All other market grades. TTP.

### HAND HARVEST

Hand harvest from public areas is a year-round fishery and has average landings of 16,274,336 clams a year (1994-2022). Most hand clamming occurs in the spring and summer when warm water is conducive to wading (Figure 6). Annual public harvest and the number of hand harvest trips a year for hard clams has declined overall from 1994 to 2022, except for a moderate increase from 2012-2014 (Figure 7). The annual catch per unit effort (CPUE; number of clams per trip) of hand harvest from public areas also reflected this increase from 2012-2014 but has subsequently dropped back down to around 600 clams per trip (Figure 8).

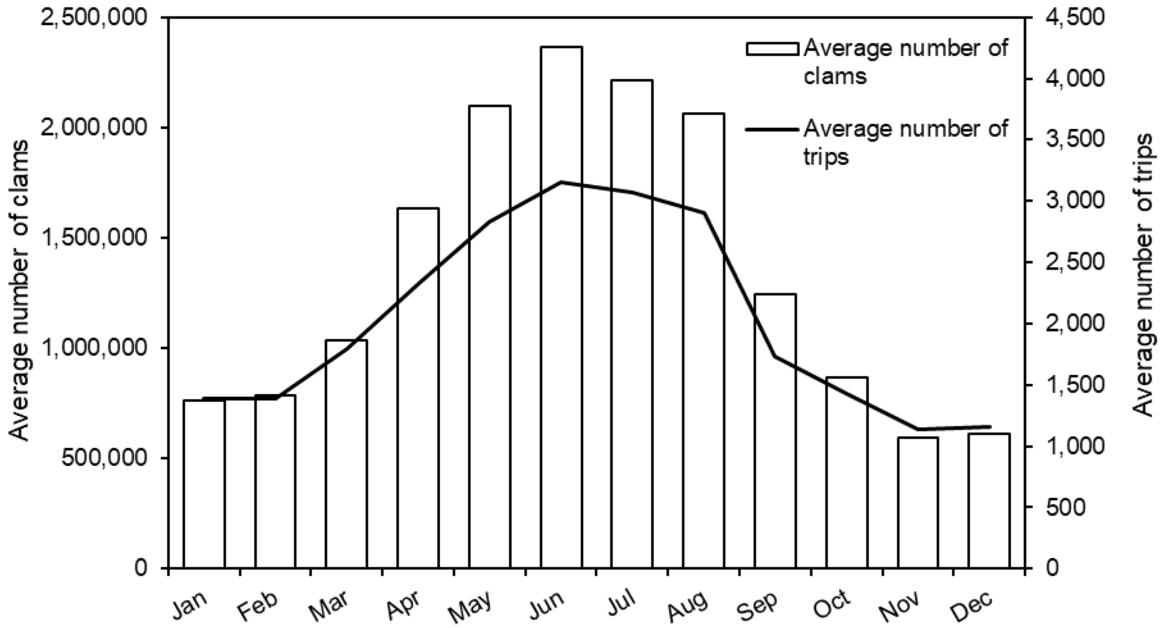



Figure 6. Average hard clam landings (number of clams) and average number of trips by month from public harvest using hand gears, 1994-2022. TTP.

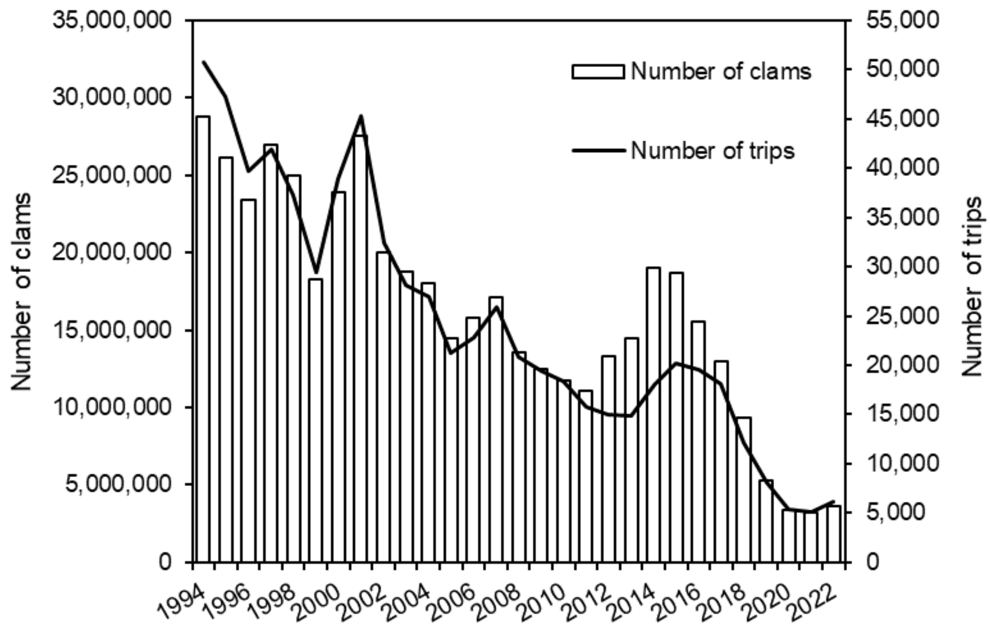



Figure 7. Annual hard clam landings (number of clams) and trips from public harvest using hand gears, 1994-2022. TTP.


Figure 8. Annual catch per unit effort (CPUE; number of clams per trip) of hand harvest from public areas, 1994-2022. TTP

### MECHANICAL HARVEST

Mechanical harvest season usually begins the second Monday in December and extends through the week of March 31st. Harvest is allowed only from 7:30 a.m. to 4:00 p.m. on Monday through Friday until before the Christmas holiday and then Monday through Wednesday after December 25th for the remainder of the open harvest season.

Hard clam landings from public harvest, using mechanical methods, has average landings of 3,319,605 clams each fishing year (1994/95 to 2021/2022). The mechanical clam harvest season usually has the highest landings at the beginning of the fishing season in December and declines as the season progresses (Figure 9). Landings outside of the usual mechanical clam harvest season are from temporary openings for the maintenance of channels and temporary openings in Core Creek when bacteriological levels are at acceptable levels to harvest clams. Hard clam landings and trips fluctuate from fishing year to fishing year and appear to be greatly influenced by harvest from the New River mechanical harvest area (Figure 10). Mechanical clam landings have remained below 1,000,000 clams per season since 2016/2017.

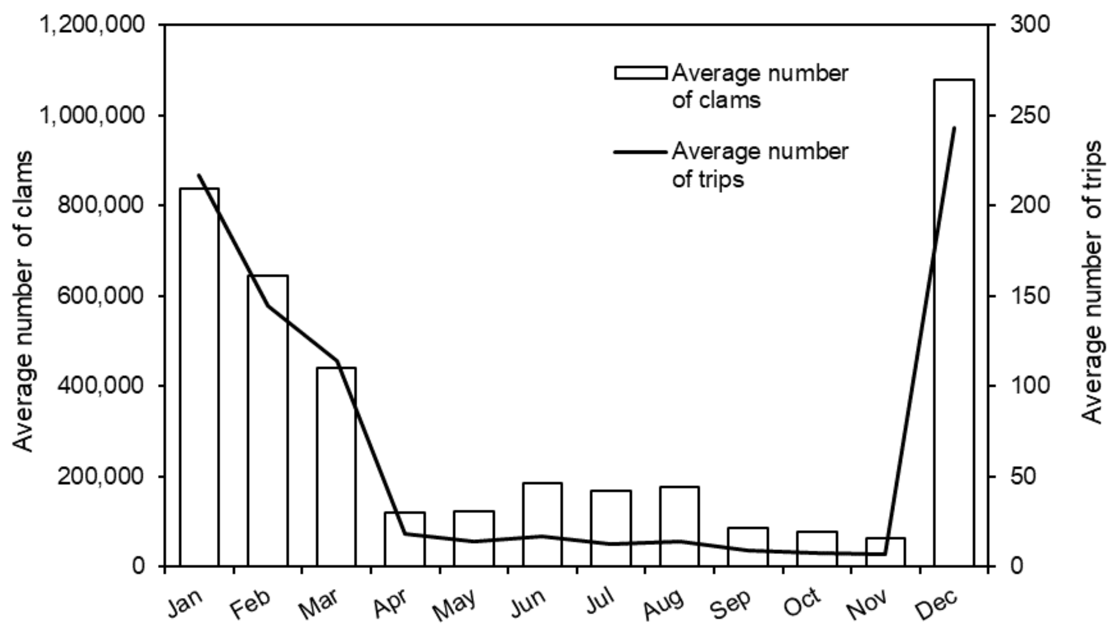



Figure 9. Average hard clam landings (number of clams) and average number of trips by month from public harvest using mechanical gears, 1994/95-2022/March 2023. TTP

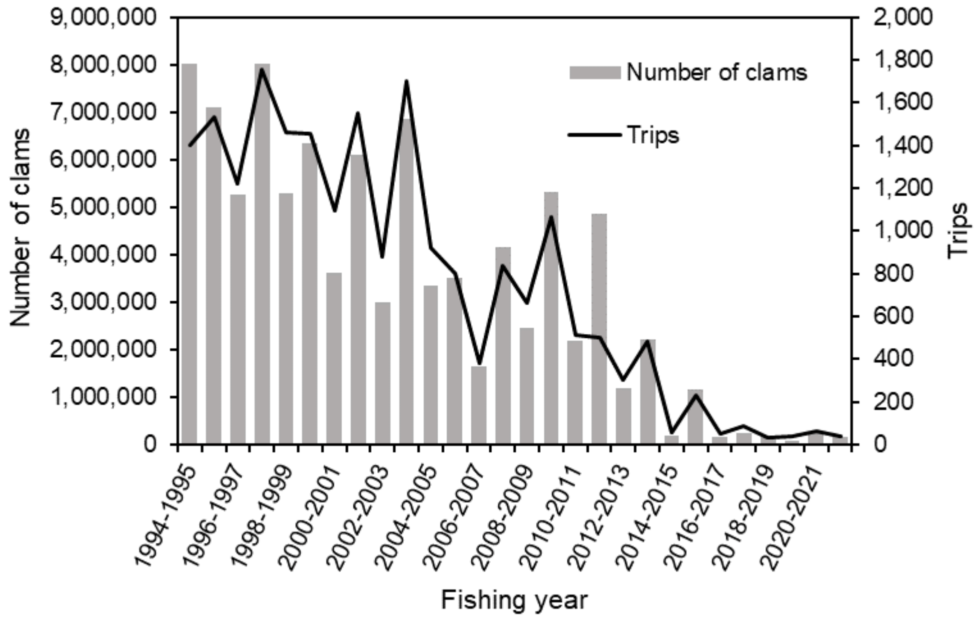



Figure 10. Hard clam landings (number of clams) and trips from public harvest using mechanical gears by fishing year (Dec-Nov), 1994/95-2021/2022. TTP.

## Private Shellfish Culture: Shellfish Leases And Franchises

This plan does not focus on the management of private shellfish culture through shellfish leases and franchises; however, detailed information on the history and management of private shellfish culture can be found in Amendment 2 of the Hard Clam FMP.

## Recreational Fishery

Hard Clams are commonly harvested recreationally year-round in North Carolina by hand and rakes. The limit allowed for personal consumption is 100 clams per person per day and 200 clams per vessel at a minimum size of 1-inch thick.

At present, recreational fishing data are collected by the Marine Recreational Information Program (MRIP) for finfish, but the survey excludes recreational shellfish data. These data limitations were further compounded in 1997 when the FRA implemented the Recreational Commercial Gear License (RCGL). The RCGL allowed recreational fisherman to use limited amounts of commercial gear to harvest seafood for personal consumption. Shellfish gears were not authorized under the RCGL due to the ability of any North Carolina resident to purchase a commercial shellfish license (at a lower cost than a RCGL) to take shellfish in commercial quantities for recreational purposes. Thus, recreational harvest from a commercial shellfish license does not get recorded because it is not sold to a seafood dealer.

NCDMF is required by the FRA to prepare an FMP for all commercially and recreationally significant species. Given that North Carolina’s shellfish fisheries are exclusively under state jurisdiction, a lack of recreational shellfish harvest data makes it extremely difficult to address potential management issues such as harvest limits, size limits, and gear restrictions for this fishery.

Recreational effort for clam harvest was reported from 60 waterbodies throughout coastal North Carolina. Overall survey results demonstrate a distinct seasonality for the recreational harvest of clams, with peak activity observed during the summer months. This, coupled with the highest concentrations of clamming activity being observed within Pamlico, Bogue, and Masonboro Sounds and during the summer months, suggests that coastal tourism may significantly impact recreational clam harvest. More background and history on recreational shellfish harvest can be found in the Recreational Harvest Issue Paper.

## SUMMARY OF ECONOMIC IMPACT

### Economic Aspects Of The Fishery

#### Ex-Vessel Value And Price

The value of hard clams to the North Carolina seafood industry has fluctuated dramatically over time. Before the mid-1970s, their economic contribution was relatively small, representing no more than 1-2% of the total value of landed seafood in the state. In 2013, clams were the sixth most economically important commercial seafood species in North Carolina. Landings of clams accounted for 4.7% of the total value of commercial non-finfish landings and 2.9% of the total value of all commercial seafood landings in the state.

The nominal value (the value that is not adjusted for inflation) of North Carolina hard clam landings have been generally declining over the last twenty years peaking at over $9 million in 1995 and declining until 2011 where ex-vessel value increased yearly until it peaked in 2015 at about $6 million before declining again in the last 7 years. When adjusted for the effects of inflation, 2012 saw the lowest landings value in the time series since 1994, landings started increasing in 2014 and 2015 then continued declining year over year to 2022 (Figure 11). The decline in total value is largely driven by a decrease in catch described in the previous section (Figure 10). Prices for most grades of clams have remained stable over time but in the last few years the price of little necks has varied significantly as seen in Figure 13.

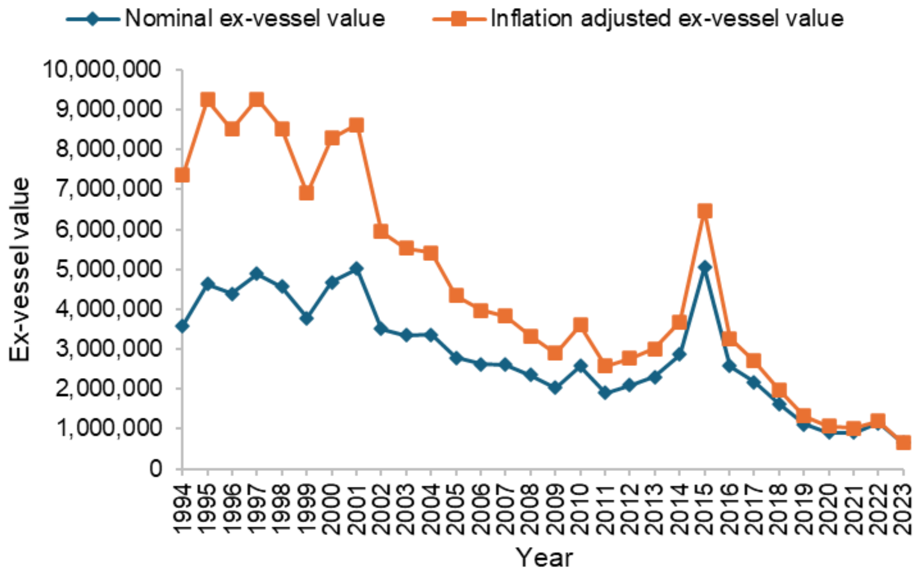



Figure 11. Annual ex-vessel value of clams in North Carolina, 1994-2022. Inflation adjusted values are in 2023 dollars. NCDMF Trip Ticket Program.

The price per clam on average has stayed constant over the time period shown in Figure 12. When adjusted for 2023 dollars, the average price per clam from 1994 to 2022 peaked in 2015 at $0.32 and was the lowest average value in 2009 at $0.15. In the last five years clam values have seen a gentle increase from $0.19 in 2018 to $0.23 in 2021 and 2022.

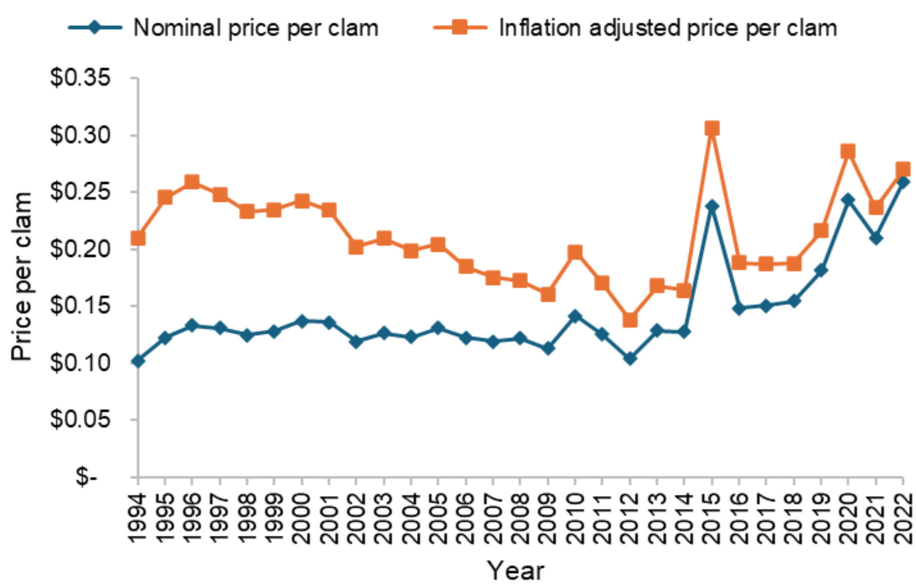



Figure 12. Annual average nominal and inflation adjusted price per clam in North Carolina 1994-2022. Data provided by the NCDMF Trip Ticket Program.

From 2004 to 2019 all clam grades were stable and did not have much variation across grades. In 2020 there was a large spike in little neck prices and then a sharp decrease in 2021 before coming back up to $0.52 in 2022. This market volatility could have been influenced by outside market drivers such as the COVID-19 pandemic.

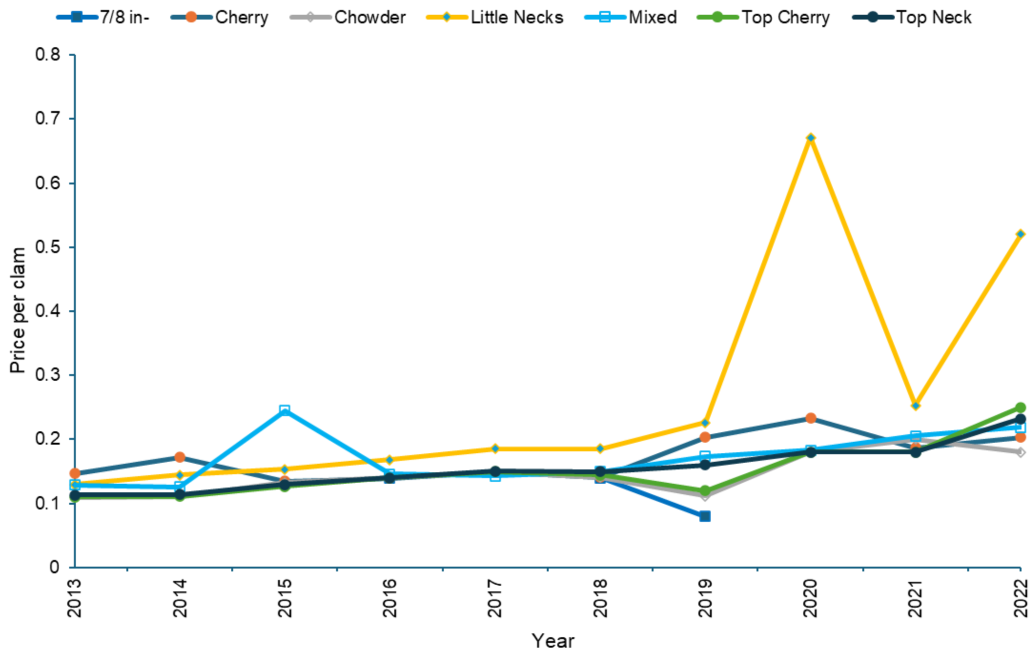



Figure 13. Annual average ex-vessel grade prices in North Carolina, 2004-2022. Data provided by the NCDMF Trip Ticket Program.

## Harvest Area

In Figure 14 below we can see most water bodies accounting for a constant amount of the clam harvest. Notably, the New River has seen a decrease in the market share of landed clams in the last two years but there was a declining portion of clams harvested in the area since 2015. Core Sound and Bogue Sound have made up more of the landed clams in the last 5 years.

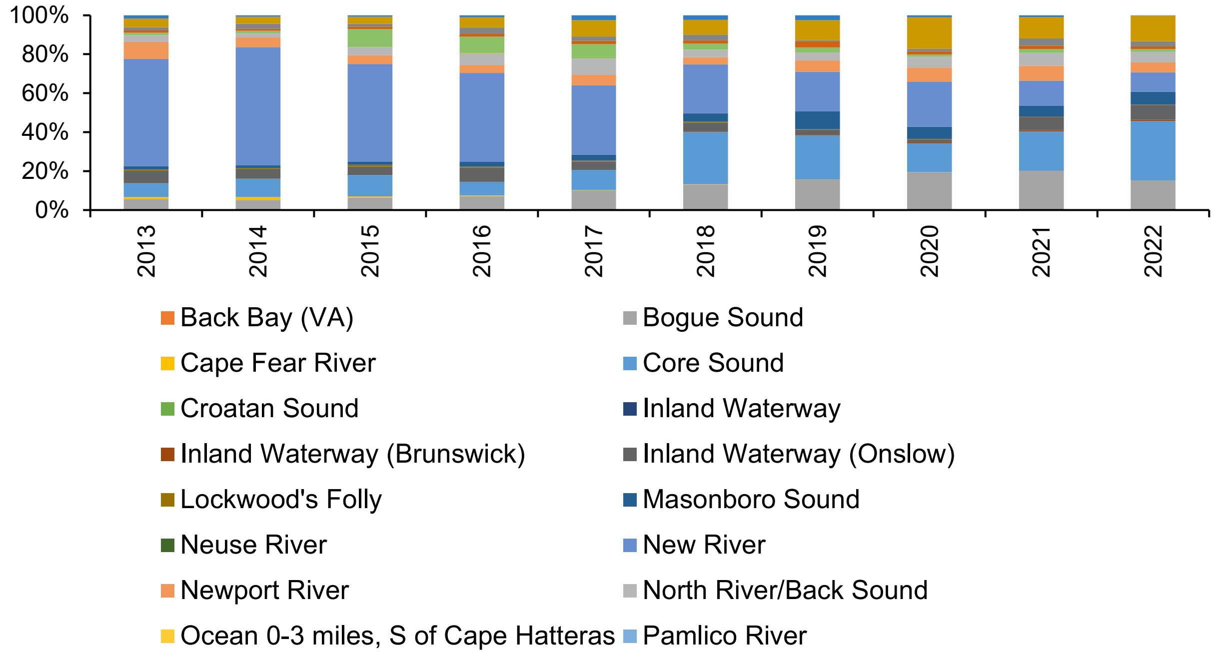



Figure 14. Percent of total annual commercial clam harvest value by waterbody, 2013-2022. Data provided by the NCDMF Trip Ticket Program

## Gear

From 2004 to 2022 we have seen hand harvest dominate the percent of total ex-vessel value of clam landings. The percentage of Mechanical harvest has seen a decrease over that period from a peak of 24% in 2004 to 13% in 2022. In 2020 Mechanical harvest dropped to a low of 2% of the market share. This is likely due to regulations and restrictions on the use of mechanical gear in North Carolina.

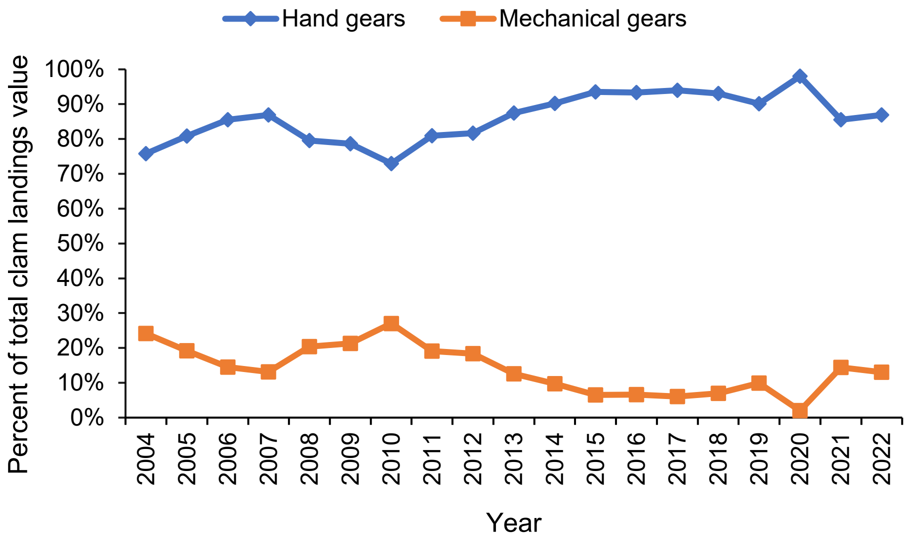



Figure 15. Annual percent of total landings value by gear type used to harvest hard clams. 2004-2022. Data provided by the NCDMF Trip Ticket Program.

## Participation And Trips

The NCDMF tracks commercial landings of all shellfish in the state. Among the variables collected, the number of participants, number of trips, gear types, location of landings and harvest, and number of dealers are all categorized and summarized in this section.

Table 2 reports the number of commercial clammers with recorded landings from 2013-2022. The distribution of participants among by number of landings has stayed relatively constant over time with over half of landings coming from participants that take 10 or less trips per year on average. Clam fishery participation has constricted by about 82% over the last twenty years. There was a bump in 2013-2015 then the number of participants continued to decline to 292 participants in 2022 (Table 2). In the last 20 years 97% of clammers have recorded landings under $25,000. 43% of clammers land $500 or less of clams a year. This indicates that most participants use clamming as a supplement to their income.

Hand gears have continued to be the dominant method of harvest through the period with the smallest proportion of the industry at 76% 2004. From 2018-2022 hand harvest has made up at least 86% of the harvest (Figure 15).

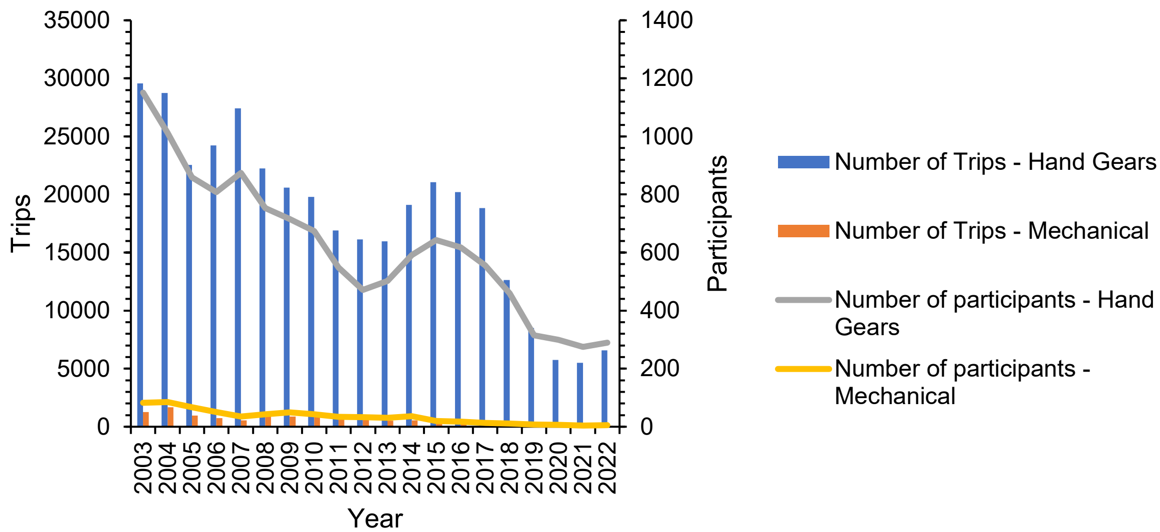



Figure 16. Participant and trip count by gear category for hard clam harvest, 2003-2022. Data provided by the NCDMF Trip Ticket Program.

As is the case in all commercial fisheries in North Carolina, clam fishers may only sell their catch to licensed seafood dealers. The number of dealers who report landings of clams since 2013 has declined. 2013 saw the highest number of dealers participating in the purchase of clams in the last decade with 107 dealers. The number of dealers purchasing clams fell to 52 in six years. Since 2019 the number of dealers participating in the purchase of clams has slightly increased annually and was at 57 in 2022. The proportion of dealers purchasing clams in the lower ex-vessel value (under $1,000) has increased by 10% while the proportion of dealers purchasing clams in the higher ex-vessel categories (over $30,000) has decreased.

**Economic Impact of The Commercial Fishery**

Tabel 2 shows the estimated economic impact of the commercial clam harvest to North Carolina's economy. The expenditures and income within the commercial fishing industry as well as those by consumers of seafood produce ripple effects as the money is spent and re-spent in the state economy. Each dollar earned and spent generates additional economic impacts by stimulating further activity in other industries which fosters jobs, income, and business sales. These impacts are estimated using the NCDMF commercial fishing economic impact model which utilizes information from socioeconomic surveys of commercial fishermen and seafood dealers in North Carolina, economic multipliers found in *Fisheries Economics of the United States, 2020,* and IMPLAN economic impact modeling software. In 2022, the commercial clam fishery in North Carolina supported an estimated 350 full-time and part-time jobs, approximately $1.6 million in income, and approximately $3.5 million in sales impacts. In the last ten years the industry has contracted in landings, participants, and economic impacts.

Table 2. Economic impact of the commercial clam fishery in North Carolina, 2013-2022. NCDMF Fisheries Economics Program.

| | | | | | Estimated Economic Impacts | | |
|---|---|---|---|---|---|---|---|
| Year | Participants[1] | Trips[1] | Clams landed (in thousands)[1] | Ex-vessel value (in thousands)[1] | Jobs[2,3] | Income impacts (in thousands)[3] | Sales impacts (in thousands)[3] |
| 2022 | 292 | 6652 | 4,426 | $1,148 | 350 | $1,636 | $3,560 |
| 2021 | 278 | 5641 | 4,308 | $978 | 331 | $1,584 | $3,551 |
| 2020 | 302 | 5799 | 3,710 | $1,020 | 354 | $1,568 | $3,383 |
| 2019 | 318 | 8635 | 6,156 | $1,279 | 380 | $2,065 | $4,742 |
| 2018 | 462 | 12828 | 10,522 | $1,898 | 556 | $2,959 | $6,484 |
| 2017 | 559 | 19037 | 14,418 | $2,596 | 672 | $3,857 | $8,752 |
| 2016 | 626 | 20466 | 17,384 | $3,143 | 759 | $4,617 | $10,058 |
| 2015 | 650 | 21393 | 21,127 | $6,221 | 924 | $8,932 | $20,023 |
| 2014 | 607 | 19644 | 22,441 | $3,543 | 767 | $5,296 | $12,169 |
| 2013 | 517 | 16496 | 17,856 | $2,883 | 643 | $4,180 | $9,444 |

[1]As reported by the NCDMF trip ticket program.

[2]Represents both full-time and part-time jobs.

[3]Economic impacts calculated using the NCDMF commercial fishing economic impact model.

## Recreational Fishery Economics

Currently, the NCDMF has limited data on recreational clamming, including the number of participants and the effect of their effort on the economy. For more information on the Recreational Fishery, see the Recreational Harvest Issue Paper.

## Social Importance of The Fishery

### COMMERCIAL FISHERMEN

The NCDMF Fisheries Economics Program has been conducting a series of in-depth interview-style surveys with commercial fishermen along the coast since 1999. Data from these interviews are added to a growing database and used for fishery management plans, among other uses. In the most recent surveys from each region of the North

Carolina coast, 130 of the fishermen reported that they commercially harvest clams. That group is used to provide a snapshot of the North Carolina commercial fishermen in this section. For an in-depth look into these responses, please see Amendment 2 of the Clam FMP. Below is a summary of the survey responses from the 130 commercial fishermen active in the clam fishery across 39 different communities along North Carolina's coast. The largest number of commercial clammers lived in Sneads Ferry, followed by Newport, Atlantic, Beaufort, Wilmington, and Morehead City.

The 130 clam harvesters surveyed by the Fisheries Economics Program had an average age of 51 and almost 28 years of commercial fishing experience. Two thirds had a high school diploma and 23% had at least some college education. Almost half had more than $30,000 in household income when surveyed, with 18% indicating $50,000 or more. A quarter of the survey respondents had less than $15,000 in annual household income. On average, commercial fishing accounted for 65% of the personal income for these fishermen, and 43% reported that fishing was their sole source of personal income. The majority (78%) of clam fishermen fished all year long.

The most important issue reported by fishermen was development of the coast. All clam fishermen in the survey lived in the central or southern part of the coast of North Carolina, which has seen intense development in recent decades. Water quality impairments are often associated with intense development, which greatly impact if and when a shellfish area is opened. Additionally, coastal development is also associated with losing working waterfronts, which was another issue of concern for many commercial clammers. Low prices for seafood and competition from imported seafood were also high on the list of issues that impact the businesses of clam fishermen. The lowest ranked issues were keeping up with rule changes and proclamations, size limits, bag limits, and quotas were all not seen as important issues affecting commercial clammers.

## ECOSYSTEM PROTECTION AND IMPACT

### Coastal Habitat Protection Plan

In the 1990s, addressing habitat and water quality degradation was recognized by resource managers, fishermen, the public, and the legislature as a critical component for improving and sustaining fish stocks, as well as the coastal ecosystem. When the Fisheries Reform Act of 1997 (FRA; G.S. 143B-279.8) was passed, it required developing Coastal Habitat Protection Plans (CHPPs). The legislative goal of the CHPP is "…the long-term enhancement of coastal fisheries associated with coastal habitats." The FRA specifies that the CHPP will identify threats and recommend management actions to protect and restore coastal habitats critical to NC's coastal fishery resources. The plans are updated every five years and must be adopted by the NC Coastal Resources (CRC), the NC Environmental Management (EMC), and the NC Marine Fisheries (MFC) Commissions to ensure consistency among commissions as well as their supporting NC Department of Environmental Quality (DEQ) agencies. The 2021 CHPP Amendment is the most recent update to the CHPP, building upon the 2016 CHPP source document.

Hard clams occur extensively in estuarine systems. Habitats for juvenile and adult hard clams include both intertidal and subtidal soft bottom (defined by Street et al. (2005) as "unconsolidated, unvegetated sediment that occurs in freshwater, estuarine, and marine systems" to include both deeper subtidal bottom and shallow intertidal flats), shell bottom (which can be commonly referred to as oyster beds, rocks, reefs, bars, and shell hash), and submerged aquatic vegetation (SAV). NCDMF's Estuarine Bottom Habitat Mapping (EBHM) Program mapped North Carolina's shellfish-growing bottom habitats between 1990 and 2021 and identified the top clam-producing bottom types across the state, as listed in Table 3.

Table 3. Average clam densities for the top five clam-producing bottom types as identified by the EBHM program.

| **EBHM bottom habitat category** | **Avg. clams per square meter** | **Habitat description** |
|---|---|---|
| Intertidal Firm Non-vegetated Shell | 2.03±0.03 | Intertidal oyster reef/reef fringe on sandy or muddy sand bottom |
| Intertidal Hard Non-vegetated Shell | 1.50±0.04 | Intertidal oyster reef/reef fringe on sandy or shelly bottom |
| Subtidal Firm Non-vegetated Shell | 0.86±0.03 | Subtidal oyster reef/reef fringe on sandy or muddy sand bottom |
| Subtidal Hard Non-vegetated Shell | 0.87±0.04 | Subtidal oyster reef/reef fringe on sandy or shelly bottom |
| Subtidal Hard Vegetated w/o Shell | 0.71±0.01 | SAV beds on sandy bottom |

By region, *Subtidal Hard Vegetated without Shell* (SAV on sandy bottom) was the most productive clam habitat in the Pamlico Sound region, but in regions south of Pamlico Sound, unvegetated intertidal and subtidal shelly bottom types both produced more clams than vegetated bottom, as they were statewide (Table 3). Other unvegetated, non-shelly bottom types (identified in the CHPP as "soft bottom habitat") also provide habitat for clams, but the EBHM program generally found clams at smaller densities in those habitats than in shell bottom and SAV habitat. The EBHM program data support findings in the scientific literature that SAV (Peterson et al. 1984; Irlandi 1994; Carroll et al. 2008) and shell bottom (Peterson et al. 1995) provide superior habitat to unstructured soft bottom habitat. In addition to hosting lower densities of clams, soft bottom habitat is by far the most extensive estuarine habitat in North Carolina, and it faces fewer threats than structured habitats. Therefore, protection of SAV and shell bottom habitats from both physical impacts and water quality degradation is the top priority for protecting clam habitats.

## ENVIRONMENTAL FACTORS, THREATS, AND ALTERATIONS

### Physical Threats

#### MOBILE BOTTOM DISTURBING FISHING GEAR

Soft bottom habitat, because of its low structure and dynamic nature, has historically been considered the most appropriate location to use bottom disturbing gear. There are fishery rules that restrict bottom disturbing gears in designated soft bottom habitat. Fishing gears with the greatest potential for damage to soft bottom include dredges and trawls. Of the factors affecting the condition of structured clam habitat, mechanical shellfish harvest of clams and oyster harvest are the most obvious. Impacts of mechanical harvest on unstructured, soft bottom sediments are less studied, and the 2021 CHPP (NCDEQ 2021) highlights the need for increased monitoring of the condition of North Carolina's estuarine soft bottom habitat with regards to chemical and microbial contaminants and benthic macroinvertebrate communities. Recommended Action (RA) 8.6 in the 2021 CHPP (expansion of DWR's benthic macroinvertebrate sampling to estuaries) could directly contribute to a better understanding of the impacts of bottom disturbing gear on soft bottom habitats, and RA 8.1 (convene an expert workgroup to document data gaps and monitoring needs) and RA 8.2 (develop and ecosystem condition report) will provide a roadmap to better understanding impacts to hard clam habitats. For more in depth information on mobile bottom disturbing fishing gear, see the Mechanical Harvest Issue Paper.

#### HAND HARVEST METHODS

Intensive hand harvest methods can be destructive to oyster rocks. The harvest of clams or oysters by tonging or raking on intertidal oyster beds causes damage not only to living oysters but also to the cohesive shell structure of the reef (Lenihan and Peterson 1998). This destruction has been an issue where oysters and hard clams co-exist, primarily around the inlets in the northern part of the state and on intertidal oyster beds in the south (NCDMF 2001a). For more history on hand harvest methods, see Amendment 2 of the Hard Clam FMP.

### Water Quality Threats

Marine bivalves, including oysters, have been shown to accumulate chemical contaminates, such as hydrocarbons and heavy metals, in high concentrations. Reductions in growth and increased mortality have been observed in soft-shelled clams (*M. arenaria*) following oil spill pollution events (Appeldoorn 1981). Impaired larval development, increased respiration, reduction in shell thickness, inhibition of shell growth, and general emaciation of tissues have been attributed to adult bivalve exposure to heavy metal contamination (Roesijadi 1996).

High concentrations of organic contaminates also result in impairment of physiological mechanisms, histopathological disorders, and loss of reproductive potential in bivalves (Capuzzo 1996). As shellfish can easily accumulate chemical pollutants in their tissues, consumption of impaired shellfish can create a health risk. Subsequently, shellfish closures occur due to chemical contamination, commonly associated with industry, marinas, and runoff.

Delivery of inorganic pollutants, organic contaminants, and harmful microbes to waterways occurs via both point and non-point sources. The accumulation of such harmful agents in the water column subjects oyster populations to the adverse effects listed above. Point sources have identifiable origins and include National Pollution Discharge Elimination System (NPDES) wastewater discharges. Although wastewater discharges are treated, mechanical failure can allow contaminated sewage to reach shellfish growing waters, thereby triggering an area to be closed to harvest.

Non-point sources of microbial contamination include runoff from animal agriculture operations and urban development. Animal agriculture produces waste with fecal bacteria, runoff from pastures, concentrated animal feeding operations (CAFOs), and land where CAFO waste has been applied as manure, all of which can be transported to surface waters and subsequently lead to shellfish restrictions (Wolfson and Harrigan 2010; Burkholder et al. 2007; Hribar 2010). Impervious surfaces (e.g., roads, roofs, parking lots) facilitate runoff and microbe transportation, facilitating significant water quality degradation in neighboring watersheds (Holland et al. 2004). For instance, in New Hanover County, an analysis of the impact of urban development showed that just 10-20% impervious cover in an area impairs water quality (Malin et al. 2000). In North Carolina, most CAFOs primarily house swine and poultry with a majority located in the coastal plain portions of the Cape Fear and Neuse basins; however, both occur in all basins across the coastal plain (DWR 2024; Off 2022).

### HYPOXIA

Point and non-point sources (developed and agricultural lands) are also sources of increased nutrient loads, which fuel phytoplankton growth and increase the strength and frequency of algal blooms. The eventual bacterial decomposition of these blooms results in a depletion of dissolved oxygen levels that can be dangerous to shellfish, particularly in warm, deep waters. Increased eutrophication leads to decreased oxygen levels (hypoxia and anoxia), which North Carolina’s estuaries can already be prone to because of salinity stratification and high summertime water temperatures (Buzzelli et al. 2002). These low-oxygen events degrade the usability of subtidal oyster reef habitats for fish (Eby and Crowder 2002) and cause high rates of oyster mortality in the deeper (4-6m) waters of the estuaries (Lenihan and Peterson 1998; Powers et al. 2009; Johnson et al. 2009). Increased state action to limit nutrient loading from urban and agricultural lands is critical for reducing hypoxia impacts to estuarine habitat and resources, including oysters and the reefs they create (DWR 2024).

### CLIMATE CHANGE

According to North Carolina's 2020 Climate Science Report (Kunkel et al. 2020), the intensity of hurricanes is likely to increase with warming temperatures, which will result in increased heavy precipitation from hurricanes. Additionally, it is likely that the frequency of severe thunderstorms and the annual total precipitation in NC will increase. The expected increase in heavy precipitation events will lead to increased runoff, which will result in an increase in chemical and microbial pollutants transferred to oyster habitats. Recent research has provided evidence that negative impacts from increased precipitation and pollutant delivery to estuaries have already begun in North Carolina (Kunkel et al. 2020; Paerl et al. 2019).

For instance, Paerl et al. (2020) investigated the impact of tropical cyclones on nutrient delivery and algal bloom occurrences in the Neuse River Estuary and Pamlico Sound. They found that high-discharge storm events, such as high-rainfall tropical cyclones, can double annual nutrient loadings to the estuary, leading to increased nutrients and dissolved organic carbon. Phytoplankton response to moderate storm events is immediate, while during high-rainfall events like Floyd (1999), Matthew (2016), and Florence (2018), phytoplankton growth is diverted downstream to Pamlico Sound, where it can persist for weeks. Additionally, increased organic matter and phytoplankton biomass from heavy rainfall events contribute to oxygen depletion, exacerbating hypoxic and anoxic conditions in the Neuse River and Pamlico Sound.

Additionally, warming water temperatures caused by climate change may benefit growth rates for pathogens that can negatively impact resources. For instance, increased water temperatures have been linked to increasing abundance of *Vibrio* over the past 60 years (Vezzulli et al. 2016). This is a significant public health issue and can also disrupt shellfish markets, as *Vibrio* species get taken up by filter-feeding shellfish and can cause life-threatening illness when consumed. Common wisdom in North Carolina has advised against consuming raw shellfish in the warm-water months for this reason, and rising water temperatures threaten to increase this risk, potentially through longer periods of the year.

In addition to causing hypoxia, the enhanced phytoplankton growth resulting from increased rainfall and nutrient delivery to estuaries will also result in negative impacts to SAV habitat. The majority of SAV loss in North Carolina has been attributed to decreases in light availability due to increased eutrophication (nutrient enrichment) and suspended sediments, and those losses are expected to increase as eutrophication increases due to climate change (NCDEQ 2021). Further, North Carolina's dominant high-salinity SAV species, eelgrass (*Zostera marina*), is already growing at the warmest edge of its thermal tolerance in NC, regularly experiencing stressful temperatures that affect growth and reproduction. While the response of eelgrass to increased water temperatures is complex, and the species may be more resilient in North Carolina than other states (Bartenfelder et al. 2022), projections of shifts in the range of eelgrass due to warming waters indicate that the species' southern limit is likely to move northward and potentially out of North Carolina altogether by 2100 (Wilson and Lotze, 2019).

To reduce the negative impacts of climate change on the hard clam fishery, it will be important for state agencies to implement policies that encourage the use of agriculture, forestry, and urban stormwater best management practices (BMPs) to reduce the amount of runoff reaching North Carolina's estuaries. This need, among others, has been emphasized in the CHPP as recommended actions to improve water quality. While the MFC has little direct control over such actions to mitigate the impacts of increased runoff, it can continue to support them through its role in developing and approving the CHPP.

#### ENVIRONMENTAL PATHOGENS

There are various environmental pathogens that can impact shellfish and those that consume shellfish. These pathogens include Neurotoxic Shellfish Poisoning (NSP), Vibrios, and Green Gill.

Neurotoxic Shellfish Poisoning is a disease caused by consumption of molluscan shellfish contaminated with brevetoxins primarily produced by the dinoflagellate, *Karenia brevis*. Blooms of *K. brevis*, called Florida red tide, occur frequently along the Gulf of Mexico (Watkins et al. 2008).

Vibrios are salt loving bacteria that inhabit coastal waters throughout the world, and with the exception of toxigenic *Vibrio cholera* 01, are not usually associated with pollution that triggers shellfish closures and can be ubiquitous in open shellfish growing areas. Vibrios are more common during the warmer summer months and are found throughout the coastal waters of North Carolina (Blackwell and Oliver, 2008; Pfeffer et al. 2003).

Green gill in clams comes from the single-celled alga called *Haslea ostrearia.* This is a blue-green diatom found in the coastal waters of North Carolina. For more detailed information on these environmental pathogens, see Amendment 2 of the Hard Clam FMP.

### Shellfish Sanitation

The NCDMF has a contingency plan in place as required by the FDA, including a monitoring program (National Shellfish Sanitation Program, NSSP) and management plan. The purpose is to ensure quick response of any harmful algal species within State waters that may threaten the health and safety of shellfish consumers. The plan also details the system to provide early warning of any potential issues, actions to be taken to protect public health and steps to reopen areas to harvest. (Shellfish Sanitation and Recreational Water Quality Section Marine Biotoxin Contingency Plan 2022). Shellfish Sanitation and Marine Patrol are the primary Sections of NCDMF responsible for North Carolina's compliance with the NSSP.

The Shellfish Sanitation Section classifies shellfish growing areas and recommends closures and re-openings to the Director that are implemented by proclamation. The entire North Carolina coast is divided into a series of management units that are referred to as Growing Areas. Each of these Growing Areas is individually managed to determine which portions of the area are suitable for shellfish harvest, and which need to be closed to harvest. Data collected and used in classifying Growing Areas include actual and potential pollution sources, rainfall and runoff impacts, physical hydrodynamic patterns, and bacteriological water quality.

Shellfish growing waters can be classified as “Approved”, “Conditionally Approved”, “Restricted”, or “Prohibited”. Approved areas are consistently open to harvest, while Prohibited areas are off limits for shellfish harvest. Conditionally Approved areas can be open to harvest under certain conditions, such as dry weather when stormwater runoff is not having an impact on surrounding water quality, and Restricted waters can be used for harvest at certain times as long as the shellfish are subjected to further cleansing before they are made available for consumption. For a map of both temporary and permanent closures, please visit the Interactive Shellfish Closure Map on NCDMF’s Shellfish Sanitation website. Additional information can be found under Current Polluted Area Proclamations.

## Enhancement Activities

NCDMF has not identified a need to target restoration efforts towards increasing hard clam populations; however, NCDMF supports enhancement programs which benefit native shellfish species through a variety of initiatives. In recognition of the eastern oyster as a keystone species in estuarine habitat, these initiatives focus on oyster restoration, while indirectly and simultaneously providing enhancement to hard clam habitat.

### Habitat Enhancement Programs

#### Cultch Planting

The objective of the North Carolina Division of Marine Fisheries cultch planting program is to provide shellfish habitat on public bottom grounds and open to commercial harvest. While cultch planting is traditionally viewed as an oyster restoration measure, it may also serve as a restoration tool for other shellfish species, including hard clams. In the 1970’s, the Virginia Institute of Marine Science planted cultch material over seed clams to protect them from predation. Through the broadcast of aggregate materials, survivorship of seed clams increased compared to controls (Castagna 1970).

While cultch planting efforts are not directly targeted towards hard clam restoration, the adjacent habitat is likely made more suitable for hard clam colonization. The emergent structure of cultch material and subsequent habitat complexity may increase food deposition, providing feeding opportunities for hard clams (Diehl 1992; Grabowski 2002; Kelaher 2003). Cultch planting areas in intertidal zones offer a variety of ecosystem services such as wave energy attenuation, marsh accretion, and stabilization of interstitial sediments all of which may benefit hard clam habitat. (Coen et al. 2007; Currin et al. 2010; Meyer et al. 1997).

2024 marks 109 years of cultch planting in North Carolina for restoration purposes. In that time, an estimated 21 million bushels of oysters have been planted in North Carolina waters (Street et al. 2005). Since 1981 the state has constructed more than 2,000 cultch planting sites. The majority of these sites are grouped in close proximity to prior sites to create larger sites of oyster habitat over time. These sites have historically used a variety of materials for restoration, including oyster, clam, and scallop shells, as well as limestone marl. Since 2003, some portion of annually deployed cultch material has been supplemented by recycled shell. These sites range in size from 0.1-10 acres with less than 100 acres of accumulative impact per year. They are distributed throughout the state and are made available to the public as harvestable bottom. Recently created cultch sites are monitored for oyster settlement, however protocol for assessing hard clam ecology in these areas has not been developed.

A comprehensive overview of the cultch planting program is available in the Eastern Oyster FMP Amendment 5, Appendix 1.

### OYSTER SANCTUARIES

Beginning in 1996, NCDMF incorporated no-take marine reserves into its shellfish restoration efforts with the creation of the Oyster Sanctuary Program. The aim of protected subtidal oyster sanctuaries is to supplement larvae to decimated natural oyster reefs and cultch sites throughout Pamlico Sound via the "spillover effect" created by these protected areas with heightened reproductive output (Peters et al. 2017). Rules 15A NCAC 03K .0209 and 03R .0117, prohibit the harvest of shellfish and use of trawls, long haul seines, and swipe nets in sanctuary boundaries, thereby protecting hard clams in these no-take reserves. Oyster sanctuaries under construction but not yet incorporated into 15A NCAC 03R.0117 can be protected under Rule 15A NCAC 03H .0103 and 03K .0103 through proclamation authority.

Oyster Sanctuaries in North Carolina are designed in such a way that enhanced habitat complexity may provide habitat for both oysters and other species typically found on or near oyster reefs. At many of these sites, soft bottom habitat between hard substrate patches may provide ideal habitat for clam colonization and also offer refuge from predation (Castagna 1970).

Hard clams, as with oysters, in harvest-protected sanctuaries can serve as broodstock populations, providing subsidies to harvestable areas (Gobler et al. 2022). While a monitoring protocol is in place for oyster sanctuaries, there is currently no provision for addressing hard clam ecology associated with these protected areas.

A comprehensive overview of the Oyster Sanctuary Program is available in the oyster FMP - amendment five, appendix 1.

### SHELLFISH AQUACULTURE

Aquaculture of hard clams has ecosystem service value similar to wild stocks. Hard clams maintain the capacity to filter large volumes of water. Water column filtration improves water quality and clarity by reducing nutrients and suspended sediments as pseudofeces. Additionally, hard clam shell growth sequesters carbon, a service beneficial to other marine and estuarine organisms impacted by ocean acidification. Shellfish aquaculture equipment may also serve secondary functions, such as sediment stabilization and wave attenuation. Effectively, aquaculture equipment truncates high energy environments, providing suitable nursery habitat to other marine species. Larval subsidies are a valuable service of shellfish populations. Depending on the ploidy of hard clams in culture, environmental conditions, and the duration of grow out, shellfish aquaculture may provide an additional source of larvae for habitat enhancement.

### CLAM RESTORATION EFFORTS IN OTHER STATES

Although a majority of shellfish restoration efforts have focused primarily on oysters, a few recent projects have looked to researching effective strategies in enhancing depleted clam populations along the east coast. The cost-effectiveness of various methods has been investigated, including the use of spawner sanctuaries, planting seeded shell, and larval release in shallow lagoons of New York and Florida (Arnold et al. 2002; Doall et al. 2009; Gobler et al. 2022). Among these strategies, spawner sanctuaries appear to have had the most success. This strategy, as suggested by Peterson (2002), takes advantage of the long lifespan and sustained reproductive output of *M. mercenaria*.

A study conducted in Shinnecock Bay, along Long Island, New York observed the 9-year impact of transplanting 3.2 million adult hard clams and placing them in high-density no-take spawner sanctuaries (Gobler et al. 2022). Compared to neighboring lagoons during the same time period, Shinnecock Bay saw a 16-fold increase in landings of clams, in addition to significant decreases in harmful algae density and chlorophyll a concentration and a significant net gain in seagrass habitat (Gobler et al. 2022). While other projects testing the spawner sanctuary strategy had mixed results, their takeaways highlighted the importance of suitable environmental conditions using healthy adult clams. For instance, shallower waters (< 2 m), higher DO, higher temperatures, and higher salinity (> 20 psu) likely all play a significant role in both the ability of adult clams to recondition between spawning years, as well as the survivability and recruitment of larvae (Castagna & Chanley 1973; Doall et al. 2009; Arnold et al. 2002; Gobler et al. 2022).

Therefore, careful consideration must be placed into environmental variables during site selection for any possible clam restoration projects. While both oysters and clams have similar ecological roles as filter feeders in shallow water estuaries, each has specific physiological tolerances and environmental needs. Oysters can survive a wide range of environmental conditions, while clams have a narrower tolerance of environmental variables and are not constrained to the tidal column upper limits (Galimany et al., 2017).

Furthermore, researchers have placed considerable emphasis on the necessity of long-term monitoring surveys (similar to protocols used for NC's Oyster Sanctuary Program) following any restoration efforts involving *M. mercenaria* (Osborne et al. 2021; Simpson et al. 2022).

**Protected Resources**

A "protected species" is defined as any organism whose population is protected by federal or state statute due to the risk of extinction. In North Carolina, these species are primarily protected by the following federal statues: the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and the Migratory Bird Treaty Act (MBTA). As mentioned in other sections of this document, hard clams are primarily harvested in North Carolina estuarine waters by hand rakes and bull rakes. Additional lesser used gears include clam trawls and escalator dredges. For the purpose of the MMPA, the NMFS splits this fishery into two distinct Category III fisheries: the Atlantic Shellfish Bottom Trawl fishery and the Atlantic Ocean, Gulf of Mexico, Caribbean shellfish dive, hand/mechanical collection fishery. As reflected by the Category III designations, neither section of the fishery has had any known interactions with marine mammals. Additionally, in either fishery there is only a remote likelihood that any incidental interactions may occur. More information on the MMPA List of Fisheries and fisheries categorizations can be found here: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-protection-act-list-fisheries.

North Carolina estuaries are also home to multiple ESA-listed species including green sea turtles (*Chelonia mydas*), kemp's ridley sea turtles (*Lepidochelys kempii*), loggerhead sea turtles (*Caretta caretta*), leatherback sea turtles (*Dermochelys coriacea*), hawksbill sea turtles (*Eretmochelys imbricata)*, atlantic sturgeon (*Acipenser oxyrinchus*), and shortnose sturgeon (*Acipenser brevirostrum*). No ESA-listed species interactions have been recorded within this fishery. Furthermore, the timing of this season (December through March) generally precludes any potential interactions as estuarine abundance of sea turtles during these months is typically low (Epperly et al. 1995). As such, it can be assumed that any potential impacts of hard clam harvest on protected species populations would be primarily indirect and at the ecosystem-level.

North Carolina is home to a diverse array of migratory bird species (Potter et al. 2006). It is unlikely that species of MBTA-protected birds are directly impacted by clam harvest. In fact, some research suggests that hand and rake harvest of clams has a negligible effect on certain species of shorebirds as (Navedo and Masero 2008). Overall, however, there is little evidence to suggest that any hard clam harvest method impacts MBTA-protected species.

## Final AMENDMENT [number] MANAGEMENT STRATEGY

****Section will be completed when the MFC selects preferred management and prior to DEQ secretary and legislative committees review****

*The purpose of this section is for readers to see exactly how we are managing this fishery and what constitutes a change in management. It should include an overview and statement of policies, as well as any adaptive management. Present the management strategies in a clear, concise, and precise way.*

## RESEARCH NEEDS

The research recommendations listed below are offered by the division to improve future management strategies of the hard clam fishery. They are considered high priority as they will help to better understand the hard clam fishery and meet the goal and objectives of the FMP. This list of research recommendations is also provided in the Annual FMP Review and NCDMF Research Priorities documents.

- Develop hard clam sampling methodology to monitor regional adult abundance
- Map and characterize hard clam habitat use by bottom type
- Develop a survey to better quantify recreational harvest
- Determine natural morality estimates
- Investigate causes of recent clam-kills and overall decline in hard clam abundance in the New River

## MANAGEMENT FROM PREVIOUS PLANS

*If applicable- this section is the carry over of management which was established in previous plans which is not addressed in appendices and needs to be contained in the new plan or management would be lost. See Shrimp FMP Amendment 2 as an example.*

## APPENDICES

### Appendix 1: Clam Mechanical Harvest Issue

### Appendix 2: Recreational Shellfish Harvest Issue Paper

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